Overview of Deconstruction in Selected Countries

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CHAPTER 1
INTRODUCTION: DECONSTRUCTION AS AN ESSENTIAL COMPONENT OF SUSTAINABLE CONSTRUCTION

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1.1 INTRODUCTION

The demolition of building structures produces enormous amounts of materials that in most countries results in a significant waste stream. In the U.S., demolition waste amounts to 92% of the total construction and demolition (C&D) waste stream of 136 million tonnes annually or about 125 million tonnes of demolition that is for the most part landfilled. In the Netherlands, C&D waste amounts to 15 million tonnes per year; however due to a high degree of environmental awareness and government regulation, over 80% of this waste stream is recycled, mostly into subbase for roads.

In general, more careful consideration of the priorities for disposal of materials from demolition and construction operations needs to be put into place to minimize virgin materials extraction and the energy needed to process used materials for further use. Figure 1 indicates just such a scheme and places reduction in materials use at the top of the materials waste processing hierarchy because this produces the most beneficial effect for natural systems. Reuse is just below reduction of materials use and includes both deconstruction and component/materials reuse.

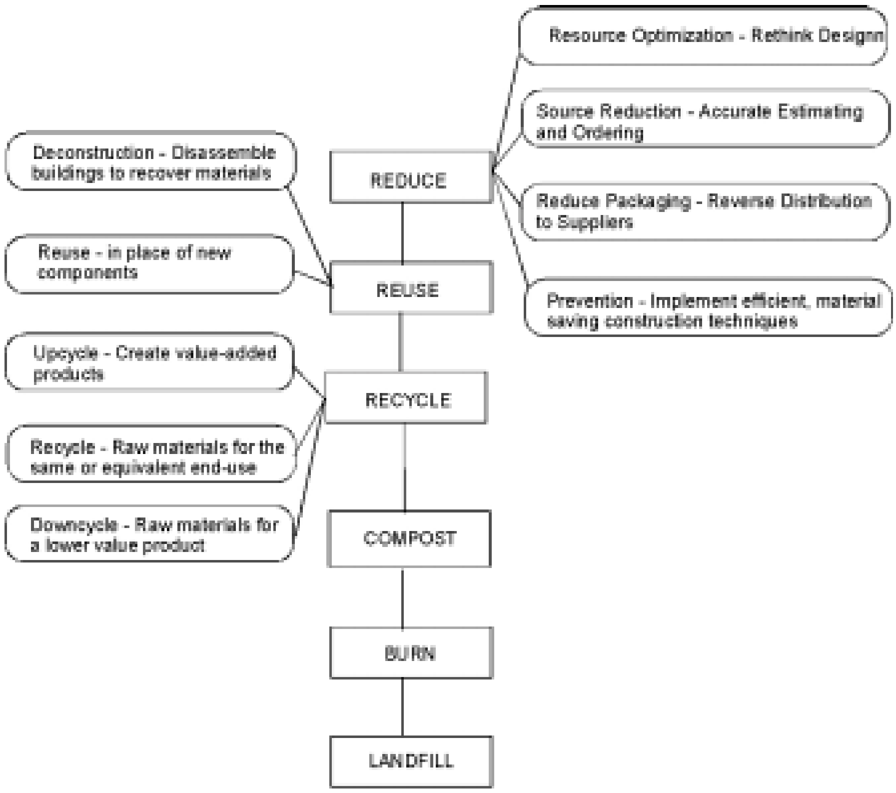

Figure 1 Waste Management Hierarchy for demolition and construction operations

Deconstruction of buildings has several advantages over conventional demolition and is also faced with several challenges. The advantages are an (1) increased diversion rate of demolition waste from landfills; (2) potential reuse of building components; (3) increased ease of materials recycling; and (4) enhanced environmental protection, both locally and globally. Deconstruction preserves the invested embodied energy of materials, thus reducing the input of new embodied energy in the reprocessing or remanufacturing of materials. A significant reduction in landfill space can be a consequence. For example, in the U.S. where C&D waste represents about one-third of the volume of materials entering landfills, a diversion rate of 80% as is being experienced in The Netherlands would preserve increasingly scarce land for other optional uses.

The challenges faced by deconstruction are significant but readily overcome if changes in design and policy would occur. These challenges include: (1) existing buildings have not been designed for dismantling; (2) building components have not been designed for disassembly; (3) tools for deconstructing existing buildings often do not exist; (4) disposal costs for demolition waste are frequently low; (5) dismantling of buildings requires additional time; (6) re-certification of used components is not often possible; (7) building codes often do not address the reuse of building components; and (8) the economic and environmental benefits are not well-established. Again, these challenges generally fit into one of two categories: design or policy.

1.2 INTERNATIONAL OVERVIEW

The initial meeting of CIB TG39 at the Building Research Establishment (BRE) in Garston, Watford, U.K., was held to assess the status of deconstruction in a variety of countries around the world. Country reports were presented from Australia, Germany, Israel, Japan, The Netherlands, Norway, the U.K., and the U.S. Below is a brief summary of deconstruction in a selection of these countries which represents the differences and commonalities in these locations.

Australia (Philip Crowther, Queensland University of Technology)

The total waste stream in Australia is about 14 million tonnesn of which somewhere between 14% and 40% is C&D waste. Deconstruction of 70 to 100 year old timber houses in Australia is a common practice with about 80% of the materials being recovered and reused for renovation and remodeling of existing homes or in the construction of new, replica housing. Additionally the relocation of houses is a common practice, with 1,000 homes being moved in the Melbourne area each year out of a total housing stock of 800,000 units (See Figure 2). For residential structures it is estimated that between 50% and 80% of materials are recovered in the demolition process. The recovery of materials from commercial buildings is significantly lower with a total recovery rate of about 69% (58% reuse and 11% recycled). In Australia up to 80% of concrete is processed to recover the aggregates for reuse in construction. For modern housing, the emergence of new systems of prefabricated buildings allows the potential deconstruction of the housing stock in the future. EcoRecycle Victoria provides guidance for waste minimization in construction and demolition including *Tender Guidelines for Construction and Demolition Projects* and includes the consideration of deconstruction as an element of the tendering process.[1]

Figure 2 Relocation of typical residential structure near Melbourne, Australia (Philip Crowther)

Germany (Frank Schultmann, Deutsch-Französisches Institut für Umweltforschung (DFIU)

The demolition waste stream in Germany is estimated to be about 45 million tonnes per year of which about 25% is concrete and 50% is bricks and stone. Between 1991 and 1999 several case studies on deconstruction were conducted and revealed an exceptionally high recovery rate, in excess of 95% for many structures. Recent studies are looking at deconstruction methods and show that optimized deconstruction combining manual and machine dismantling can reduce the required time by a factor of 2 with a recovery rate of 97%. The Deutsch-Französisches Institut für Umweltforschung (DFIU) in Karlsruhe has several research programs underway that are investigating various aspects of deconstruction. One of these is the process of auditing an existing building for its deconstruction potential for the purpose of predicting the cost of dismantling the building versus the value of the extracted materials. Computer models have been developed to assist in this process and cover both the technical and economic aspects of deconstruction.[2]

Israel (Amnon Katz, Technion - Israel Institute of Technology)

The amount of construction waste in Israel is estimated to be 350 to 700 thousand tonnes per year. Deconstruction activity is currently relatively low due to the type of construction (reinforced concrete frame with plastered concrete block walls), small number of structures to be demolished, and the lack of willingness of the public to accept second hand materials. Design for deconstruction initiated the development of a 4-story pre-cast parking garage that can be dismantled and relocated according to market demands. The need to relocate army camps has also initiated careful planning for deconstruction of existing buildings in closing camps to maximize reuse of the building elements. [3]

Japan (Mikio Futaki, Building Research Institute- Ministry of Construction)

Construction waste consists of 20 % of Japan's industrial waste, and uses about 40 % of disposal volume in landfills. Construction waste comprises 90 % of illegal dumping, and hence promotion of recycling of construction waste is an important problem. Recycling of construction waste lags far behind the recycling of waste in other sectors. Consequently it is especially important that reuse and recycling of construction and demolition waste be addressed in an urgent manner. The waste disposal and recycling system in Japan is based on

‘The law concerning waste disposal and public cleanliness which, was passed in 1970. Starting in 1988, substantially stronger waste reduction and recycling laws were introduced and additional laws were passed between 1991 and 2000. The major law addressing recycling was passed in 1993 (The law concerning the promotion of recycled material use: Ministry of Health and Welfare) and new government policies based on this law were enacted.
For buildings beyond a certain minimum size, selective dismantling to recover specific materials such as concrete, asphalt, timber and wood products is required. It is expected that these requirements will expand and recycling will increase in the future.

The Netherlands (Ton Kowalczyk, J. Kristinsson, and Ch.F. Hendriks, Technical University Delft)
C&D waste in The Netherlands is generated at a rate of 14 million tonnes per year. Strict government regulations ensure that about 80% of these materials are reused in other construction, generally in creating materials for road base. The Dutch Government passed a law on the first of April 1997 which in short states that “...dumping of reusable building waste is prohibited,” thus forcing even higher rates of recovery. Reusing components of existing buildings is hampered by two factors. First, the building stock is comprised largely of reinforced concrete structural materials that are difficult to take apart and for disassembly, they must be sawn apart. After disassembly, the recovered component must undergo testing prior to its direct reuse as a slab, column, or beam in a new building. Second, recovered components such as brick are costly to remove and process and are therefore not competitive with new products. Efforts are underway to begin the process of informing architects and other actors in the construction industry about the potential for designing buildings for deconstruction.[5]

Norway (Lars Myhre, Norwegian Building Research Institute)
Total C&D waste in Norway is about 1.5 million tonnes per year of which 978,000 tonnes is demolition waste. In the Oslo region, between 25% and 50% of this waste stream is estimated to be recycled or reused (See Figure 3). Significant private and public initiatives are underway with a goal of reducing the C&D waste stream by up to 70%. The GAIA group of architects is promoting perhaps the most ambitious plan for including design for deconstruction in planning. They established the “Building System for Reuse” or BfO system which decouples building systems, eliminates the uses of composites, and relies on traditional, locally produced building materials and well-known simple technology. The BfO system includes 88 standard wood and concrete components that can be assembled into a wide variety of configurations. The ability to easily assemble and dismantle the components also allows the capability of easily changing or reconfiguring the building to meet the user’s needs over time. A follow on project that takes advantage of the BfO system is called ADISA or Assemble for DIS-Assembly and consists of 45 standardized components with space planning based on a module of 600 mm. Presently a pilot project at the Prestheia eco-village is building 19 dwellings using the ADISA system.[6]

Figure 3 Disassembly of log house in Norway

United Kingdom (C. McGrath, Building Research Establishment; S.L. Fletcher, Sheffield University; H.M. Bowes, University of Salford)

Within Europe as a whole C&D waste amounts to some 180 million tonnes each year with only about 28% being reused or recycled. Throughout the UK 53 million tonnes of C&D waste are produced annually with approximately 24 million tonnes of inert C&D waste being recycled. Construction waste comprises inert and active wastes that if mixed, will incur the higher landfill tax rate (£11/tonne). Separated wastes can incur lower landfill tax rates (£2/tonne), are much more suitable for recycling and reuse, and can become an asset rather than a liability. The introduction of the landfill tax in 1996 has contributed to a big increase in the number of fixed and mobile crushing and recycling sites. Estimated at fewer than 100 sites in 1994 there are now thought to be more than 400 of these sites. Approximately 3 million tonnes of C&D waste is reclaimed as shown in Table 1. Reclamation involves less processing, greater employment and is often a more efficient use of resources than recycling. Therefore if deconstruction was a standard process, it would in turn increase the amount of materials being reclaimed and have many benefits for new construction and society.[7]

Table 1 - Size of reclamation industry and market (U.K.)

Sector	**Sales £ million**	**Employment**	**Tonnes 000's**
Architectural antiques			
Stone	17	2100	71
Timber	4	1100	7
Iron & steel	4	800	7
Clay	1	800	2
Ornamental antiques			
Stone	16	1170	22
Timber	36	1740	22
Iron	9	1000	9
Clay	1	100	1
Reclaimed materials			
Timber beams	42	3600	137
Timber flooring	29	2960	105
Clay bricks	31	4300	457
Clay roof tiles	63	3600	316
Clay and stone paving	19	1300	694
Stone walling	29	2450	1118
Salvaged materials			
Iron and steel	11	2800	77
Timber	36	7800	383
Antique bathrooms			
Sinks, baths, taps, WCs	41	1900	1
TOTAL	**389**	**39520**	3430

United States (Charles J. Kibert, Abdol R. Chini, and Jennifer Languell, University of Florida)

Deconstruction and materials reuse in the U.S. is highly decentralized and growing rapidly, especially in areas of the country where construction and demolition waste disposal fees exceed \$50 per tonne. The main actors at present are the federal government and non-profit organizations. The federal government, while in the process of closing excess military bases, is including deconstruction as an alternative to demolition for removal of older buildings. Dimensional lumber and wood beams have historically been the most prevalent materials used in the construction of homes and the wood in pre-World War II housing is of particular interest due to its high quality. The U.S. Forest Products Laboratory has been engaged in research efforts to re-grade western lumber extracted from buildings so that it can be re-certified for new construction. A similar effort has been underway at the University of Florida to re-grade Southern Yellow Pine, the most common source of wood in the southeast U.S. Figure 4 shows progress in the deconstruction of a church in Gainesville, Florida as part of a research project by the Center for Construction and Environment at the University of Florida to assess the economics and techniques of deconstruction.[8]

Figure 4 Deconstruction of a Unitarian Church in Gainesville, Florida

1.3 CONCLUSIONS AND RECOMMENDATIONS

As its primary purpose, deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the materials that comprise the structure. Deconstruction is emerging as an alternative to demolition around the world. Generally the main problem facing deconstruction today is the fact that architects and builders of the past visualized their creations as being permanent and did not make provisions for their future disassembly. Consequently techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at institutions around the world, and government policy is beginning to address the advantages of deconstruction by increasing disposal costs or in some cases, forbidding the disposal of otherwise useful materials. Designing buildings to build in ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. CIB TG39 is in the process of conducting a 4-year study of deconstruction and coordinating an exchange of information among research organizations and practitioners around the world.

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CHAPTER 2
BUILDING DECONSTRUCTION IN AUSTRALIA

Philip Crowther (Queensland University of Technology, Brisbane, Australia)

SUMMARY

This report presents information on current issues regarding the state of deconstruction in Australia. These issues include; quantities of waste and recycling, embodied energy, policy and legislation, design practice, demolition, initiatives in recycling, initiatives in deconstruction, and current research in design for deconstruction. The report concludes with recommendations for future research and for changes in design practice and government policy.

As an industrialised nation Australia has achieved high levels of consumption and correspondingly high levels of waste disposal. The construction industry is a major contributor to these levels of waste creation and consequently a major potential market for reused and recycled materials. Recent government policies have attempted to address aspects of these issues but as yet they are neither wide reaching enough nor coordinated enough to have any real effect.

The recycling of small scale residential building materials is well established and high rates or reuse are achieved, but this is not the case for commercial and industrial buildings where the only major recycling to occur is the crushing of concrete for aggregate.

There is some research in Australia into recycling technologies, issues of embodied energy, and design for deconstruction. This research is not however well integrated with the construction industry in general. Deconstruction, like other environmentally sustainable issues, is at present an interesting concept that fails to achieve wide spread understanding or implementation.

KEYWORDS: Australia; Disassembly; History; Policy; Recycling; Technology.

ACKNOWLEDGEMENTS

The assistance of the Queensland University of Technology, Professor Gordon Holden, and Professor Bill Lim, in the production of this report is greatly appreciated.

2.1 INTRODUCTION

Australians have one of the highest standards of living in the world. Unfortunately part of the price that is paid for this standard is major environmental degradation. Current industrialised practice in Australia, as in many parts of the world, results in the production of large amounts of waste. A major part of this waste is the result of building demolition. This problem has only recently received attention. Government policy, building practice, and design education are now starting to address the issues of waste associated with the built environment and in particular demolition.

Deconstruction, the systematic taking apart of a building for the purpose of materials reuse as opposed to destructive demolition, is not a new concept, but it has not previously been the topic of research in Australia. This report presents the current state of building deconstruction in Australia. It is a compilation of information from many sources and relies heavily on related research.

Information Sources
The information presented in this report has been sourced through contact with: government departments - including Environmental Protection Agencies in each state; universities and academics - including all universities with architecture schools; government and private research organisations; and a literature review of the field.

2.2 QUANTITIES OF WASTE AND RECYCLING

Australia, as an industrialised nation, consumes large amounts of materials and energy and produces large amounts of waste and pollution per capita. The creation and maintenance of the built environment is responsible for a major part of this consumption and production.

The role that demolition plays in this waste production scheme is unclear, as is the role of recycling and reuse. It can be seen below, that there is no comprehensive understanding of the quantities and types of demolition waste and recycling, but rather a scattering of research studies in small scale.

Quantities of Waste
Australia has one of the highest rates of solid waste disposal in the world. Nearly one tonne of solid waste is sent to landfill per person each year, approximately 14 million tonnes [1]. Of this the amount, construction and demolition waste has been measured and estimated at from 16% to 40% [2] [3].

Type and Sources of Waste
There is no Australia wide research into the types and sources of construction or demolition waste. There are however some recent isolated local studies. Research has been conducted in Melbourne to investigate the sources of demolition waste and the quantities of waste that are recycled [4], see Table 1.

Table 1 Amount of demolition waste in Melbourne 1993 by building type, in tonnes per m^2 of floor area.

BUILDING TYPE	**MEAN WASTE t/m^2**	**MAXIMUM WASTE t/m^2**
Residential detached	0.5	2.3
Residential other	1.2	6.3
Residential total	0.7	6.3
Non residential total	0.6	2.0

In another study, published in 1998, EcoRecycle Victoria conducted a series of surveys at landfill sites to identify quantities and type of solid waste in the Melbourne metropolitan area [5]. Construction and Demolition waste was estimated at 40% of the volume of total landfill waste. The sources of construction and demolition waste are presented in Table 2, and the type of materials presented in Table 3.

Table 2 Percentage of construction and demolition waste in Victoria by building type.

BUILDING TYPE	PERCENTAGE OF TOTAL C&D WASTE
Residential demolition	39.3
Commercial demolition	33.3
Residential construction	10.5
Commercial construction	4.9
Civil construction	4.0
Road and landscape construction	1.7
Road and landscape demolition	1.2
Civil demolition	0.8
Other	4.3

Table 3 Percentage of total solid waste in Victoria by material type (building materials only).

MATERIAL TYPE	PERCENTAGE OF TOTAL SOLID WASTE STREAM
Timber and wood	26
Concrete	14
Brick	6

While this research shows timber as a major contributor to the solid waste stream, many other research projects suggest that concrete and masonry represent the major portion of construction and demolition waste, at least 75% [6]. With no Australia-wide data, comprehensive figures of overall demolition waste quantities and types can only be estimated from the data of local studies.

Quantities of Recycling

Australia wide figures for the recycling and reuse of construction and demolition material are similarly not available, but some local research has been conducted. Generally, reuse and recycling of residential building materials is much higher than for commercial and industrial buildings, with most states having well established markets for second-hand residential components and materials [7].

For example, in Brisbane, the traditional detached timber house has achieved high levels of popularity in inner city suburbs. As such there is a well-developed market for reused doors, windows, floorboards, wall lining boards, framing, and the like, to be used in residential restoration, renovation and in new replica character housing. These activities extend to whole house relocation, (discussed later). This trend in reused materials is however generally limited to niche markets.

It should be noted that the construction technology used in these houses (typically from 70 to 100 years old) is very conducive to their deconstruction. These buildings are primarily made from standard dimensional lumber, nailed in place, with a very limited amount of 'wet' trade work (such as plastering, concreting, tiling). The technology used in contemporary houses by comparison may be considerably less conducive, particularly with modern glues and sealants, and increased reliance on 'wet' trades.

Figure 1 Typical timber house built in 1920's, now derelict and awaiting relocation or deconstruction for materials recycling.

Research in Melbourne has shown quite high rates of material reuse and recycling of residential building materials [8]. This survey, though of a relatively small sample, shows percentages of building components and materials that were recovered for reuse by residential demolition companies, Table 4.

Table 4 Percentages of materials by weight recovered from residential building demolition in Melbourne, and the type of recovery (as the number of traders out of the total surveyed).

TYPE OF MATERIAL	**TOTAL PERCENTAGE RECOVERED**	**REUSED OR RENOVATED**	**RECYCLED**
Brick	77	10/10	-

Timber	79	10/10	-
Structural steel	78	3/5	2/5
Doors	71	11/11	-
Windows	73	12/12	-
Iron roofing	88	7/7	-
Flooring	78	2/2	-
Roof tiles	50	1/1	-
Plumbing	73	6/6	-

As well as the recycling and reuse of demolition materials there is a large market for relocating whole houses. Timber houses are regularly cut into large sections to be transported to new sites for reassembly and reuse. Research has suggested that as many as 1000 houses a year are relocated in the Melbourne district alone, which has a total housing stock of 800,000 detached houses [9]. This practice is certainly not limited to Melbourne, and similar rates of relocation could be expected in other areas.

The same research shows that while rates of recovery in residential building demolition are quite high, commercial office building demolition results in much lower rates of recovery [10]. The study also shows that while the majority of materials and components from residential salvage are reused in their existing state, the majority of materials from commercial salvage are recycled or reprocessed, Table 5.

Table 5 Percentages of materials by weight recovered from CBD office building demolition in Melbourne, and the type of recovery.

TYPE OF MATERIAL	**TOTAL PERCENTAGE RECOVERED**	*REUSED*	**RECYCLED**
Concrete	70	-	70
Brick and tiles	75	60	15
Structural steel	95	15	80
Steel reinforcing	50	-	50
Timber & timber products	50	50	-
Cast iron pipe	80	40	40
Concrete block	25	25	-
Copper	90	-	90
Aluminium	90	-	90
Screenings	80	20	60
Other	5	1	4
TOTAL	**69**	**11**	**58**

Also in Victoria, EcoRecycle Victoria provides some information on quantities and types of materials that were recycled in 1996, including construction and demolition waste, see Table 6 [11].

Table 6 Quantities of building materials recycled in Victoria in 1996.

TYPE OF MATERIAL	QUANTITY RECYCLED in tonnes
Concrete	748,000
Steel	630,000
Brick and brick rubble	102,000
Timber	12,000
Plaster	10,000

In Sydney, where demolition waste represents approximately 43% of the total solid waste stream, 40% of that demolition waste is recycled, the majority of this being crushed concrete, see Table 7 [12].

Table 7 Quantities of building material recycled in Sydney.

TYPE OF MATERIAL	QUANTITY in tonnes
Concrete	510,000
Other	90,000

Approximately 350,000 tonnes of demolition waste was recycled in South Australia in 1998 [13] and solid waste disposal in landfill has been reduced by 27% in the past eight years. This is partly due to a dramatic increase in demolition material recycling in the state.

Quantities of Waste and Recycling Summary

Australia wide there are quite good rates of reuse and recycling for demolished residential building materials. From 50% to 80% of materials are salvaged, and the majority of this is reused without any form of reprocessing. The rates of recovery for commercial buildings is much lower, in some places up to 69% of demolished materials, but the majority of this is reprocessed or recycled to make new materials and components. The majority of this recycled material is crushed concrete. Approximately 70-80% of demolished concrete is recovered for crushing and reuse as aggregate.

Figure 2 Concrete recycling plant, Brisbane.

2.3 EMBODIED ENERGY

One of the more significant issues related to reusing materials, is that of embodied energy. Embodied energy is the energy required to produce or manufacture a product. This includes all or the direct energy used in the manufacturing process, and all of the indirect energy required to obtain the raw materials, transport them, and to produce the machines and infrastructure used in these production activities.

Reusing materials can greatly reduce, or avoid, the energy required for the production of new materials to replace those already in service. Reduction in energy requirements from reusing materials produces a corresponding reduction in environmental damage, particularly greenhouse gas production. Several researchers have pointed out the energy benefits of reusing materials, and the benefits of a design for disassembly or design for deconstruction strategy that would make it easier to recover materials for reuse [14] [15].

Data Quality
Embodied energy analysis in Australia is not well developed, primarily due to the lack of reliable process analysis data for building materials and components, and the lack of consensus in the mater of measurement systems [16]. While there are recent databases for embodied energy values, the validity of those values has been questioned by several researchers [17] [18] [19].

Significance
Despite these concerns there has been valuable research into the significance of embodied energy within the life cycle energy of the built environment. This research highlights the potential

energy savings that could be made through the reuse of materials and components. Different researchers show that embodied energy can be from 30% to 50% of total life cycle energy [20] [21] [22] [23]. One of the reasons for these high percentages of embodied energy, is the low level of operational energy in Australia compared with other developed countries. This is due to the relatively mild Australian climate that results in buildings that need much less artificial heating or cooling than those in more severe climates.

These studies show that while research into reducing operational energy is still important, more research on reducing embodied energy is needed. Deconstruction for reuse and recycling is emerging as one strategy that has the potential to significantly reduce the overall embodied energy consumed by buildings.

The embodied energy significance of different parts of the building has also been investigated [24]. A study of the refurbishment of a multi story office building, has shown that the retained structural frame and floor slabs represented approximately 60% of the total embodied energy, while the removed cladding, internal walls, services, and fit-out represented approximately 40%. The potential energy saving in reusing removed items is very high. In the case study building, the removed items were replaced with new materials and components whose embodied energy represented more than half as much again as those removed.

One Australian study of embodied energy significance, using international data, has also considered the energy of refurbishment within the whole life cycle energy consumption scenario. This study highlights further the significance of energy savings to be made through reuse of materials and components by showing the comparatively large portion of total energy use that is embodied in the building fabric, see Figure 3 [25].

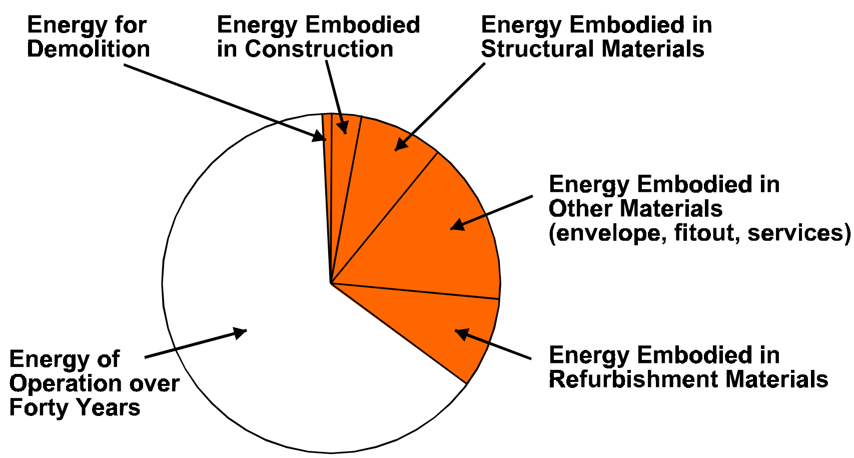

Figure 3 Total life cycle energy use over the typical forty year life of an office building, showing embodied energy to be 30% of total energy use.

Recycling Energy
There are several Australian research projects that have investigated the energy savings to be made through reuse and recycling of demolished or deconstructed building materials.

Research at Deakin University has investigated the embodied energy values of timber wall studs, steel studs, and recycled steel stud [26]. The study shows that 'recycled steel' studs require approximately half the embodied energy of 'average steel' studs, but the study also points out that the methods of assessment are not consistent enough to draw any meaningful conclusions.

Research has been conducted by the government research organisation CSIRO into the energy expenditure of recycling demolished concrete [27], which as mentioned previously has high recovery rates of up to 80% in Australia. Surprisingly this case study showed that using recycled crushed concrete as aggregate used 37% more energy than using new quarried aggregate. The greater energy requirement is primarily caused by increased transportation requirements. In the case study the concrete rubble was transported further to the crushing plant than if it had been transported to a landfill site. The study points out that:

"With all other factors remaining unchanged the recycling option becomes favourable (break-even) when the (demolished) concrete rubble has to be transported to a (landfill) tip more than 13km from the demolition site".

This study is obviously limited to energy consumption issues and does not take into account other environmental burdens associated with the disposal of demolished concrete. Despite this, this study does show that it is not always reasonable to assume that recycling is the most environmentally beneficial option, and that a holistic life cycle assessment needs to be made.

Embodied Energy Summary
Embodied energy, and other life cycle assessment knowledge, is not well developed in Australia, but there is a growing awareness of the significance of the energy of consumption and the part that materials reuse can play in reducing energy consumption. In Australia, with its mild climate where the majority of the population lives, the issues of embodied energy are highly significant in comparison with operational energy issues. As yet though, operational energy research is far ahead of that for embodied energy.

2.4 POLICY AND LEGISLATION

Australia has three hierarchical levels of government: the Commonwealth Government, which represents the whole country, the State and Territory Governments, and the local Governments and Councils. All three levels of government have various responsibilities in the areas of environment, waste minimisation, recycling, and construction and demolition.

Table 8 Australian waste management and recycling legislation and policy [28].

STATE/TERRITORY	LEGISLATION	POLICY

Commonwealth	Natural Heritage Trust of Australia Act 1997 National Environment Protection Measures (Implementation) Act 1998 Environmental Protection and Biodiversity Conservation Act 1999	Waste Management Awareness Program Natural heritage Trust – Waste Wise Construction Program Building Code of Australia
Australian Capital Territory	Environmental Protection Act 1997	No Waste by 2010 strategy Development Control Code for Best Practice Waste Management in the ACT 1999
New South Wales	Waste Minimization and Management Act 1995 Protection of the Environment Operations Act 1997	Construction and Demolition Waste Action Plan 1998 Waste Planning and Management Fund Waste Reduction and Purchasing Policy – A Guide for Agencies 1997 Waste Education Strategic Directions Statement 2000-2002
Northern Territory	Waste Management and Pollution Control Act 1999 Environmental Assessment Act 1994	Waste Management and Pollution Control Strategy 1995
Queensland	Environmental Protection Act 1994	Waste Management Strategy for Queensland 1996
South Australia	Environment Protection Act 1993	Environment Protection (Waste Management) Policy 1994 (Draft) Environmental Protection (Waste Reduction, Recycling and Disposal) Policy 1999
Tasmania	Environmental Management and Pollution Control Act 1994 Land Use Planning and	

	Approvals Act 1993 Environmental Protection (Waste Disposal) Regulation 1974	
Victoria	Environment Protection Act 1970 Environment Protection (Amendment) Act 1996	Becoming Waste Wise Education Program EcoRecycle Victoria
Western Australia	Environmental Protection Amendment Act 1998 Environmental Protection (Landfill) Levy Act 1998	WA Waste Reduction and Recycling Policy Waste Management and Recycling Fund

Commonwealth Government
Australia is a signatory to the United Nations *Agenda 21*, and since 1992 has been committed to the *National Strategy for Ecologically Sustainable Development*.

Australia, as a member of the *Australian and New Zealand Environment Conservation Council* (ANZACC), is committed to achieving a target of a 50% reduction in waste going into landfill by the year 2000, based on 1990 levels. The Commonwealth Government's primary initiative to help achieve this goal has been the *Waste Management Awareness Program*, which among its funding initiatives supports the *WasteWise Construction Program*. The construction and demolition industry has been specifically targeted for waste reduction because up to 40% of landfill waste is generated by the building industry [29].

The *WasteWise Construction Program* was initiated in 1995 as an agreement between five major construction companies and the Commonwealth Government, with an aim to develop best practice in waste minimisation during construction and demolition. The program achieved greatly improved rates of recycling and reuse though most attention was centred on construction rather than demolition. The first stage of the program has resulted in the publication of a guide, *WasteWise Construction Program Handbook: Techniques for reducing Construction Waste*, but as the title suggests this publication does not cover demolition material recycling or reuse [30].

Other Commonwealth Government initiatives include the Housing Industry Association's *Partnership Advancing The Housing Environment* (PATHE) program which was launched in 1999 and which will deliver projects that aim to reduce waste, encourage recycling and enhance the housing industry's overall environment management practices.

The Commonwealth Government will also shortly commence the program *Lifecycle Assessment In Building And Construction*, which will seek to promote life cycle considerations in the construction and demolition industry to improve understanding of material and building impacts and opportunities for reuse and recycling of building materials and components.

The *Commonwealth Environment Protection Agency* is responsible for many issues regarding waste management and pollution but does not directly address issues of demolition waste. It does however identify common barriers to greater waste minimisation in general, and these barriers are true for demolition waste in particular [31];

- Absence to uniform national approach to waste minimisation.
- Lack of information on the extent, types and source of waste.
- Waste management charges that are; too low to be an incentive to avoid waste, unable to provide funding for the environmental cost of waste disposal, and poorly structured.
- Insufficient private sector interest for investment in waste management technologies.

The Commonwealth Government is also responsible for the *Building Code of Australia*. This code is not in itself legislation, but is called up by individual state legislation. The code is one of the primary sources of building regulations that affect the design of buildings. The code however has no reference, recommendations or restrictions on the use of reused, recycled or second-hand materials, nor does it address the issues of deconstruction.

While Australia seeks to improve its rates of recycling and reuse, particularly in the construction and demolition industry, Commonwealth Government policies have been quite broad and unspecific with no particular guidance, initiatives, or legislation on the topic of building deconstruction and material reuse. In general, most controls over construction and demolition issues rest with the state, territory and local governments.

Australian Capital Territory Government

In 1996 the Australian Capital Territory (ACT) Government launched the *No Waste By 2010 Waste Management Strategy*. This strategy aims at elimination of all waste going to landfill by the year 2010. In the last five years significant gains in resource recovery have been made, particularly with demolition waste, which now represents 50% of total waste being recycled or reused. The new *Development Control Code for Best Practice Waste Management in the ACT*, which at present relates only to the demolition sector, is expected to guide the way to total landfill elimination, though it is too early to judge results [32].

Legislation

Unlike other State governments, who rely on environmental legislation to achieve waste management policy, the ACT Government relies upon building and development legislation. Amendments to the Building Act 1998 require a waste management plan be incorporated into the approval process for demolition of any building. Any application for building demolition must be accompanied by a waste management plan, which must outline the proposed reuse, recycling or disposal of materials and components.

Market development

The ACT Government has established the *Canberra (ACT) Resource Exchange Network*, an Internet exchange base for reusable materials and items. The ACT Government is also the administrator of the *Australian Reusable Resource Network*, an Australia wide Internet exchange service where individuals and companies can list items for exchange, or requests for items they seek. Both of these networks include building materials and components. They can be found at:

http://www.act.gov.au/nowaste/exchange.html

http://www.arrnetwork.com.au/workplace/sb_sab.main

New South Wales State Government

The New South Wales (NSW) Government introduced the *Waste Minimisation and Management Act* in 1995, and the *Protection of the Environment Operations Act* in 1997. Under these acts the government established eight regional Waste Planning and Management Boards and initiated a number of waste management programs targeted at the construction and demolition industry. These initiatives include the development of a waste exchange directory for construction and demolition materials. This directory lists businesses that transport, recycle and reuse construction and demolition materials and building components [33].

Building approval

Under the *Local Government (Approvals) Regulation NSW 1993*, all applications for permission to build in New South Wales must identify the reuse of second-hand materials [34].

"The specification of the building is … to state whether the materials will be new or second-hand and give particulars of any second-hand materials to be used."

This requires the person preparing the application, usually the architect, to identify all reused and recycled materials at the time of seeking council approval. Since approval is usually sought as soon as possible, before all construction details are resolved, this requirement means that architects must attempt to predict the use of reused materials. Any changes to the reused materials specified during the project must be later processed through council as an amendment to the application. Such bureaucratic requirements are unlikely to encourage creative thinking about specifying reused materials and components.

All applications for construction and demolition work to be undertaken in NSW must also now be accompanied by a waste management plan that outlines the quantities and types of waste that will be generated and the intended means of treatment. This is the first step in legislation that will eventually set compliance levels in an effort to increase the rates of reuse of demolition materials.

L*andfill levy*

The NSW Government, like many other states, has introduced a waste levy on materials going to landfill with a view to encouraging recycling and reuse as alternatives, this levy is currently set at $17.00 per tonne.

Grants

The NSW Government has also provided grants to private industry, each up to $50,000 for the development of recycling and reuse technologies and practice. Projects funded to date under this scheme include [35]:

- Development of new methods of blending recycled brick to meet existing engineering specifications as new construction products.

- Development of an air classification process to extract lightweight contaminants such as wood, paper and plastic from residual hard waste collected at demolition sites.

- Support of the on SITE Internet site for construction and demolition waste minimisation, developed by the Centre for Design at RMIT, this Internet site includes a database of contacts for used building materials exchange.
  http://onsite.rmit.edu.au

Northern Territory Government
Although the Northern Territory Government recently implemented the *Waste Management and Pollution Control Act 1999*, no particular actions or strategies were identified for the construction and demolition industry. There are policies on waste minimisation, but no reference to construction or demolition waste.

Queensland State Government
In 1996 the Queensland State Government introduced the *Waste Management Strategy for Queensland*. This strategy identified a number of objectives with direct relevance to the construction and demolition industry, two of which address the reuse of demolished building materials:

- Objective 7.1 states that *'where any government building is being demolished or any site redeveloped by a government agency, a waste recovery program for all useable materials will be introduced where practicable'*.

- Objective 5.9 the Queensland Government is to develop material specification guidelines for the recycling of secondary aggregates.

These initiatives have not yet produced any measurable results or case studies that have been researched.

Building Approvals
The *Queensland Standard Building Law 1991*, like that of New South Wales, requires the use of any reused or recycled materials to be specified at the time of application [36].

"lodge specifications … stating whether the materials will be new or second-hand and, if second-hand materials are to be used, giving particulars as required by the appropriate building officer; …"

Landfill Levy
There is currently no landfill levy in Queensland.

Grants

In 1993-94 the Queensland Government initiated the *Recycling Industry Incentive Scheme* with an aim of increasing the demand and supply of recycled materials. This scheme provides grants for establishing or developing industry that utilises recycled and reused materials or produces equipment for new recycling processes [37].

South Australian State Government

The primary piece of waste management legislation in South Australia is *the Environment protection Act 1993* which operates in conjunction with the *Environment Protection (Waste Management) Policy 1994*. The legislation does not however have any particular references to construction and demolition waste, nor the recycling of it.

Landfill Levy

The South Australian landfill levy is $4.00 per tonne.

Tasmanian State Government

The *Environmental Management and Pollution Control Act 1994* is the primary piece of legislation dealing with waste management and recycling in Tasmania. The act sets out many objectives for waste reduction and improved recycling but has no specific requirements for the construction and demolition industry.

The Tasmanian Government has established a target of 50% solid waste reduction by the year 2005 compared with 1990 levels. To this end the government is producing a *Waste Recovery and Recycling Directory* that will list organisations involved in the reuse and recycling of materials including construction and demolition waste.

Landfill Levy

There is currently no landfill waste levy in Tasmania

Victorian State Government

The government body, EcoRecycle Victoria, is the agency responsible for waste minimisation and recycling in Victoria. EcoRecycle Victoria is not a legislative body but attempts to achieve its goals through co-operation with local government and private industry. EcoRecycle Victoria is funding a number of activities with construction and demolition industry relevance [38]:

- a market development program for recycled and reused materials including an Internet site with recycling guidelines and information on material availability in the form of an exchange database.
  http://www.ecorecycle.vic.gov.au/

- best practice education and promotion through conferences and exhibitions such as *The Business of Recycling* (June 1999).

- Government purchasing procedures including tender guidelines that address issues of, waste management, material recycling, design for disassembly, and standardisation, (discussed in section on 'Design Practice' in more detail).

Landfill levy

EcoRecycle Victoria is primarily funded by the landfill levy, which is currently set at the comparatively low rate of $3.00 per tonne.

Western Australian State Government

The Western Australian Government's *Waste Reduction and Recycling Policy* of 1997 is an attempt at addressing the rates of waste disposal in that state. The policy does not however specifically address the issues of construction and demolition waste. Despite this the government has initiated a number of demolition waste reduction and recycling projects.

Grants

The Western Australian Government established a landfill levy in 1998, the funds from which have been used in the form of grants to fund a variety of industrial waste minimisation and recycling projects including [39]:

- Develop guidelines to recycle concrete and masonry aggregate for use in new concrete construction.
- Develop certified road base to Main Roads specifications from recycled demolition waste.

Policy and Legislation Summary

In general, Australian legislation and policy is silent on the issues of demolition and deconstruction, and demolition material recycling and reuse. There are some government programs in place that encourage or promote building material recycling and reuse but these are fairly limited:

- Commonwealth commitment to a 50% reduction in solid waste creation, with the construction and demolition industry targeted as a major contributor.
- Landfill levies in most states used to discourage waste disposal, but fees are generally set too low to encourage wide scope recycling.
- Grants for the development of new recycling and reuse technologies including construction and demolition waste, primarily concerned with recycled concrete and aggregate.
- The promotion and development of markets for reused building materials, particularly through Internet exchange databases.

2.5 DESIGN PRACTICE

The use of reused and recycled materials in new construction is often controlled by a variety of documents that are used both before and during the construction process. These include contracts, specifications, tender applications, building codes, and building approval applications.

These various design process documents can have a major bearing on the decision to reuse or recycle materials. In Australia there are so called 'standard' forms of many of these documents that may be used and adapted for individual projects. Unfortunately the standard forms of some of these documents, in their current draft, actually work to discourage the creative deconstruction of buildings and the reuse of second-hand materials.

Contracts

Australia has a number of widely used standard forms of building contract. These contracts are written and recommended by organisations such as the Australian Standards Association, the Royal Australian Institute of Architects, the Master Builders Association, and the Commonwealth Government. While none of the commonly used standard contracts specifically cover deconstruction or the use of reused materials, many of them do prohibit the use of reused materials through a default clause that states that materials should be new unless otherwise specified [40]. Typical examples include:

- AS 4000 clause 29.1 *"Unless otherwise provided the Contractor shall use suitable new materials.."*

- JCC clause 6.08.02 *"Any material not otherwise specified shall be new."*

- EJCDC clause 6.5 *"All materials and equipment shall be of good quality and new, except as otherwise provided in the Contract Documents."*

- AIA A201 clause 3.5.1 *"The Contractor warrants ... that materials and equipment furnished under the Contract will be of good quality and new unless otherwise required or permitted by the Contract Documents, …"*

- C21 clause 53.2 *"Where the nature of materials is not specified in the Contract, new materials are to be used unless the Principal agrees in writing to the use of recycled materials of equivalent standard."*

- PC-1 clause 9.1 *"The Contractor must in carrying out the Contractor's Activities … use materials which … if not fully described in the Contract, are new … and of merchantable quality …"*

The effect of these default clauses is to require the person preparing the contract documents, usually the architect, to specifically state which items are to be of reused or recycled materials. In large projects this task is quite onerous, and any changes to the specifying of reused materials during the project will require the issue of notifications to the contractor and the processing of paperwork. This all has the risk of encouraging the architect to simply leave the matter alone and let the default clause take effect.

Although these contracts represent a large portion of the standard contracts used in Australia, there are some standard contracts that do not default to the use of new materials. These include SBW-2, UAV, JCT-80, and ICE.

Specifications
There are several forms of standard specification used in Australia, the most widely used is perhaps *Natspec*. This family of standard specifications does make reference to demolition, and provides for a 'salvaged items disposal schedule' and a 're-used items schedule' that can be used to list any demolished items or materials that are to be reincorporated into the works.

In new construction work, Natspec does not make any default requirements for the use of 'new' materials, but also offers no guidance for the specifying of reused or recycled materials.

Tender Guidelines
EcoRecycle Victoria provides guidance for waste minimisation in construction and demolition including *Tender Guidelines for Construction and Demolition Projects*. These guidelines are intended for inclusion in general tender guidelines for construction and demolition projects. They require tender applicants to submit information on a variety of topics, generally in the form of proposals for how the tenderer will deal with certain issues, including [41]:

- Integrated waste minimisation
- Waste avoidance
- Building for disassembly
- Use of recycled and recyclable materials
- Deconstruction

These tender guidelines are intended to allow clients and architects to select a contractor who will be in sympathy with client aims regarding waste reduction and recycling.

Building Code
The *Building Code of Australia* is one of the main legislative instruments covering the design and construction of buildings. It consists of recommendations and minimum standards for a variety of structural, and health and safety issues. It makes no requirements or restrictions on deconstruction, nor the use of reused or recycled materials or components (see also 'Policy and Legislation').

Building Approvals
Some state government building regulations require that an application for building approval includes a specification of the building design that states whether any reused or recycled materials are to be used (see also individual state sections in 'Policy and Legislation').

Design Practice Summary
Many of the standard documents and mechanisms of design control and realisation work to encourage the use of new materials rather than reused materials. Most specifications, contracts, and materials standards are based on the use of new materials with the idea that new is better. Some are silent on the issue, but none, other than the EcoRecycle Victoria tender guidelines, actively promote the use of reused materials over new.

2.6 DEMOLITION METHODS

The most common method of demolition, particularly of commercial and industrial buildings, is a stage by stage removal of the building's fittings and fixtures, then the demolition of the building proper using large plant such as bulldozers, cranes, and excavators [42]. There is only limited explosive demolition conducted. As discussed elsewhere in this report the demolition of residential buildings is often conducted by manual labour to more successfully recover large amounts of materials.

The Australian Standard for demolition is *AS 2601-1991 The Demolition of Structures*. This standard allows for both destructive demolition, and deconstruction for the recovery of reusable materials and components. The standard requires the preparation of a demolition work plan for approval by the local government authority, which is to include description of the handling and disposal methods to be employed [43].

2.7 INITIATIVES IN RECYCLED MATERIALS

As discussed, high levels of residential material recycling occur in Australia. Up to 80% of all residential deconstructed materials and components can, and are, reused or recycled.

In Australia up to 70-80% of demolished concrete is crushed for reuse as aggregate. The majority of this is used for new road base aggregate. Recent increases in the rates of concrete crushing have altered the economic patterns of waste disposal. A few years ago concrete recyclers charged to remove demolished concrete, now competition is such that they remove it for free.

Demolished concrete is broken up using mechanical machinery and the reinforcing steel is removed for recycling. The concrete is then further crushed and the remaining steel is electro-magnetically removed before any other contaminants are removed by hand. In the mid 1990's crushed concrete sold as aggregate for up to $15 per tonne [44].

The Commonwealth Government research organisation, CSIRO, and Alex Fraser Recyclers Pty Ltd are currently conducting research into the use of crushed concrete as an aggregate for use in new concrete. This research includes trials of premix concrete made with 100% recycled concrete aggregate. Trials are currently for use in non-structural applications such as paths and driveways [45]. While there are definite environmental and economic benefits from recycling concrete in this way, the energy requirements of such a process have come under scrutiny as discussed elsewhere in "Embodied Energy".

2.8 INNITIATIVES IN DECONSTRUCTION

For forty thousand years Australians have lived with temporary structures that have reused materials in primitive dwellings. Even in the last two hundred years of European settlement there has been considerable activity in the area of reuse, and in particular, design for disassembly.

Portable Cottages

In 1788 when the first European settlers arrived in Sydney Cove in Australia, Governor Phillip brought with him from England a prefabricated portable house with a structural frame of timber and a roof and walls of painted cloth [46]. This house was designed to be deconstructed for relocation. In the following decades many similar designs for portable cottages were seen in Australia. The success of this technology was in part due to the shortage of suitable material for building and the shortage of skilled labour.

Among the most successful manufacturers of these cottages was John Manning of London. Manning's cottages, which came in standard designs of from one to four rooms, were constructed of a bolted timber frame and interchangeable timber panels [47]. A newspaper advertisement of 1837 described the Manning portable cottage as being;

'manufactured on the most simple and approved principles . . . complete for habitation in a few hours of landing. They may be taken to pieces and removed as often as the convenience of the settler may require' [48].

Timber was a popular choice for construction, but it was not the only material used in these prefabricated buildings. With the development of corrugated sheet iron in the early 1820's and the patenting of hot-dip galvanising in 1837, portable iron cottages became a common way of dealing with the building shortage in Australia. The sheet metal's light weight made it ideal for transport and for re-use, and it was soon used, and re-used, for everything from cottages to churches and from warehouses to hotels [49].

Timber Cottages

The development in the later part of the Nineteenth Century of modern timber framing techniques saw the proliferation of standard timber sizes for structural members and for wall and floor linings. Such developments eventually led to the kit house, a more permanent version of the portable cottage. The standardisation of materials and components allowed the houses to be easily adapted, extended or relocated.

Contemporary Houses

The continuing high rates of material and component re-use in the residential sector (as discussed earlier in 'Quantities of Waste and recycling') are perhaps best illustrated through two recent developments in residential construction. These are the use of relocated houses and parts of houses in projects by architects, and the emergence of new systems of prefabricated buildings that have the added advantage of being deconstructable for reuse or recycling.

Relocation

The relocation of timber houses has traditionally been the realm of speculative builders developing subdivided suburban blocks. Architects who have explored the greater possibilities from this activity are now adopting this common practice. In these projects, the halves or sections of relocated houses are re-joined in a new geometry that makes better use of environmental aspects such as solar access, cross ventilation, and general aspect [50]. In this way whole sections of houses are reused in a relatively intact form, Figures 4 and 5.

In these examples the nature of the material (timber), the joining techniques, and the standardisation of members, has allowed for large-scale reuse of building elements in a creative manner. This relocation of timber houses continues a strong history of building alteration and refurbishment for re-use.

Figure 4 House during relocation – house has been relocated in two halves that are set apart to create new relationship (by Jeremy Salmon Architect).

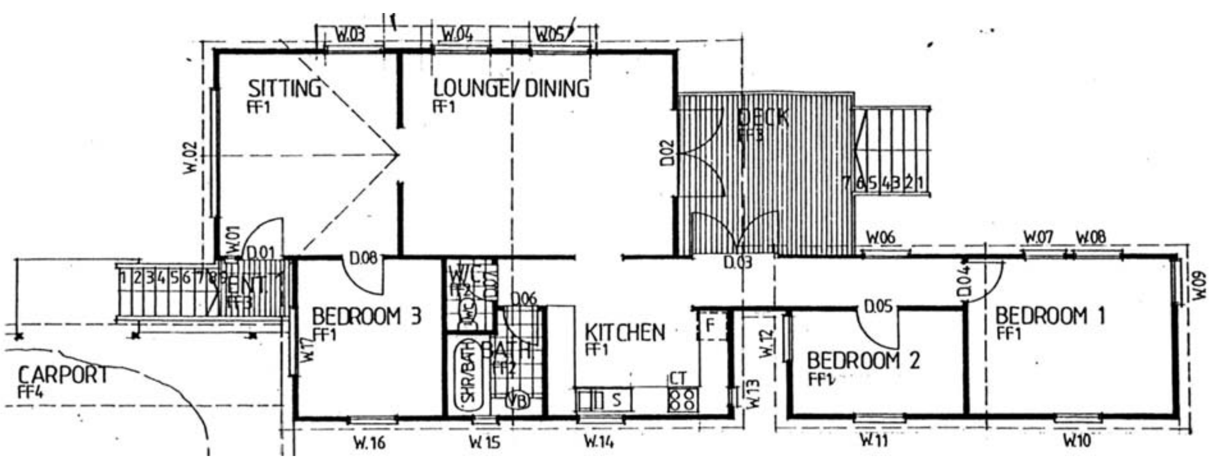

Figure 5 Floor plan of house relocated in two halves set apart (by Jeremy Salmon Architect).

Prefabrication

Prefabricated housing has not reached high levels in Australia where most new housing is in the form of detached houses built on site by major ‘project’ building companies. Some companies are however attempting to break into the ‘project home’ dominated market with prefabricated low-cost building systems. These companies are using various technologies, sometimes patented, to develop modular systems that allow not only assembly, but also future disassembly. Such disassembly is presented as an advantage for future adaptability of the house should the family structure alter. While the re-use of elements is limited to the same building or other buildings utilising the system, the environmental and waste management benefits of this practice have been identified [51] [52].

Non-residential Examples

Although housing is the major area of deconstruction activity there are some other interesting examples and initiatives. The much-publicised ‘Green’ Olympics of Sydney 2000 have sadly failed to deliver much environmental sustainability. Deconstruction and reuse has been limited to the reuse of crushed concrete from demolished buildings on the site and relocation of rock and soil from excavations. The principle stadium for the games is believed to be the first major Australian building to have undergone a full life cycle assessment [53]. The building does not however utilise recycled or reused materials though 76% of the structure is capable of being recycled in the future.

The Olympic Games site has also provided the opportunity for a relocatable viewing platform. A 200m^2 platform was designed to allow for relocation to different parts of the site to best allow viewing of the various construction projects. Features of the structure that allow disassembly include; steel and timber construction as best to reduce size and load, paired structural members that support edges of roofs during disassembly, and stainless steel dowel connections [54].

The World Exposition of 1988 in Brisbane saw the construction of numerous temporary buildings that were designed to be dismantled after the event and relocated for reuse. The prefabricated panel system and bolted external structural frame have allowed the buildings to be easily disassembled, relocated, and converted for use as commercial and industrial buildings.

There are other deconstruction projects, though most, such as remote research stations and the relocatable viewing platform in the Royal Botanical Gardens in Tasmania [55], are isolated projects that are not accompanied by any research or greater intent other than fulfilling their own brief.

Initiatives in Deconstruction Summary

While these non-residential examples do illustrate the potential of deconstruction as a strategy for both economic and environmental benefit, they are isolated incidents. The vast majority of deconstruction activity in Australia is in the residential sector. Australia has a strong history of building material reuse that is in part due to;

- the construction technology and materials of older detached houses

- the history of the pattern of European settlement
- the current popularity of 'historic character' houses

2.9 RESEARCH IN DESIGN FOR DECONSTRUCTION

Design for deconstruction has a notable history in Australia, but an understanding of this as a strategy for environmental benefit is only just developing. A few authors and researchers have highlighted the environmental benefits of such a strategy and conducted some research into this area.

Research

In research led by an Australian academic, a survey of worldwide designers and construction professionals was used to develop a number of guidelines for designing for building systems replacement [56]. The resultant guidelines provide design assistance for designing for future disassembly of building services components. Though the research provided a large number of guidelines, many of them are very specific to certain building systems and services and have no apparent general relevance to disassembly issues.

Other authors have discussed deconstruction issues in a more general way and presented broad guidelines and policies for designing for deconstruction [57] [58]. These studies point out the environmental benefits of deconstruction in a generic sense.

Guidelines

A more comprehensive study of design for disassembly guidelines is currently being conducted at Queensland University of Technology [59]. This study has analysed disassembly guidelines from industrial design practice, and guidelines from architectural technology, to develop a list of architectural guidelines to assist designers in creating a building that is easier to deconstruct. The guidelines can be used to assess the extent to which a building, or building design, can be deconstructed for material recovery. The guidelines will eventually be used in an assessment matrix to identify opportunities for the redesign of the building to achieve improved rates of material and component reuse. The environmental benefits of such a strategy have also been investigated in a life cycle scenario [60]. The guidelines being developed will be related to four possible scenarios of recovery (see Figure 6), which are presented as a hierarchy where reuse is preferred to reprocessing or recycling.

Strategies for Material Recycling

- Use recycled materials – increased use of recycled materials will encourage industry and governments to investigate new technologies for recycling, and to create a larger support network for future recycling and reuse
- Minimise the number of different types of materials – this will simplify the process of sorting materials on site and reduce transport to separate reprocessing plants
- Avoid hazardous or toxic materials – this will reduce the potential of contaminating materials that are being sorted for recycling and will also reduce the potential for human health risks during disassembly that may make recycling a less attractive option

- Make inseparable sub assemblies from the same material – this means that larger amounts of one material will not be contaminated by small amounts of a foreign material that can not be separated
- Avoid secondary finishes and coatings where possible – such coating may contaminate the base material and make recycling less practical, where possible use materials that provide their own suitable surface finish or use separate mechanically connected finishes (some protective coatings such as galvanising will still be desirable in some situations for other reasons)
- Provide permanent identification of material types – many materials such as plastics are not easily identified and should have some form of non removable and non contaminating identification mark to allow future sorting of materials

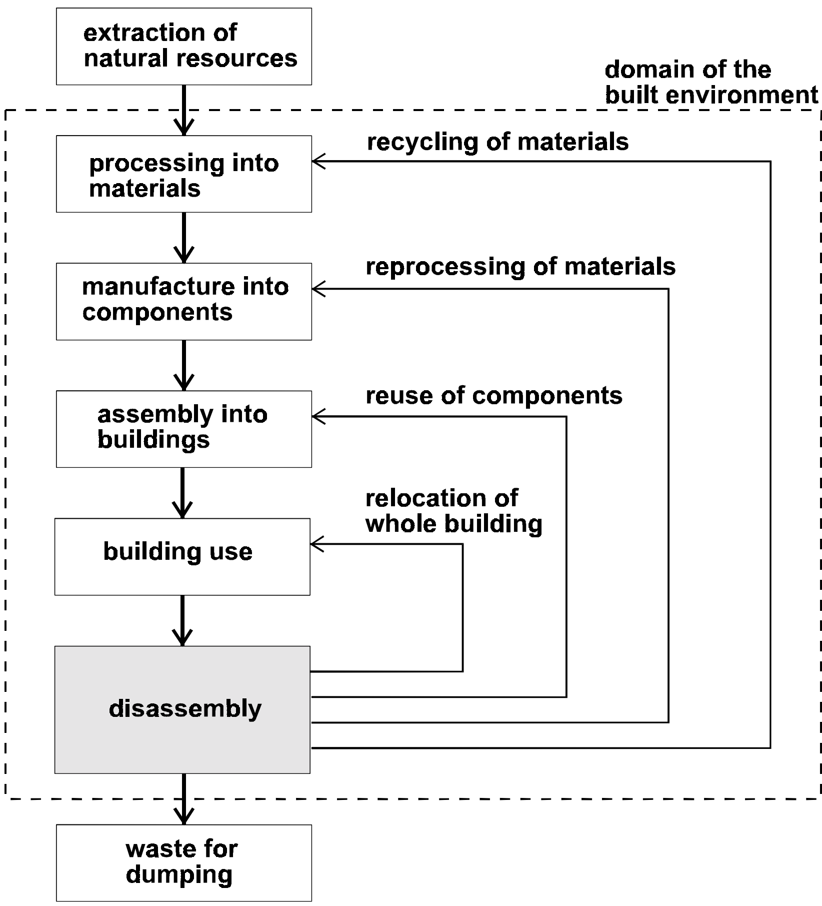

Figure 6 The four scenarios for materials reuse in the built environment.

Strategies for Component Reprocessing

- Minimise the number of different types of components – this will simplify the process of sorting on site and make the potential for reprocess more attractive due to the larger quantities of same or similar items
- Use a minimum number of wearing parts – this will reduce the number of parts that need to

be removed in the remanufacturing process and thereby make reprocessing more efficient

- Use mechanical connections rather than chemical ones – this will allow the easy separation of components and materials without force, and reduce contamination to materials and damage to components
- Make chemical bonds weaker than the parts being connected – if chemical bonds are used they should be weaker than the components so that the bonds will break during disassembly rather than the components, for example mortar should be significantly weaker than the bricks

Strategies for Component Reuse

- Use an open building system – this will allow alterations in the building layout through the relocation of components without significant construction work
- Use assembly technologies that are compatible with standard building practice – specialist technologies will make disassembly difficult to perform and may require specialist labour and equipment that makes the option of reuse less attractive
- Separate the structure from the cladding, the internal walls, and the services – to allow parallel disassembly where some parts of the building may be removed without affecting other parts
- Provide access to all parts of the building and all components – ease of access will allow ease of disassembly, if possible allow for components to be recovered from within the building without the use of specialist plant equipment
- Use components that are sized to suit the intended means of handling – allow for various possible handling options at all stages of disassembly, transport, reprocessing, and reassembly
- Provide a means of handling components during disassembly – handling during disassembly may require points of connection for lifting equipment or temporary supporting devices
- Provide realistic tolerances to allow for movement during disassembly – the disassembly process may require greater tolerances than the manufacture process or the initial assembly process
- Use a minimum number of different types of connectors – standardisation of connectors will make disassembly quicker and require fewer types of tools, even if this result in the over sizing of some connections, it will save on assembly and disassembly time
- Use a hierarchy of disassembly related to expected life span of the components – make components with a short life expectancy readily accessible and easy to disassemble, components with longer life expectancy may be less accessible or less easy to disassemble
- Provide permanent identification of component type – similar to material identification, may use electronically readable information such as barcodes to international standards

Strategies for Building Relocation

- Standardise the parts while allowing for an infinite variety of the whole – this will allow minor alterations to the building without major building works
- Use a standard structural grid – grid sizes should be related to the materials used such that structural spans are designed to make most efficient use of material type
- Use a minimum number of different types of components – fewer types of component

means fewer different disassembly operations that need to be known, learned or remembered – it also means more standardisation in the reassembly process which will make the option of relocation more attractive

- Use lightweight materials and components – this will make handling easier, quicker, and less costly, thereby making reuse a more attractive option
- Permanently identify point of disassembly – points of disassembly should be clearly identifiable and not be confused with other design features
- Sustain all information on the building manufacture and assembly process – measures should be taken to ensure the preservation of information such as 'as built drawing', information about disassembly process, material and component life expectancy, and maintenance requirements

Research in Design for Deconstruction Summary

The first research steps in understanding how to achieve better building deconstruction through design are being taken. Several researchers have presented strategies for designing for better deconstruction. These strategies or guidelines are presented as a starting point in thinking about design for deconstruction. As each building project is unique there can be no universal strategies that will always apply, and some of these strategies may be in direct conflict with other environmentally sustainable strategies. Like all attempts at improving our environmental performance, design for disassembly must be considered in a holistic way along with all of the environmental life cycle factors that may affect a project.

2.10 RECOMMENDATIONS

There are many issues regarding deconstruction in Australia that need to be reformed. The high rate of material and component reuse in the residential building sector offers a good example, but performance in the commercial and industrial building sector is poor. In general government policy is neither helpful nor encouraging, and it is still too easy to simply throw used materials and components away.

Waste and Recycling

As is evident in this report, there is no comprehensive understanding of current rates of building material waste or recycling and reuse. Better information on the rate of waste disposal is needed to highlight the extent of the problem and the need for more action. Similarly, more comprehensive information on the rates of recycling and reuse is required, and could be used to set benchmarks for compliance. It is not yet known if the Commonwealth Government will reach the target of a 50% reduction in waste going into landfill by the year 2000.

Policy

There are no effective Australia wide policies on building material and component reuse. Individual state legislation is patchy and in general does not address demolition waste directly. Since demolition waste is such a major part of the waste stream, specific policy and legislation on these matters are required, covering issues such as;

- Waste reduction
- Second-hand materials usage
- Levies and fees for waste disposal that work to encourage reuse and recycling
- Grants for research and development of reuse and recycling technologies
- Market development for reused materials and components

Design Practice

Many of the documents associated with building design, and building procurement, (specifications, contracts, applications) work directly against the encouragement of using reused materials and components. Existing documents need to be redrafted to make specification of second-hand materials easier, and to make the salvage of materials during demolition or deconstruction a more attractive option for the contractor, the client, and the designer.

Initiatives in Deconstruction

There are high rates of deconstruction and material reuse in the residential sector. The demolition of commercial buildings however does not result in such high rates of reuse. One of the possible problems is the development of suitable stable markets for these much higher quantities of materials. Some recent attempts at establishing Internet materials exchange networks have been attempted but are as yet not well supported at a commercial scale.

Other problems include the perceived economic costs associated with the time required to deconstruct rather than demolish. Experience in residential deconstruction, and research in other countries, suggests that the income from material salvage can outweigh the time costs. Research is needed to illustrate these benefits in case study building deconstruction projects in Australia.

In general, while deconstruction is practiced widely in the detached residential building sector, there is not a good understanding of it economically, or environmentally. It is also strongly reliant on the construction technology employed in those buildings. Therefore this level of reuse may not be sustainable in the decades to come when ‘modern’ buildings utilising ‘modern’ construction techniques are to be demolished or deconstructed.

Regardless, current residential practice should be used as an example to the greater construction industry of how improved levels of reuse can be achieved.

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CHAPTER 3
THE STATE OF DECONSTRUCTION IN GERMANY

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SUMMARY

This paper deals with the state of the art of deconstruction in Germany and case studies of deconstruction projects in Germany and France. Based on an overview of the national legislation concerning waste management and demolition, demolition waste is classified, recycling and reuse options are described and methods to reduce harmful substances are presented. Case studies carried out in Germany and France show a considerable potential for preserving and reusing material. Furthermore, a detailed planning, supported by adequate decision support systems for deconstruction and recycling offers improvements in construction site-management resulting in economic and environmental benefits. Sophisticated deconstruction planning tools can contribute to achieve a high quality recycling as well as cost efficiency.

KEYWORDS: Deconstruction; Dismantling and Recycling Planning; Building Audit; Case Studies; Optimal Dismantling

3.1 INTRODUCTION

Although recycling of construction materials has a long tradition in Germany the use of recycled materials is still mainly focused on low grade applications. One of the main obstacles to the use of recycled construction materials in high grade applications is the heterogeneity of the composition and the contamination of construction and demolition waste (C&D waste) resulting from demolition of buildings. As an improvement in the quality of recycled materials in processing is technically limited, efforts have been made to improve the quality of the waste arising on demolition sites. While demolition often leads to mixing of various materials and contamination of non hazardous components, deconstruction or selective dismantling of buildings instead of demolition help to preserve and reuse material. The latest developments in the German law on waste management encourage the efforts of deconstruction.

In recent years several projects have been conducted to analyse the technical and economical feasibility of various deconstruction strategies. Even though, in most cases the information published on these projects is not very detailed and the results of most of the projects conducted by private companies have not even been published, some projects are well documented and allow deriving valuable information for future activities.

In the following, the state of the art in deconstruction in Germany is shown and some case studies in Germany and France are presented. Moreover, a sophisticated planning approach and a computer tool for decision support and optimisation of deconstruction work will be introduced.

3.2 REGULATORY ASPECTS

The process of deconstruction is not well suited to regulation by conventional German legislation. In the following, the main fields of national regulation with respect to deconstruction are shortly surveyed.

Waste mangement

Legislation in the field of deconstruction is mainly focused on construction and demolition waste management, which has already quite a long history in Germany. The Recycling and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz - KrW-/AbfG) contains the basic principles of German waste management and closed-loop recycling strategies [2]. It implements the European Council Directive 91/156/EEC (revised Framework Directive on Waste, amending Council Directive 75/442 EEC) and Council Directive 91/689 EEC on Hazardous Waste, into national legislation1. The Recycling and Waste Management Act came into force two years after promulgation, on October, 7th, 1996. The hierarchy of the Act assigns priority on waste prevention. Waste that cannot be prevented should be recovered. When neither prevention nor recovery are feasible or economically reasonable waste has to be disposed. In order to comply with the principle objectives, waste designed for recovery is to be kept separate and treated separate. Recovery of waste has priority to disposal to the extent that recovery is technically possible and economically reasonable (Art. 5 Krw-/AbfG). Art. 7, 23 and 24 KrW-/AbfG authorises the federal government to enact administrative orders and statutory ordinances with the aim of enforcing prevention, recovery and to reduce contamination on wastes. The supplementary subsidiary regulations of the Recycling and Waste Management Act consist of various ordinances. These can be classified as follows:

- Ordinances that restructure supervision under waste management law and align it with EU law:
  1) The Ordinance on the Classification of Waste Requiring Special Supervision (Verordnung zur Bestimmung von besonders überwachungsbedürftigen Abfällen - BestbüAbfV) [3];
  2) the Ordinance on the Classification of Waste for Recovery that Requires Supervision (Verordnung zur Bestimmung von überwachungsbedürftigen Abfällen zur Verwertung - BestüVAbfV) [4];
  3) the Ordinance on the Furnishing or Proof (Verordnung über Verwertungs- und Beseitigungsnachweise - NachwV) [5] and

1 An overview about European legislation can be found in [1].

4) the Ordinance on Licensing of Transport
   (Verordnung zur Transportgenehmigung - TgV) [6].

- Ordinances that create a basis for further deregulation of supervision:
  5) The Ordinance on Waste Management Concepts and Waste Life Cycle Analysis
     (Verordnung über Abfallwirtschaftskonzepte und Abfallbilanzen - AbfKoBiV)
     [7];
  6) the Ordinance on Specialised Waste Management Companies
     (Verordnung über Entsorgungsfachbetriebe - EfbV)) [8] and
  7) the Directive on the Activities and Approval of Waste Management Partnerships.

One of the major general administrative orders concerning construction and demolition waste is the Technical Instruction for Municipal Waste (TA Siedlungsabfall) [9] that is originally based on Art. 14 of the former Law on Prevention and Disposal of Waste (Abfallgesetz of 27 August 1986). The TA Siedlungsabfall will come into force in stages, 2001 for construction and demolition waste and in 2005 for municipal waste. It describes that construction and demolition waste should be collected and prepared for recovery separately at the place of arising. The responsible municipalities should encourage the utilisation of mobile or semi-mobile recovery installations. It also contains requirements concerning the disposal of waste. Fractions which do not meet the requirements set out in the TA Siedlungsabfall will not be allowed to be landfilled and will have to be treated further.

The federal states (German Bundesländer) count on their own and more specific laws and regulations on waste (e.g. [10]). Some states have already introduced topics for demolition requiring organised dismantling and separation of waste on-site or at specialised treatment facilities. The municipalities or local authorities have further regulations like demolition permits or dismantling ordinances. In some cities it is already compulsory to add a deconstruction plan presenting the phases of preparation, the method of deconstruction or demolition and detailed information on the recycling of the various materials when demolition permits are required.

The German government has drafted a statutory ordinance of their objectives in the context of construction and demolition waste [11] already in 1992, which contains the requirements of waste prevention, recovery and disposal without affecting the quality of the environment. The draft also contains targets for waste management. For demolition waste ("Bauschutt") a recycling rate of 60% should be accomplished by 1995. In 1993 a draft of an ordinance of construction and demolition waste was formulated and in 1996 a new draft of the objectives of the federal government was launched which contains certain requirements for the demolition or deconstruction, respectively [12]. For the first time the draft requests, among other things, a deconstruction planning that enables a separation of recyclable materials. The recycling rates of the former draft were modified in a way that the disposal of recyclable construction and demolition waste should be reduced by 50% based on 1995 levels by 2005. The mentioned drafts have not come into force yet but instead a Voluntary Agreement has been signed (see below).

Requirements for the environmental compatibility of recycling material
In order to utilise processed construction and demolition waste it has to compete with new materials. In Germany several instructions and regulations determining quality standards for recycling materials have been elaborated. Most of them are for the use in road construction (e.g. regulations by the research institute for road and traffic systems [13,14] or RAL quality labels (RAL 501-1: Recycling-Baustoffe für den Strassenbau) [15].

The Länder Working Group Waste (Länderarbeitsgruppe Abfall – LAGA) elaborated technical rules for the valuation of mineral residue and waste, especially building waste [16]. In these, the parameters to be examined, as well as standardised examination methods, were laid down. Installation classes containing reference values for the examination of building waste were set up as in accordance with Figure 1. Decisive in the lay down of these reference values is, by rule, the protected groundwater. In addition to this, effects on the natural ground function by the inserted recycling materials should be minimised. This is why values for both eluate and solid materials were supplied.

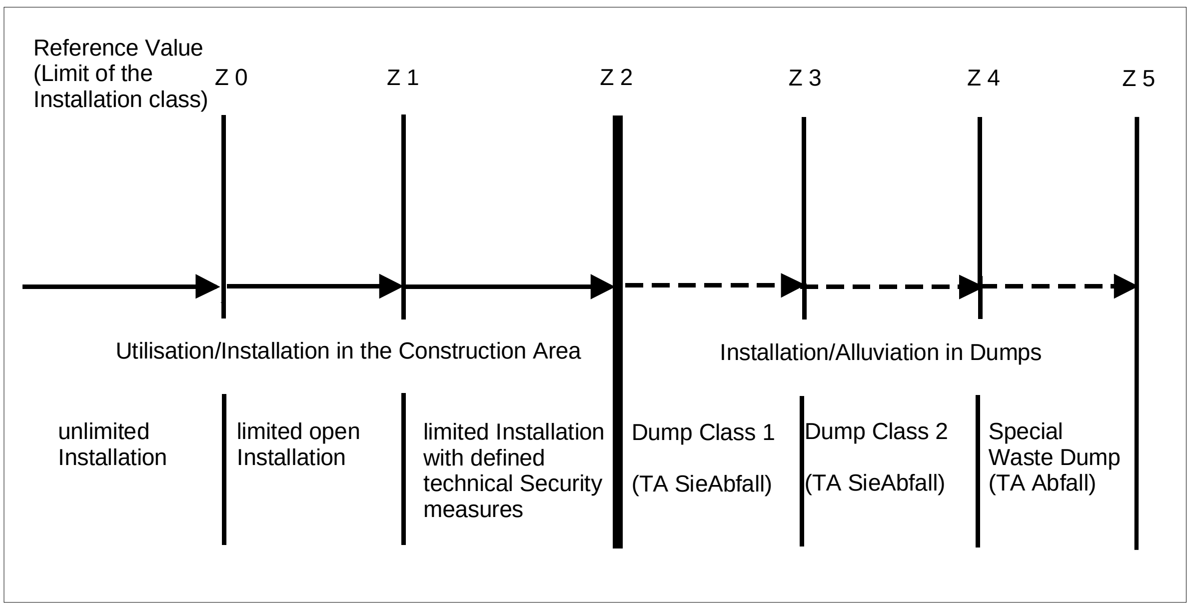


Figure 1 Installation Class with the relevant Reference Values

An unlimited installation (complying with reference value Z 0) is permitted if the recycling material shows similar pollutant content to the regionally occurring ground/rocks. If Z 1 is not exceeded, a limited open insertion under agreed user limits is allowed. Depending on the hydro-geological requirements of the area Z 1 is divided into Z 1.1 and Z 1.2. By exceeding these values Z 2 becomes effective. This gives the limit for the insertion of recycled building materials with defined technical safety measures, so that the transfer of substances into the subsurface and the groundwater is prevented. If Z 2 is exceeded, then the reference criterion for the disposal of waste in accordance with the TA Siedlungsabfall (see above) becomes effective. By exceeding Z 4 the rules for special waste deposit, laid down in the Technical Instruction for Waste (TA Abfall) [17] take effect.

Regulations for demolition
Up to now, no general regulations concerning demolition works are available in Germany. According to the Recycling and Waste Management Act, federal authorities and many other public agencies under federal supervision are obliged to contribute to the attainment of the aims of the Act. In the field of construction and demolition, the Ministry of Transport, Building and Housing has published a guideline for construction, renovation and demolition activities undertaken as public works on behalf of federal authorities and the Ministry of Defence [18].
As mentioned above, some states (Bundesländer) have already introduced requirements for demolition. The municipalities or local authorities have further regulations like demolition permits or dismantling ordinances.
A Voluntary Agreement, signed 1996 by several industrial organisations, is mainly focused on construction and demolition waste management ensuring that the objectives of the federal government concerning the targets for waste management are met. It contains the following measures [19,20]:

- information and advisory services to be made available to construction and demolition companies;
- R&D about avoidance of construction and demolition waste, separation and sorting of wastes and recovery measures, quality assurance for recycled materials and promotion of applications for recycled materials.

The industrial organisations that signed the agreement will set up an advisory committee or board responsible for monitoring progress and for reporting annually to the Ministry of Environment. These reports should also contain information about the development of dismantling techniques.

A new standard for demolition (DIN 18007) [21] has recently been published. The objective of this standard is to specify definitions for demolition and to describe different demolition activities.

3.3 CHARACTERISATION OF DEMOLITION WASTE

Classification and Composition of Demolition Waste
In general, figures about the amount and composition of demolition waste are found together with construction waste. The term construction and demolition waste covers a wide range of materials, for instance [20]:

- waste arising from the total or partial demolition of buildings and/or civil infrastructure;
- waste arising from the construction of buildings and/or civil infrastructure;

- soil, rocks and vegetation arising from land levelling, civil works and/or general foundations;
- road planning and associated materials arising from road maintenance activities.

One characteristic of construction and demolition waste arising from demolition (and construction) is the heterogeneity of its composition depending on the different construction types, as well as the multitude of materials, elements and aids, used in the construction area. Cross-contamination and general mixing of materials have to be avoided according to the regulations mentioned above. Nevertheless, demolition still often results in a mixture of materials.

In Germany, construction and demolition waste was classified according to a waste catalogue issued by the Länder Working Group Waste (LAGA Katalog) which distinguishes between the main groups shown in Table 1.

Table 1 Construction and demolition waste according to LAGA-classification

Waste Code	Description
31409	demolition debris
31410	road construction debris
31411	excavation debris
31441	contaminated demolition waste and excavation debris
91206	waste from construction sites
31407	ceramic and stone wastes
31408	glass waste
31423; 31424	contaminated soil
31436	asbestos waste
31438	gypsum waste
54912	bitumen, asphalt waste
55508	painting materials
57	various plastic and rubber waste
58	textile waste

The former LAGA catalogue was not compatible with the European Waste Catalogue (EWC) due to the different approaches selected for structuring. Since 1 January 1999 EWC came into force in Germany enforced by the corresponding national ordinance (Verordnung zur Einführung des Europäischen Abfallkataloges (EAKV)) [22]. For an intermediate period a combined catalogue [23] gives references as far as possible in order to facilitate the introduction of the EWC. According to the EWC, construction and demolition waste is grouped in Section 17 00 00 comprising the materials listed in Table 2.

Table 2 Construction and demolition waste in the European Waste Catalogue

Waste Code	Description
17	**Construction and Demolition Waste**
17 01	concrete, bricks, tiles, ceramics and gypsum based materials
17 01 01	concrete
17 01 02	bricks
17 01 03	tiles and ceramics
17 01 04	gypsum based construction materials
17 01 05	asbestos based construction materials
17 02	**wood, glass and plastic**
17 02 01	wood
17 02 02	glass
17 02 03	plastic
17 03	**asphalt, tar and tarred products**
17 03 01	asphalt (containing tar)
17 03 02	asphalt (not containing tar)
17 03 03	tar and tar products
17 04	**metals (including their alloys)**
17 04 01	copper, bronze, brass
17 04 02	aluminium
17 04 03	lead
17 04 04	zinc
17 04 05	iron and steel
17 04 06	tin
17 04 07	mixed metals
17 04 08	cables
17 05	**soil and dredging spoil**
17 05 01	soil and stones
17 05 02	dredging spoil
17 06	**insulation materials**
17 06 01	insulation materials containing asbestos
17 06 02	other insulation materials
17 07	**mixed construction and demolition waste**
17 07 01	mixed construction and demolition waste

Up to now, no official statistics are available about the arising and composition of waste resulting from the demolition or deconstruction of buildings. Some hints about the composition and amount of demolition waste are given in [24,25]. Recent figures can also be found in [20]. It can be assumed that demolition waste arising from the demolition of buildings in Germany sums up to 45 Mio. tonnes per year [26].

In order to obtain reliable data about the amount and composition of demolition waste resulting (only) from the demolition or deconstruction of buildings, the French-German Institute for Environmental Research has carried out studies to determine these composition using a model where existing buildings were first classified by the criterion size, age and building type [27]. Based on detailed bill of materials for the predominant buildings the average composition of demolition waste from buildings can be determined.

A validation of these models for the Upper-Rhine Region (Baden (D) - Alsace (F)) shows that the major share of the components are minerals (cf. Figure 2).

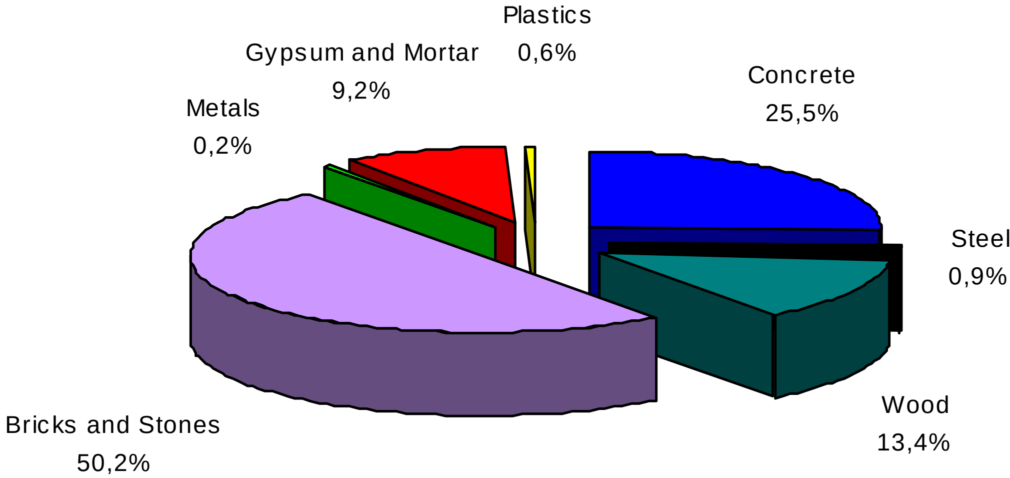


Figure 2 Composition of demolition waste from residential buildings

Pollutant Sources in Buildings

Recycled construction materials from deconstructed buildings should be available in such quality, that they meet the required profile for natural construction materials. It should also be observed that both plain and mixed grades of building waste could contain pollutants, which could damage the environment during storage or re-use. These pollutants are contained in construction materials due to their natural material composition, or were artificially added during manufacture, for example in the form of additives. Nevertheless very few materials in demolition waste are invariably hazardous (as defined in European Council Directive 91/689/EEC). The major pollutant sources in buildings were identified mainly through studies in building examination laboratories and are to be seen in Table 3 [28,29]. A great share of pollutants is caused by surface area treatment such as paint. They are added partly for improvement and partly to protect the construction materials.

Table 3 Potential Pollutant Sources in Buildings

Origin	Relevant Pollutants
natural stone	heavy metals
gypsum	sulphate, heavy metals
asbestos	Asbestos
treated wood	heavy metals, lime, phenol, PCP
plastics	phenol, CH_x, organic components
sealant	PCB
roofing felt	CH_x, PAH, phenol
tech. installation	PCB, Hg, Cd
soot	heavy metals, PAH
dust	heavy metals
fire	PAH, PCDD/PCDF
accidents (use)	includes oil, alkalis, acid

In order to classify pollutants according to their damaging properties, a modelling approach has been developed (cf. [30]). This methodology helps to set up a detailed deconstruction planning with the aim of minimal pollutant remaining in materials arising after deconstruction (cf. below).

3.4 RECYLING AND REUSE OF CONSTRUCTION MATERIALS

Collection, recycling and reuse

In Germany, about 1600 landfills for construction and demolition waste exist. In general however, according to the requirements set up in the TA Siedlungsabfall (see above), mineral and unsorted construction and demolition waste may not be disposed to landfill. Disposal of other construction and demolition waste is strongly affected by the Recycling and Waste Management Act and by the corresponding ordinances (see above).

Additionally, there is a considerable capacity for the treatment of demolition waste. There are about 650 companies operating around 1000 crushers (mobile, semi-mobile and stationary/fixed facilities). Nevertheless the availability of processing facilities highly depends on the regions. Figure 3 demonstrates as an example the location of recycling facilities for demolition waste in the region of the upper Rhine Valley, covering an area of 16450 km² (Baden (D), Regierungsbezirk Freiburg/Karlsruhe and Alsace (F), Département Du Bas-Rhin/Haut-Rhin) [27,31].

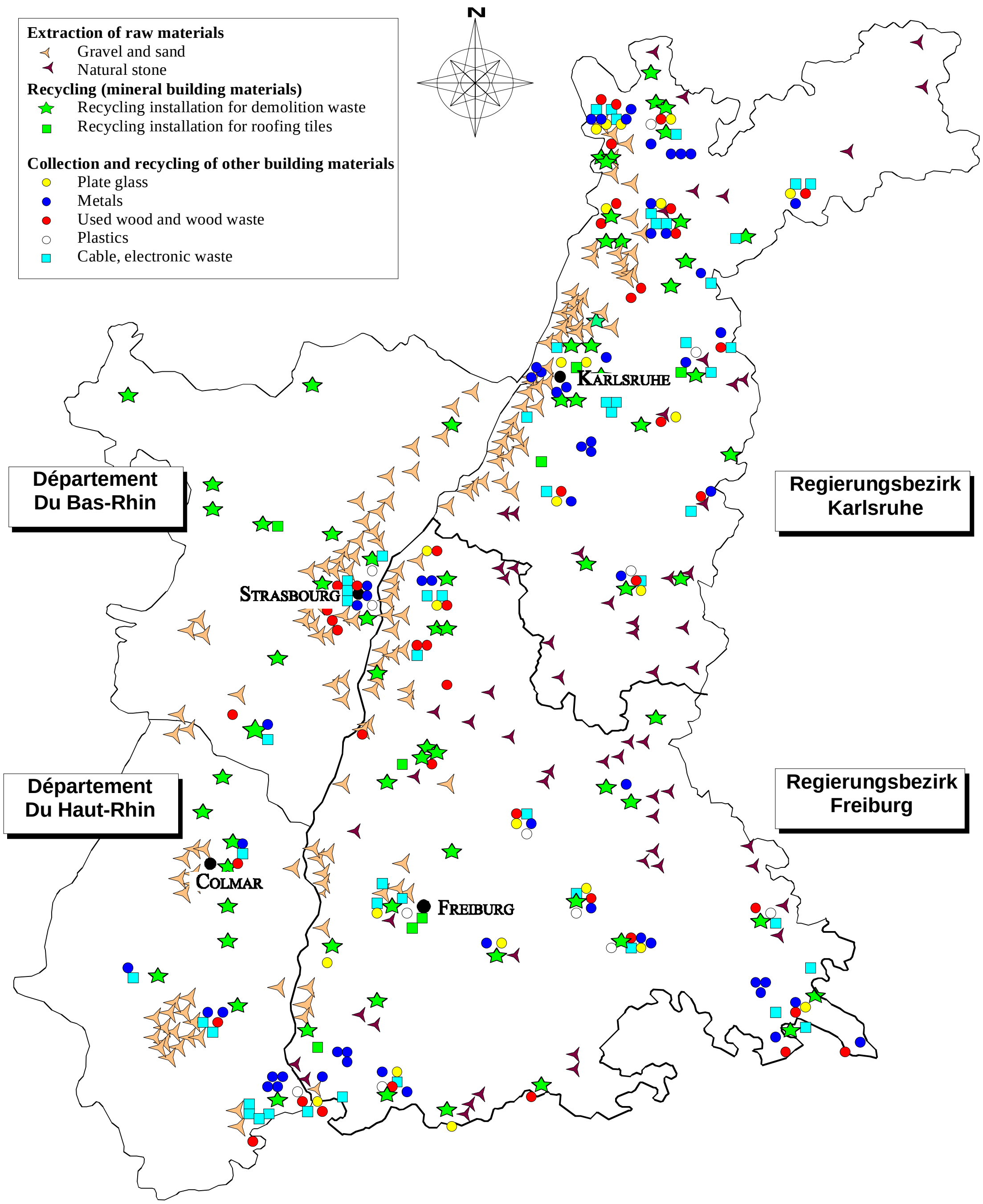


Figure 3 Extraction of raw materials and recycling in the Upper Rhine Valley

Recycling and direct re-use can be supported by waste exchanges that have been established both, on national and regional levels. Furthermore, specialised operators dealing with used construction materials have established several outlets in Germany.

Taxes for Construction and Demolition Waste

In Germany, no federal taxes or levies are charged to the disposal of construction and demolition waste. Apart from the obligation of recovery imposed by the Recycling and Waste Management Act, an incentive to separate and sort construction and demolition waste is given to landfill tariffs. These tariffs show considerable differences depending on the composition of the waste and the region where the landfill is located. For example, in 1996 the tariffs for mixed construction and demolition waste, not considered as being hazardous, ranged between 100 and 800 DM/tonne [20,32].

No official statistics are available concerning the tariffs for recoverable construction materials charged by the operators of processing facilities. These tariffs vary wildly depending mainly on the market conditions and the region. Table 4 gives a survey of the prices based on a market study of 195 recycling facilities operating in the South West of Germany [31].

Table 4 Prices for demolition waste

Materials		Average price charged (∅) [DM/tonne] Variation (Δ) [DM/tonne]				
Demolition Waste (minerals)		Quality 1	Quality 2	Quality 3		1)
	∅	16,5	50,1	66,7		
	Δ	5,8 - 30	19,5 - 150	25 - 160		
Roofing Tiles	Δ	-20 - 18				
Used Wood		untreated	treated			
	∅	151	217			
	Δ	70 - 262	155 - 360			
Metals		Scarp Iron	Copper	Brass	Zinc	
	Δ	0 - 80	-2600 - 1500	-1700 - 400	-450 - 200	
Cable, Electronic Waste	Δ	400 - 850				
Plate Glass		Plate Glass		Windows incl frame		
	Δ	-55 - 110	90 - 320	275 - 320		
Plastics	Δ	350 - 600				

1) Quality 1: Demolition waste without fine fraction or mixed materials
Quality 2: Demolition waste with low content of mixed materials (<30%)
Quality 3: Demolition waste with high content of mixed materials (>30%)

3.5 **DECONSTRUCTION PLANNING OF BUIDLINGS**

The aim of efficient deconstruction is to reduce the whole duration for dismantling on the site, to lower the costs, to improve the working conditions and to assure the required quality of the materials. In order to optimise deconstruction, a methodology for the deconstruction and recycling management for buildings has been developed at the French-German Institute for Environmental Research, which is explained in the following. In order to facilitate the task described, a sophisticated computer aided dismantling and recycling planning system is used [31,33,34]. The structure of this system is illustrated in Figure 4.

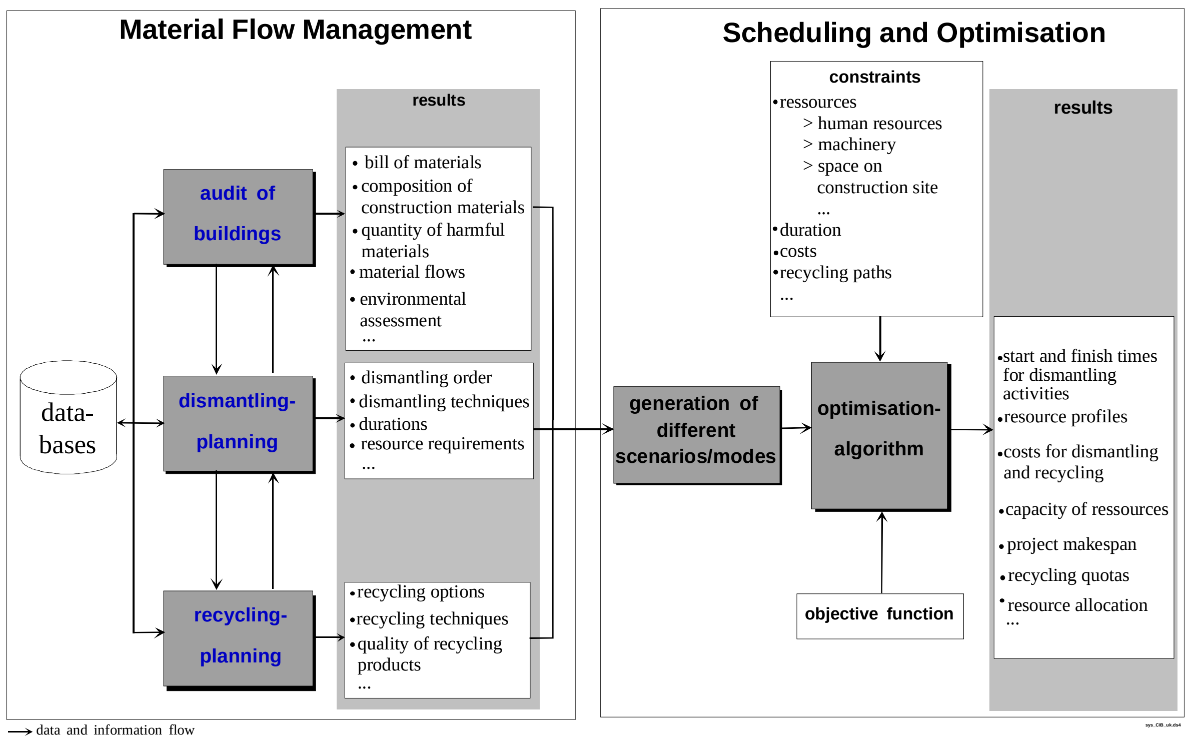


Figure 4 Structure of the deconstruction planning system

Audit of Buildings

An essential step both for deconstruction planning and for the quality assurance of materials that are encountered as a result of demolition is a proper pre-deconstruction survey, also called building audit. Although it is not absolutely certain what will be found when structures are broken open during dismantling of demolition, much uncertainty can be reduced by carrying out such a building audit. The building audit mainly consists of making a detailed description of the building and identifying materials. Based on the documents of the building (construction plans, descriptions, history) detailed data on the composition of the building has to be collected and analysed. Due to the fact that deconstruction normally effects older buildings, reliable information documenting the current state are rarely available. During this audit indications of substances contained in the building, which may influence the quality of the materials must be collected and analysed. The audit also gives precise information for further investigation on possible pollutant sources and contamination of the building.

The planning system supports the audit by the preparation of bills of materials which contain details of the materials and the locations of building elements and pollutant sources (cf. Table 5). The content of pollutants can be addressed by a methodology using so-called pollutant vectors for materials and surfaces [30].

Table 5 Bill of materials for a residential building (excerpt)

no.	construction element	room no.	con-nected room	length [m]	width [m]	area [m²]	height [m]	volume [m³]	volume [kg]	quan-tity	no.	building material	density [kg/m³]	portion [%]	coating
33120	masonry	01010	01001	4,67	2,95	10,58	0,5	5,29	12375	1	1140	sandstone	2500	80	
	(exterior)										2110	lime mortar	1700	20	
33410	door	00070	00001	0,85	2,10	1,79	0,03	0,04	36	1	5100	cast iron	7800	8	
	(exterior)										6300	spruce	600	92	paint
33411	door-frame	00070	00001	6,00	0,35	2,1	0,02	0,04	20	1	5100	cast iron	7800	2	
											6300	spruce	600	98	paint
33430	window	01090	01002	0,60	1,22	0,73	0,05	0,04	83	2	4100	sheet glas	2500	80	
											5100	cast iron	7800	2	
											6300	spruce	600	18	paint
33440	window-ledge	01080	01002	2,20	0,20	0,44	0,15	0,07	165	1	1140	sandstone	2500	100	
33450	window-frame	01090	01002	3,60	0,20	0,72	0,2	0,14	360	1	1140	sandstone	2500	100	paint
33510	plaster (exterior)	02080	02002	2,89	3,20	5,45	0,02	0,11	185	1	2110	lime mortar	1700	100	paint
34120	masonry	02020	02090	4,90	3,20	15,68	0,08	1,18	1682	0,5	3300	solid brick	1400	90	
	(interior)										2110	lime mortar	1700	10	
		02090	02020	4,90	3,20	15,68	0,08	1,18	1682	0,5	3300	solid brick	1400	90	
											2110	lime mortar	1700	10	
		total:					0,15	2,36	3364	1					
34410	door	00140	00150	0,86	1,98	1,70	0,01	0,017	16	0,5	5100	cast iron	7800	5	
	(interior)										6300	spruce	600	95	paint
		00150	00140	0,86	1,98	1,70	0,01	0,017	16	0,5	5100	cast iron	7800	5	
											6300	spruce	600	95	paint
		total:					0,02	0,034	33	1					
34510	plaster (interior)	01010	01020	3,60	2,65	7,86	0,02	0,16	189	1	2210	gypsum mort	1200	100	adhesive
35110	ceiling	00010		11,14	2,86	31,86	0,15	4,78	6834	1	2110	lime mortar	1700	10	
											3300	solid brick	1400	90	
35112	ceiling filling	02050		4,97	3,71	18,44	0,22	4,06	1988	1	1530	expanded cla	600	35	
	material										1610	slag	700	30	paint
											6830	thatch	200	35	
35210	floor covering	03100		3,60	1,20	4,32	0	0,02	26	1	7100	plastic	1500	100	adhesive
36300	roof covering	03010		0,40	0,25	0,1	0,02	0,0015	3	280	3600	roofing tile	1700	100	
36370	downspout			9,00	0,20	1,8	0,01	0,01	15	2	5600	zinc	7200	100	
41242	W.C.	01060							21	1	3900	porcelain	1100	100	

Dismantling Planning

With the available information about the composition of the building combined with the information about the regional framework for waste management, the planning of the dismantling work can be carried out.

On the basis of the bill of materials, appropriate dismantling techniques are selected and aggregated to dismantling activities. Information about dismantling techniques and corresponding costs can be found in [31,35]. The configuration of the dismantling activities comprises the determination of the corresponding construction elements (found in the bill of materials) and the selection of the resources necessary. Since the aim of the dismantling planning can be dismantling with minimal costs, dismantling with the aim of preserving building elements intact for later re-use, or dismantling due to technical restrictions etc., the determination of dismantling activities may vary considerably. The computer supported configuration of a dismantling activity is illustrated in Figure 5 [36]. For the temporal planning of the dismantling work reference numbers, stored in a database, can be chosen for each construction element depending on the dismantling techniques available (cf. Figure 6).

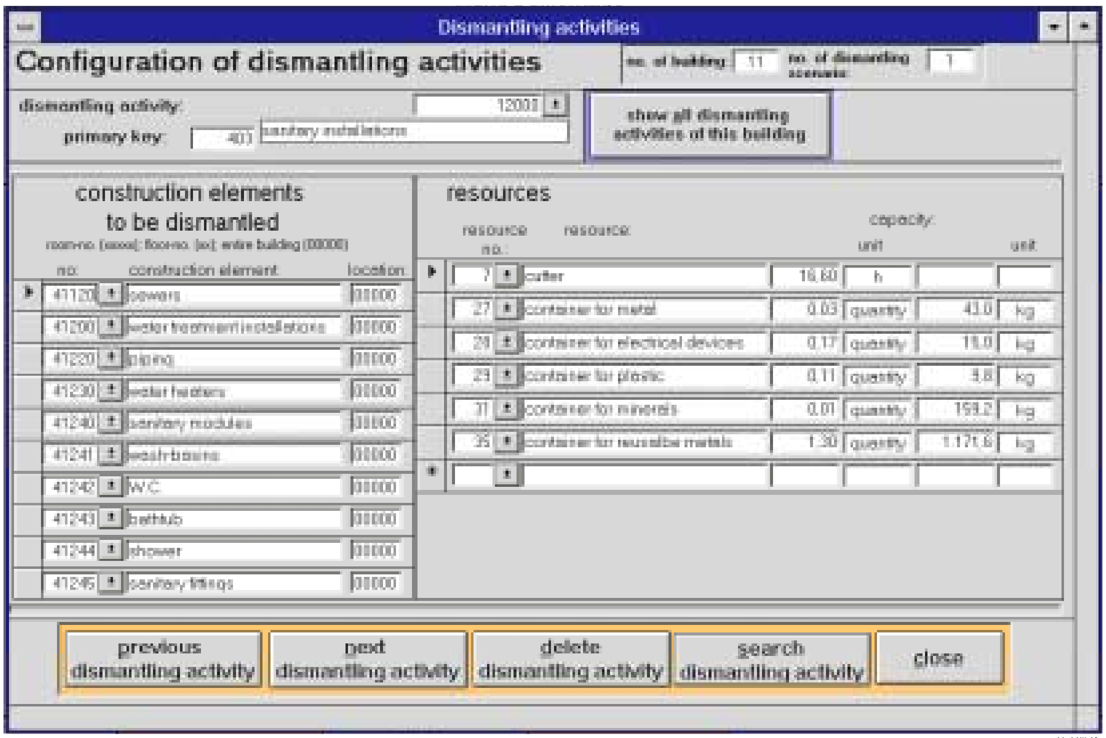


Figure 5 Configuration of dismantling activities

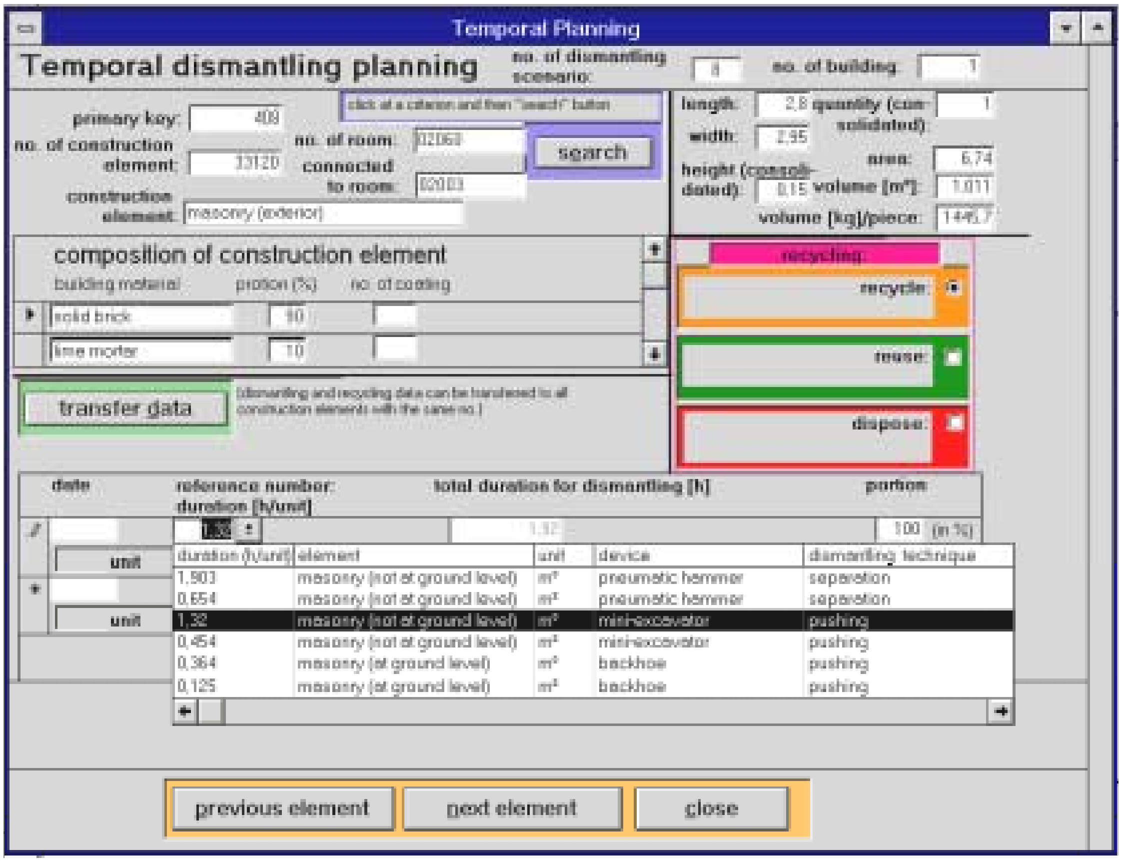


Figure 6 Computer aided dismantling planning

The dismantling order respecting technological relations as well as security aspects and environmental requirements (like the decontamination of buildings) can be illustrated in so called dismantling networks. Figure 7 gives an example of a dismantling network for a residential building [30].

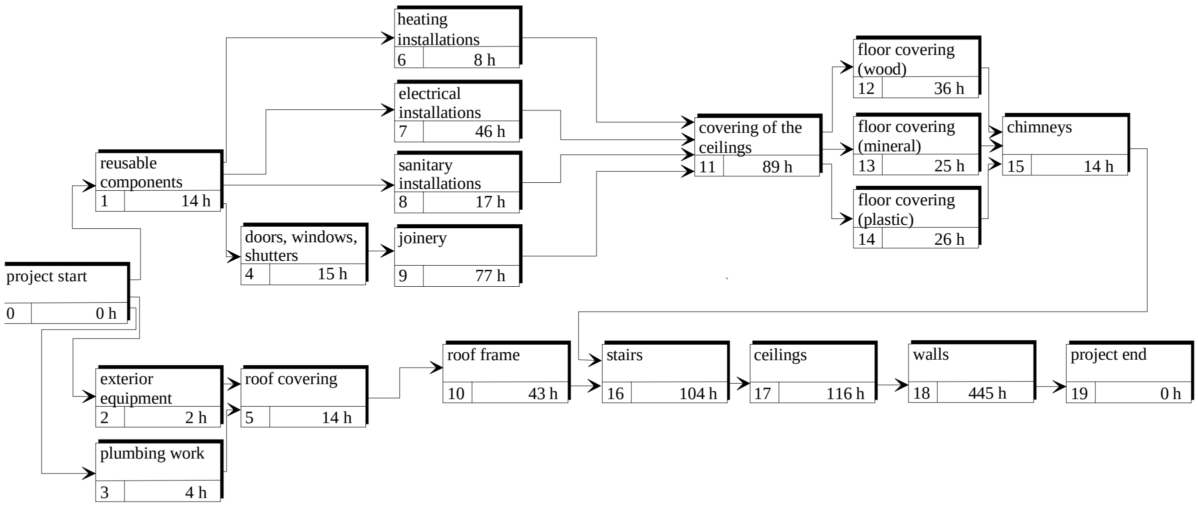


Figure 7 Dismantling-network for a residential building

After determining the dismantling activities and precedence relations the target of dismantling planning is to find feasible or “optimal“ working schedules. If resources (machines, workers, space on the construction site, budget) are limited this problem becomes extremely complex.

Recycling and Reuse Planning

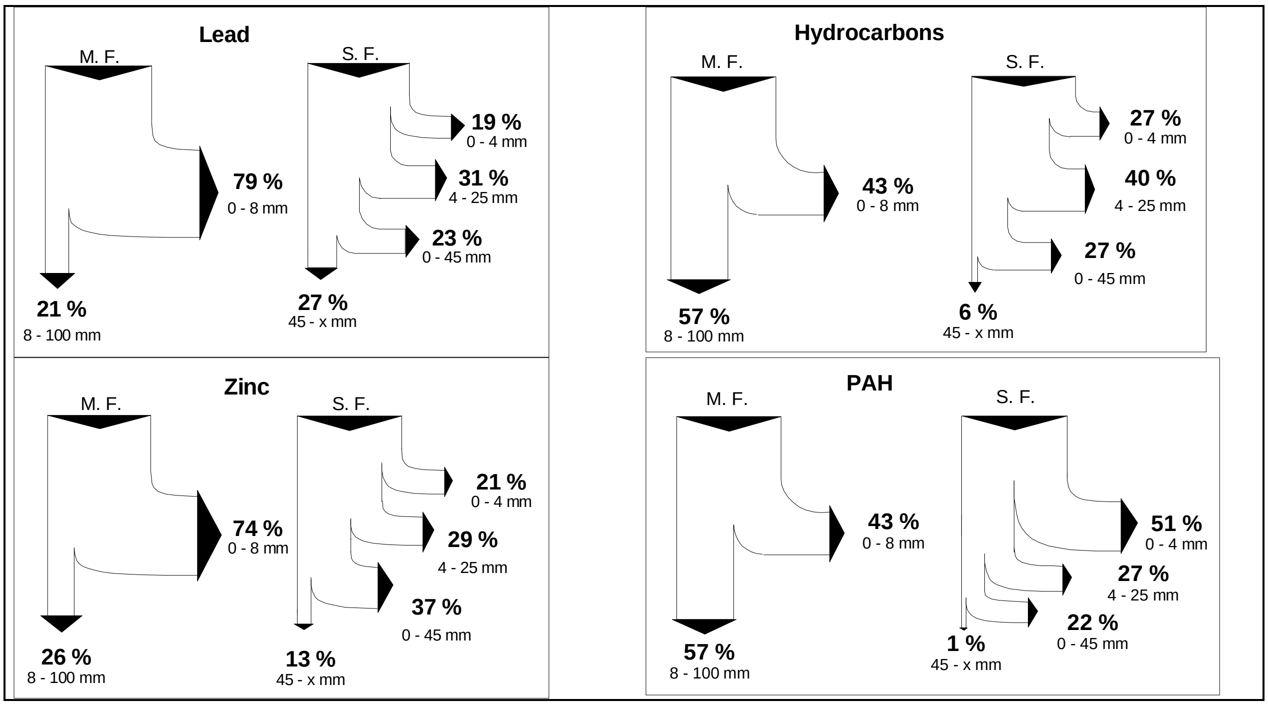
The objective of recycling planning is the design of optimal recycling techniques for processing dismantled materials and building components into reusable materials. Depending on the stage of dismantling, the feed can be either a single material or a mix of all building materials. For certain individual materials such as metals, glass and minerals or plastics, recycling techniques already exist. In this case recycling planning is a simple co-ordination. Recycling is difficult, when materials are mixed, when composite materials occur or when pollutants like hydrocarbons or asbestos are present. In order to obtain materials in an optimal composition for recycling facilities, the available recycling techniques as well as the location of processing facilities (see above) have to be considered during dismantling planning. Case studies have shown, that direct re-use of elements can be a promising alternative if dismantling is planned well (cf. [37,38,39,40]).

3.6 INFLUENCE OF THE DECONSTRUCTION AND RECYCLING TECHNIQUES ON THE QUALITY OF THE RECYLING MATERIALS

Although, in Germany sophisticated recycling facilities for demolition waste are already available since several years, recycling becomes problematic when mixed materials or materials containing pollutants are introduced in recycling facilities.

In order to examine the influence of the processing techniques on the environmental compatibility on the components of the recycling material, unsorted material from the demolition of similar buildings was processed and characterised (for details see

[28,29,41,42]). This was carried out in two recycling plants of different configuration, one mobile and one stationary facility. Mobile facilities are set-up on larger demolition sites, so that the demolition waste can be processed on site. The advantage of processing building waste in a stationary facility is that this process type, due to its' complex configuration, makes it possible to produce high quality recycling material.
Pollutant balances show that the coarse fraction has a low pollutant content (see Figure 8). Most of the pollutants were to be found in the finer fractions, so that through the removal of these fractions the total pollutant content can be significantly reduced (e. g. up to 51% of polycyclic aromatic hydrocarbons (PAH) and 79% of the lead content.



M.F. = Mobile Facility S.F. = Stationary Facility

Figure 8 Distribution of Pollutants in Processing Facilities

The examinations demonstrated in the previous show the borders of the pollutant removal through the existing process technical operations. Therefore in this section it should be shown, which influences the composition of the demolition waste has on the quality of recycled components, with regard to environmental compatibility.

Different compositions can be reached through division of the material before processing, for instance through a pre-sorting in a sorter facility, or even through separation of the demolition waste on-site by application of adequate deconstruction methods. By the use of appropriate deconstruction techniques construction elements containing pollutants can be dismantled and the quality of the remaining materials can be improved. Figure 9 illustrates the influence of the deconstruction, respectively the demolition method on the environmental compatibility of processed recycling materials.

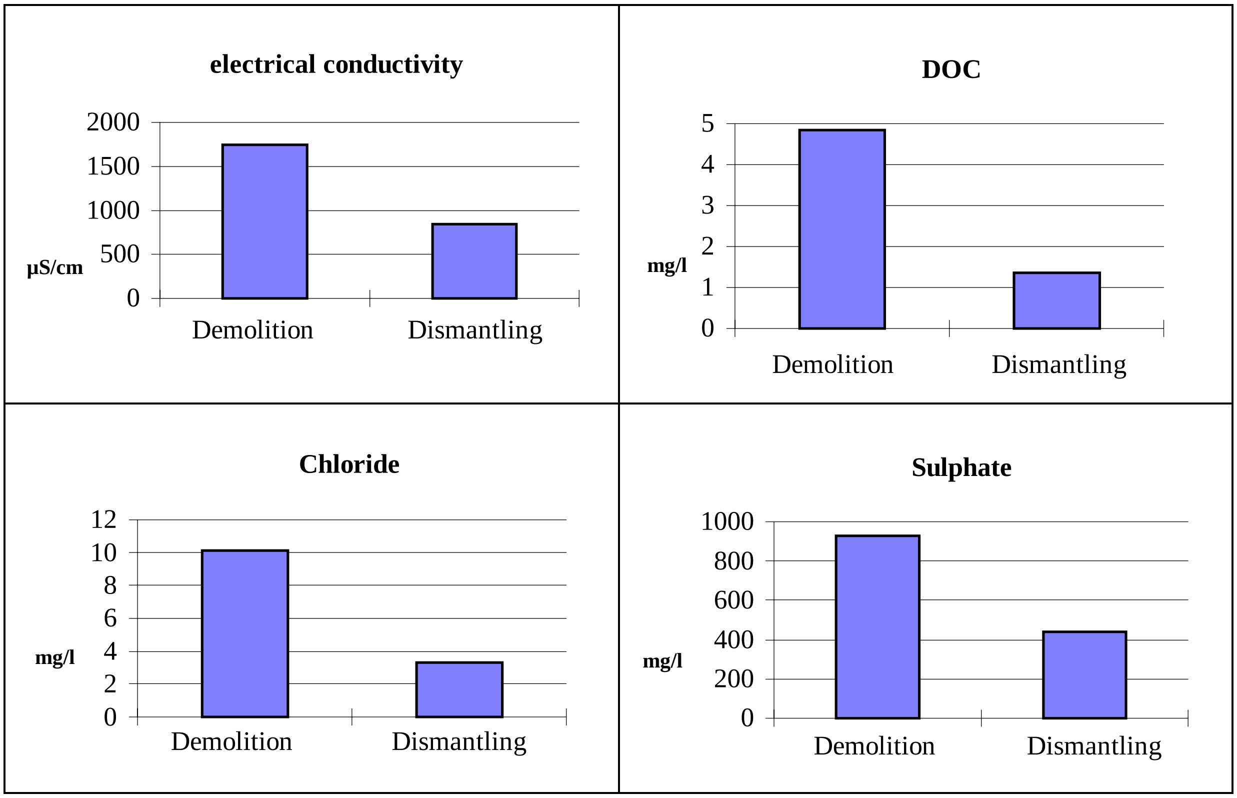


Figure 9 Eluate analysis of demolition waste (Fraction 0 - 8 mm) resulting from demolition and dismantling

It could be shown for instance that only by the separation of chimneys, or more specifically their inner walls from the rest of the demolition waste the pollutant content could be significantly reduced. Dismantling or separation techniques for the removal of chimneys must be found so that the occurring masses of the deposited chimneys are not excessive. Options here include the use of a milling cutter or sandblaster, to wash the chimney or the surface construction of the inner walls of the chimney.

3.7 CASE STUDIES OF THE DECONSTRUCTION OF BUILDINGS IN GERMANY AND FRANCE

In recent years, several case studies about deconstruction have been carried out in Germany and France (cf. [37, 38, 39, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59]). Nevertheless, only few studies are well documented. An overview about different deconstruction studies can be found in [31,60]. A comparison between these studies is impeded not only because of the heterogeneity of the documentation, but also the scope of the projects and the different conditions. In fact, the same aspects in the studies are not addressed in the same way (e.g. costs, recycling rates etc.). As a consequence, results have to be compared with great care. Bearing in mind these obstacles, Table 6 shows a coarse comparison between some of the case studies indicated above.

Table 6 Comparison between different case studies

Project	Location, Year	Type of building	Construction	Volume	Dismantling Time, Project duration [weeks]	Costs	Recycling rate
1	**D, 1991**	Foundry	Masonry	263000 m^3	n.a.	11,8 EUR / m^3	94 %
2	**D, 1993**	Brewery	Concrete and Masonry	210000 m^3	n.a.	n.a.	> 96 %
3	**D, 1994**	Residential Building	Timber Frame	4950 m^3	6	13,5 EUR / m^3	94 %
4	**D, 1993**	Industrial	Concrete	58000 m^3	11	27,1 EUR / m^3	74 %
5	**D, 1993**	Residential	Concrete	684 m^3	n.a.	n.a.	> 90 %
6	**D, 1994**	Industrial Building	Masonry	183100 m^3	13	n.a.	n.a.
7	**F, 1995**	Residential Building	Masonry	4200 m^3	11	13,3 EUR / m^3	95 %
8	**D, 1995**	Industrial Building	Masonry, Steelframe	22086 m^3	6	9,7 EUR / m^3	98,5 %
9	**D, 1995**	Office Building	Masonry	11000 m^3	n.a.	n.a.	n.a.
10	**D, 1996**	Industrial Building	Masonry	n.a.	22	n.a.	97 - 98 %
11	**F, 1997**	Industrial Building	Masonry	13250 m^3	4	1,5 EUR / m^3	98%
12	**D, 1998**	School Building	Masonry	50000 m^3	18	15,1 EUR / m^3	98%

n.a.: no inform. available D: Germany; F: France

Case studies using the same approach concerning cost allocation, recycling rates etc. could be compared quite well.

For the evaluation of different dismantling techniques and the determination of the resulting dismantling times and costs, the French-German Institute for Environmental Research launched several projects in Germany and France. During the first project in Germany that was well documented [43,44], a timber framed building located in the black forest was completely dismantled and more than 94 % of all the materials could be recycled (cf. Figure 10).

Figure 10 Dismantling of the Hotel Post in Dobel [43]

In order to compare deconstruction with demolition, the deconstruction carried out in practice has been analysed and compared with the alternative of demolition. While in this project, demolition was calculated using simulation with the computer tool described above, another project was especially focused on the comparison between deconstruction and dismantling in reality [38,45,61]. The buildings located in Mulhouse (F) were divided into two parts, of which one was demolished (using a backhoe) and the other was dismantled (cf. Figure 11 and 12). The location of the building near to the Swiss and German border also allowed the analysis of the possibilities of recycling of materials on an international level.

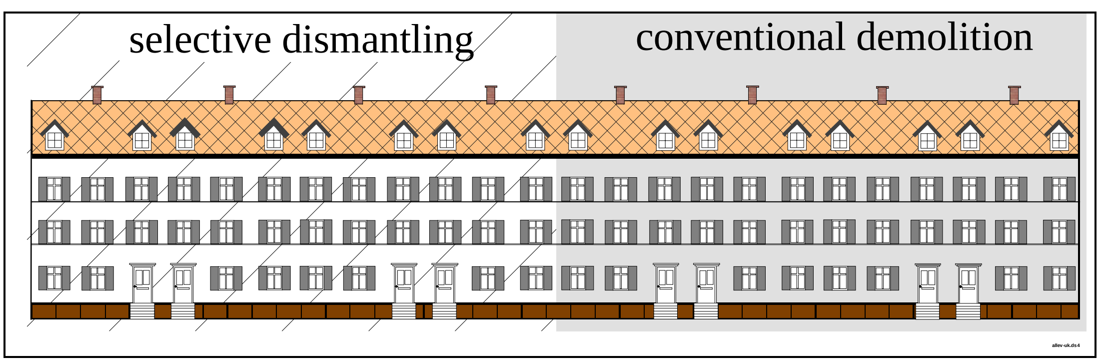


Figure 11 Dismantled and demolished buildings in Mulhouse


Figure 12 Dismantling in Mulhouse

During these projects detailed data on the composition of the dismantled buildings, the duration of the dismantling and demolition activities, the associated dismantling costs and on the recycling options were collected and analysed. Results show that dismantling can already be an economical solution, depending on the type of the building, the recycling options available and the prices charged for mixed and sorted demolition materials. As Figure 13 shows, the costs for deconstruction were in some cases lower than those of demolition (data based on [43,45,47,48]). Due to different types of buildings, different disposal fees and different transportation distances, costs for dismantling and recycling show tremendous variations.

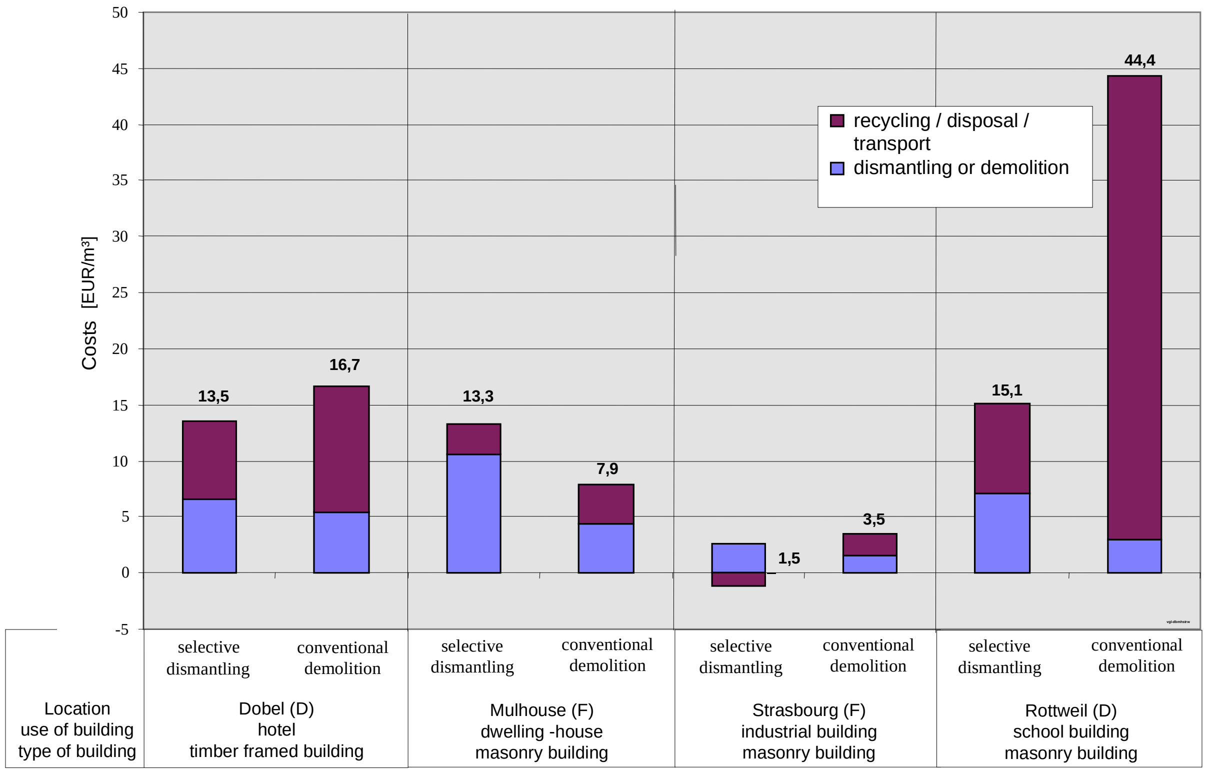


Figure 13 Comparison of selective dismantling and demolition

In the next section, some approaches for the optimisation of deconstruction works are presented.

3.8 EVALUATION OF OPTIMAL DECONSTRUCTION SCHEMES

The projects analysed so far have shown a potential for further improvements concerning cost reduction as well as environmental benefits. Based on these results, computer simulation helps to reveal improvement potentials for deconstruction. In order to show some possible improvements, various simulations and optimisations using the planning tool described above were carried out. Due to this high complexity of the dismantling and recycling planning a sophisticated mathematical optimisation model is used as decision support. The model takes into account the interrelations between material flow management (concerning dismantling and recycling) and project management. The consideration of both, material as well as monetary flows during the various planning stages, enables the elaboration of time and cost efficient as well as environmental friendly deconstruction strategies.

In order to evaluate optimal schedules for dismantling different scenarios might be applied, for instance:

- Dismantling of buildings using of the possibilities of parallel work as much as possible,

♦ dismantling using mainly manual techniques,
♦ dismantling using partly automated devices and a
♦ dismantling strategy strictly focused on “optimal” recycling possibilities according to the material flow analysis.

Computational results for different deconstruction strategies for a building show considerable economic improvements compared with a deconstruction project in practice. As illustrated in Figure 14 construction site management can be drastically improved. Optimised dismantling schedules, based on the same framework as in practice, show cost savings up to 50 %. In some cases the dismantling time can be reduced by a factor 2 applying partly automated devices. Furthermore, a recycling rate of more than 97 % can be realised [30,31].

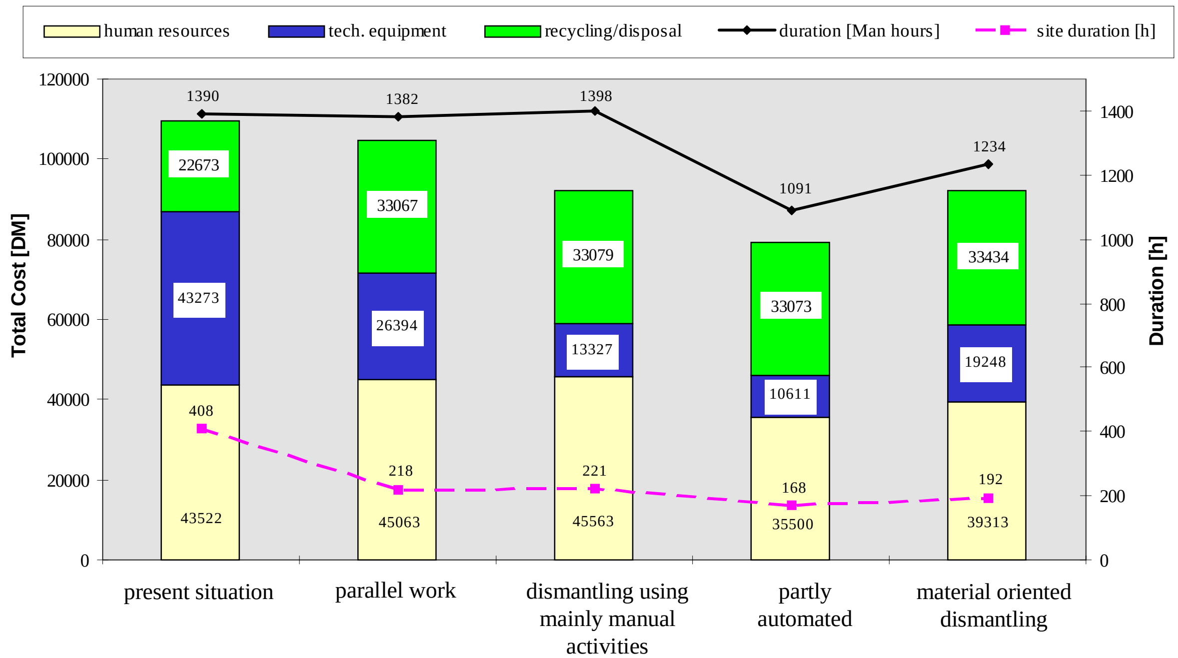


Figure 14 Cost and duration of different dismantling strategies for a residential building

Based on selected deconstruction strategies the detailed planning and optimisation of deconstruction work can be done. Figure 15 shows the results of minimising the duration of deconstruction. The complete schedules for two different dismantling scenarios (*partly automated* and *material oriented*) and the corresponding project costs show that an environmental oriented dismantling strategy, imposes a higher effort to the dismantling work. That is, more jobs have to be carried out in order to avoid a mix of hazardous and non hazardous materials. Nevertheless, environmental oriented dismantling strategies are not necessarily disadvantageous from an economic point of view, if disposal fees are graded according to the degree of mixed materials.

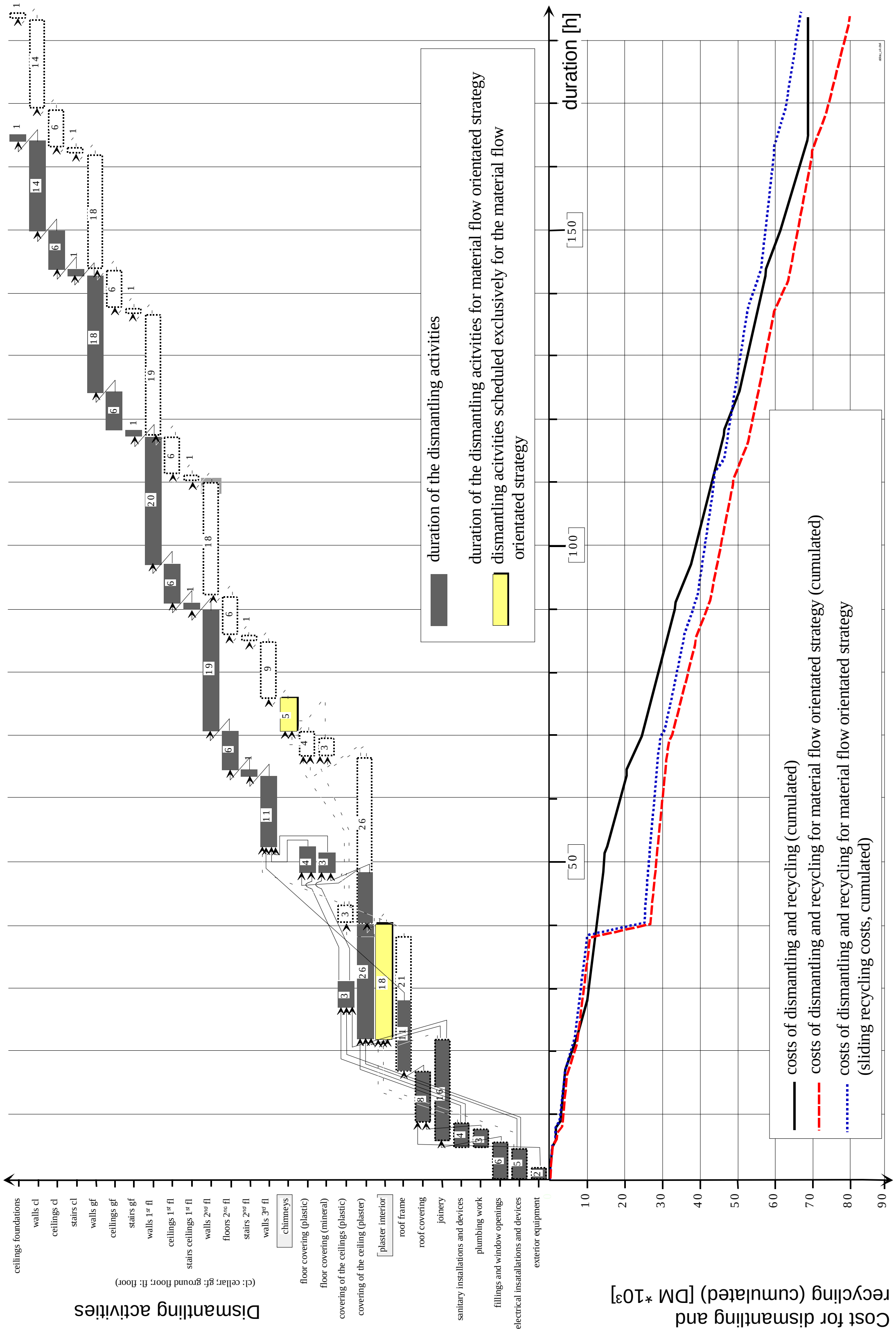


Figure 15 Schedule and project costs for the dismantling of a domestic building

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CHAPTER 4
THE STATE OF DECONSTRUCTION IN ISRAEL

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4.1 General Overview

As a relatively new country with a large growing rate, the amount of construction removal is relatively limited. The number of buildings that are to be destroyed is estimated by 5-10/year in the large cities. This amount is relatively too little to be considered as effective enough for finding a special solution for recycling or re-use of the building elements. In addition, most of these structures were erected during the 40' and 50' that were years of depression and were made from low-grade materials. Therefore, in most of the cases only basic materials are removed from the structure (like valuable aluminum, copper or steel that are molten for the production of raw materials) and the rest of the structure is demolished and landfilled in certified locations.
The amount of construction waste was estimated as 350,000-700,000 ton/year, which is approximately 60% of the solid waste in Israel (not including household waste). Most of the waste comes from the erection of new structures.

Regulations regarding construction waste forbid landfilling of the waste unless dumped in certified locations. Certified locations become rare and only few of them are now available in certain local municipalities. This process takes place gradually, leading to shortage with landfilling sites, increased landfilling fees and increased transportation distance and cost. This process increases the motivation for recycling and reclaiming of materials and elements from old structures.

4.2 Structure Type in Israel

The common structure in Israel is made of reinforced concrete frame with partition walls made of concrete blocks. The walls are then covered with cementitious plaster. Utilities lines of water, electricity, communication etc are placed trough the walls before plastering. Floors are mostly covered with tiles (ceramics, terrazzo etc).

When considering recycling of these materials, deconstruction or design for deconstruction the structure habits need to be considered. Careful dismantling of building elements as those noted above is almost impossible, unless special considerations are taken during the erection of the building. Structures made of precast concrete elements might be suitable for deconstruction, under two restrictions: 1. Connection of the element is done in dry methods. 2. The amount of internal finishes (plastering, floor tiling etc) is reduced to a minimum.

Adding on top of it the low image of using used elements in new structures, it appears that only limited types of structures might be considered for deconstruction: industrial structures including parking lots, and military structures. Examples to these two are listed below.

4.3 Examples of Deconstruction

Design for Deconstruction of a Parking Garage

A commercial company in Israel (design: Villa Nir,: structure: Moshe Peer, construction: Solel Boneh) has design lately a parking garage (See Figure 1) with a total area ranging from a few hundreds to several thousands square meters, allowing parking space for hundreds of cars (see Appendix A for more details). The structure was designed for dismantling and transference after a relatively short using time of 5-10 years. On the one hand, this period of time is too short for using normal grade building materials and elements that usually have life expectancy of 50-70 years. On the other hand, this time period is long enough to prevent the use of low-grade materials and elements that commonly used in temporary structures. The solution to the conflict is to design a full size structure that is made from high grade materials and can be dismantled at the end of using time and transferred, with some modifications, to a new location.

This solution is suitable for empty spaces in urban areas where the destination of the land has not been determined yet, or for parking lot near commercial centers that are built in several stages. This type of structure can provide with a good solution until a final destination for the land will be determined.

Military structures

Most of the military structures comply with the terms defined earlier for easing deconstruction. It should be noted that full size structures of the permanent army camps are discussed and not the small temporary structures that are designed for dismantling. A good example of this type of a process of deconstruction took place during the evacuation of the Sinai Peninsula after the peace agreement between Israel and Egypt in 1979. Following the agreement, all army camps had to be removed. Many structures (mostly steel structure) were dismantled and most of their elements were used in new locations for the erection of similar structures. The process was done in a methodological manner as follows:

1. Preliminary survey to define the structures for removal and relocation.
2. Preparation of a detailed program for deconstruction, including a detailed list of items that can be used again (down to details of small items like doors lock, door/window hinges etc).
3. Deconstruction
4. Transportation
5. Reconstruction using new elements where needed
6. Control

Figures 4 and 5 present an example for this activity done for one type of structure (architectural design office of Amos Livnat, Nurit Shapira- architect in charge for the project). Figure 4 presents an example of a look at the west facade and Figure 5 is the plan for this wing. All the elements of the existing building were marked and numbered, including structure elements, wall cladding, windows frames, doors, etc. All the elements that could be retrieved from the building were listed and an attempt was done to find a suitable use to them in the new building. Later, a new list that included all unusable elements was prepared in order to use these elements in other buildings.

An example of unsuccessful trial for deconstruction is taken also from the period of time of the evacuation of the Sinai Peninsula in 1981. Some of the civil structures were dismantle and moved away from the area in order to use the elements again. The structures were made of precast concrete and were used for residential housing. After the elements were carefully disassembled they were moved to a special area where they were kept for further use in the future. Unfortunately it appeared later that these elements can not be used again from the reasons previously discussed: the low image of using used elements for the construction of high value structure (high value is also from the emotional view of the potential owner). In addition, the architectural style became old during the time that passed between the erection and disassembling, in a way that prevented motivation for re-using these elements.

This last case, strengthen the hypothesis that not all the structures can be considered for deconstruction and re-use. Only structures and elements that can withstand the changes that occur in the period of time between the first erection and the second use (durability, strength, standards, social and fashion) might be suitable for the implementation of the deconstruction concept.

4.4 Research on Secondary Use of Materials

Several studies on the secondary use of materials in the construction industry have been done at the National Building Research Institute (NBRI) and they will be described briefly in the followings:

1. Re-use of construction waste. This is an ongoing study that began a couple of years ago. The purpose of the study is to test solutions for the re-use of construction waste in Israel. The study is carried out in three phases. The first phase is conducting a survey on the type and quantities of construction waste, the second phase is identifying proper solutions to the different wastes that will be identified in the first phase, and the last phase is testing the proposed solutions in terms of quality, properties and sustainability.

2. Using industrial by-products for the production of Controlled Low Strength Materials (CLSM). Large part of the industrial by-products are not suitable for the construction industry because of it fineness. CLSM, however, needs to be of low strength. Therefore low-grade materials that can not be used for the production of high strength concrete can be used for CLSM. Good results were obtained for various types of industrial by-products that are made of dust collected from different industries.

3. Using coal fly ash as partial replacement of Portland cement or natural sand. The utilization of coal fly ash as partial replacement of cement is a well known worldwide and a wide study on this topic was done in the past decade at the NBRI. Lately, the sources of natural sand became short in Israel and a partial replacement of the sand by fly ash was considered. The quantity of the fly ash in the concrete became much larger than before (similar to the one of the cement) and its effects on the properties of the fresh and hardened concrete in our region

are considered in this study.

4.5 Summary.

The activity on deconstruction is currently relatively low in Israel due to the habits of construction (various types of concrete), relatively small number of structures for destruction and a poor image of a product that is made from used elements.

Two niches, however, were defined: parking lots and military structures. Design for deconstruction initiated the development of a 4-story parking lot that can be dismantled and relocated according to market demands. The need to transfer army camps initiated careful plan for deconstruction of existing structure, in order to maximize second use the building elements.

4.6 Appendix A.

The design of the parking garage is based on a three dimensional concrete element seen in Figure 2. The basic elements are connected by hollow prestressed slabs of different lengths allowing the erection of a structure of various sizes as seen in Figure 3. A 4-story structure is designed to withstand a mild earthquake without additional supports. Additional stability is gained through external prestressing that is accessible for dismantling at any time when deconstruction is needed.

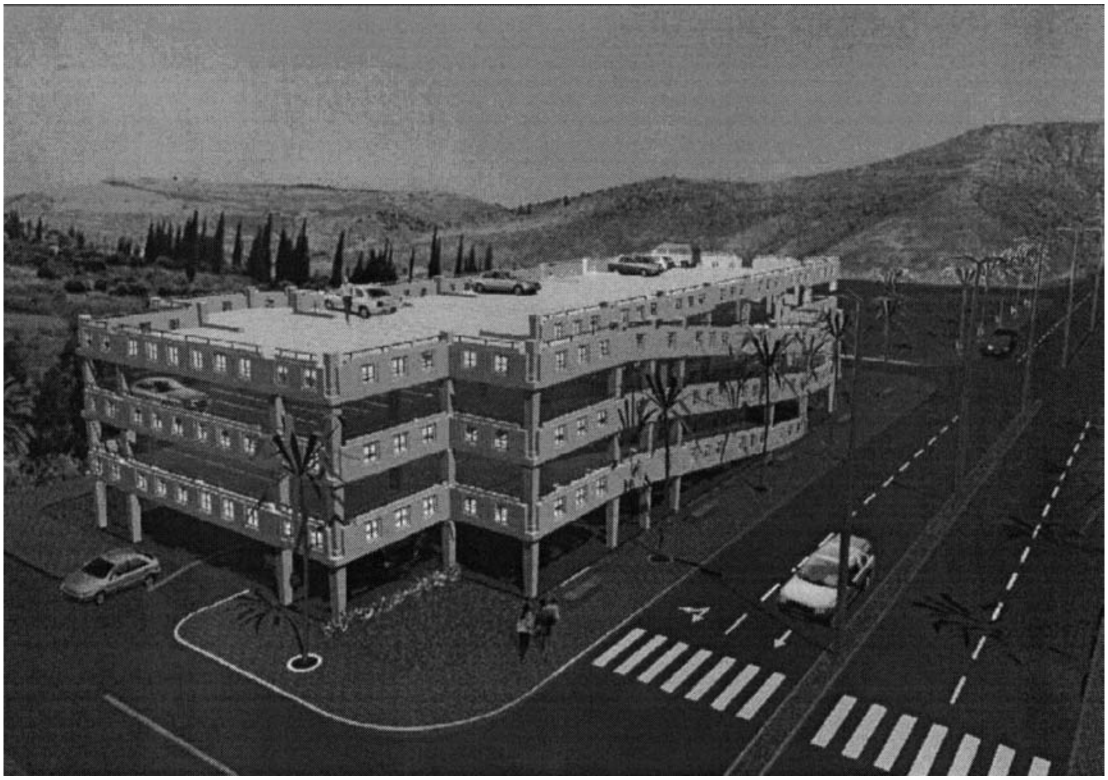

Figure 1: Computerized image of a full size parking structure designed for deconstruction (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

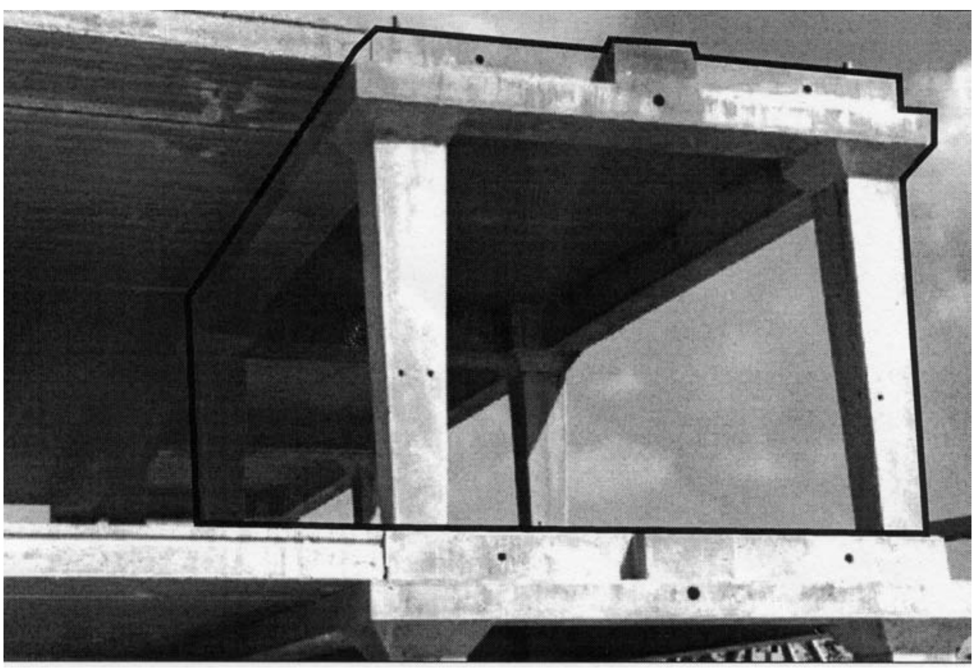

Figure 2: Basic 3-D element of the parking lot structure (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

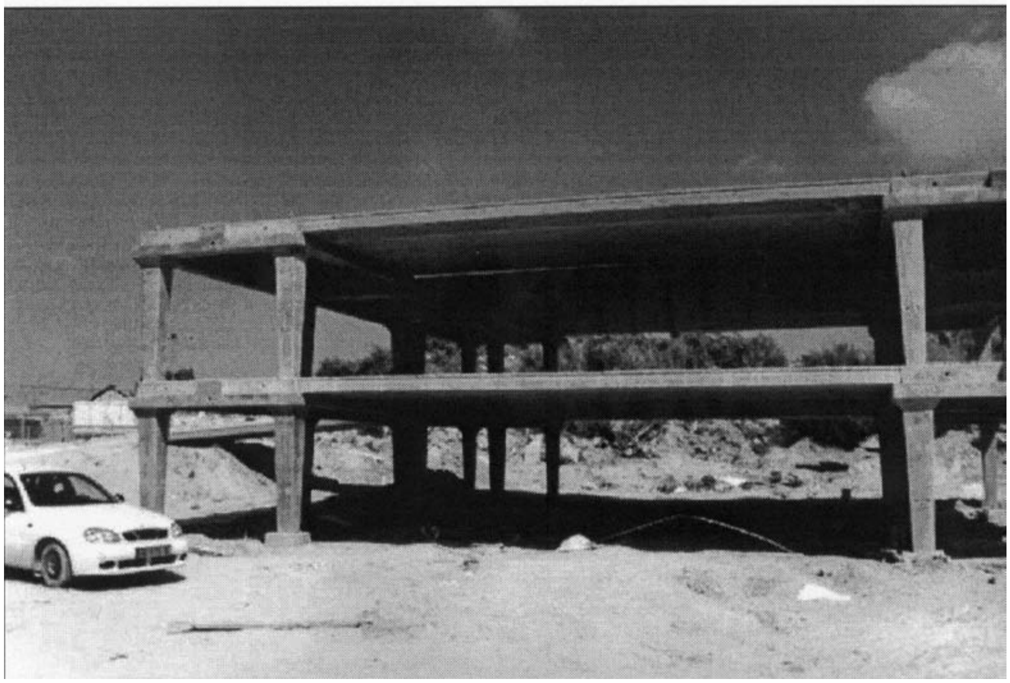

Figure 3: A full size structure of a parking lot at erection (design: Villa Nir, structure: Moshe Peer, construction: Solel Boneh).

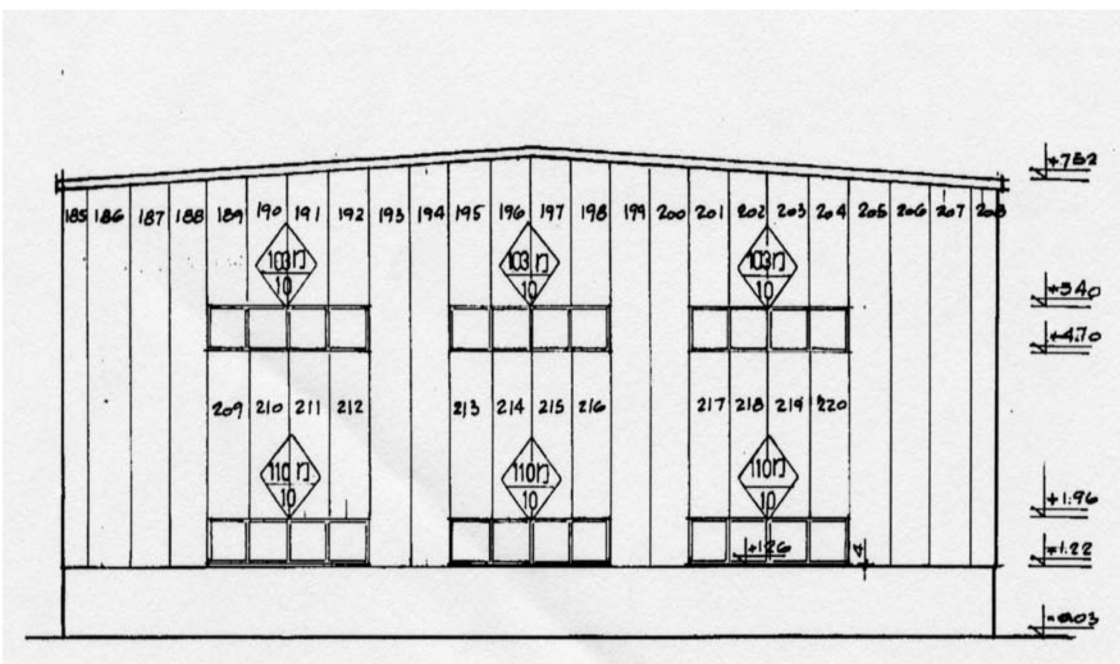

Figure 4: Plan for deconstruction of the west facade, windows frames and wall cladding are numbered (architectural design office of Amos Livnat, Nurit Shapira-architect in charge for the project).

CHAPTER 5
THE STATE OF DECONSTRUCTION IN JAPAN

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ABSTRACT

This report deals with the state of demolition in Japan. Demolition includes the dismantling, recycling, reuse and re-construction of buildings. In addition to addressing demolition, this report discusses Japanese law and regulations, the process of deconstruction and demolition for four types of structures (reinforced concrete structure, steel structure, wooden houses, and building foundations). Four issues are addressed for each type of structure: methods; designing in consideration of deconstruction; recycling and reuse; and research. Japan has begun enforcing new laws addressing demolition effective 2000.

KEYWORDS: Law, waste material, recycle, reuse, demolition

5.1 OUTLINE OF LAWS AND REGULATIONS RELATED TO WASTE DISPOSAL AND RECYCLING

Waste disposal and recycling system in Japan are based on "The law concerning waste disposal and public cleanliness," which was passed by the Diat in 1970. In the past, reducing and recycling domestic waste was strongly addressed. This attitude toward waste reduction and recycling was extended to industrial waste and public sanitation administration in the 1960s. Starting in 1988, substantially stronger waste reduction and recycling laws were introduced and additional laws were passed in the time frame 1991 to 2000. The major law addressing recycling was passed in 1991 and new government policies based on this law were enacted. The following is a list of major legislation addressing the reduction and recycling of waste in Japan:

* The law concerning waste disposal and public cleanliness (1970: Ministry of Health and Welfare)
* The law concerning the promotion of recycled material use (1993: Ministry of Health and Welfare)
* Recycle law of packaging materials and containers (1995: Ministry of Health and Welfare)
* Recycle law of electric equipment for home use (1996 and 1999)
* The law concerning the promotion of the recycle for the food resources (2000:Ministry of Agriculture Forestry and Fisheries)
* Recycle law concerning materials of construction works (2000:Ministry of Construction)

The purpose of these laws is to decrease domestic and industrial waste through voluntary actions by the various parties involved in waste generation. A new law, the Green Law, is also being considered to focus on appropriate behavior that would result in a significant reduction in waste quantities.

Waste disposal and public cleanliness law (1970)
The following is a brief history of this law.

Filth cleaning law (in 1900)
This law was converted into the law for cleaning (in 1954). It was established to force towns and villages to appropriately dispose of human excrement and domestic waste.

The law concerning waste disposal and public cleanliness (1970)
Industrial pollution became a big social problem, and industrial waste was taken in the regulation in addition to domestic wastes.

The revised law concerning waste disposal and public cleanliness (1976)
When industrial waste with significant chromium content became a social problem, the regulations for industrial waste were strengthened, including the regulations concerning the final disposal site.

The revised law concerning waste disposal and public cleanliness (1991)
Reducing waste and recycling were being demanded by society as well as measures to control industrial waste. Because of the demands of the public, waste reduction and reuse were specified by this law. This was a major attempt to strengthen waste reduction regulations, especially in the industrial arena.

The revised law concerning waste disposal and public cleanliness (1997)
The following points were strengthened in the revised law.
1. Establishment of the authorization system for the recycling
2. More demands to decrease waste

The law concerning the promotion of recycled material use (1995)
This is a new law to promote the use of recyclable resources. Several industries are prime candidates for this type of law because the resources they use are readily recycled. These industries are the paper manufacturing industry, the glass manufacturing industry, and construction. The law first defines products that are easy to recycle. These are cars, air-conditioners, televisions, refrigerators and others. It then indicates the materials that must be collected after use, such as alkali dry cells, aluminum and steel cans (secondary specified products). Specified by- products, such as blast furnace slag, coal ash, soil, concrete, asphalt, timber and wooden product, are specified as recyclable materials to promote recycling.

The law for recycling packaging materials and containers (1995)
The law obliges the recycling of containers such as bottles and packaging materials such as paper packaging. Both the consumer and manufacturer are required to participate in recycling to decrease waste. The manufacturers are required to recycle the containers and packaging materials while consumers are required to cooperate in selective collections. Another organization, which mediates between manufacturer and consumer and which promotes the commercialization of recycled materials is a characteristic of this law.

Recycle law of household electric appliances (1996 and 1999)
This is a special law concerning the recycling of home electrical appliances such as televisions, refrigerators, washing machines, etc. The manufacturer retains the responsibility for collecting and recycling these appliances at the end of their useful lives.

The law concerning the promotion of the recycling of waste food (2000)
To decrease food waste, this law required a reduction in food wastage and recycling of the waste that does occur into materials such as feed or manure.

Basic law concerning the promotion of forming circulated society (2000)
This law, also called the “organic law,” integrates the recycling law with the law concerning waste disposal and cleanliness. The law promotes the minimization of consumption, perhaps the major step toward a healthier environment. This law also promotes renewable energy systems such as sun and wind energy, and aims to achieve good economic development. The priority of this law is waste reduction and it also protects the citizens from the impacts of illegal dumping. The development of recycling as a “social system” and the need for this approach are also addressed in this law.

The law concerning the promotion of supplying ecological goods procurement (2000)
This is the so-called the “green” procurement law. Taking the leadership, the government offices try to buy ecological goods and aim to expand the market of these goods by helping lower the cost. Government agencies are required to create a plan for the procurement of goods and participate in the education of the public about environmentally preferable goods, many of which carry the Japanese Eco-Mark ecolabel.

Law concerning the recycling of construction/demolition materials (2000)
Construction waste consists of 20 % of Japan’s industrial waste, and uses about 40 % of disposal volume in landfills. Construction waste comprises 90 % of illegal dumping, and hence promotion of recycling of construction waste is an important problem. Recycling of construction waste lags far behind the recycling of waste in other sectors. Consequently it is especially important that reuse and recycling of construction and demolition waste be addressed in an urgent manner.

Requirements for selective dismantling and recycling
For buildings beyond a certain minimum size, selective dismantling to recover specific materials such as concrete, asphalt, and timber and wood is required. Thus recovery and recycling of certain materials is required and it is expected that these requirements will expand and increase in the future. (Figure 1).

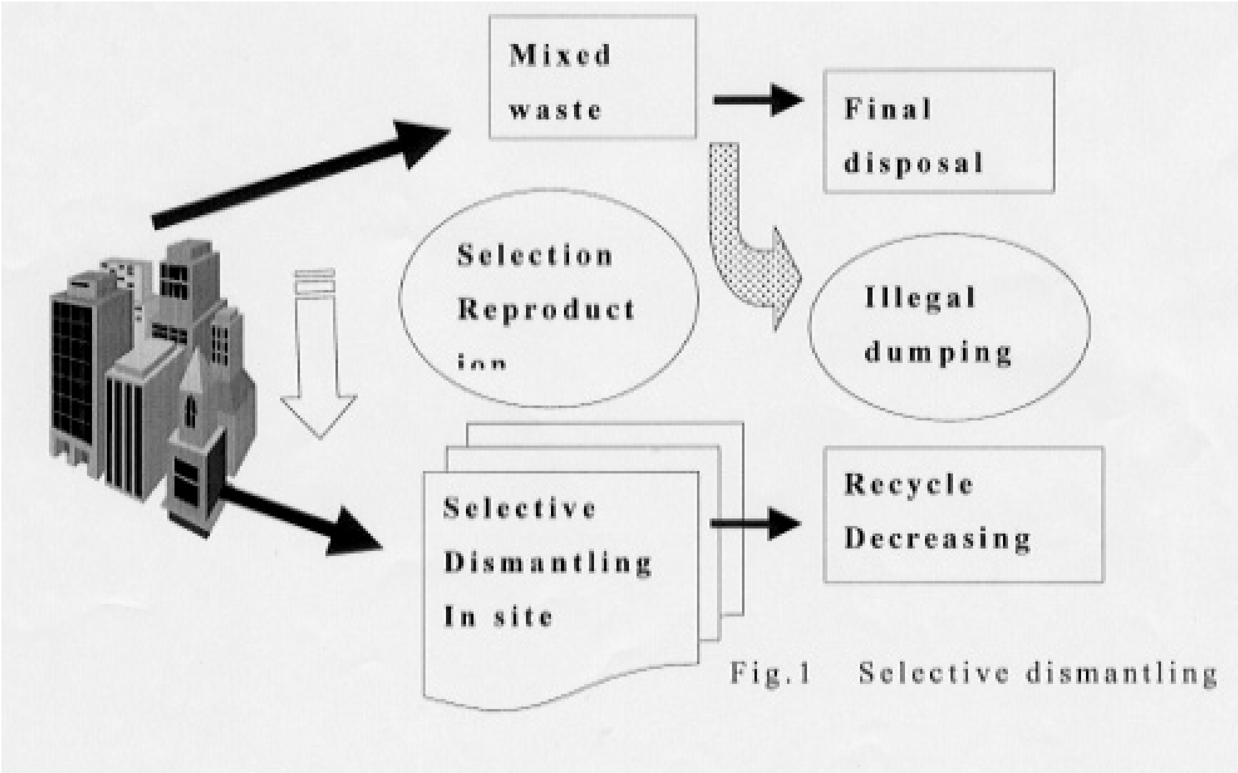

Fig.1 Selective dismantling

Actions to promote recycling and demolition
The owner of a building scheduled for removal is required to report the removal prior to demolition and the results of dismantling and recycling of materials at the end of the process. (Figure 2).

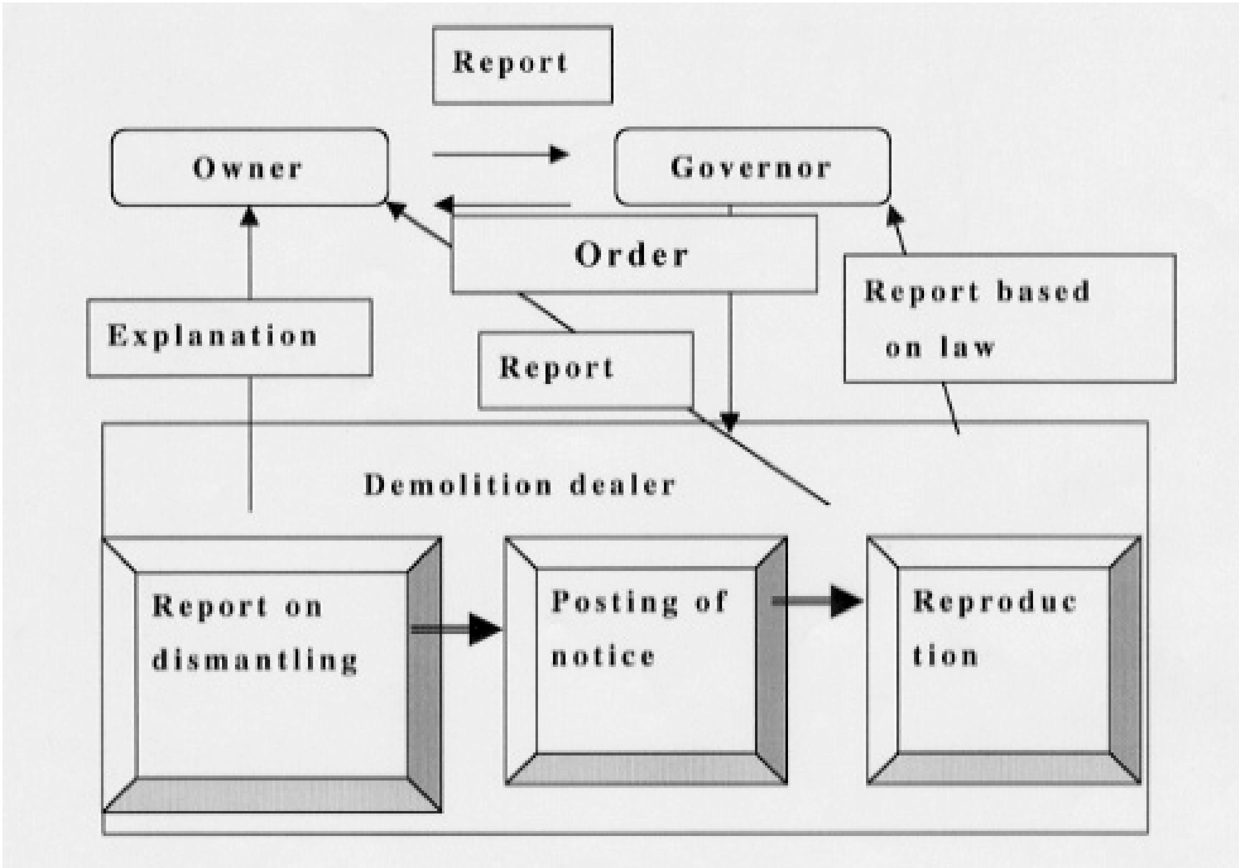

Figure 2 The action to achieve recycling

Adjust the contract between the owner and the dealer

The subcontractor undertaking deconstruction must provide a plan for selective dismantling to the owner. The method of selective dismantling and the expense must be specified for the demolition work.

The establishment of registration system to demolition dealer

The subcontractor undertaking demolition needs to be registered with the municipality and local district. The demolition subcontractor must engage an engineer who manages the various technologies for demolition. Because the budget for demolition is typically small, it is not necessary to get the permission of local government. Thus it is easy for an unqualified and unlicensed contractor to provide demolition services. This is one of reasons why illegal dumping of waste occurs as well as indiscriminate dismantling (called mince dismantling) of structures (Figure 3).

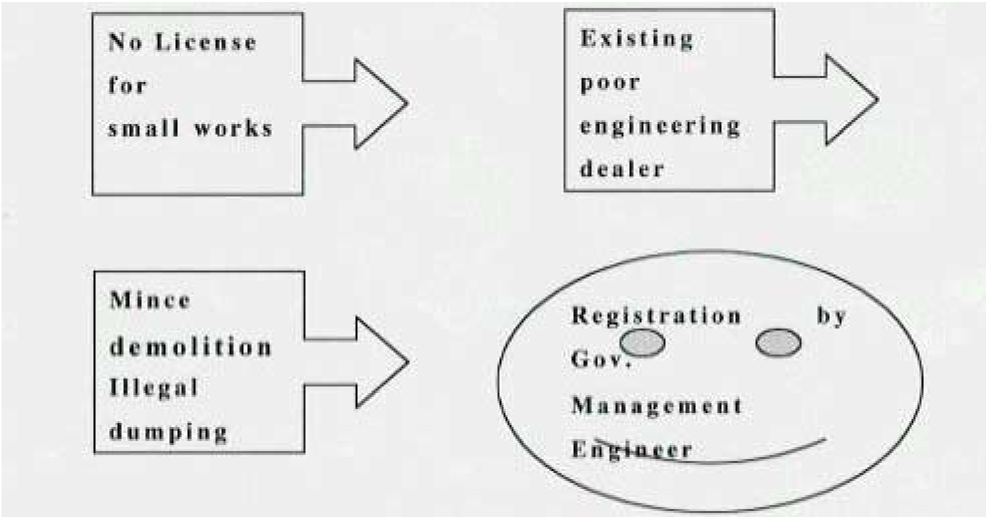

Figure 3 Registration of demolition dealer

The setting of objectives concerning recycle
As the basic policy, the recycling and the reuse of construction materials are promoted by creating an action plan. Getting the cooperation of the owner is very helpful in recycling and reuse.

5.2 THE STATE OF DECONSTRUCTION OF BUILDINGS

Reinforced concrete structures

Demolition Practices
Demolition works of general reinforced concrete building in the city are proceeded under many limitations such as regulation of the noise, vibration, mine dust, work time or work time period. The method to dismantle building is different by kinds of energy, such as the blowing power, oil pressure, water pressure, electricity or heat, and by the form of dynamic or static method to dismantle. In addition, it will be affected by kinds of the dismantling locations such as walls, floors, pillars, beams or foundations, and by the way in carrying out dismantled waste or the shape of it. Until around 30 years before, steel ball method or giant breaker method has been used for demolition works in Japan. But many problems such as vibration or the noise are closed-up. Therefore, new dismantling methods in place of these methods have been investigated. Arranging them by a form of dismantling method, it is classified as followings.

Compressive smash method
A concrete member is inserted in a small frame to be compressed and bent. Next, it is smashed by using a hydraulic jack through the compressive smash mechanism. The compressive smash frame is equipped with a large-scale boom and can cut the reinforcement. This machine is the most widely used tool for demolition these days, because it can be used for demolition of pillar, beam, wall or floor slab. Its capacity to smash is approximately four or five tons /h.

Wire-sewing method
This is a method in which a wire with diamond beads coils a concrete member, and cuts it off by spinning in high speed. This system has the ability to cut 0.4-0.6 tons/h of reinforced concrete members. It is suitable for narrow, dangerous places or in the water.

Cutter method
Special diamond blade is equipped with the machine being able to drive and press, by which a building would be cut off and be dismantled. This is low pollution, and it is possible to work systematically with high safety

Abrasive water jet method
The mixture with ultra high pressure liquid and abrasive fluid is jetted from a nozzle of 3-5 mm in diameter, by which reinforcement and concrete is cut off simultaneously with around 50 cm in depth by cutting and with ability of 1.2 m^2/h approximately. Water supply of around 50*l*/min, is necessary in cutting, but with the countermeasures to high noises during operation.

Static dismantling method with crusher material
In case of crusher to foundations concrete, usual crusher has small opening width of blade. Under the hydraulic breaker, static crusher material is effective for decreasing strong vibration and high noises. The static crusher materials are installed into holes, which generate expanding pressure toward outside in halls, resulting of many cracks in concrete 12 to 24 hours later.

<u>The current situation of recycling and reuse</u>
At present, concrete pieces are almost recycled in place of crushed stones and sands being used for reclaimed ground or roadbed. The type of concrete dismantled wastes varies with the demolition method. In particular, larger ones have less adhesive and mixtures of small ones in products at the case of reproductive concrete aggregate. On the contrary, smaller ones would contain much soils and impurities, and hence, the most suitable demolition method must be applied, taking into account of secondary product, waste disposal or transportation construction with enough. Regarding to usage in reproduction aggregate of concrete, It has noted to be available for no reinforced concrete in the common specification applying to public building constructions (1997). Japan architecture society has introduced examples for building foundations, the underground beams in temporary works, precast concrete piles in the publication of "Manual of demolition works in reinforced concrete building (temporary)" But it is very difficult to realize the recycle as artificial aggregates because of the mixture with finishing or lath materials, which should be collected selectively. We have to investigate about the following issues in future: (1) certificate of quality for recycled aggregate, (2) production technology for recycled aggregate, (3) establishment of supply system for recycled concrete aggregate, and (4) durability of recycled concrete aggregate.

<u>The current research and development in demolition of reinforced concrete buildings</u>
There are few on-going research projects for demolition and recycling of reinforced concrete buildings at present in Japan:

*The development of easy demolition and reproduction in design and materials

*Development of new systems with prefabricated structures and proper units considering demolition and recycle
*Development of high performance machines for demolition works with remote control and automated dismantling
*Development of small size machines suited for partial collections with low powder scattering, low vibration, low noise
*The development of effective usage of refuses (concrete pieces, surplus soil) in construction site

Deconstruction of Steel Buildings

The current situation of demolition method

First of all, all interior decoration materials are removed from the structure in the dismantling of steel building. These interior decoration materials are taken out to intermediate disposal factory and would be disposed. For steel building, fireproof coating is disposed in site with only the structure removed interior decoration materials. When asbestos is used as fireproof coating materials, the dismantling work is done while monitoring the asbestos density in air with keeping good conditions in circumferences as same as rock wool. After steel frame members are cropped out, the structures are dismantled by using hydraulic compressive smash machine used by the demolition subcontractor. Then elements, such as the slab, which is mixed with deck plate (iron and floor slab), are crushed into pieces by compressive smash, and reinforcement of floor slabs are also selected to some extent, resulting that collecting dealer brings them to intermediate dealer. As the dismantling cost is contracted by a unit price of square mete, the selectiveness is realized decently in the site. Collected wastes in intermediate disposal factory are recycled or turn to final disposal site in part. By management list (manifest) system, In demolition works for steel structure, illegal dumping is rare, because of direct money delivery and receipt between prime contractor company and each disposal supplier (the dismantling, collection and transportation, intermediate disposal, the final disposal). As for iron material, it is recycled in the electric furnace as scrap. As general consideration, scrap includes own scrap and the city scrap. The city scrap includes one from the factory and waste scrap. Scraps derived from cars, ships and buildings, are classified in waste scrap. As for waste scrap, press (empty cans), shirring (cutting by guillotine for the materials with long length like pipes), shredder (non-ferrous metals is contained), gas cutting, are adopted according to the process. In particular, wastes through shredder are selected by using dust separation device, collection dust device, magnetic device, and non-ferrous metals sorting device. Scraps are generally classified in quality by grade.

The current situation of recycling and reuse

In recent years, production of steel is between 90 to100 millions tonnes in Japan. Revolving furnace, in which all scraps are recycled as raw materials completely, has a 30% share of the market. Most converters produce pig iron of blast furnace. According to the statistics, scraps are around 10 %. A mount of demand for scraps of iron is around 45 million tonnes. Scraps, which are called waste taken out by demolition, are around 27 million tonnes and 8 million tonnes are from construction sites. It is uncertain how much steel becomes waste in the actually existing dismantling buildings. As mentioned above, steel materials are recycled by scraps to a great content, but reuse of it, however, seems not to be done at all. The wastes are also taken out of steel buildings, resulting that these would be recycled to roadbed etc. or transported in final disposal site through the intermediate dealers.

The current research and development in demolition of steel buildings

Design for dismantling or deconstruction has not yet been considered for steel structures. Development regarding life cycle resources (LCR), life cycle cost (LCC), and life cycle energy (LCE) seems to be proceeded by general contractors. The noise during demolition is such a major concern that a new machinery and technique for low vibration and noise are under development. It would be a right direction of selective demolition as possible from a point of view to decrease steel wastes. There, however, seems to be no idea to recycle with the same form as being used in present buildings.

Deconstruction of timber and wooden houses

The state of demolition method

There are three methods for selectively dismantling wooden houses in Japan: by hand, by machine and by composite way with machine and hand. Demolition methods are affected by building structure, scale, years, and other conditions of neighbor environment, road condition, budget and term of works, but cost cannot be ignored. It generally seems suitable to dismantle by hand. It, however, is difficult to select which method is better, because of the Indispensable transportation to recycle facilities after the selection of waste. The outlines of three kinds of methods are as followings. Selective dismantling by hand this is traditionally used to be in Japan. Most demolition are carried out selectively by hand in the case that a suitable machine can not be used for the reason of road condition, lot condition, neighbor environment, hope of the owner, or house of reconstruction. Selective dismantling by machine is available to use when suitable machine can work without the restriction of road condition, lots condition, and neighbor environment etc. It is very familiar in Japan with the high working efficiency, selecting a small machine for the reason of higher noise by bigger machine in general. By the difficulty in selection, wastes should be selected in unit as much as possible before the working by machine. The mince dismantling is the indiscriminate (mince) dismantling method from a roof at a stretch by machine. It was used most in the case of such mince demolition for wooden buildings. It is almost impossible to select wastes and recycle them, resulting that it has given mixed wastes and remarkable bad influence to environment. The selective dismantling by hand and machine together makes use of good points in hand dismantling and in machine, resulting that it is possible to collect wastes in unit selectively by hand and to improve recycling rate as much as possible. Table.1 shows the example of the rates of recycling and the cost to dispose by three methods.

Table.1 The rate of recycling and cost [1]

	Method 1	Method 2		Method 3	
Kinds	No mixed	mix->sele	mix->disp	mix->sele	mix->disp
Rate of recycle	75%	74%	73%	50%	0%
Ratio of cost	1.05	1.00	1.13	1.06	1.54

Recycling timber and wood products

Use of timber resources is often touted as a root cause of environmental destruction because of the effect on tree and forest ecosystems. At the same time, however, timber and wood products represent the only basic construction material that can be reproduced repeatedly using natural energy. Timber and wood products in fact consume far less fossil fuel resources in manufacturing and recycling than other construction materials, and hence generate much lower levels of carbon dioxide emissions. Furthermore, the plantation trees from which we make timber and wood products absorb carbon dioxide from the atmosphere. And finally, carbon-the main constituent element of plants-is fixed by the action of the sun and remains within the tree after harvesting, eventually finding its way into urban areas in the form of timber and wood products.

The average Japanese timber house contains 76 kg/m2 of carbon, calculated on the basis of the quantity of wood used in construction. This figure is roughly equal to the amount of carbon generated in the manufacture of all the materials required in a timber house. Taken in isolation, then, the timber materials account for just 6% of the total carbon generated, thus providing some 16 times more carbon than they generate.

Timber houses - the most common type of house in Japan-contain the equivalent of 22% of natural Japanese forests or 48% of artificially produced forests. Timber and wood resources therefore represent an effective and very substantial stockpile of carbon.

Reforestation and ongoing management of plantations continues the cycle of carbon dioxide absorption and carbon fixing through new trees. Thus, if the volume of carbon generated from harvest through to ultimate incineration or natural decay is less than the volume produced via natural growth, then the net amount of carbon generated by this sub-system actually falls. In order to maintain carbon-fixing levels in housing construction, we need to work towards long-term usage of resources through strategies such as:

* Reusing off-cuts produced during the manufacture of timber and wood products
* Improving the durability of timber used in structural members (such as beams and posts) and non-structural members
* Recycling wood scraps generated during the construction and subsequent dismantling processes.

Recycling of timber and wood materials at present

Wood scraps can be broadly divided into off-cuts (from the factory) and waste timber (from on-site construction and dismantling). While off-cuts are generally used as boiler fuel or to make other wood products, waste timber from construction and dismantling is usually burnt in the open or disposed of as rubbish, since sorting and processing costs effectively render recycling economically unfeasible. In any case, most waste timber transported to intermediate processing yards is turned into wood chips for boiler fuel, which instantly releases the stored carbon into the atmosphere.

Timber resources are utilized in stages, beginning with finished timber and pre-cut sections, and moving through laminated lumber, particle and fiberboard to woodchips. While technology for recycling wood scraps from construction and dismantling exists to some extent, the general lack of progress in this area can be attributed mainly to social and economic factors and poor environmental awareness. Recycling of timber materials, like any other natural resource, presents a number of problems, but these are not insurmountable. With the right strategies, we can help to increase the rate of carbon fixing on the ground and help to reduce global warming. Timber resources are the keys to solving many environmental problems.

The current research and development in demolition of reinforced wood buildings

In Japan, projects concerning research and development on design and construction works of wooden houses considering recycling after the dismantling, have already begun. Easy dismantling for wooden structures will be developed between2000 and 2002 at Building Research Institute, Ministry of Construction. The Ministry of Construction had developed technical information on waste reduction and recycling of construction waste (secondary products) twice previously:

*Technical development to use wastes in construction (1981-1985: called “the waste project”)

*Technical development of waste reduction and recycling technology of secondary products (1990-1994: called “the secondary products project”)

Technical development for use of waste in construction

Finding possibility to use construction waste in site, various technical developments have been carried out concerning usage to the ground, reclaimed ground, roadbed, pavement, civil structure, and buildings. As for using in buildings, amount of waste of each type of buildings has been estimated and various technical results have been proposed to recycle such materials as wastes of timber scrap, concrete, decoration finishing materials in concrete, scrap wood, bed materials etc. On recycling of timber scrap, the followings have been developed.

* Comparison of possibility to use waste between hand demolition and machine
* Comparison of quality of new wood and waste wood
* Usage as laminated lumbers, core tips of panel, wooden brick, particle board
* Reuse in new construction as structural members (column, beam):

A model house has been constructed in the site of B.R.I Technical Development of Waste Reduction and Recycling Technology of Secondary Products. This has been investigated regarding the law concerning the promotion of recycled material. A new concept, Secondary Products in Construction (not wastes), has been introduced.

A study to reduce waste from wood house construction
Three technologies are necessary to reduce waste from construction of a wooden house. First, the technology to build wooden houses to last long, which results in restrained wastes. Second is a technical issue in designing a new house using salvaged timber or wood. Lastly, using recycled wastes from wooden houses in new construction or remodeling.

The development to construct long life house
B.R.I started this project from 1998 (for 3 years). The aim of this project is to propose a social system able to realize long life houses by developing new technologies such as increasing good stocks of houses resulting less wastes.

Housing construction method to restraint waste (2000-2002)
Buildings have a long life in comparison to electric appliances. As the effect of long life measures would not be seen for a short time, it is difficult to decide how to take care of this matter. It, however, is necessary to develop new construction methods considering easy reuse of existing house elements. To achieve this aim, the effects to restraint waste in future are considered at the stage of planning and designing for new houses.

The usage of dismantled wastes as resources
Various ideas have been proposed to reuse timber and wooden products. Reuse as resources is a way to get effective result for a short time. But, we should note that the reuse of some material is difficult at the end of their life such as boards with adhesive. The similar researches have started in several institutes or universities. Other researchers have introduced a new concept, LCW (life cycle waste) and are considering new materials, construction methods, evaluation method of emission etc. to recycle and reuse.

Deconstruction of building foundation and excavated soils

<u>The state of demolition method</u>
Foundations are generally demolished and not dismantled because new buildings cannot use existing foundations. In general, spread footings can not be reused because of the difference in plans or different bearing capacities. Foundations are dismantled and recycled as aggregates the same as superstructures. As for pile foundations, existing piles can be used even if the plans are different. If the bearing capacity is not satisfied, additional piles would be constructed. In few cases some piles should be removed from site because of change in floor plan and elevation. It is difficult to dismantle and remove piles from deep ground

<u>The state of recycle and reuse</u>
The situation for reuse and recycling of foundation materials is similar to reinforced concrete structures. As for soils from construction site, details are noted in the guideline related to 'The law concerning waste disposal and public cleanliness"(mentioned above). The amount of soil excavated from public works was about 450 million tonnes in 1995 and only around 30% was reused. Soils from construction site are classified in construction soil and mud (or sludge). Mud

is also classified as construction mud, dredged soil and others. Only construction mud is regulated as industrial wastes.

<u>The state of research activities</u>
There have been a lot of investigations about construction wastes related to foundations. Construction mud is industrial waste and is taken a lot out of sites and this has been studied quite extensively.

5.3 References

1 Sakamoto Ko, The state and problems of the dismantling disposal materials from wooden houses, (Wood Industry), 54 (11).

CHAPTER 6
STATE OF THE ART DECONSTRUCTION IN THE NETHERLANDS

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6.1 INTRODUCTION

This Country Report describes the state of the art of deconstruction and reuse of construction and demolition waste in the Netherlands. It contains the current situation, dismantable building systems, dismantling- and demolition-, crushing- and separation techniques, current research and some cases.

The production of construction and demolition waste (DCW) in the Netherlands is about 15 million tonnes each year, for example: this quantity can be used for a road base for a 250 km, six lane speedway, 20 meters wide and 2 meters thick. No explanation is needed for saying that this is an enormous amount for a small country like the Netherlands. The policy of the Dutch government aims at reuse of this DCW in its own cycle, at the highest possible level.
In 1980 the Dutch government published an order for waste treatment [1] this order was called the Ladder of Lansink. This order was a fixed top-down approach:
Prevention,
Element reuse,
Material reuse,
Useful application,
Incineration with energy recovery,
Incineration and
Landfill.

Since 1980 more waste treatment options were developed, therefore the Ladder of Lansink must be extended. This new order shouldn’t be a fixed top-down order, but it should be flexible. This new tool is called the Delft Ladder [2], and three new options were added:
Prevention,
Construction reuse,
Element reuse,
Material reuse,
Useful application,
Immobilisation with useful application,
Immobilisation,
Incineration with energy recovery,
Incineration and
Landfill.

Prevention tries to prevent the production of waste. This step must be taken before a building is demolished, in the design and building stage. This is so called Design For Recycling (DFR). This can be done by using a dismantable building system like LEGO is for children, or using recyclable or renewable materials, which are easy to separate in and can be used in their own material cycle.
Five dismantable building systems are being described in chapter three. In this state of the art most commonly used dismantling-, demolition-, crushing- and separation techniques are described. In the chapter of demolition techniques a few techniques from other disciplines like techniques used for dismantling nuclear power plants have been added. These techniques could be used for dismantling buildings, which were never designed for dismantling into reusable

elements. The chapters of the crushing- and separation techniques describes the whole field even techniques which aren't used for processing construction and demolition waste, but it gives a good view of all techniques used in the Netherlands.

The chapter current research describes only the research done at this moment at the Delft University of Technology. The research covers the whole field: Design for Recycling, Dismantling buildings, Integral chain management and material recycling. To support this state of the art a few project have been chosen to explain what has already been done in the Netherlands with preventing the landfill of demolition and construction waste.

6.2 CURRENT SITUATION

Role of the government

Introduction

Prevention and reuse are unlikely to grow if this is purely left to market forces. Hence, the government aims to direct the DCW market through legislation and other forms of regulation. The primary role of government in this is to set the constraints and take care of related policies. The nature of the Implementation Plan for Demolition and Construction Wastes is such that the objectives set by it are compatible with the market conditions wherever possible, within the confines set by government for the disposal of DCW.

There is a range of instruments available to the authorities to steer the DCW quality and quantity. The main government measures in the Netherlands will be discussed in this chapter so that we can analyse the resulting problems and how high level reuse can be promoted through legislation and other regulation. These measures include the Landfill Ban, Provincial Environmental Ordinances and the Building Materials Decree.

Demolition and Construction Wastes Landfill Ban

The Demolition and Construction Wastes Landfill Ban is an important measure to promote waste reuse. It prohibits, *inter alia*, the landfilling of reusable or burnable DCW and the use of unprocessed DCW.

One of the objectives of this ban is to promote the separation of DCW into component streams, which are transported to processing plants rather than going outside the construction industry cycle. The landfill ban applies not only to reusable DCW but also to the residues from DCW processing (sorting and crushing). These residues, such as pre-crusher fines, often contain significant volumes of reusable material.

As a result of the landfill ban these residues are taken to sorting plants where they are separated into fractions. This often results in a significant further reduction in the volume of waste to be landfilled.

Before the introduction of the landfill ban, on 1 April 1997, landfill operators were permitted to accept DCW without charging for it (no 'gate fees'). In practice this applied to clean rubble which could be used without further processing as hardcore for roads, etc.

Only the Provinces could discourage the landfilling of DCW by regulating landfill rates and through the licences governing the design of the landfills. The introduction of the landfill ban means that DCW processing companies no longer have to compete with the relatively low landfilling charges.

The ban also means that the capacity, or overcapacity, of the waste incineration plants is used. Despite the environmental levy introduced in 1993, non-reusable burnable DCW was often landfilled as the landfilling charges were lower than the incineration charges.

The effective enforcement of the Landfill Ban requires certification of the sorting plants. As of the date of introduction of the Landfill Ban, landfill operators may only accept residues from certified companies.

These sorting operators can apply the landfill mark to materials to be landfilled if the residues contain no more than 12% of reusable materials. However, differences in enforcement between the Provinces have been found to complicate the effective enforcement of the Landfill Ban.

Demolition contractors who separate DCW at source are faced with the problem that they have to take the separated, non-reusable material to a sorting plant to get the landfill mark before they can transport the material to a landfill site. This imposes significant additional costs on them. In certain cases these costs could make at-source separation less attractive. Demolition contractors should also be eligible for certificates to take non-reusable materials directly to landfill sites. Such a certificate could be included in a Demolition Process Certificate.

The Landfill Ban is an important instrument to increase the reuse rate. It also promotes improvement in the quality of material for reuse through the application of more sophisticated separation and cleaning technology. Hence, it not only increases the reuse rate but also significantly expands the options for high level reuse.

Asbestos

Further to the Asbestos Removal Decree a certified company has to remove any asbestos present in the building before it is demolished. This will often require an asbestos analysis by a certified company. When the demolition wastes are delivered to a processing company it is again checked if they contains any asbestos. This asbestos management system ensures that the DCW to be processed does not contain unacceptable asbestos concentrations.

Provincial Environmental Ordinances

Waste disposal is primarily organised at the provincial level. Central government competency is decentralised to the provincial authorities. They can include regulations in their Provincial Environmental Ordinances (PEO) to implement their Provincial Environmental Policy Plans. The Provinces can pursue environmental policies, which are stricter than the general environmental policies, within the constraints imposed by the general quality requirements laid down in Orders in Council and other regulations.

The twelve Provinces in the Netherlands regulate the disposal of commercial wastes (trade wastes) through their Provincial Environmental Ordinances. By requiring notification of commercial waste disposals the Provinces intend to obtain more information about the waste streams and to monitor disposal and processing. These Ordinances require waste collection and processing companies to present quarterly reports to the Province on the waste volumes they have received. Commercial wastes may not be transported between Provinces, unless an exemption is obtained. In this way the Provinces want to prevent unnecessary waste transport and they also want to ensure that the capacity of the processing plants and landfill sites (created at great cost) in their Province is used. Wastes on the ‘Green List’ are not subject to this prohibition. Stony wastes are covered by this exemption, but only if the wastes are actually reused.

Provincial authorities have two clearly overlapping roles in this area. Firstly as policy makers and regulators and secondly as landfill operators and competitors of private industry. For example, in North Holland the incineration charges are maintained at a very low level to offset the overcapacity created by the rapid increase in capacity.

Provincial authorities can direct waste streams through the environmental ordinances. In this context they should not only be guided by financial considerations but they should also promote high level reuse of wastes. They have to support the policies of the national government in enforcing their ordinances. For example, the enforcement of the ordinances should be consistent between provincial authorities.

Building Materials Decree

The application of secondary materials should always be accompanied by an assessment of the long-term environmental impact of the introduction of these materials onto or into the soil. The Building Materials (Soil and Surface Waters Protection) Decree was introduced to do justice to the sometimes conflicting interests of the greatest possible reuse and the greatest possible protection of the soil and water.

The Building Materials Decree introduced regulations on the use of building materials: when they are placed they may not be mixed with the soil already present on site, it should be possible to remove them, and the materials must be removed when the structure is demolished.

The Decree introduced two categories of materials. Category 1 building materials fully meet the requirements and may be used without isolation. Category 2 building materials only meet the requirements if they are isolated and are also subject to further requirements.

These requirements (standards) were set on the basis of the maximum acceptable soil contamination due to the leaching of building materials. If there are no leaching tests of sufficient accuracy for building materials then their organic compound composition is considered.

Hence, the Building Materials Decree establishes a link between the emissions from a building material and the resulting soil contamination (immission). When determining the leachability of building materials a distinction is made between shaped (e.g. bricks and blocks) and unshaped (loose) materials. A material is shaped if the volume of a unit is greater than 50 cm^3 and has a strength exceeding 2 N/mm^2.

Some building materials obtained from secondary materials arising in the construction industry cycle, such as crushed asphalt aggregate, crushed concrete aggregate, mixed crushed aggregate, crusher fines and washed crushed brickwork aggregate are partly classified as Category 1 materials. Pre-crusher fines and undefined DCW are generally Category 2 materials. This is because DCW may be contaminated with organic compounds. Hence, some of the waste cannot be reused (particularly as unshaped material) or requires sorting and/or processing.

The Building Materials Decree provides sufficient options for the use of unshaped building materials derived from secondary materials from the construction industry cycle. Secondary materials may also be used in shaped building products, for example, the replacement of gravel in concrete by recycled aggregate.

Together with the Landfill Ban, the quality requirements introduced with the Building Materials Decree have improved the acceptance and processing of DCW: two important conditions for high level reuse.

Role of the market

Apart from the policy of the Dutch government, there came demands from the market. Especially from the road building industry, which needed the secondary materials (asphalt, concrete and mixed granulates) for their constructions. Concrete and mixed granulates proved to be a good alternative for the construction of road basements, asphalt could be reused in new asphalt. The availability of these materials was even cost effective.

The building and constructing industry researched the use of pulverised fuel ash, or simply fly ash, and granulated blast furnace slag as an aggregate in cement and concrete. The fly ash is a puzzolanic material, which is collected from the exhaust gases upon combusting of powder coal in power plants. Granulated blast furnace slag, a by-product from the production of iron and steel, is a (latent) hydraulic material witch may react slowly by it self to form cementituous compounds [3]. Both materials are primarily used because the cements made with these materials are cheaper. Therefore all the fly ashes and granulated blast furnace slags, produced in the Netherlands, are used right now in the cement producing industry.

Amounts

The use of secondary materials in the building and constructing industry proved to have an enormous effect on the total amount of waste. The production of these construction and demolition wastes is, as mentioned, about 15 million tonnes [4]. It is the second largest waste-stream in the Netherlands (after dredge mud, 55 million tonnes, and before municipal wastes, 7 million tonnes). The use of secondary materials, produced from building and constructing waste, is nowadays about 90%, 13,5 million tonnes. The use of wastes from other industries in the building and constructing industry is about 11,5 million tonnes. So the total amount of wastes used in this industry is about 25 million tonnes each year, this is about 18% of the total need for raw materials in this industry. 25 million tonnes, that is 25 football fields covered with waste with a height of 30 meters, each year. So the building and constructing industry uses more waste than it dumps on a landfill or incinerates. Due to the use of secondary materials, the need for raw materials is lower. Therefore the scenic deterioration is less.

Not all the effects of reusing secondary materials are positive. The breaking of the stony fraction takes a lot of energy. And sometimes the use of secondary materials needs additional materials. For the use of concrete or mixed aggregates in concrete, more cement is required in order to reach the same quality. The quality of products with secondary materials is an important point. Not only the strength and the stiffness of the material must be (at least) the same as that of the primary material, also the leaching (Dutch building decree) and radiation must be restricted to narrow limits. By the use of concrete, mixed or masonry aggregates in road construction is the sulphate leaching rising extremely with a little bit of gypsum in the secondary aggregates. Also radiation in the inner climate is improved by using these secondary materials as an aggregate in concrete.

6.3 DISMANTABLE PRECAST CONCRETE SYSTEMS

Introduction

The concept of Demountable Building was first introduced in the Netherlands by professor H.W. Reinhardt during his inaugural speech at the Technical University of Delft on May 19th, 1976. Focusing on the multi-purpose character of modern buildings, he recommended the application of demountable connection within precast concrete systems. A variety of steel connections such as bolts and screws form the basic of the structural joints in the demountable system. The conventional poured connections were no longer the only option to achieve stability, unity and rigidity within precast structure. Dry assembling methods using steel connection devices are gaining territory in an increasing degree.

Later on, a special committee D7 (a division of CUR-VB) was founded in order to explore the possibilities for research and development of Demountable Building for concrete structures in the Netherlands. This committee executed many laboratory experiments regarding the innovation and safety aspects of demountable connections in precast concrete. On May 1985 an international symposium on this topic was held in Rotterdam, featuring worldwide challenge and research topics on demountable building.

Despite of two decades of research on this topic, the demountable building systems have less than 1% market share in the current building industry in the Netherlands. The barriers to introduce Demountable Building as a form of reuse has failed to reduce the waste production within the building industry in the Netherlands, which has meanwhile reached the annual amount of 15 million tons.

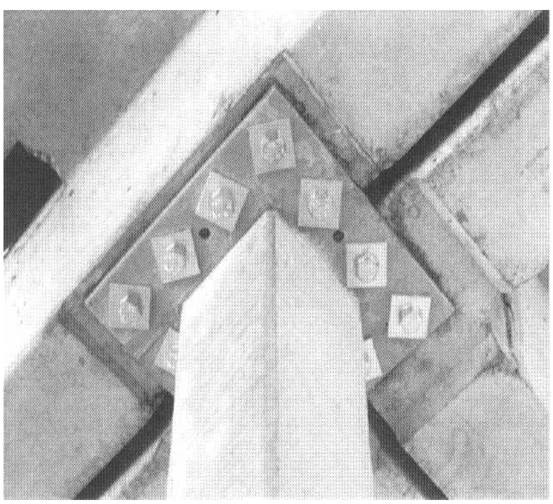
The Dutch authority took responsibility to promote further development of demountable building and stimulated new interest from the environmental point of view. Governmental contributions were given to projects, which applied flexible and demountable assembling methods on precast concrete structure instead of conventional poured connections. The authority took action by means of new policy and regulation concerning flexibility and demountability of buildings, which also involve increasing the cost for waste disposal and waste treatment.

The Government Buildings Agency, a division of Ministry of Housing, spatial Planning and Environment, performed research in analyzing the existing demountable building-systems in the Netherlands. This assignment resulted in classification and comparison study of five major precast concrete systems, published in final report “Demontabele bouwsystemen in beton” (Demountable building systems in concrete) on July 1996. Those five demountable systems, accompanied with figures featuring basic principle of the systems and its connection details, are concisely summarized in the following pages.

MXB-5 system

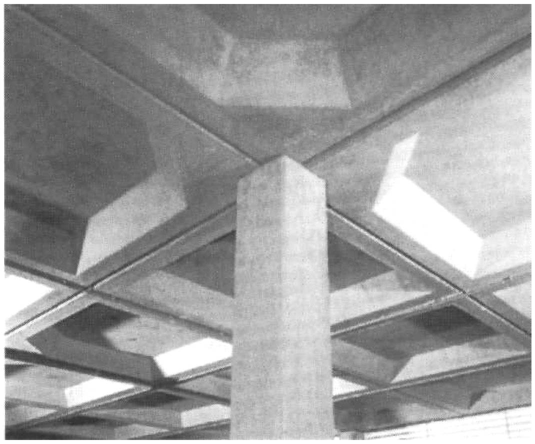
The Mxb-5 system is completely assembled with dry-mounting method. The columns have steel plates on both ends. The floor-elements are provided with anchor bushing, embedded in concrete. The columns and the floor-elements are connected through tightening bolts.

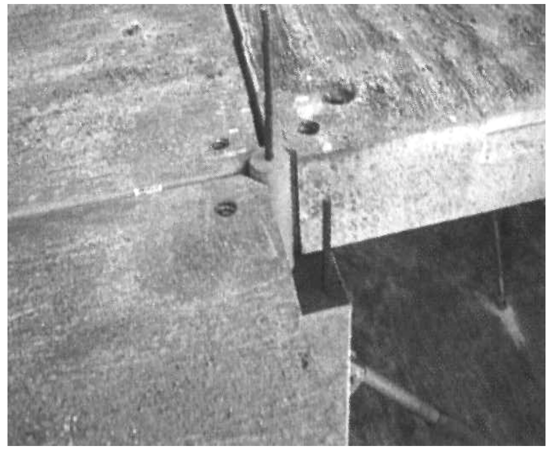
Standardized floor-elements	: 3600 mm x 5400 / 7200 mm
Standardized columns	: 200 x 200 mm / 300 x 300 mm
Mounting speed	: 800 m2 / day
Permissible Load	: 10 kN/m2, rib floor, thickness: 60/320 mm



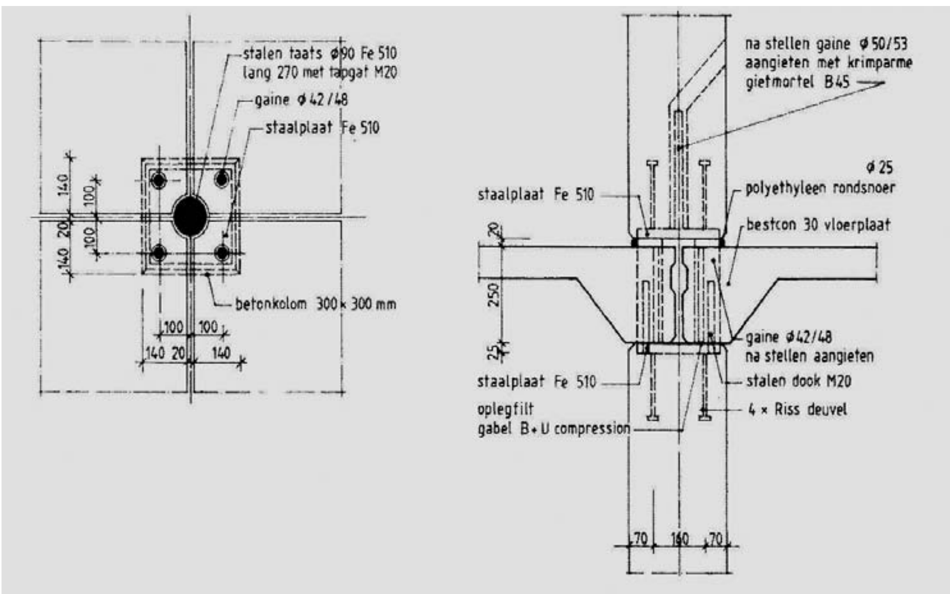
Bestcon-30 system

Four threaded ends on the upper side of the columns and openings for grouting in the floor-elements form the connection. The structure is dry-mounted at first, and the connections are sealed by pouring non-shrink mortar afterwards.





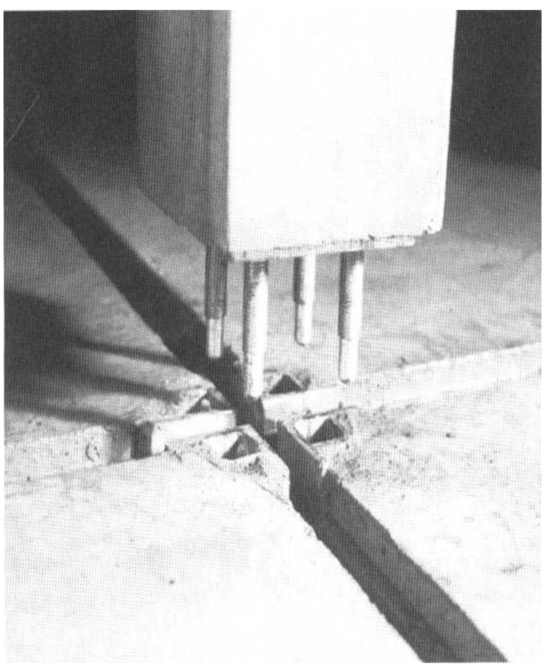
Standardized floor-elements	: 3600 mm x 5400 / 7200 mm
Standardized columns	: 300 x 300 mm
Mounting speed	: 500 m2 / day
Permissible Load	: 8 kN/m2, cassette floor, thickness: 80/250 mm

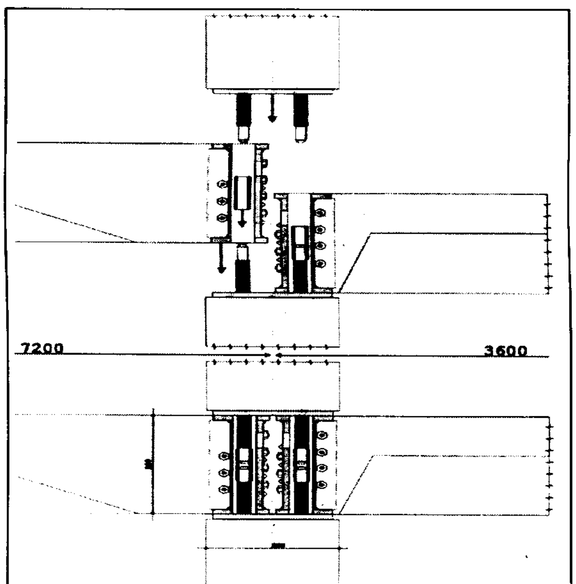


CD-20 system

Four short pens each on the upper and lower side of the columns and grouting slots in the floor elements form the structural connection. Pouring the grouting slots is needed for providing horizontal stability as well as for fixation of the columns.

Standardised floor-elements	: 3600 mm x 4800 / 5400 / 6600 / 7200 mm
Standardised columns	: 200 x 200 mm / 300 x 300 mm
Mounting speed	: 800 m2 / day
Permissible Load	: 4,7 kN/m2, rib floor, thickness: 80/200 mm



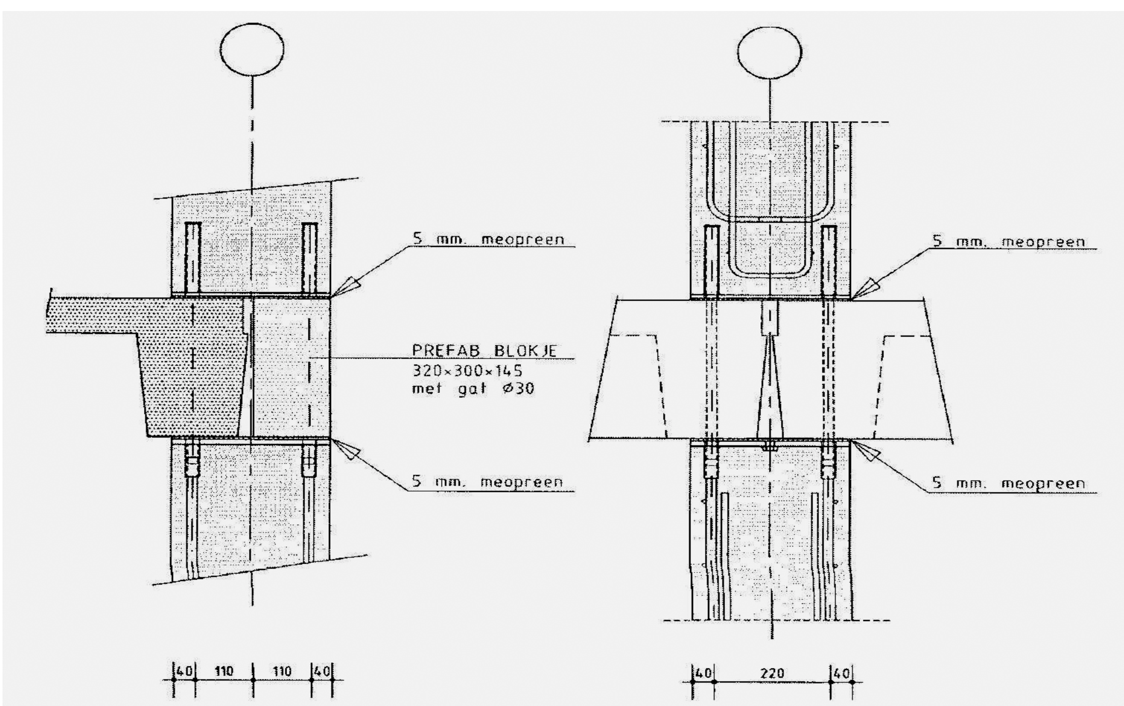


CD-20 column-floor connection detail

Moducon-2000 system

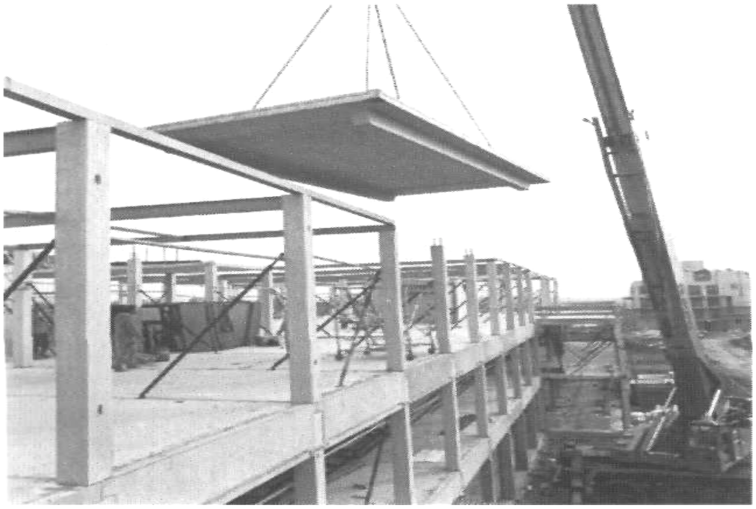
Four insert bolts on the upper side of the columns and openings in the floor elements forms the structural connection, poured with non-shrink mortar. The following column has four fitting pieces on the lower side, which form connection with previous columns.

Standardized floor-elements	: 3600 mm x 5400 / 7200 mm
Standardized columns	: 300 x 300 mm
Mounting speed	: 400 m2 / day
Permissible Load	: 6 kN/m2, cassette floor, thickness: 80/200/320 mm

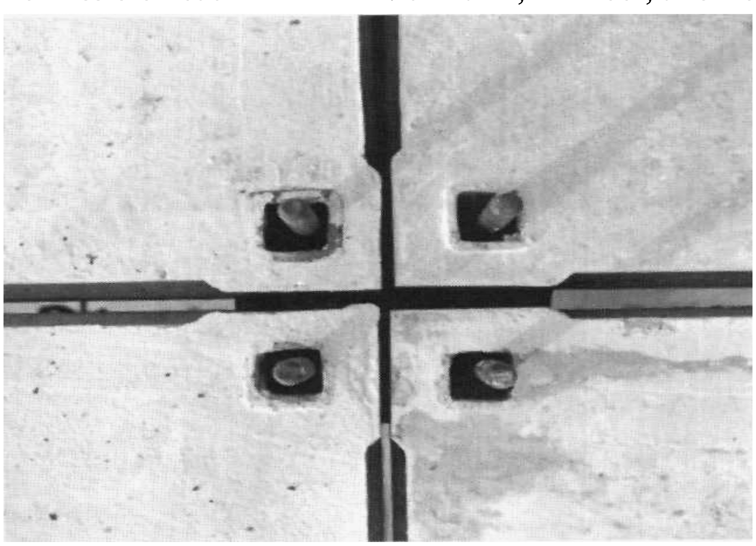


SMT system

On the upper and lower side of the columns fitting pieces were casted, in which dowels were inserted. The floor elements with grouting slots are fixed over these dowels and finally poured with non-shrink mortar.



Standardized floor-elements	: 3600 mm x 5400 / 7200 mm 3750 mm x 5625 / 7500 mm
Standardized columns	: 250 x 250 mm
Mounting speed	: 500 m2 / day
Permissible Load	: 6 kN/m2, TT-floor, thickness: 100/160/400 mm



Conclusions and research recommendation

Development of demountable systems should not be the ultimate goal of research. Demountability of a particular building system does not guarantee a demountable assembling on site. Interaction between precast manufacturer, constructor, and building contractor is one of the decisive factors to achieve demountable building. For further implementation in the future, issues as assembly-methods and hierarchy, connection devices and logistics should be taken more seriously into account. Several major research considerations and key-questions are being displayed in the table below.

Research fields	Key-questions	Key-words
Optimization of demountable systems Most of the demountable systems available in the Netherlands are assembled with poured-connections. Such connections are fixed with cement mortar. This is the cause why sometimes even demountable systems have to be demolished.	How to detect the bottle-neck-joints, which could cause barriers in future demounting?	Connection or Bottle-neck-joints?
	Which mounting-hierarchy would allow partial demounting (for repair or replacement) in the future?	Mounting hierarchy
	Would it be rewarding to invent a whole new demountable precast system? Or is it much better to redesign the precast joints in the available systems?	System redesign
Introduction demountable mortar Cement mortar is by far the mostly applied filling mortar for poured-connections between precast concrete components. Unluckily that is the main reason why (sometimes even demountable) precast concrete structures cannot be demounted without damage.	Which favorable characteristics of cement mortar resulted in its wide application?	Benefits of cement mortar.
	Could another alternative filling mortar such as epoxy or natural resin possibly compete with or even exceed the benefits of cement mortar?	Alternative mortar
	Could dry-mounting systems with bolted connections entirely replace mortar joints?	Dry-mounting

6.4 DEMOLITION TECHNIQUES [3]

Introduction

Architects and structural engineers are taught a great deal about how to build buildings, but little if anything about what happens to buildings during their life and at the end of it. In the Netherlands about 90% of DCW are currently being reused. Is the term 'wastes' appropriate, or should we refer to 'secondary raw materials'? If a building is to be demolished then the demolition process should aim for the reuse, at the highest possible level, of the materials released by the demolition activities. A demolition plan is essential when a building is demolished. Although developing such a plan costs time and money but it will reduce the costs of landfilling.

CONTRACT AMOUNT = COST OF DEMOLITION + LANDFILL COSTS - REVENUES

The ‘cost of demolition' includes all costs of equipment, labour, overheads, profit margin, etc. If the revenues (from the sale of materials) are high then a demolition contractor might even pay to get the work, but this would be an exception. Demolition contractors include the following factors in their assessments: location, type of building, construction method, materials used and the presence of any hazardous substances. These factors determine how the building will be demolished.

Demolition process

Firstly, it is investigated if the material contains any hazardous substances such as asbestos. If there are any such materials then a specialist contractor is engaged to remove them. Asbestos stripping in particular requires extensive safety measures.
After completion of this investigation an architectural reclamation (salvage) company checks the building for any components, which can be reused as they are. These include leaded glass, marble fireplaces, precious woods such as walnut and oak, central heating boilers, water heaters and radiators. Demolition contractors prefer it if these components are removed first, as this saves them work and their sales provide revenues.

Demolition contractors divide buildings into the following types:

1. Buildings constructed of brickwork with wooden floors, wooden roof structures, flat roofs with bitumen roofing or roof tiles.
2. Buildings with concrete skeleton frames, which may also include prestressed concrete elements.
3. Buildings with steel frames.

Generally, all three building types are treated as follows:

First, the buildings are stripped of unusual or reusable components such as leaded glass, traditional sanitary ware, etc. Next, floor coverings and ceilings (plaster) are removed. Burnable and non-burnable materials are separated. Glass is removed from the window frames. Building services installations and plant are removed. Metals are removed. Piping is generally removed before the real demolition work starts. Roof tiles are removed. Roofing is removed and landfilled. The roofing ravel is contaminated with PAH (polycyclic aromatic hydrocarbons) and should be treated as chemical waste. The gravel can be washed and reused. The question arises if gravel could be reused on roofs without washing as this simply moves the chemical contamination rather than eliminating it.

Stripping a building produces a number of waste streams and a range of different materials. These are transported to a sorting plant where they are separated in burnable and non-burnable materials. The burnable fraction is incinerated in a waste incineration plant and the non-burnable fraction is landfilled.

1. Buildings constructed of brickwork with wooden floors, wooden roof structures, flat roofs with bitumen or roof tiles

<u>Demolition:</u>

When only the brickwork and floors are left the building is taken down floor by floor. Joists (beams) and wooden floors are removed from the building using a crane and equaliser beam. The nails in joists and planks are removed by punching. The punching unit pushes the wood around the nail down and then extracts the nail by its head. There is currently a good market for second-hand wood. It is often used for floors and has the advantage that it is fully seasoned - it will not shrink. Wood, which cannot be reused as planks or beams is transported to Germany for the production of chipboard.

Brickwork is cut into sections and taken to a crusher plant. Occasionally, the client intends to build a new building using the bricks from the old building. However, the mortar used after the Second World War is so strong that the bricks will break before the mortar does. In that case, the bricks are carefully removed one by one. This is mostly relevant in renovation projects when dealing with unusual and rare types of brick.

2. Buildings with concrete skeleton frames, which may also include prestressed concrete elements

<u>Demolition:</u>

The roof, which is generally covered with bituminous material, is removed first. The gravel is removed from the roof. The wooden roof structure is removed with a crane and equaliser beam. The wood is sold on the second hand market or to the chipboard industry. The concrete structure is cut up using breaker shears and taken to a crusher. In the past, the rubble was reduced in size on site and the iron was removed from it. However, current crusher plants can handle large sections (2 m x 2 m) and it is more economical for demolition contractors not to break up larger sections. If the rubble fits in to a truck then the crusher can handle it. Hence, the maximum dimensions are what fit into a truck.

Prestressed concrete structures pose special problems. Often, nobody knows that there are prestressed elements. If it is suspected that a structure may be prestressed then a section is cut away to investigate this. If it is indeed found to be prestressed then the terminations are first cut away at the ends of the structure, which will often lead to its collapse. Structures with unexpected prestressed sections can be dangerous, because the structure may suddenly give way and the concrete may fly around.

3. Buildings with steel frames
If the beams can be reused then the structure is disassembled. Otherwise, the steel structure is cut up and sent to a steelworks. Occasionally, structures such as steel bridges are sold as a whole and shipped overseas.

Further demolition activities for all three types of buildings:
The foundations (masonry or concrete) are broken up, like the rest of the building, and removed by diggers or they are pulled out of the ground. If the foundations include a deep basement then it may be necessary to create an excavation in which the work is carried out. Groundwater lowering will then be necessary to work in the dry condition. This will be very expensive. It is difficult to remove wooden piles and piles formed in situ as they tend to break. However, they can be broken up at some depth below the surface. In contrast, precast concrete piles can be successfully removed through simultaneous vibration and pulling.

Trends and developments:
If a building contains both brickwork and concrete then these materials are normally not separated. However, crushed concrete secondary aggregate is stronger than crushed masonry secondary aggregate and is therefore easier to sell. As a result, the crushing companies are left with the crushed masonry aggregate. Hence, they want to mix it with the crushed concrete aggregate to produce mixed crushed secondary aggregate. This material is mostly sold to the road construction industry. The demand for the brickwork fraction is expected to increase as a number of major road construction and water engineering projects are being planned.

The operators of fixed crushing plants, members of the BRBS, want to avoid competition from mobile crusher plants and demolition contractors selling crushed rubble directly to the road construction industry. Their plant and associated provisions for safe and efficient operation, such as impermeable floors, required substantial investments and enables them to deliver materials of consistent quality. According to the BRBS, demolition contractors and mobile crusher plants cannot provide this constant quality. Another argument they use is that fixed crusher plants have to meet a range of environmental standards relating, to noise and dust emissions, etc. which mobile crusher plants cannot meet.

Selective demolition is actually nothing new in this industry. It was only in the period from 1970 to 1985 that demolition was not done selectively At that time the capacity of the machines had developed so much that it was possible to demolish buildings quickly and it was assumed that our resources were inexhaustible.

Techniques

Balling, knocking down a building with a heavy steel ball, is no longer widely used. It has a major impact on the surrounding area through noise and vibration. The most difficult aspect of balling is aiming the ball accurately. A limited jib movement develops the large pendulum movement of the ball and this takes a great deal of experience.

Demolition by blasting is only used in the Netherlands when a building has to be brought down very quickly, for example if it is close to a major road and there is not enough space to screen the demolition site. Generally, buildings will only be demolished by blasting if the local authority or the client requires this. Removing the rubble takes a great deal of work.

As the economic life of buildings is getting shorter and shorter it is expected that there will be more demolition activities. Another development is that buildings are stripped, but not demolished in their entirety. In itself stripping is not a new development as all buildings are stripped before demolition. When a building is stripped and the structure should therefore remain intact, smaller builders' plant is used, which can move inside the buildings. These smaller diggers and cranes are more compact which allows them to work on intermediate floors and they are light enough to be supported by normal floors.

Demolition contractors can choose from a range of methods to demolish buildings and civil engineering structures. These range from manual demolition to the use of explosives, each with their own applications. A number of common techniques will be discussed below.

Mechanical methods

Balling

Balling is carried out with a heavy steel or cast iron ball, with a weight of 500 to 5000 kg (figure 5). The ball can be brought into contact with the building by swinging or free fall. For swinging the ball is attached to a dragline (crawler mounted unit with a rotating frame with engine and control cab).

The ball can be made to swing by slewing (rotating) the dragline or pulling in the drag rope. In this way, the direction in which the rubble falls can be controlled. Balling can be used for masonry, mass concrete and reinforced concrete. Balling has become less popular due to the associated nuisance (dust, noise and ground vibration) and as it requires a considerable amount of space, which is not normally available in built-up areas. Balling produces large sections of rubble, which have to be reduced in size with other plant. Currently, the demolition industry in the Netherlands no longer trains operatives in balling. The free-fall method is used at all large steelworks to break up large blocks of slag from iron and steel production. In this case, the ball is hoisted up by a large magnet and then dropped on the material to be broken up.

Impact breakers

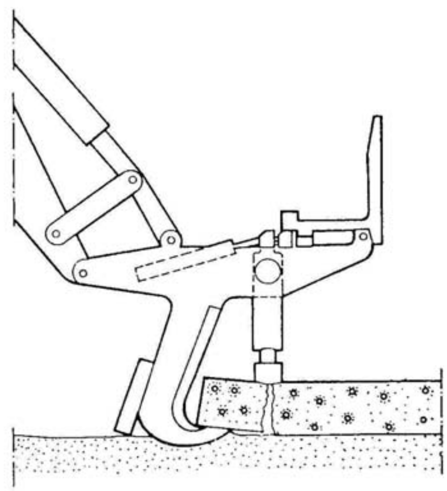
Both pneumatic breakers (powered by compressed air) and hydraulic breakers (powered by oil under pressure) are available. Their operation is similar, but they have different characteristics. Pneumatic breakers are noisier, have a lower impact energy and are less energy efficient, however, they are cheaper to buy and maintain. Breakers are used on brickwork, mass and reinforced concrete, stone and asphalt. Both pneumatic and hydraulic breakers are available as portable tools for minor demolition and refurbishment projects. For heavier duty applications they are attached to hydraulic excavators. There is a wide range of picks (chisels) available for a range of applications.

Hydraulic shears

These large shears have a high capacity and have to be mounted on hydraulic excavators. They are available in a range of sizes and for different materials such as concrete, steel and wood. The shears have two sets of knives that slide past each other to cut materials or they have toothed jaws to break up concrete.

Crushing and breaking

Crushing and breaking operations rely on the fact the materials will fail and break into smaller pieces if they are subjected to high enough compressive or bending forces (figure 8). This is done with the following plant:



Breaker bucket (nibbler): a special bucket attached to a hydraulic digger. The bucket, with a capacity of 0.6 to 2 m³, is fitted with replaceable teeth. The teeth are placed under slab that is then broken by moving the bucket towards the digger. The bucket can also be used to remove the broken materials.

Ripper: heavy duty curved tooth attached to a hydraulic digger arm, instead of a bucket. The size of the ripper depends on the nature of the work and the capacity of the hydraulic digger. It is used for masonry, concrete and asphalt.

Thermal cutting

In cutting operations the object is divided into smaller parts by creating narrow slots. Heating them to a high temperature to initiate combustion and then maintaining the combustion cuts iron and steel. Another common method is to heat the material to melt it.

Cutting torch (oxygen/fuel gas cutting)

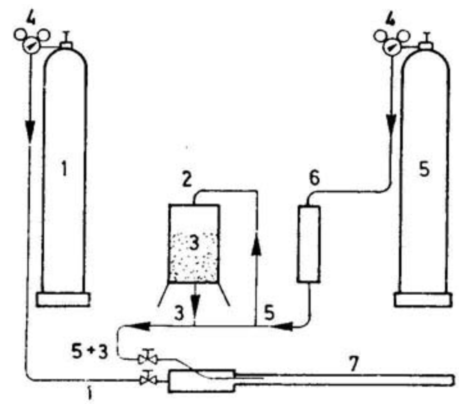
Cutting torches are fed with oxygen and a fuel gas (acetylene, maximum temperature 3260°C; propane, 2850°C; or natural gas, 2630°C). The gases are obtained from high pressure cylinders and flow to the torch through hoses. The choice of gas and burner depends on the thickness of the material (iron and steel). Once the iron is heated it will oxidise (burn) in the oxygen stream (figure 9).

Powder cutting torch

These burners are supplied with iron or aluminium powder, or a mixture of both. Powder cutting torches have three connections: for oxygen, fuel gas (generally acetylene) and the powder, which is supplied by air pressure (figure 10). Powder cutting torches, which reach a temperature of 4500 °C, cut slots rather than holes. The cut can only be started at a free edge or a hole cut using another method. This technique requires a skilled operator and is relatively expensive. It is used for highly alloyed refractory (heat resistant) steels and cast iron.

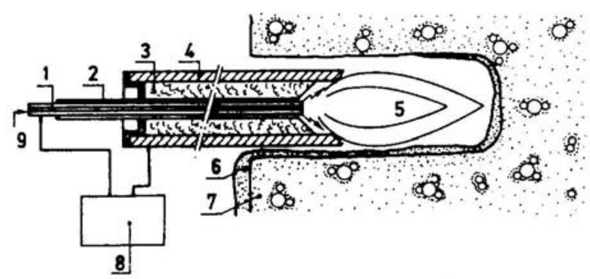
Powder cutting lance

Powder cutting lances (figure 11) are similar to powder cutting torches. The unit consists of a holder for pipes with a length of 3 m and a diameter of 6, 9 or 12 mm. The holder has connections for oxygen and the powder/air mixture. Powder cutting lances are used for steel and other metals, mass concrete and reinforced concrete and other stony materials.



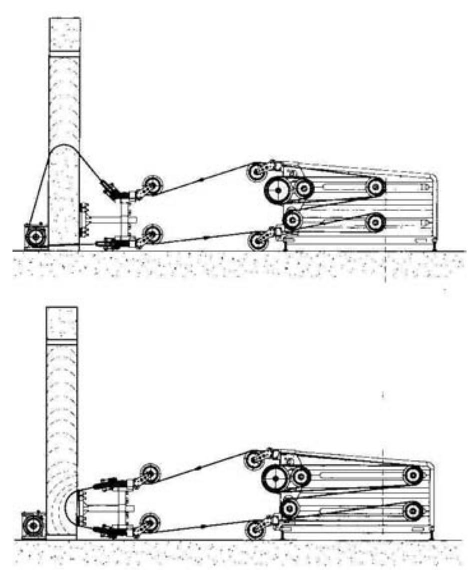
Plasma cutting torch

Plasma is an electrically conductive gas. Electric energy is supplied to the torch to ionise mono-atomic noble gasses such as argon and helium. Unlike in oxygen/fuel gas cutting the material does not burn, instead it is molten and blown out of the kerf (cut). A plasma-cutting rig includes a power supply (transformer) and gas cylinder. Plasma cutting can be used to cut highly alloyed and structural steel (170 mm), aluminium (180 mm) and copper (100 mm). This method is very productive, it may be four times as fast as powder torch cutting. This may be relevant in certain situations, for example when a road or canal may only be blocked for a limited time.



Mechanical cutting and grinding

In mechanical cutting a structure is divided into smaller elements but cutting slots by abrasive or chip-forming action. The cutting tools use: teeth shaped to cut chips of the material, diamond-coated discs, or resin bonded discs containing an abrasive such as carborundum. These three types can be used to cut almost any material. Diamond cutting blades are available in many sizes, from 10 cm to over 1.5 m diameter, depending on the object to be cut. Diamond tooling is cooled and lubricated with water, to which an additive such as oil may be added. The water also removes the grinding dust. Diamond cutting equipment can be electrically, pneumatically or hydraulically powered. For bigger structures a diamond wire sawing technique can be



used, this technique uses a long diamond wire of a maximum length of 16 metres. With this technique two cuts can be made at the same time.

Expansion

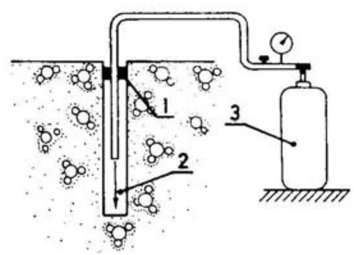
Expansion is based on the principle that some substances exhibit a great increase in volume, which may occur very slowly or very rapidly. Very rapid increases in volume are explosion. Explosives, gasses and solids may be used for expansion demolition. Generally, after expansion breaking, the materials need further size reduction and transport. However, the object being demolished will then be more accessible to building plant.

Explosives

There is a wide range of explosives, all with their own special properties, which have been used for civil demolition operations. Depending on the circumstances and the materials to be broken, explosives with a high or low detonation (0.000,05 sec.) speed may be used. The detonation pressure ranges from 10,000 to 50,000 MPa. Using a range of detonators such as immediate, millisecond, and delay detonators, and detonating cord carefully controls blasting operations. In this way, the sequence in which a building collapses can be controlled quite accurately. Blasting certain elements just before others can control the fall of the building. However, there are many examples of blasting operations going wrong. Cordoning of a large area around the blasting site prevents accidents.

Gas expansion

The expansion of liquid CO2, which changes to the gas state builds up the pressure in a round hole in the material to be demolished (figure 15). A cartridge filled CO2 with is placed in a round metal holder. The holder has clamps to secure it in the hole so that it is not ejected when the gas is released. The evaporation of the gas is initiated by an electrically heated filament, and occurs in 0.02 to 0.05 s. The resulting pressure ranges from 125 to 275 MPa.



Bristar

Bristar is a chemical substance, which sets after mixing with water, and the setting is accompanied by a great increase in volume (figure 16). Bristar is charged into drilled holes with a diameter from 35 to 51 mm. The holes have to be dry. The pressure is developed over 24 to 72 hours and ranges from 30 to 40 MPa.

6.5 CRUSCHING TECHNIQUES

Introduction

After a construction is demolished, the materials must be crushed and separated in order to create useful secondary material. Therefore there are several crushing plants in the Netherlands. At a crushing plant the material will be sieved to get rid of the sieve-sands. After this first sieving the materials are fed into a pre-crusher to create smaller particles so that the largest parts will not damage the main crusher. Between the first and the second crusher, the materials are de-ironed by a magnetic separator and screened; the largest parts are fed back into the pre-crusher, the rest is fed into the second crusher. Other materials, like glass, plastic, wood etc are removed by washing, air separation or manual separation. At the end, the material is sieved in order to create the right fractions for the road building and concrete industry.

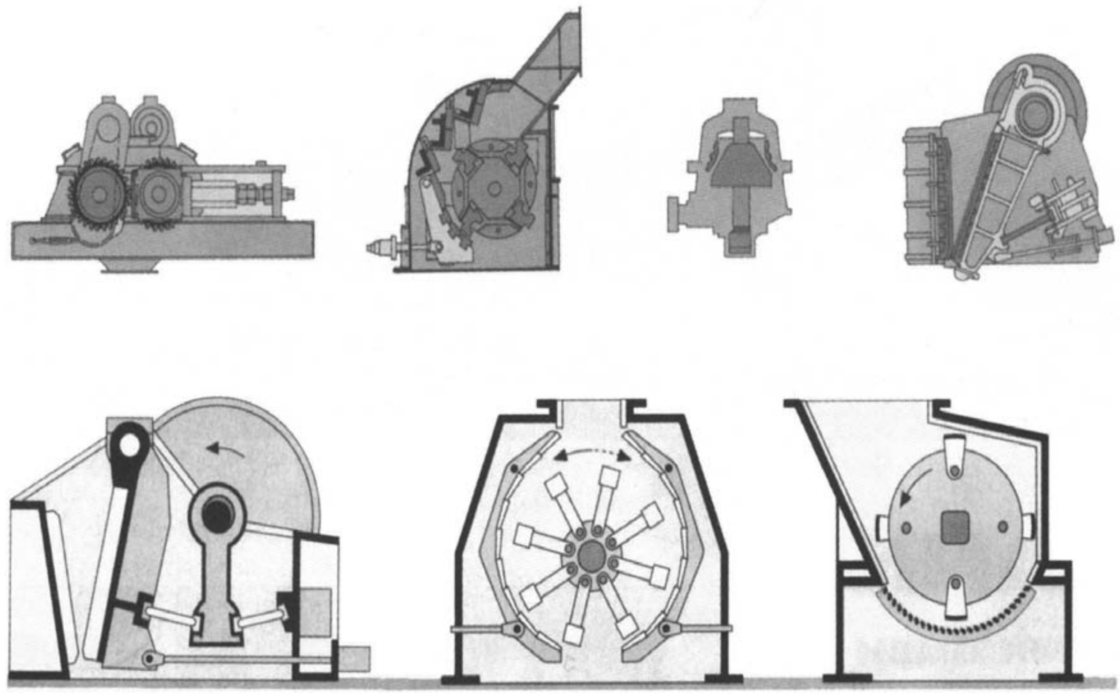
Techniques

Toggle crusher
Large pieces of (reinforced) concrete can be fed to the toggle crusher, and therefore this crusher is mainly used as a pre-crusher. There are two different types of toggle crushers [7]; the jaw crusher and the knee crusher. By both of these crushers are the materials crushed between a fixed and a moving plate. The jaw crusher has a moving plate what moves in two directions.
The knee crusher has a moving plate that moves in one direction (the jaw is opening and closing), but it moves faster. Therefore the materials are broken into smaller pieces. This crusher is mainly used as a second rusher.

Impact grinder
In an impact crusher or prall-mill the materials are smashed against the prall-plates at high-speed. Therefore the weak materials are crushed into smaller pieces than the strong materials. This crusher can be used as a pre-crusher and as a second crusher.

Cone breaker
The cone breaker is mainly used as a second crusher [7]. A moving cone that is pressed against the fixed plate crushes the materials. The crusher can’t crush very large pieces of material and is therefore used as a second crusher.

Grinder with double (toothed) rolls
This grinder has two rolls [7], with or without teeth. These rolls are rotating and the material is crushed between them. This grinder is not useful for very strong materials.



6.6 SEPARATION TECHNIQUES [6]

Dry separation techniques

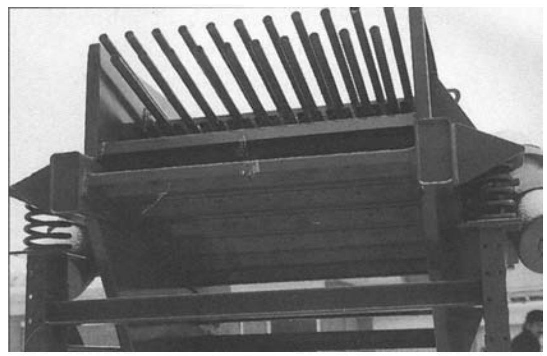
Gravity separation

<u>Sieving</u>

One of the most important separating methods that are using the gravity force is separating by sieving or screening [8]. Although there are various types of sieves, the most common are shaking and vibration screens, sometimes as a multiple deck systems. The screens are usually made of metal or plastic mesh or perforated metal. The separation takes place at particle size. The smaller parts can pass the sieve or screen, the bigger ones can't.

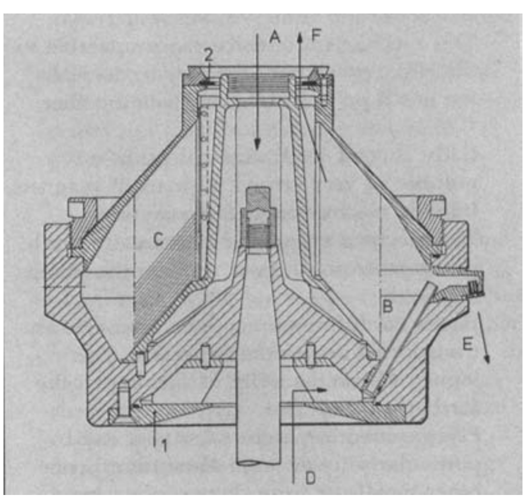
<u>Bar sieves</u>

A special sieving technique is used in bar sieves [8]. The bars are parallel with predetermined spaces between, and they form a bed with a free area at one end (figure right). As the bars vibrate, smaller particles fall through the spaces, while the larger ones move to the end of the bars and fall of on a conveyor.



<u>Sorting mat</u>

Another special technique that uses the gravity force is the sorting mat [8] for construction and demolition waste. The mat has a banana shape form with steel ribs in the horizontal plane. The material falls on the horizontal part, and the mat start to move upwards. The smaller particles will pull up and fall of at the highest part. The larger ones will roll back to the horizontal part. Afterwards the mat will move in the other direction and the larger parts will fall of at the lowest side.



Centrifuge
Separation can be carried out with the aid of centrifugal force [8]. Differences in specific density cause the separation. It is widely used by the metal-working and in the aircraft industry to rid turnings of oil and to separate water from finished machine oil.

Air separation
There are different methods to separate materials with air [8]. These methods use the difference in specific weight of materials. The material is fed through an air stream. The lighter materials are blown out. This blowing can vertically (under a perforated conveyor) or horizontally (during the free fall of a conveyor). The so-called zig-zag air classifies uses more air streams after each other.

Shaking tables
The shaking table [8] consists of a porous deck through which air is blown. The air picks up small particles and these are removed via a hood above the deck. The deck is inclined several degrees and vibrates in the horizontal plane. The combination of forces will separate the lighter particles from the heavier ones. The heavier particles a collected at the lower end of the deck, the lighter parts will move to the higher end of the shaking table.

(Electro) magnetism

Magnetic separation
Magnetic separation techniques are used commercially for about a century with particular emphasis on:

- the removal or recovery of strongly magnetic materials such as tramp iron in solid processing,
- the separation of magnetic from non-magnetic ores in the mineral and mining industries,
- separation of ferrous from non-ferrous metals in the metal scrap industry, and
- recovery of steel cans from municipal trash.

Magnetic may be either of the permanent or the electromagnetic type. They are available in three configurations, namely, the drum, the magnetic head pulley, and the magnetic belt . They may be assembled and suspended in line, cross belt, or mounted as conveyor head pulleys.

The bed depth of the waste stream affects the efficiency of magnetic separation. For more complete removal of ferrous, a secondary magnetic separator may be considered. The applications of magnetic separation are divided into three classes: conventional separation processes, high gradient separation processes, and eddy current separation processes. Conventional magnetic separations include:

- removal of tramp iron from all sorts of process streams,

- recovery of iron and steel from scrap metals,
- recovery of tramp iron and steel cans from solids waste, and
- benefaction of minerals.

The high-gradient applications require the higher forces that can be generated with high-gradient fields. The eddy current processes are used in waste reduction to recover aluminum cans for recycling and in recovering non-ferrous metals from car shredding operations.
The major applications of magnetic separation to waste minimization are in:

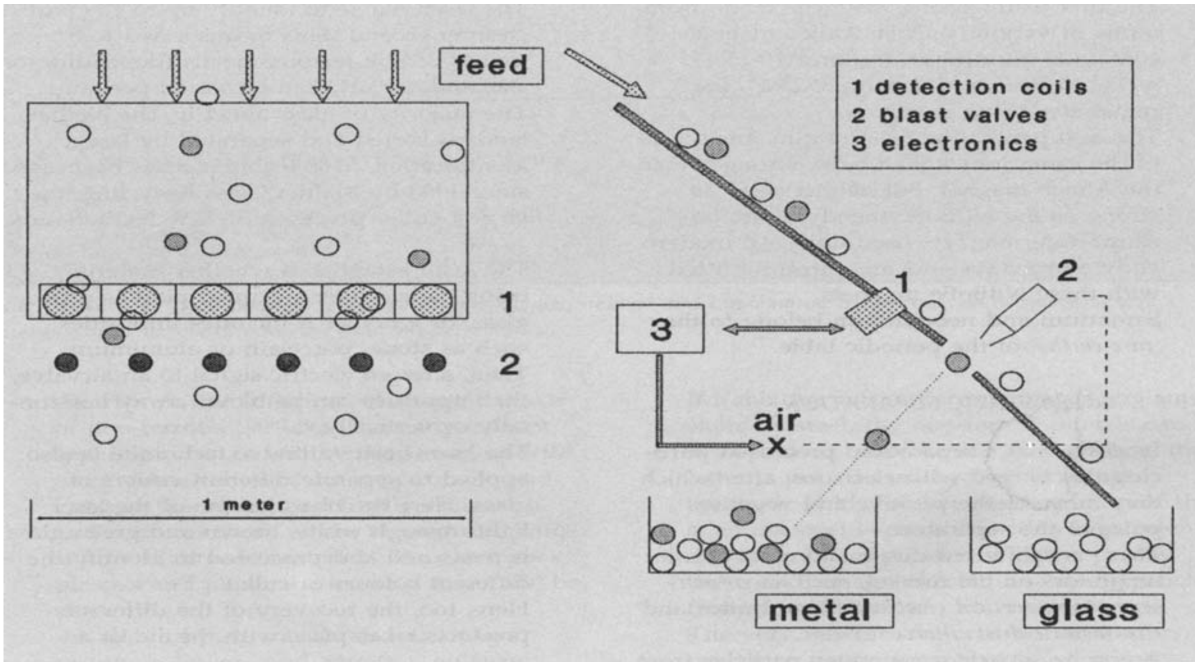
- the recovery of magnetic materials from waste streams to permit their recycling as raw materials and
- removal of non-ferrous metals from non-metals.

<u>Eddy Current Separation</u>
A relatively new addition to the arsenal of magnetic separations is the eddy current separator. This unit can separate non-ferrous metals from non-metallic materials after the ferrous metals have been removed. Eddy current separation is based on the following principal: In a conducting object, which is passed through a changing magnetic field, eddy currents will arise which are opposed to this field. This mechanism of forces is comparable to the effect produced when trying to place the north poles of two magnets together.

Eddy current separators consist of a number of very strong permanent magnets. The higher the conductivity of each metal the further it is repelled. And also, it can not only be used to remove aluminium soft drink cans from municipal waste, or to separate aluminium bottle screwcaps from glass; but also to separate copper and brass and other metals from incinerator residues.
Apart from the influence of shape and size of non-ferrous particles, the eddy current separation forces will be the strongest with aluminium, followed by copper, zinc and brass in this order, and finally with lead and stainless steel, where the induced force is almost zero. In materials like glass, rock, plastics and paper the induced force will be zero.

Electrostatic
In electrostatic separation, processed particles are charged with electrons, after which they move to the positive and negative poles of the separator. It is used:
to recover valuable materials such as the precious metals in gold and silver processing and
to remove pollutants such as acid droplets or fly ash from exhaust streams being discharged to the atmosphere. There are different designs of electrostatic separators, such as corona separators, vertical electrostatic separators and electrostatic separators dust filters.

Separation on transparency
This system relies on the fast analysis of materials with the aid of a laser [9]. After identification the electronic control system passes an electric signal to an air valve, which opens and closes by means of a magnetic field. This system is used for glass sorting in the Netherlands and Germany.



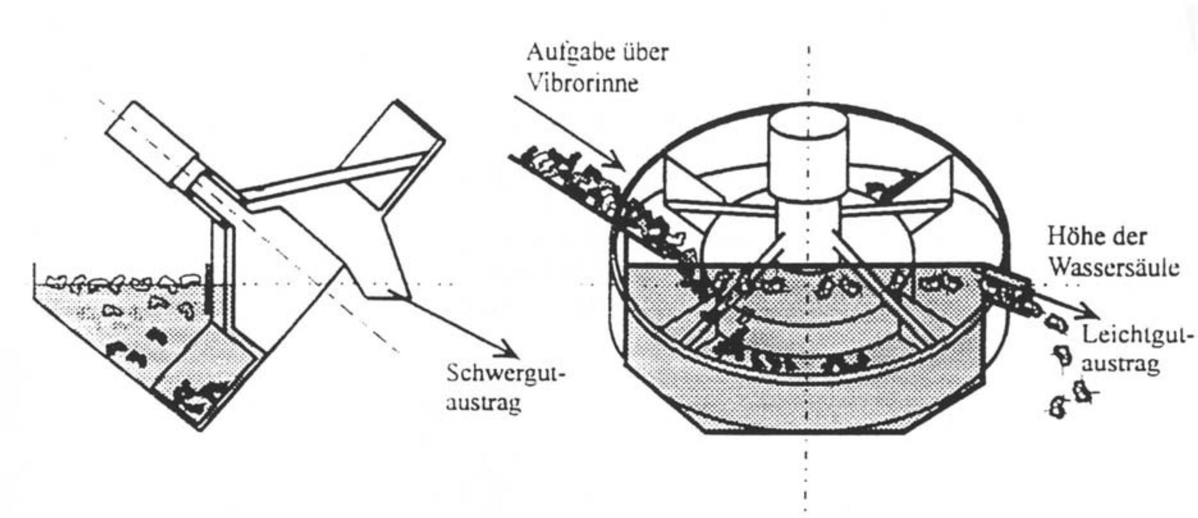
Microwaves
The top layer of asphalt can be removed by using microwaves [9]. The temperature of the asphalt will rise due to the microwave radiation. Therefore the bitumen will soften, and the asphalt can be removed.
Peeling off concrete is another utilisation of microwaves. The top layer of concrete can be removed, as it is heavily contaminated.

Wet separation techniques

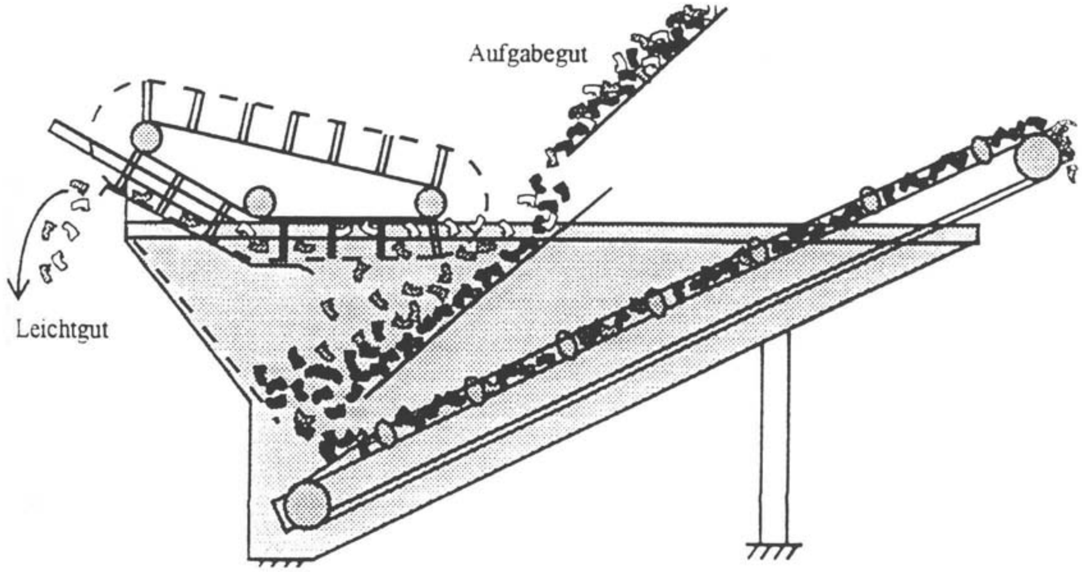
Sink-float methods [10]
The material to be separated is fed into a medium whose density lies between the lightest and the heaviest component of the feed material and has to be determined for each concrete case in relation to the process objective. In the separation medium the particles of higher specific weight sink, and those of lower specific weight float. For building rubble recycling, separation densities of about 1.4 g/cm3 and higher should be achieved. As a rule, suspending ultra fine particles together with the process water form an autogenous heavy medium, which is in a rage of about 1.2-1.4 g/cm3 depending on the respective process conditions and process water treatment. Processing units able to technically implement this principle in building rubble recycling are the Drewboy and the Beyer light material separator.

<u>Drewboy dense medium washer</u>
The Drewboy dense medium washer, also referred to as Drewboy separator, is a processing unit with widespread application for raw materials extracted by mining for separation of bulk materials according to density in a working medium. Depending on the medium solids, densities of about 3.1 g.cm3 can be achieved. Since separation takes place in the static gravity field, a minimum separable lower particle size is obtained related to the rheological properties of the working medium.

The Drewboy separator is basically a box type dense-medium bath with an inclined bucket wheel. This is in a conically shaped basin filled with working medium at the side and rotating at a peripheral speed of 0.2-0.4 m/s. The wheel, whose axis is located approximately at the level of the medium surface, is divided into single chambers by radial performed metal plates. The working medium enters the basin from below, however, partly also together with the feed material from above. Here the material with higher density compared to the working medium sinks and slides into a chamber of the inclined wheel. The sinks are then lifted out of the water form an inclined plane located under the wheel and they fall through an opening of the base plate. The perforated plates allow a return flow of the working medium to the basin
Since the floats do not simply flow off over a weir with the medium, the separator is equipped with a discharge aid opposite the feed side, which consists of a rotating bar cage with chain pieces.



Beyer light material separator
The light product separator developed by the Beyer Company is a unit of simple design. Basically, it consists of a trough filled with water in witch the separation process occurs. The building rubble is fed into the trough via a split chute. The sinks are transported from the trough whit a conveyor while the floats is discharged by a separate, circulating flight conveyor. The formation of an autogenous heavy medium can raise the cut point. In addition it is possible to generate an up-current in the equipment to influence the cut point.



Flotation methods
Flotation uses the buoyancy provided by the attachment of small bubbles of a gas (usually air) to the dispersed particles. This lifts them to the surface of the liquid in the separation chamber. Because of the air bubbles adhering to a particle, the density of the material becomes less than 1 so that flotation occurs. When air cannot be used because of its oxidizing properties, natural gas or nitrogen can be substituted for it.

The bubbles usually attach to hydrophobic particles such as oils and grease and can thus be used to remove them from mixtures with water. However, some particles are also hydrophobic or can be made so by surface treatment with additives. This permits them to be removed from aqueous system by flotation along with oils and grease. It also permits their removal from hydrophilic particles in a mixed suspension in water. Thus, a flotation unit can lift hydrophobic particles and allow hydrophilic particles to sink at the same time.

There are two major types of flotation, named for the manner in which the gas bubbles are produced. One is called dissolved air flotation while the other is induced air flotation. With DAF the air is dissolved in the feed stream under pressure and then released in the form of tiny bubbles as the pressure is reduced in the flotation chamber. In IAF the air is dispersed in the water using motor-driven mixers, which draw air from the atmosphere and disperse it under the surface of the feed to be separated.

Flotation can only be used in the range of 10-500 microns in mineral applications and from 5 to 10 mm in the flotation of plastics. The major areas of application other than mineral benefaction are:

Industrial wastewater
Intake water for industrial use
Transportation wastewater

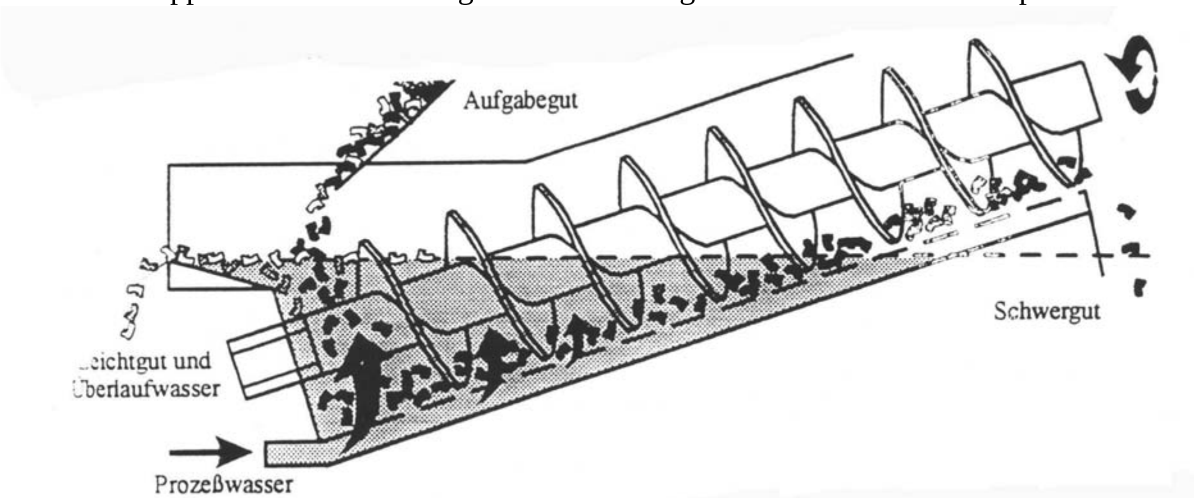
Food processing wastewater
Municipal sludge thickening

For municipal sludge thickening, it is used to increase the solids content of the sludge from municipal water treating plants.

Rising current [9]
With rising current separation a continuous rising column of water is projected through a pipe. The feed material to be separated is fed in the rising column of water. The material, which sinks faster than the water column, will sink to the bottom of the separator. The material transported by the column of water is separated from the water with a screen or a sieve. The water can be reused again.

Up-current [10]
With up-current cleaning, material separation of bulk material occurs according to terminal velocity of its particles in a continuous upward flow. Among others, the terminal velocity of a particle is dependent upon size and density. A separation according to terminal velocity will thus require a preliminary classification of the feed material – in relation to density differences of the materials to be separated.

Screw-type up-current sorter
The building rubble to be cleaned is fed in the bottom zone of the equipment and transported by the screw shaft. The feed material is desagglomerated by the rotation of the shaft. This can be enhanced by additional by additional blades at the shaft. Process water enters from below in the feed zone of the trough thus generating an up-current. The floats are discharged over a weir together with the process water. The rotation movement of the screw results in a transport of sinks to the opposite end of the trough. The sink charge is located above the suspension surface.



Hydro-cyclone
In hydro-cyclone separation water, or a heavy media suspension sometimes called “heavy water”, is brought into rotation in a piece of equipment which is a combination of a cylindrical and a conical part. As a result of the rotation, larger and heavier particles first move to an apex in the bottom. Lighter, or smaller, materials will remain suspended and leave the cyclone via the

vortex at the top of the cyclone. This is because of centrifugal force. Forcing the flowing fluid to swirl in a tight spiral as it passes through a separation vessel generates the centrifugal force. The carrier fluid can be either a gas or a liquid, and the particles can be either liquid or solid because the cyclone can operate at high ambient temperatures and pressures (up to 1800^{o}F and 7500 psig). The gas–carrier version has found extensive use as a dust collector for catalysts in the process industries and for pollution control in size reduction and combustion processes. It is also frequently used to collect mists generated by either vapour condensation or vapour/liquid contacting. The liquid-carrier version is often called a hydro-cyclone and is used to separate either liquid or solid particles from a carrier liquid. It finds its major uses in:

- removing sand, grit, and other solids from intake, waste, or recycle waters and
- recovering solids or liquids from process streams.

Jigging

Density separation by jigging is one of the oldest cleaning technologies utilised for solid raw mining. Particularly in West European mining, it is a widespread procedure since it represents an action with high precision of separation and cost-effectiveness addition enables high throughput rates (up to 700 tph). Jigging is also used in the sand and gravel industry as well as in recycling industry.

The separation process is based on a formation of layer particles according to density in a pulsating fluid bed, which is generated by a periodically upward and downward fluid flow. It is possible to separate feed materials with a broad particle range. In building rubble recycling, for instance, the 8-56 mm separation is separated in one unit.

Properties of the feed material such as particle size, particle shape and density of the material affect the jigging process. The process parameters also play an important role: besides viscosity of the medium, the number of strokes per minute and the amplitude of stroke and the jigging diagram are of special significance for the separation process.

<u>Pneumatic jig</u>

Pneumatic jigs [10] can be pulsated at the side or from below. Bottom-pulsated jigs will enable wider jigging beds. However, such wide jigging beds are not necessary for processing of building rubble so side-pulsated jigs are favoured here since these are somewhat more favourable in terms of energy.

The pre-screened material is led continuously via a feed on top onto the screen plate of the jig. By pulsating the water bath, which is achieved by feeding controlled periodical compressed air on the screen plate at the opposite side of the u-shaped hutch. The material is fluidised during the upward movement and settles during the downward movement according to its density. The heavy mineral fraction settles direct on the screen plate while the lighter interfering materials accumulate at the surface of the jig. The transport of material is ensured by an overlapping of the pulsating bed with an underwater current led into the hutch under constant pressure, which acts in the direction of the discharge.

The light material flows over a weir at the end of the jig over a dewatering screen. The heavy product is removed with float-control from a highest possible reserve layer.

Pilsator jig

In the pulsator jig [10], a vibration box is located under the jig box where a flat inclined screen plate, which is connected by rubber membranes. This vibration box is excited via connecting rods to an eccentric drive located below it, whose stroke length of 14-40 mm and strokes per minute is adjustable from 60 to 120. The up-current water flowing in nearby the feed is aimed to promote a fast arrangement of light material in the jig bed. Before the end of the jigging box, the light materials flow over a vertical adjustable discharge into a transverse launder. The coarse sinks are led off via a weir with float-control. Fine sinks move through the screen plate into the vibration box and are discharged there with a part of the underflow water in channels arranged at the side.

Thin film separation

The concentration of higher density due to the effect of fluid flow over a solid surface can be used to advantage for density separation [10]. The separation effect can be explained analogue to sedimentation in currents. At equal particle size, frictional forces of different magnitude prevail between particles of different density and the solid surface, which counteract the drag force of fluid flow. This results in different transport speeds of the particles. Besides the density difference, also position and width of the particle range, particle shape, current velocity and profile as well as surface conditions influence the separation effect.

Aquamator

The aquamator [10] was already developed in the seventies for the separation of organic contaminants from gravel. Since the early eighties, this equipment already has been implemented successfully on several occasions in building-rubble recycling plants.

The aquamator consists, in principle, of a frame, a circulating, transverse-stable endless belt with vulcanised Flexowell edges, corresponding drive and tension drums as well as belt guide rolls and spraying unit.

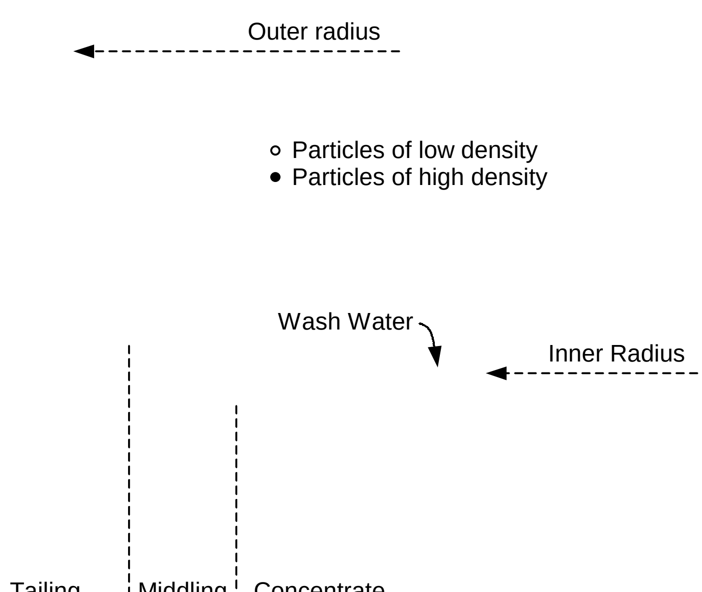
The contaminated fraction is fed, generally divided into fine and coarse fraction, into the aquamator via a feed chute on witch the material is already charged with water. It arrives in the separating and washing bed section, which is formed by the endless belt. The material is fed against the direction of the belt movement. The separately adjustable spray jets are arranged underneath the feed chute as well as over the water bed. These promote the separation between mineral content and the light material to be removed. Due to the wash water flowing out in the direction of the deeper tension drum and the opposing frictional force of the belt, a separation of the fractions according to density occurs in the washing bed. The feed fraction of higher specific weight settles on the belt and is discharged as treated product via the higher driving drum. The lighter, floating contaminants are washed over the overflow rim to the tension drum together with the wash water. If required, a rapper roll placed underneath the endless belt effects a recleaning of settled material. Contaminants covered and/or trapped by mineral particles are collected and discharged again by the current of wash water.

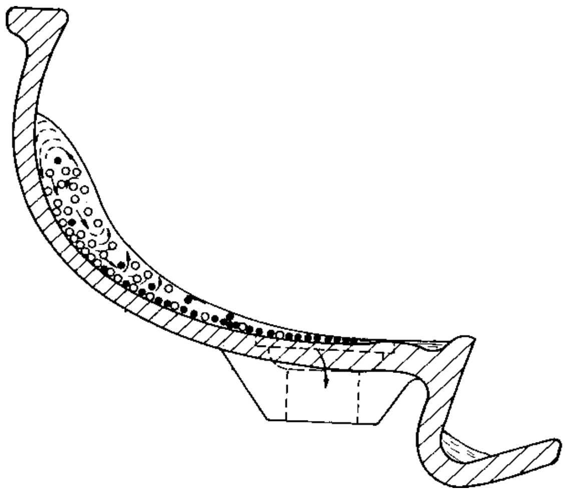
Hydrodrum
Another unit used in wet building rubble processing is the washing drum with hydro-separation [10]. The hydrodrum separator is composed of a conical washing and separating drum with subsequent discharge chamber. The drum is stepped in a longitudinal direction and has guide segments of spiral shape. Nozzles are located at the stepped drum shell and at the face side of the discharge chamber; this favours the washing and flotation process.

The building rubble, feed from fines, is led via a chute into the drum filled with water. In the slowly rotating hydrodrum, the heavy product sinks and is transported through the guide segments to the discharge wheel. Besides the material transport, the rotation of the unit causes intensive washing and a loosening of the contaminated rubble due to the steeped design of the drum wall. The installed nozzles provide a continuous supply of new wash water in the drum, so that a current is formed which counteracts the transport direction of the sinks. The floating light and foreign substances are entrained by this current and thus discharged onto the dewatering screen at the material feed side. The heavy products arrive at the drum end in the discharge wheel, is lifted from the water bath by the dividers formed as screen plates, drained and then dropped into a discharge chute.

Coal spiral
The coal spiral consists of a curved channel arranged in the form of a spiral. The principle is that the water is flowing down the spiral, it is subjected to centrifugal forces, which places much of the water near the outer rim until the flowing stream reaches an equilibrium between centrifugal force outward and gravitational force downward. In the curved channel the bottom layer of water, retarded by friction, has less centrifugal force and consequently will flow sidewards along the bottom towards the inner edge, carrying with it the heavier particles. Simultaneously with this bottom flow of water inward, the upper mass of water must flow outward to replace it. The spiral is therefore an exaggerated form of the flow in a river bed. A Coal spiral has a low installation cost and low operating cost and is suitable for large tonnage operations.

Principle of a Coal spiral





6.7 ONGOING RESEARCH AT THE DELFT UNIVERSITY OF TECHNOLOGY

BELCANTO: Cost and environmental impact of building products after demolition

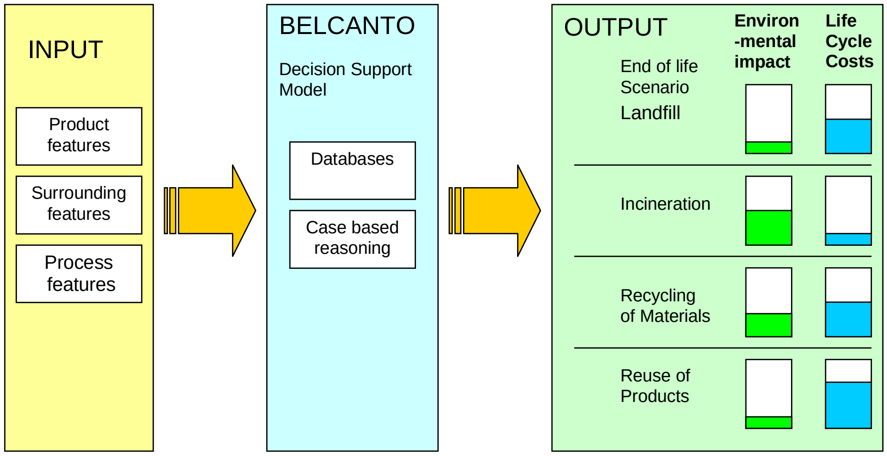
Nelleke Guequierre PhD, Faculty of Architecture

In the Netherlands, 15 million tons of demolition and construction wastes are produced every year, of which about 90 percent is recycled on a material level as rubble is used for road foundations. The government however, prefers product-reuse above material-reuse or landfill and incineration because this seems better for the environment. However at the same time a good instrument is lacking for making a considered choice for the most Eco-efficient end-of-life scenario for a building product.

Reuse of building products is a very complicated matter. Following problems can occur: Products are damaged during deconstruction, not all the products can be repaired, they have a shorter lifetime left, the quality might not be sufficient for applying in a new building et cetera. Even if all these problems can be solved and the environmental load is low comparing to applying a new building product it might not be interesting from economical point of view. We have to seek a balance between environmental profit and the end-of-life cycle costs.

With the end of life of a building is meant the last phase of the lifecycle of a building and can be subdivided in the following stages: demolition/disassembly; transport; sorting, cleaning, repairing and storage of products and materials; landfill, incineration, material recycling and product reuse. These various options for the end of the life of a building are called End of Life Scenarios (ELS).

This research project aims to develop a tool to assess both qualitative and quantitative aspects of the end of life of a building product that effect the product's environmental impact and life cycle costs. This article describes in detail the structure of this model, called BELCANTO (Building End of Life Cycle Analysis Tool). BELCANTO is a decision support system that uses product features and databases to calculate the environmental load and the life cycle costs of the possible end-of-life scenarios.



Recycling of masonry

Koen van Dijk PhD, Faculty of Civil Engineering and Geosciences

In the Netherlands 90 % of the building demolition debris is recycled. The stony fraction consisting masonry and concrete is used as a road construction material. The recycling of clay-bricks as such doesn't hardly take place. Only in the recycling market of monumental building materials, clay-bricks are chipped off and reused. In the building history of the Netherlands, lots of type of clay-bricks were in use. At the beginning of the century there where thousands of clay-brick factory's and every self respecting town made her own clay-brick type. Because a lot of buildings, which were built at the beginning of the twentieth century are renovated nowadays the demand for monumental clay-brick is high. This is the reason that monumental clay-brick are chipped off and reused in renovation work. It is very labor intensive and therefore the prices of monumental clay-bricks are very high. This year an old clay-brick factory was renovated to produce new 'monumental' clay-brick with their special sizes and color.

From the 1930's the standard Walloon format became more and more in use. In this research one wants to find a solution for recycling clay-brick by using a thermal process to decompose the mortar. Portland cement mortar decomposes at 600 °C, but earlier lime mortar was in use. This lime mortar decomposes at 400 °C.

The typical mortar for brick setting is made of lime, sand and water. Cements have the property of setting without heat. Calcination: The raw materials for lime are limestone (calcite, $CaCO_3$) or oyster shells (aragonite, $CaCO_3$), which on calcination become quick lime, or CaO. This reaction takes place at about 900 °C and is carried out in shaft or rotary kilns. The oxide is very reactive and may be slacked with water to form hydrated lime $Ca(OH)_2$ with the evolution of considerable heat. Mortars: The lime hydrate is mixed with sand to form a mortar. This mixture slowly sets by absorbing CO_2 from the air to form $CaCO_3$, as well as by reacting with the silica to form calcium silicate.

In the laboratory research pieces of masonry are heated up to various temperatures. It seemed that the clay-brick mortar interface was already cracking at a much lower temperature than was expected. This was caused by the difference in thermal extension coefficient and Young's modulus. The clay-brick mortar interface is the weakest part of the masonry and will first collapse. This will make it possible that total clay-bricks can be reused. During the technical lifespan of masonry and during demolishing the building clay cracking can occur in the clay-brick. This will make the loss of clay-brick about twenty percent, even when a thorough demolition process is used.

Dismantling an Existing Building into Reusable Elements or Components

Ton Kowalczyk PhD, Faculty of Architecture

The Netherlands produces 14 Million tons of Demolition and Construction Waste (DCW) a year, for example: this quantity can be used for a roadbase for a 250 km, six lane speedway, 20 meters wide and 2 meters thick. No explanation is needed for saying that this is an enormous amount for a small country like The Netherlands. The Dutch Government passed a law on the first of April 1997, which states: “ dumping of reusable building waste is prohibited” (short version).
To deal with the implications of the legislation we consider three possible solutions. Firstly, all new buildings can be built and assembled with renewable materials. Secondly, existing buildings can be upgraded if possible. And finally, if upgrading is not an option then buildings should be dismantled into elements and components when possible. This final option is the subject of this research topic.

The top down hierarchy in building is: Building → Building part → Components → Elements → Half-Products → Materials → Raw Materials [Eekhout 1997]. Every step higher in the hierarchy means that there has been an increasing value of: labour, energy, material and use of equipment. So product reuse should have the advantage over material reuse because of the fact that less value is lost. But what if the used building method doesn’t permit dismantling easily? Are there then still advantages?

The question arises in what way, and in which order, a building which is never meant to be dismantled? Dismantling a building into elements and components is a way to keep the building materials in their own cycle for as long as possible. The main advantage of this approach is that buildings will not be downgraded to secondary raw materials or building waste but into reusable elements and components. This results in more positive effects than just reducing the building waste. Other (expected?) results are:

- Less use of raw materials, which leads to less reduction of the landscape;
- Less use of energy, which leads to a lower greenhouse effect and less acidification;
- Building materials will remain in their own cycle for as long as possible.

This research project aims to develop a decision support model, which contains the following variables: dismantling techniques, building regulations, material requirements, economical and environmental costs. This model will be used to compare the use of a reclaimed (secondary) element or component with a new one. With a balanced and thorough result it should be possible for an architect or contractor to decide whether to use a reclaimed (secondary) or a new element or component.

Demountable building

Pauline Boedianto PhD, DIOC-DGO The Ecological City

Research Perspectives
In the past 20 years, research and development on Demountable Building has mainly been limited to structural aspects. Most attention was given to the development of demountable connections between precast elements [1]. But all those technical inventions for Demountable Building were not yet implemented in the building codes, neither supported by development on appropriate building-management systems nor logistics [2]. The framework displayed in fig. 1 puts Demountable Building in a wider context, which can help defining several of its possible stages and consequences.

The Stages of Demountable Building

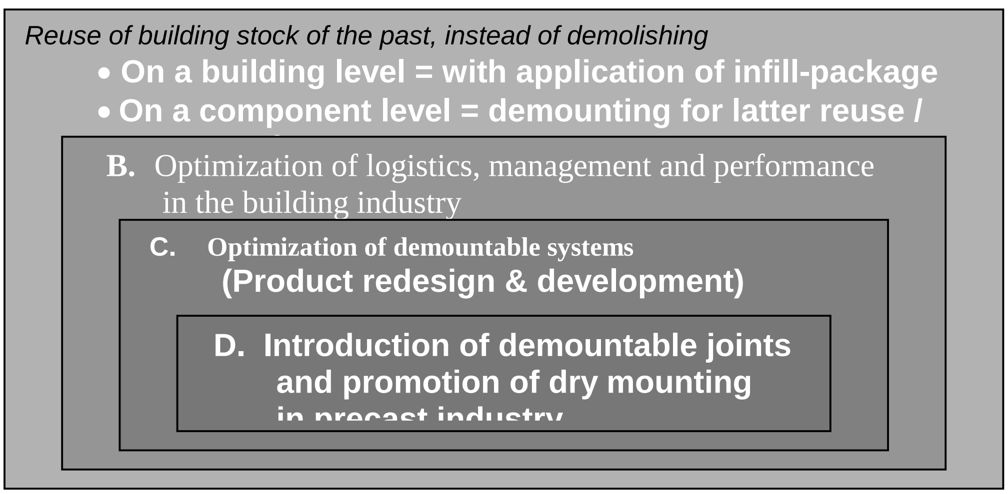


Fig.1 – Different stages of Demountable Building, varying from macro to micro level

Research Questions for each Stage of Demountable Building

A1 Building-stock of the past- Reuse on building level: Which other functions would fit into the available module system? Which infill-package is suitable?

A2 Building-stock of the past- Reuse on component level: How to identify the state, the composition, reinforcement, strength and stiffness of demounted components? How to detect corrosion, cracks, shrinkage and creep in demounted components?

B Building Management and Logistics: Where to store the demounted components before reuse? Would the new location also be available for storage? How to promote the reuse of these demounted components to the market?

C Optimization of Demountable systems: How to detect the bottle-neck-connections, which could cause barriers in future demounting?

D Introduction demountable mortar: Could another alternative grouting mortar such as epoxy or natural resin possibly replace the present benefits of cement mortar?

Integral chain management

Bart te Dorsthorst PhD, DIOC-DGO The Ecological City

The production of construction and demolition waste in the Netherlands is about 15 million tons each year. Nowadays about 90 to 95 percent of this waste is being reused, for the main part as a road base material. The policy of the Dutch government aims at reuse of this DCW in its own cycle, at the highest possible level. Nowadays the problem with the DCW occurs at the moment that a construction will be demolished. This can be called waste-management.

Integral chain management in the building and constructing industry, means that all actors, at all building stages (initiative, design, building, use, maintenance and demolition) must do all they possibly can to improve the use of constructions, construction elements or materials after the demolition-stage.

Level of reuse
The “Delft Ladder” shows different reuse levels. This is not a fixed order, but a flexible one. The reuse options are: prevention, construction reuse, element reuse, material reuse, reuse of material in a useful application, immobilisation with useful application, immobilisation, combustion with energy recovery, combustion and landfill.

Way of reuse
There is a difference in the recycling of construction and demolition waste. This waste can be recycled, down-cycled or up-cycled. When the material is used for the same function again, it is called recycling. When the material is used for another function it is called down-cycling, and when the recycled material is used for a better function than the original material it is called up-cycling.

Building stages
Reuse at the highest level is only possible if every actor in the building cycle is aware of the fact that the used materials are to be reused after demolition. So at every building stage, from the initiative, design, building, use, maintenance to the demolition stage, measures must be taken to improve reuse at the highest possible level. So to reach an optimal reuse of the construction, construction element, or materials, there are a few important preconditions:

- Design for recycling. Materials, which are difficult to recycle, should not be used at all, or it must be (technically) easy to separate them, before or after, demolition; and

- Assembling and dismantling techniques. To use building elements a second time they must be dismantled carefully in order to prevent being damaged as much as possible.

Advantages of integral chain management
Integral chain management helps with the following items:
- Less waste is produced because most of the waste will be used again after a construction is demolished;
- By closing the material cycle, the need for raw materials will be reduced, due to secondary materials;
- And so, by using more secondary material, save on the use of space for landfills.

Degradation factor
The degradation factor calculates the degradation of building materials during their ‘X’ lifetimes. Therefore a degradation model is developed. This model has 5 steps:

- Firstly, shortly before the demolitions, the actual state of the construction is examined. Material qualities, like stiffness, strength, frost-resistance and so on, are compared with the demand of the current standards.
- Research at the technical possibilities for reusing the construction at the different levels of the Delft Ladder; the end of life scenarios. The information from step one is essential for this step.
- The third step is to quantify or qualify the effects, like emissions, energy use, added materials and waste production during transportation and material improvement.
- Comparison of constructions with ‘virgin’ materials and constructions with reused materials. These comparisons must be done for the building of this construction, and during the use of this construction.
- Repeat this model when the second lifetime has ended (start over with step one).

The result of this model is a advice of how to use construction and demolition waste, in such a way that the materials can be used time after time.

6.8 CASES

Office XX – Requirements for flexibility, demountability and adaptability

The changes and challenges in building industry
Rapid changes have occurred regarding the use and the layout arrangement of office buildings. An increasing number of office buildings have been drastically renovated or even demolished much earlier than necessary on the basis of the structural behavior. Dutch annual production of demolition waste already reaches up to 15 million tons. The assignment for Project XX was to design a flexible building that will stay adaptable during the building's use-phase, applying materials which are tuned to maximize its function during the material's complete life-span.

Flexibility and adaptability requirement
An interview with Mr. G.D.J.Verweij from Wereldhave (the owner of the Office XX) reveals a few of those requirements:

"We wanted a building that could be changed. If you remove the first floor – then you have a space of 8 meters up to the ceiling – and it can be used as an industrial building. So you can easily transform an office into an industrial building. Of course the rent is lower – but you do not have to spend too much money to change the use. It is better to have a full industrial building, than an empty office building."

Flexibility in the horizontal lay-out
This will provide an open working space without partition walls. The user, the XX-Architects in this case, will have the freedom to apply modern values and standards regarding working space in relation to several characteristic of working activity.

Flexibility in the vertical lay-out Project XX
New design-guidelines offer outrageous perspectives regarding flexibility and demountability. The result of this approach should be to provide accommodation for changes in the distant future, such as a functional change from a utility into an industrial building.

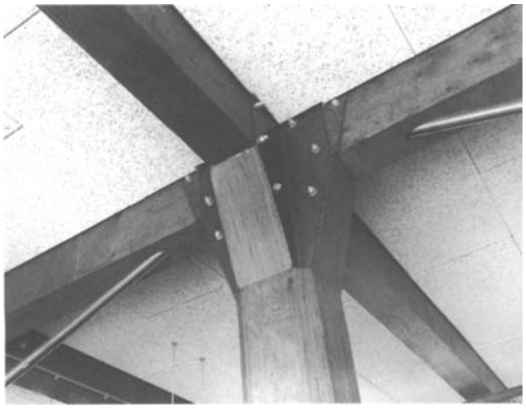
Flexibility during the use-phase
Besides the environmental aims there are two more goals concerning this strategic design-concept:

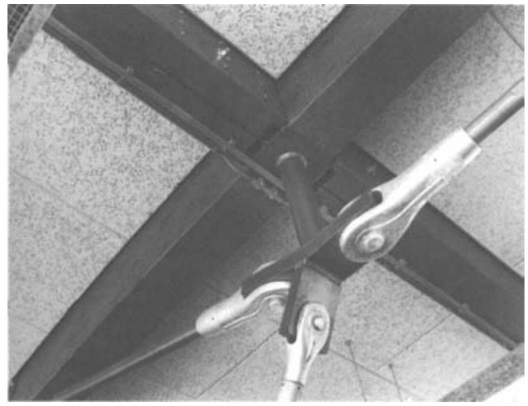
- Clear lay-out and highly qualified architectural connection-details.
- Aesthetically attractive and flexible for the users during the whole life span of the building.

The choice of building materials
Project XX is executed with an open building system, several independent systems, and not particularly a demountable system with demountable applications. Instead of using one particular closed system or product, Project XX is combines several construction systems implicating an open-building system, and providing a high level of flexibility and demountability.

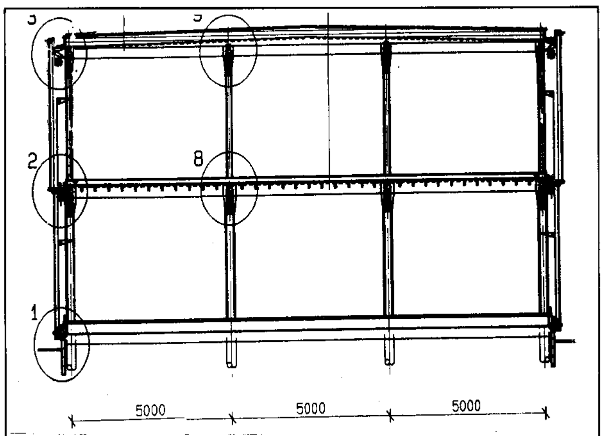
Technically an average building structure could last 75-100 years while the materials have different life span varying from 5 up to 75 years. Nowadays the buildings are subject to change every 20 years.

"After 20 years of use-phase the building will be demounted, all materials will be recycled for reuse. The manufacturers agree to take back their products. In the car industry, more than 85 % of the cars is recyclable. And more than 80 % of the limestone being used in construction today are reused limestone", Quote by Mr. G.D.J.Verweij, Wereldhave.

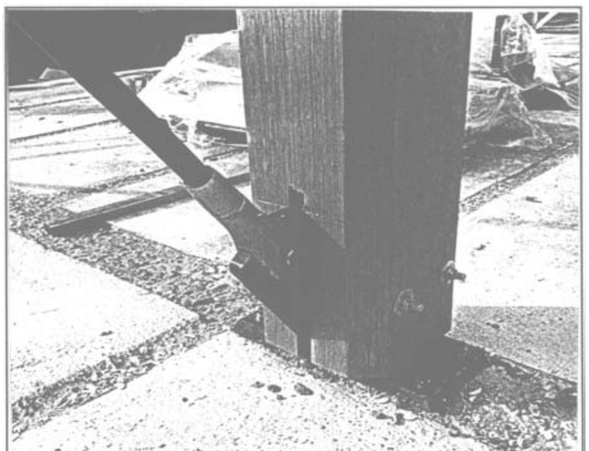




Demountability of the columns
Hollow-core slabs are used for the ground-floor. The wooden columns are connected to the floor by bolt-insert connection. Although dry mounted, this connection device would not be easy to demount it non-destructively. Damage would likely occur during the mounting and demounting of those wooden columns.



Vertical lay-out of Project XX



Floor-column joint – Project XX – ground floor.

Possibilities for remounting
The possibilities for reusing elements vary from secondary material-reuse up to the primary elements-reuse (remounting). After 20 years the supplier will take back their building materials, and the supplier will be responsible for the remounting, reuse or recycling of those building materials.

Conclusions:
Requirements for demountable building:
Concerning flexible and demountable building, there are still major areas that demand thorough consideration, even in such an experimental project as Office XX:

Would the structural connection and ties form obstacle for demounting?
Would the components / connecting-device suffers serious damage during the demounting?
How would storage, revision and repair be arranged in most efficient logistics?
How real and affordable is the possibility for reuse of demounted?

Open system, demountable application**:** It is not necessary to apply a specific demountable system when you perform the open building method to attain flexible demountable building. With well-considered application of dry-mounted connections, separated building elements could easily being demounted after their use-phase.

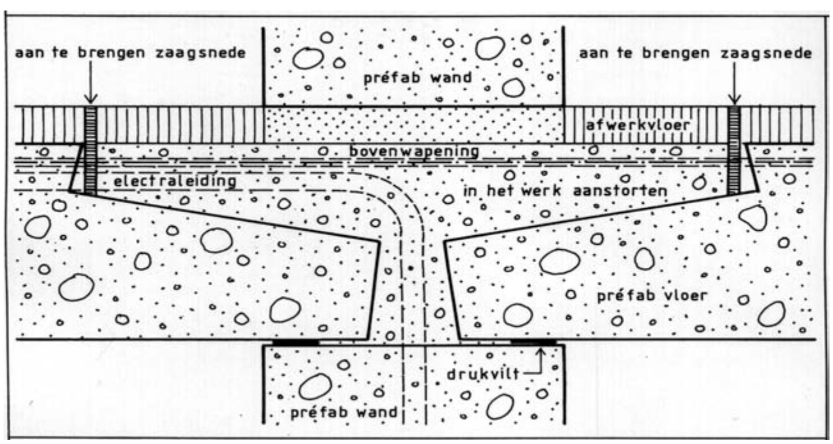
Demountable system, non-demountable application: On the other hand, applying a specific demountable system will not guarantee the demountability of the building elements. When the particular demountable system performs the so-called poured connections for their construction joint, the demountability grade will be diminished immediately.

Deconstruction and reuse of an apartment building in Middelburg

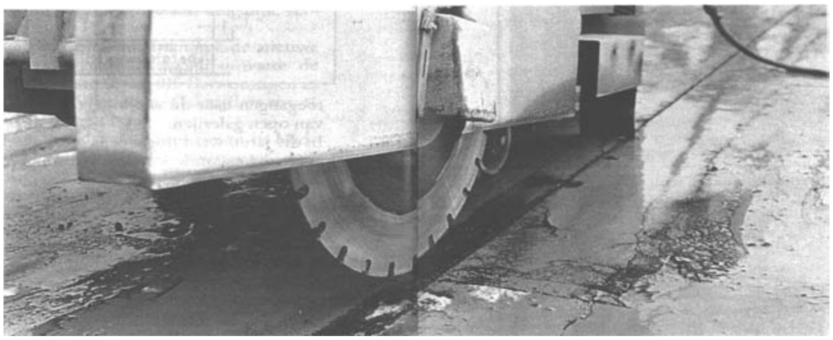
New approach for the housing industry in the Netherlands
Responding to the local housing rental problems resulting in phenomenon as unoccupancy and deterioration, housing corporation Middelburg in Zeeland-province of Holland had chosen the pioneering role in the housing renovation. Instead of demolishing, seven upper levels of a twelve-story apartment building are being demounted, leaving five lower layers to be renovated thoroughly. The structural components released by demounting were also being reused for constructing 'new' single-family housings.

1 Oorspronkelijke opbouw in 12 bouwlagen, met toepassing van corridors

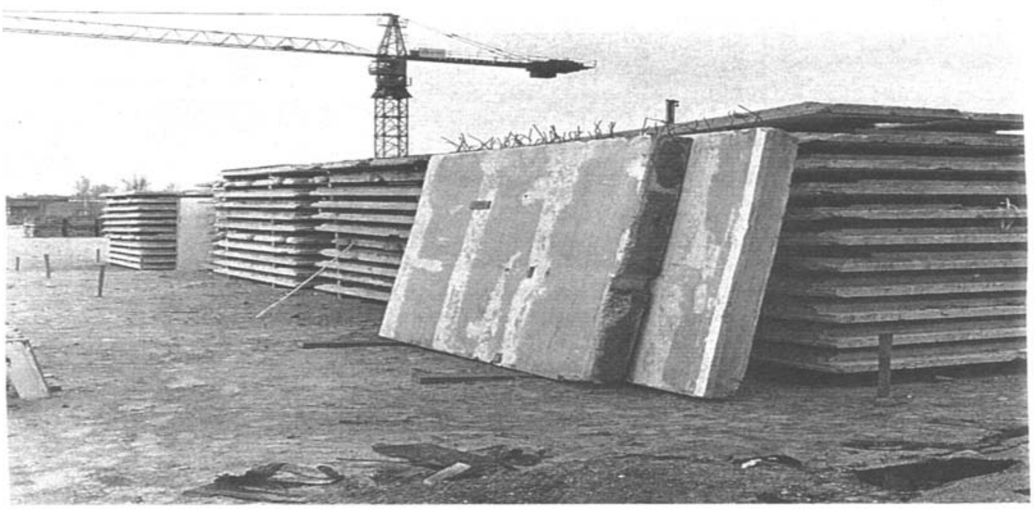
The Delta BMB system
Architect J. van de Woestijne developed this prefabricated building system. The name BMB refers to the mounting method Brick Assembling Method. The connections between the concrete components are established by means of dry-mounting, such as steel-strips or bolted connections. Grouted connections are avoided as far as possible, but still being applied for connections between floor components to achieve diaphragm-action of the floor surface.



The Deconstruction
The fact that the concrete structure of this building was constructed mainly with dry-mounting methods has contributed to the decisions of demounting. Grouted connections applied at floor-floor connections could easily being detached after 2 saw-cuts have been brought with sawing machine especially developed for this project. By this action, support reinforcements were also broken. Subsequently the floor components are being disconnected from its support by special hydraulic jackscrew.



Logistics
Directly after the demounting, several activities were carried out to prepare the components for reuse. Each component was provided with brand and codes to facilitate the reuse. Subsequently repair work was carried out, and then the components were transported to the storage. To maximize the impact and efficiency of the reuse, the new building site was used as storage site at the same time. When all components had been demounted and transported to this storage site, the construction of the new building could start.

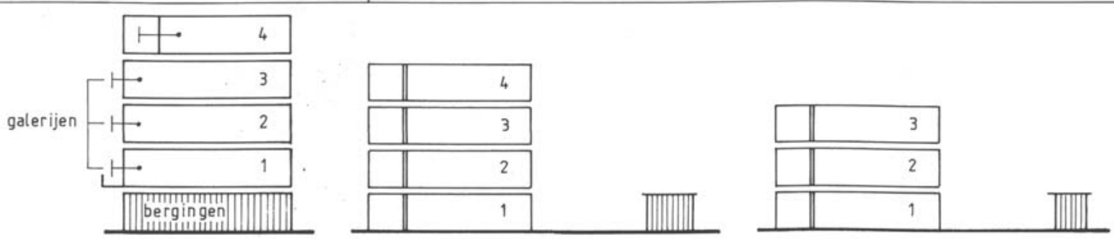


The reuse of the demounted components
The components that had been demounted are the essential building stones for the construction of 114 new housings at the new site near the shopping center of Middelburg.
Three housing blocks were constructed, each consists of 3 or 4 stories. For the greater part of the original 4-room housing layout were being split into 2-rooms housings.

For the construction of the new housings, not only the structural concrete components were reused, but also infill components such as window frames and glass panels.

3 Twee van de drie flatgebouwen (april 1986). Het gebouw op de voorgrond wordt gedeeltelijk gedemonteerd, wat inmiddels bekend is komen te staan als 'aftoppen'

4 Principe van de gekozen oplossing. Zeven woonlagen worden gedemonteerd. Met de vrijkomende elementen worden nieuwe woningen gebouwd in blokken van 3 resp. 4 lagen



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CHAPTER 7
THE STATE OF DECONSTRUCTION IN NORWAY

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Summary

This paper presents the status in Norway on deconstruction related issues. The share of the building and construction waste that is being reused or recycled is currently rather low, and Norway is far from a forerunner with regard to deconstruction related issues. The annual production of waste related to building and construction works has been estimated to be about 1.5 million tons of building waste from the construction, renovation and dismantling of buildings, and about 22 million tons from the construction of bridges, ports, roads, railroads, airports etc.

Important laws and regulations concerning waste handling are referred to, and waste charges and taxes are commented. Several initiatives taken by the trade and the authorities to promote reuse and recycling of building materials are presented, and three examples of deconstruction projects in Norway are shown. These three are the ADISA principles developed by the GAIA architects, the RESIBA project which aim is to make recycled aggregate a competitive product, and Pilestredet Park which is a project on the conversion of an old hospital in Oslo centre into a small town with nearly 1,000 apartments, a college and many offices and shops.

Currently, Norway lies behind many other European countries with regard to reuse and recycling of building and construction materials. Many promising deconstruction initiatives however indicate that the general awareness about deconstruction related issues is increasing, and that more reuse and recycling will take place in the future.

KEY WORDS: Deconstruction, Reuse, Recycling, Building

7.1 Introduction

There is a growing interest for deconstructed related issues in Norway. Waste handling is attracting increasing attention, and several initiatives are taken by trade and the authorities to encourage recycling of building and construction waste. Several pilot projects on reuse and recycling are also being undertaken.

Reuse of buildings and building materials was common in former days in Norway. Log houses are very well suited for deconstruction and transport, and in Norway as well as in other countries with tradition for log houses, removing of houses was rather widespread. The logs in many of the old log houses in Norway show marks from having been removed once or several times. It was common practice several places in Norway to expand houses by adding a new unit. Houses were often given as wedding presents, or removed in connection with inheritance or sale of property. Some rural districts in Norway even made business on fabricating log houses and storing them in order to wait for the demand for temporary houses that would rise when a town or city in the vicinity was struck by fire.

Figure 1 Removing of a log house. Dismantling (left) and assembling (right). Photos: K.I. Edvardsen.

A growing interest for protecting the cultural heritage arose in the early 19th Century. Many buildings were removed to save them when other forms of protection did not succeed. A stave church in an inland valley in Norway (Valdres) was the first building to be saved this way. This specific church was actually removed to Schlesien, Preussen (now Poland) where it was assembled in 1844 [1]. From the turn of the century, several outdoor museums in Norway started collecting old houses to save them and exhibiting them to make them available for visitors.

7.2 Deconstruction status in Norway

The share of the building and construction waste that is being recycled or reused in Norway is currently rather low. Little has been done up to now to reduce the amount of building and construction waste when designing and constructing buildings. For the Oslo region, it has been estimated that between 25 and 50 % of the waste are recycled or reused, while the corresponding share is estimated to be close to zero for the rest of the country [2]. In Denmark, in contrast, as much as 90 % of the building and construction waste is being recycled or reused, and only 10 % disposed of. It thus seems to be a long way to go before Norway can be said to be a forerunner with regard to waste handling and reuse and recycling.

Building and construction waste

The statistical information about the Norwegian building and construction related waste is rather weak, and large uncertainties are involved in the estimation of the annual waste volumes being generated in the building sector.

Statistics Norway and Green Warriors of Norway has analysed the average waste volumes being generated during building works as seen from Table 1. The figures vary significantly within each type of waste. The amount of wood being generated during renovation works, as an example, is estimated to range from 2.3 kg per square metre to 42.6 kg per square metre. The large variations may be explained by different types of constructions used in the case buildings in the surveys, as well as different routines and practise on the building site with regard to minimising the waste volumes.

Table 1 Building related waste. Waste volumes (kg per square metre) being generated per square metre floor space during construction, renovation and demolition of buildings [3].

	Construction	Renovation	Demotion
Concrete and brick	6.5 - 15.7	18.8 – 40.4	387 – 1164
Wood	2.8 - 1.1	2.3 – 42.6	23.6 - 98.5
Paper/plastic	0.3 - 2.6	0.1 - 1	0.3 - 6.5
Metals	0.2 - 1.2	0.2 - 4	3.3 – 29
Plaster boards	0.8 - 3.5	2.3 – 5.9	0 - 4.1
Mineral wool	0.1 - 1.2	0.1 – 0.6	0.1 - 2.2
Asbestos	0	0.5	1
Special waste	0.017	0.05	0.57
Glass	0 - 0.3	0.4	0.3 - 3.3
Polluted waste	0	0	9.9
Unsorted waste	8.8 - 9.6	2.2 – 10.8	22.8 - 35.3
Asphalt	0.7	0	1
Soil, rock etc.	2	2	2

Based on information about the total floor space of new buildings in Norway in 1998 and the space of buildings being renovated or demolished, the total amount of building waste has been estimated to be about 1.5 million tons as shown in Table 2., whereof about 70 % concrete and brick tiles and 14 % wood.

Statistics Norway does not provide a similar statistics on waste from construction works (waste generated during the construction of bridges, ports, roads, railroads, airports etc.). Instead, in Table 2 the amount of such waste has been estimated by using Finnish data, correcting to Norwegian conditions by adjusting for different population sizes. This way, the total amount of construction waste (predominantly soil and rock) has been estimated to be 22 million tons. Even though the waste generated during construction works is about eight times the waste from building works, the construction related waste is not considered as a big environmental problem. Construction waste predominantly consists of non-polluted soil and rock and is more considered as a space problem than a pollution problem by the authorities. The waste is often used for road fillings and in foundations.

Table 2 Building and construction waste in Norway in 1998 by type of waste (1,000 tons). Building waste includes waste from the construction of new buildings, and renovation and demolition of existing buildings. Construction waste includes waste from works related to bridges, ports, telecommunication, roads, railroads, airports, sewage systems, hydro power plants etc. [3].

Type of waste	Building waste					Construction waste	Total waste
	Const-ruction	Reno-vation	Demo-lition	Total			
Concrete and brick	77	155	799	1,031	69%	0	1,031
Wood	41	96	76	213	14%	36	249
Paper/plastic	8	2	6	16	1%	0	16
Electric cables	0	0	0	0	0%	10	10
Metals	3	8	31	42	3%	1	43
Plaster boards	14	18	2	34	2%	0	34
Mineral wool	4	2	1	6	0%	0	6
Asbestos	0	2	4	6	0%	0	6
Special waste	0	0	1	1	0%	1	2
Glass	1	2	2	4	0%	0	4
Asphalt	5	0	2	6	0%	226	232
Polluted waste	0	0	15	15	1%	0	15
Unsorted waste	61	26	40	127	8%	14	141
Total	213	311	978	1,502	100%	287	1,790
Soil, rock etc.	13	0	3	16		22,090	22,106

The Norwegian building waste of 1.5 million tons per year correspond to about 340 kg per capita which is lower than in most other European countries. The average waste volume per capita in 1996 in the member countries of the European Union has been estimated to range from 140 kg per capita in Sweden, to as much as 6,750 kg per capita in Luxembourg as seen from Table 3. Different types of constructions and consequently different composition of the waste may be one reason for the variations in the table. Lightweight, wooden constructions are for instance very common in Norway. This contributes to a lower density of the building and construction waste in Norway than in other European countries where brick and concrete constructions are more common. A survey conducted by Statistics Norway, for example, shows that more than 90 % of all one-family and divided small houses in Norway had wood as main construction material.

Table 3 Building and construction waste in Norway and the member states of the European Community [4].

Country	Million tons	kg/capita/year
Norway	1.5	340
EU-countries		
Belgium	7.5-8.0	700-800
Denmark	2.3-5.0	460-1000
Finland	1.6	320
France	20-25	340-450
Greece	?	-
The Netherlands	13-14	870-930
Ireland	2.5	710
Italy	35-40	600-930
Luxembourg	2.7	6750
Portugal	?	-
Spain	11-22	280-560
Great Britain	50-70	880-1220
Sweden	1.2	140
Austria	52-120	840-1900
Germany	22	2860
EU, total	221-334	607-918

In addition to the effect of different constructions types used in the countries, the large variations in Table 3 are probably also caused by different definitions on what is considered as building and construction waste, and different routines concerning registration of the waste.

The authorities involvement in deconstruction

The involvement of the authorities is important for what is happening in the building and construction industry with regard to deconstruction related activities. The main strategy of the authorities within the field of waste handling is:

- first of all to prevent waste from being produced and to reduce the amount of harmful substances,
- secondly to promote reuse, recycling and energy utilisation of the waste,
- and finally to ensure an environmental sound treatment of the remaining waste being disposed of.

Laws and regulations

The Pollution Law from 1981 is one important law regulating the handling of building waste. This law is based on two principles; the first principle is that waste should be handled in a way that minimise damage and inconvenience, and recycled where this is environmentally beneficial, resource efficient and economic acceptable. The second principle is that the polluters should pay the full costs of the environmental damage they are causing (Polluter Pays Principle).

According to the law, building and construction waste is defined as production waste, and the same requirements therefore apply as for other types of waste. Stricter control of the waste handling according to the Pollution Law has contributed to significantly reduce illegal dumping which was considered as a problem before. The Ministry of Environment has delegated some local councils the power to develop local regulations on building and construction waste. The councils can require that the builder shall produce an overview of the waste amounts that will be generated during the building and construction works, and to develop a plan on how this waste shall be handled. Oslo is one of the councils having developed such local regulations on waste, and the results have been promising with regard to reuse and recycling of heavy building waste. The Ministry of Environment therefore plan to delegate this power to develop local waste regulations to all local councils in Norway.

The Planning and Building Act shall ensure that building and construction works are executed correctly and technically safe. Supplementary to the act, there are technical regulations that regulate building and construction works and the products used in buildings. A main goal of the act and the regulations has been to improve the quality of the building process. All building and construction projects, including demolition projects, should be executed by approved enterprises. There are strict requirement on the skills and qualifications of the persons involved in the process, and the requirements for documentation have been significantly enhanced.

The need for long-term perspectives and environmental concerns are emphasised. In the technical regulations, for instance, it is stated that:

> *"The life of works shall in all phases, i.e. execution, usage and demolition, be managed with a reasonable load on resources and environment, and without worsening quality of life and living conditions. Materials and products for use in construction works shall be manufactured with justifiable use of energy and with the aim of preventing unnecessary pollution. Construction works shall be so designed and executed that little energy is consumed and little pollution is caused during the life of the works, including demolition." (§ 8.1)*

The Working Conditions Law from 1977 shall ensure the safety, health and welfare of the employees. There are several regulations under this law. One regulation (Byggherreforskriften) instructs that the builder shall ensure that safety, health and working conditions are taken care of in all stages of the building project. The builder is responsible for the handling of materials on the building site, the storing and removing of waste [5]. Another regulation instructs works involving contact with asbestos. This regulation directs that only specially trained employees are allowed to handle asbestos or products containing asbestos.

Charges and taxes

There are local charges for delivering waste on disposal sites. These charges are levied to cover the full costs of establishing and running sites. The charges may therefore vary between the different local councils in the country.

A national tax on depositing waste was enforced in 1999. The tax is 300 NOK (35 USD) per ton of organic or unsorted waste. If the waste is incinerated, a basic tax of 75 NOK per ton and a supplementary tax of 225 NOK per ton apply. The supplementary tax is reduced according to the degree of energy recovery. If the waste is incinerated without energy recovery, the tax will be 300 NOK per ton, which is similar to the tax for depositing unsorted waste. The national tax is intended to stimulate waste reductions, increased material recovery and utilisation of the energy content of the waste.

Deconstruction initiatives

The general environmental awareness in the building and construction trade is increasing, and several initiatives have been taken by the trade and by the authorities to reduce the waste volumes and increase the recycling rate.

NORSAS is a national competence centre for waste and recycling. NORSAS shall promote waste reductions, increased recycling and safe handling and final treatment of waste. Furthermore, the centre shall support local councils, the industry and the authorities in the work for reduced waste volumes and increased recycling rates. NORSAS shall collect, treat and disseminate information and knowledge about waste handling. One important task for NORSAS is to operate a national register on waste handling, where all enterprises involved in waste handling are registered. The enterprises are instructed to report annually the volume, type, origin, transport and handling of waste. This information will contribute to increase the knowledge about the waste streams in Norwegian.

EcoBuild (Økobygg) is an initiative from the building and real property trade to contribute to environmental improvements and the achievement of national, environmental goals. The programme, which runs over five years (1998 - 2002), shall engage the whole trade in a co-ordinated and comprehensive effort on environmental improvements. The total budget is around 50 million NOK per year (close to 7 million USD) The financing comes from both governmental and private funds. Four ministries are involved; Ministry of Local Government and Regional Affairs, Ministry of the Environment, Ministry of Trade and Industry, and Ministry of Petroleum and Energy. A board of representatives from the building and real property trade directs the programme. Eight main areas of work are defined for EcoBuild. One of these is building and construction waste. The goal is to reduce the building and construction waste by more than 70 % by establishing a commercial market system for recycling of waste. Improved waste handling in the industry and improved practise on waste minimisation, sorting of waste and controlled handling of toxic waste in connection with building projects will be important factors to reach the waste reduction goal.

Two trade organisations, BNL and TELFO, are developing a national action plan for building and construction waste. Phase I of this work, a state of the art report on building and construction waste, was completed in December 1999 [3]. In Phase 2, specific goals for waste reductions and recycling will be established together with measures to reach these goals. The work is partly financed by EcoBuild.

Norsk betongforening (The Norwegian Concrete Association) has developed national guidelines for classification of the use of recycled aggregate in the production of new concrete. Depending on the classification of the aggregate and the quality of the concrete, up to 30 weight-% of recycled aggregate is allowed.

7.3 Examples of Deconstruction related projects in Norway

There is a number of deconstruction related projects ongoing in Norway. In the following, three interesting examples are shown. The first one is a system for reusing building components developed by the GAIA architects. The second is a large project on the use of recycled aggregate in the building and construction industry. The third is a large renovation project in Oslo city where reuse and recycling of materials, components and buildings are emphasised.

GAIA architects

The GAIA group is a small group of idealists promoting ecological construction in Norway. Professional architects sharing an interest in ecological issues in house building and area planning established the group in 1983. The members of the GAIA group promote the use of traditional, locally produced building materials and well-known and simple technology. Many of their constructions are also rather labour intensive, which make the GAIA solutions rather controversial, and often difficult to implement in modern, industrialised building production.

The GAIA architects early saw the need for developing building systems that were adapted for future replacement, reuse and recycling of materials and components. But, they did not succeed in obtaining the required financing to do this until the mid 1990s when the project "Building System for Reuse" was carried out [6]. In this project, a building system called BfO was tested out. The system was based on three main principles:

- separation of the different layers of the building (with reference to Brand's principle of "Shearing layers of change" [7])
- easily dismantling and replacement of components within each layer (extensive use of screws, weak mortar in brick works, and avoidance of glue),
- the use of mono-materials (no composites).

The BfO system included 88 specially designed wood and concrete components that could be assembled with standard components into a large number of different constructions. The specially designed components were meant to be produced locally. It was aimed at utilising wood from small-sized timber. It was further a goal to use mono-materials that could easily be dismantled for replacement or reuse in another building. A main idea behind the BfO system was that easily dismantling would make it easy to change the size and the shape of the building according to the occupant's needs.

In the project, the BfO system and the reusability of the BfO components were tested out by first erecting a pavilion using such components. Thereafter, the pavilion was dismantled, and the components used in the construction of a prototype BfO house with gross floor space of 130 square metres. In the project, the dismantling and reuse of the BfO components were successful. It was however also learned that the number of special components should be reduced to simplify the system, as well as it was a need for more standardised wood components, even though this would mean larger pieces of wood and not the same potential for utilising small-sized timber.

Based on the idea of the BfO system, and the experience from the BfO pilot project, the ADISA principle was developed. ADISA (Assemble for DIS-Assembly) consists of 45 standardised components (as compared to 88 for BfO) [8]. Space plans are flexible within a module of 600 mm. This ADISA principle has not been fully tested in a pilot project yet. But, some of the ideas and principles are currently used in the design of Prestheia eco-village outside Kristiansand. At Prestheia, several row houses consisting of totally 19 dwellings will be constructed during 2000 and 2001. In the design of the houses, it is aimed at using dismantleable solutions, and to obtain flexible space plans.

The original intention behind the ADISA principles was to establish a market based system where the used components could be returned to the local manufacturer for quality control, and thereafter used in a new building project within the region. But, in practise, it has been difficult to establish a market based system based on the ADISA principles.

RESIBA

RESIBA (Recycled Aggregate in Building and Construction) is a three-year research project carried out by a number of manufacturers, enterprises and organisations in the Norwegian building and construction trade. The project is financed by the involved industrial partners and the EcoBuild programme. The aim of RESIBA is to make recycled aggregate to a competitive product, and to bring Norway up to the same level as rest of Europe with regard to the use of recycle based building materials [9].

The background for RESIBA is the fact that concrete, brick and rock represent the dominating part of the total waste produced by the building and construction industry. The benefits of recycling heavy building and construction waste should be large. Crushed concrete, brick and rocks can be recycled in unbound form (as filling material in foundations etc.) as well as in bound form (as aggregate in concrete).

RESIBA consists of three sub-projects. The first sub-project is titled “Declaration and quality control”. The aim of this project is to provide basis information about the most important technical properties of recycled products, and to estimate possible environmental burdens. The development of routines for quality control of recycled product is also an important. The project is linked to the European research programme “Use of Recycled Aggregate in the Construction Industry”.

The aim of the second sub-project, “Demonstration projects”, is to evaluate the use of recycled aggregate in full-scale constructions and initiate pilot projects. The use of recycled aggregate in roads, ditches and different types of concrete shall be investigated through these pilot projects. One interesting pilot project that already has been carried is the use of recycled aggregate in sprayed concrete. The sprayed concrete was used to cover EPS insulation used in the foundation of a tramcar line in Oslo. The project is claimed to be the first in the world where recycled aggregate has been used in sprayed concrete. Totally 720 square metres of EPS were covered with four different types of sprayed concrete: without recycled aggregate, and with 7 %, 14 % and 20 % recycled aggregate. The project showed promising results with regard to mixing, spraying and mechanical properties of the concrete.

The aim of the third sub-programme, “Information dissemination”, is to spread knowledge and results from the project to the building and construction trade, as well as to the politicians and the authorities.

Pilestredet Park

A new State Hospital will open just outside Oslo in July 2000. The old State Hospital is located in the centre of Oslo. A project called Pilestredet Park has been established to convert the old hospital area into a small town with about 900 apartments, the Oslo University College and it’s 3,000 students, and a number of offices and shops.

It is a goal that Pilestredet Park shall be a leading example on sustainable urban development. An urban ecology program has been established, providing requirements and recommendations for different environmental issues. Pilestredet Park is expected to be completed in year 2004 or 2005.

Today, the hospital buildings comprise approximately 110,000 square metres above ground, whereof about 50,000 square metres will be demolished. When completed, Pilestredet Park will include 63,000 square metres of renovated buildings, and 72,000 square metres new buildings [10]. One important reason for demolishing such a large share of the existing buildings, and not to renovate them, is the need for private car parking. The new buildings will be constructed with parking in the basement.

The old hospital was owned by the state, but most of the site has now been sold to private developers. The contracts include strict requirements with regard to reuse and recycling of the demolition materials. It is a general goal to recycle at least 90 % of the waste materials generated during the building and construction works, and maximum 10 % of the total demolition waste is allowed to be deposited. It has been estimated that the development of the Pilestredet Park projects will generate about 85,000 tons of building and construction waste, not included soil and rock from the digging works. The waste from digging works is estimated to be between 300,000 and 400,000 tons. Since Pilestredet Park is located in the centre of Oslo, it will be aimed at reducing the transport of waste as much as possible. Most of the waste will therefore be seeked reused or recycled on the site. A large share of the concrete and brick waste, for instance, will be used as aggregate in new concrete.

The state has kept some part of the site for public buildings. One of the existing buildings (The Pathology Building) will be converted into the head office of the National Insurance Administration with 560 employees, another will be the new National Medical-Historical Museum. A pilot project has also been started called “The Reused House”, where the goal is to construct a house on the Pilestredet Park area using recycled and reused materials and components. The house will contain apartments for members of the Norwegian Parliament (Storting), and it will hopefully contribute to increase the members’ awareness about deconstruction related issues and the need for increased reuse and recycling.

7.4 Discussion

Behind the concept of deconstruction lies the need for reducing the overall resource consumption in the society. Deconstruction promotes resource efficiency by focusing on reuse and recycling of materials and components. Deconstruction includes several issues, such as:

- the reuse and recycling of the waste materials currently being generated,
- the use of reused and recycled products in the construction of buildings,
- the design of buildings for future dismantling and optimum reuse and recycling of the materials and products used.

The primary focus in Norway with regard to deconstruction efforts is short-termed on reducing the total amount of waste being disposed of. Reuse and recycling are promoted since it contributes to reduce the amount of waste being disposed of, and not because it contributes to reduce the overall resource consumption in the society.

Statistics show that Norway in many ways lies behind many other European countries with regard to reuse and recycling of building and construction materials. Only a small share of the total building and construction waste is being reused or recycled in Norway. There might be several reasons for why recycling and reuse are less practised in Norway than in other European countries. Lack of market for reused and recycled products is probably one important reason.

To be cost-efficient, recycling plants must treat a certain volume of building waste. Such a volume may be difficult to achieve many places in Norway since the country is sparsely populated. The population of 4.45 million people is spread over a total land area of 324,000 square kilometres. The corresponding population density of 13 persons per square kilometre is close to 20 times lower than in for instance Germany and United Kingdom [11]. Long transportation distances in Norway also contribute to increase the costs of reusing and recycling building and construction waste.

Land is expensive in central parts of Europe. This gives an important economic incentive for reusing and recycling waste instead of using land for waste disposal sites. In Norway, in contrast, the costs of establishing waste disposal sites may be taken to be lower since there is still much available space left. This contributes to make waste disposing more economic attractive than reuse and recycling.

Norway has good supply of natural resources like gravel, rock and timber, in contrast to many other countries where the supply is more limited. The good supply may have contributed to reduce the attention around resource efficient handling of building and construction waste in Norway.

By introducing the national tax on waste disposal in 1999, the authorities are now trying to promote reuse and recycling of waste instead of disposing. With regard to buildings, however, and the measures taken to reduce future waste volumes, this tax will have limited influence due to the effect of discounting. Most buildings have long services lives. The present value of waste disposal costs occurring 50 or 100 years into the future is close to zero for ordinary interest rates.

This way, there are almost no economic incentives in designing and constructing buildings that are suited for future reuse and recycling. It is consequently a fundamental problem that discounting in cost-benefit analyses does not favour design for disassembly and future reuse and recycling of buildings. Other than economic instruments should therefore be applied to promote long-termed reuse and recycling in the building sector.

Many promising deconstruction initiatives are taken in the building and construction trade, and there are signs indicating that the general awareness about deconstruction related issues is increasing in the population. The demolishing of a 15-storey office block in the centre of Oslo in April 2000 can for instance be used as an example of the public's interest in deconstruction. The building that was demolished was the first high-rise building erected in Norway (in 1960), and it was the highest building ever demolished in Scandinavia. Using 75 kg of dynamite, it took 4.5 seconds to take the building down. More than 10,000 people had appeared on the scene to see the building go down, and the demolishing was headline news in most media.

Information technology and internet solutions opens for easily organisation of the trading of used (and new) components. If a system for reusing building materials and components was widespread implemented in the building and construction market, it would significantly contribute to reduce the overall resource consumption and waste volumes. In the work towards such a system, the ADISA principles developed by GAIA architects may serve as an inspiration and example on how the building and construction industry could be organised in a more sustainable way.

7.5 Conclusions

The share of the building and construction waste that is being recycled or reused in Norway is currently rather low, and Norway is far from being an international leader with regard to deconstruction related issues.

The annual production of building waste has been estimated to be about 1.5 million tons, whereof about 70 % concrete and brick tiles and 14 % wood. The waste from the construction of bridges, ports, roads, railroads, airports etc. has been estimated to be 22 million tons, or eight times the building waste. The construction related waste is however not considered as a large environmental problem since it predominantly consists of non-polluted soil and rock and more represents a space problem than a pollution problem.

The handling of building waste is regulated through several laws and regulations. In compliance with the Pollution Law, some local councils have been delegated the power to develop local regulations on building and construction waste. Oslo has been one of the councils, and results so far are promising. The Planning and Building Act with the corresponding Technical Regulations put strict requirements on the skills and qualifications of the persons involved in the building process, and the requirements for documentation have been enhanced.

There are local charges for delivering waste on disposal sites. These charges are levied to cover the full costs of establishing and running sites. A national tax of 300 NOK per ton for depositing waste was enforced in 1999. The tax is intended to stimulate waste reductions, increased material recovery and utilisation of the energy content of the waste.

Several initiatives have been taken by the trade and the authorities to promote reuse and recycling of building materials. Amongst these are NORSAS - a national competence centre for waste and recycling, and EcoBuild – a five year action programme which aims to contribute to environmental improvements in the building and real property trade, and the achievement of national, environmental goals. Furthermore, two trade organisations (BNL and TELFO), are developing a national action plan for building and construction waste.

Several projects with focus on reuse and recycling have been initiated. The GAIA architects have developed the ADISA principles which is a building system adapted for future replacement, reuse and recycling of materials and components. Some of the ideas and principles behind ADISA are now being used in the design of an eco-village outside Kristiansand.

RESIBA is another interesting project. The aim of this project is to make recycled aggregate to a competitive product, and to bring Norway up to the same level as rest of Europe with regard to the use of recycle based building materials.

Pilestredet Park is a project established to convert an old hospital area in Oslo city into a small town with nearly 1,000 apartments, a college with many students, and a number of offices and shops. Pilestredet Park shall be a leading example on sustainable urban development. There are strict requirements with regard to reuse and recycling of the demolition materials. At least 90 % of the waste materials generated during the building and construction works shall be recycled, and maximum 10 % of the total demolition waste is allowed to be deposited as waste. The construction of a "Reused House" will be a show-case project at Pilestredet Park.

The primary focus in Norway with regard to deconstruction efforts is short-termed on reducing the total amount of waste being disposed of. Reuse and recycling are promoted since it contributes to reduce the amount of waste being disposed of, and not because it contributes to reduce the overall resource consumption in the society.

Statistics show that Norway in many ways lies behind many other European countries with regard to reuse and recycling of building and construction materials. But, many promising deconstruction initiatives are currently taken in the building and construction trade, and there are signs indicating that the general awareness about deconstruction related issues is increasing in the population. Hopefully, the deconstruction examples referred to above can serve as an inspiration and contribute to increase the reuse and recycling of materials and components in the building and construction trade.

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CHAPTER 8
UK DECONSTRUCTION REPORT

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SUMMARY

The aim of this report is to give an overview of the waste arisings in the construction and demolition (C&D) industries, the legislative, strategic, fiscal and policy issues relating to deconstruction and finally to investigate the how the deconstruction process can work effectively within the C&D and recycling industry.

Keywords: Deconstruction, demolition, construction, design, recycling, reclamation.

8.1 CONTEXT

At the recent deconstruction closing the loop conference, there was a lot of debate about the definition of deconstruction, disassembly, demolition, refurbishment, retrofit and adaptable. The following was the consensus and these are the definitions that will be used throughout the text.

- *Disassembly*- taking apart components without damaging, but not necessarily to reuse them
- *Demolition*- a term for both the name of the industry and a process of intentional destruction
- *Deconstruction*- Similar to disassembly but with thought towards reusing the components
- *Refurbishment*- Improving building performance
- *Retrofit*- Change of use or purpose after construction from which a building was designed
- *Adaptable Building*- A multi-use building which allows for an easy change in its use

8.2 COMPOSITION OF CONSTRUCTION AND DEMOLITION (C&D) WASTE.

The following information is based on a survey of 1200 UK business that supply and receive reclaimed building materials. This information is important to quantify the waste arisings and to identify what proportion of the waste is currently reclaimed as part of the deconstruction process.

Recycling and Disposal

Approximately 40% of all construction and related wastes are believed to arise from the repair, maintenance and new build of domestic buildings, the remainder coming from other construction sectors.

Construction Waste

Table 1 shows the approximate quantities of waste predicted to arise from the construction process. The majority of this waste goes to landfill because of the way construction sites are operated. Much of this waste is avoidable and reduces the already small profits of construction companies. Some estimates indicate that this waste is a large proportion of those profits – typically 25%. If 10-20% reductions in waste could be achieved, 6 million tonnes of material might be diverted from landfill saving approximately £60m in premium rate disposal costs. The cost of construction waste includes the cost of materials, disposal, transport and labour to clear it up.

Construction waste comprises inert and active wastes that if mixed, will incur the higher landfill tax rate (£11/tonne). Separated wastes can incur lower landfill tax rates (£2/tonne), are much more suitable for recycling and reuse and can become an asset rather than a liability.

Table 1 - Estimated Annual Construction Waste [1,2,3,4,5,6,7,8,]

Construction Material	Quantity
concrete, bricks, blocks, aggregate	3.5 million tonnes
metals	2.8 million tonnes
excess mortar/concrete	1.2 million tonnes
timber & products	0.8 million tonnes
plastic packaging & plastic products	0.9 million tonnes
plasterboard & plaster	0.3 million tonnes
paper and cardboard	0.2 million tonnes
vegetation	0.1 million tonnes
other	0.2 million tonnes

Excavation Waste

30 million tonnes per year of excavated soil/clay waste are estimated to arise from construction site preparation. This could be minimised by appropriate architectural, structural and landscape design. At present, this is not a serious consideration even for environmentally sensitive design teams. Landscaping often provides important opportunities to utilise this type of waste.

Demolition Waste

There is much variation between estimates of how much waste is generated, most reports use figures from previous work, which are often based on estimation or informed guesswork. Howard Humphries report does make that observation “the surveys have been carried out in a period of economic recession, when construction and demolition activities were depressed” [2]. This fact, and the increased interest in so called ‘brownfield’ sites probably means that the actual figures related to waste production from demolition at present will be higher than those in any of the previous reports, assuming that they are representative initially.

Demolition waste is taken to include waste from the demolition of structures and parts of structures and include recycled/reclaimed materials where appropriate. The breakdown of the estimated 30m tonnes of demolition waste arising each year is shown in *Table 2*.

Table 2 - Demolition Waste, Estimated Annually [1,2,3,4,5,6,7,8]

Material	Quantity
concrete	12 million tonnes
masonry	7.2 million tonnes
paper, cardboard, plastic and other	5.1 million tonnes
asphalt	4.5 million tonnes
wood based	1.0 million tonnes
other	0.2 million tonnes

An example of the variation in waste statistics is the survey of representative demolition firms that was carried out in 1990 jointly by the Institute of Demolition Engineers and the National Federation of Demolition Contractors [9]. This suggested a figure of 25 million tonnes of demolition debris produced annually in the UK. This figure was derived from returns received from firms representing about 10% of demolition production, who indicated that between them they produced 1.87 million tonnes of concrete and masonry debris and less than 0.2 million tonnes each of asphalt and wood.

The Recycling Industry

Approximately 24 million tonnes of inert C&D waste is recycled per annum. The average transport distance to the recycling site and back to the customer is 25km each way.

Recent work being carried out by the Environment Agency & Minerals Planning Department of the Department of Environment, Transport and the Regions (DETR) will give a more accurate picture of the amount and type of inert waste recycling occurring throughout the UK. Their estimate so far is that 53 million tonnes of construction and demolition waste are produced annually, but they consider that this is probably an underestimate.

Within Europe as a whole C&D waste amounts to some 180 million tonnes each year, with only about 28% being reused or recycled [10]. As a result of the current situation the Worldwatch Institute estimates that by 2030 the World will have run out of raw building materials and we will be reliant on mining landfills for primary resources [11].

Timber recycling is increasing with new markets being sought in horticulture and energy recovery. The chipboard manufacturers are all now replacing virgin feedstock with up to 25% recycled wood fibre. The main constraints to this market are the location and quality of the material arising.

Other materials such as plastics, cardboard and paper are not reaching the recycling sector from construction and demolition works. This would require greater segregation and the creation of collection systems that are currently not available.

Metals recycling involves traditional recycling routes such as scrap yards. Metal from construction and refurbishment is far less likely to be recycled than that arising from demolition.

The Reclamation Industry
Approximately 3 million tonnes of C&D waste is reclaimed as per *Table 3*. 30% of this material is reclaimed within 30km of its source, 60% within 150km and 10% beyond 150km distance (including import and export).

Greater reuse of materials in mainstream construction would further increase the amount of materials being reclaimed. Reclamation involves less processing, greater employment and is often a more efficient use of resources than recycling. Therefore if deconstruction was a standard process, it would in turn increase the amount of materials being reclaimed and have all the benefits to new construction and society as described above.

Table 3 - Size of reclamation industry and market [3]

Sector	**Sales £ million**	**Employment**	**Tonnes 000's**
Architectural antiques			
Stone	17	2100	71
Timber	4	1100	7
Iron & steel	4	800	7
Clay	1	800	2
Ornamental antiques			
Stone	16	1170	22
Timber	36	1740	22
Iron	9	1000	9
Clay	1	100	1
Reclaimed materials			
Timber beams	42	3600	137
Timber flooring	29	2960	105
Clay bricks	31	4300	457
Clay roof tiles	63	3600	316
Clay and stone paving	19	1300	694
Stone walling	29	2450	1118
Salvaged materials			
Iron and steel	11	2800	77
Timber	36	7800	383
Antique bathrooms			
Sinks, baths, taps, WCs	41	1900	1
TOTAL	**389**	**39520**	3430

Waste Disposal Impacts
The total landtake for waste disposal and recycling facilities is estimated at 800 hectares. At present, this is dominated by landfill operations. However, this reliance on landfill is expected to change because of the targets in the Landfill Directive and the Waste Strategy 2000. In the near future, there will be more recycling sites and waste to energy plants. The introduction of the landfill tax in 1996 has contributed to a big increase in the number of fixed and mobile crushing and recycling sites. Estimated at fewer that 100 sites in 1994 [2] there are now thought to be more than 400.

8.3 LEGISLATIVE, STRATEGIC, FISCAL AND POLICY FRAMEWORK AFFECTING DECONSTRUCTION

Current and future legislation will be a key driver in sustainable waste management. It will also challenge the construction and demolition industry to manage their resources effectively and drive the deconstruction process forward. The following sections will describe the UK and European legislative, strategic, fiscal and policy issues that may have an impact on the deconstruction process.

Legal Aspects of Waste management

UK LAW
Prior to 1972 there were minimal controls over the disposal of wastes. The Public Health Act 1848 was the first attempt at national legislation in the UK. It was this Act, which created the term "Statutory Nuisance" in relation to any accumulation or deposit which was prejudicial to health or a nuisance. The Act enabled local government to take action on behalf of the public. Between 1848 and 1936 a series of Acts were enacted before the consolidating Public Health Act 1936. This Act gave local authorities the powers to police and inspect waste arisings. It also gave authorities the power to remove household and trade waste and to inspect for, and require the removal of, noxious materials.

Current Legislation

The Environmental Protection Act 1990
The Environmental Protection Act 1990 (EPA 90) was the culmination of a long period of discussion of amendments to environmental law. The Act covers a wide range of environmental topics, not all of which are relevant to waste management.
Part I of the Act introduced the system of Integrated Pollution Control (IPC) which is applicable to the release of pollutants to air, water and land from certain processes, establishing the important new criteria of Best Available Techniques Not Entailing Excessive Cost (BATNEEC).
Part II of the Act deals specifically with the deposit of waste on land. (Most waste management activities fall under the provisions of Part II.) Many of the provisions of the EPA 90 have been implemented by Regulations made by the Secretary of State for the Environment.

The Environment Act 1995

The Environment Act 1995 established the Environment Agency and the Scottish Environment Protection Agency. The creation of these Agencies represented a major step towards truly integrated environmental management and control, as they brought together the regulators responsible for Integrated Pollution Control, water management and waste regulation.

The 1995 Act makes numerous amendments to the Environmental Protection Act l990 and the other major environmental statutes. Many of these amendments relate to the powers and duties of the regulators, who now have greater scope to take preventative action when there is a likelihood of pollution.

Current Proposals for UK legislation

Development of Waste Classification Scheme

Working in partnership with the waste industry, the Environment Agency is developing a UK system of classifying waste. The UK system will contain more information about the polluting potential of wastes than the existing EC Waste Catalogue. It also differs from the European system in that it presents separate information on:

a. the composition of the waste (with 341 available codes)
b. the industrial process that produced the waste (classified according to the 586 standard industrial classifications).

The aims of the classification scheme are:

a. to provide the Agency with better quality data on waste arisings and disposal
b. to provide waste holders with better and more consistent hazard information, as part of the existing Duty of Care system.

Once the classification system has been formalised, there is a likelihood that waste producers will be given a statutory duty to enter the code on the Duty of Care transfer note.

National Strategies

Draft Scottish waste strategy

In May 1999 the Scottish Environment Protection Agency (SEPA) published a draft national waste strategy. It contains proposals for meeting the targets in the Landfill Directive as well as covering wider issues of waste reduction, recovery and recycling and the planning of waste management facilities.

Waste Strategy 2000 England and Wales

The DETR published a statutory waste strategy for England and Wales in May 2000. This strategy describes the government’s vision for managing waste and resources better. It sets out the changes needed to deliver more sustainable development.

The strategy stresses that the quantity of waste produced must be tackled by breaking the link between economic growth and increased waste. The main theme of the strategy is ‘where waste is created we must increasingly put it to good use – through recycling, composting or using it as a fuel’.

The strategy also recognises the need to develop new and stronger markets for recycled materials. To address this, a major new Waste and Resources Action Programme will be set up. This Programme will deliver more recycling and reuse, help develop markets and end-uses for secondary materials, and promote an integrated approach to resource use.

Sustainable Construction Strategy

The need to reduce waste at all stages of construction was central to the message of *Rethinking Construction* the 1998 report of the Construction Task Force on the scope for improving the quality and efficiency of UK construction. Improving the efficiency of the construction industry is a key objective for the Government, as set out in its strategy for more sustainable construction. The strategy published in April 2000, identifies priority areas for action, and suggests indicators and targets to measure progress. It sets out action that the Government has already taken and further initiatives that are planned, highlighted what others can do. The Government will use the strategy as a framework to guide its policies towards construction, and will encourage people involved in construction to do the same.

The sustainable construction strategy emphasises the importance of reducing waste at all stages of construction by focusing on the need to consider long term impacts of design, construction and disposal decisions so that materials and other resource use is optimised. The strategy encourages the industry (including the clients) to consider refurbishment or renovation as an alternative to new buildings and structures. It highlights the need to avoid over-specification in materials and the scope for standardisation of components.

Fiscal

The Landfill tax

The landfill tax was introduced on 1st of October 1996 and it applies to waste, which is disposed of in licensed landfills. Exemptions for the tax have been provided for dredged waste, mineral waste from mines and quarries and wastes arising from the clearance of contaminated sites. Landfill tax rates for inert wastes have been held at £2 per tonne unless, from 1 October 1999, they are used for landfill restoration when they will become tax exempt. The tax seeks, as far as is practicable; to ensure that the price of landfill fully reflects the impact which it has upon the environment. It provides an incentive to reduce the waste sent to landfill sites and to increase the proportion of waste that is managed at higher levels of the waste hierarchy.

There are two rates of tax, a standard rate of £10 per tonne (increased from £7 per tonne in April 1999) and a lower rate of £2 per tonne. The higher rate will increase £1 every year from 2000 until it reaches a rate of £15 per tonne in 2004. The categories of waste to which the lower rate of tax apply – generally inert waste – are set out in the Landfill tax (Qualifying Materials) Order

1996 (SI No 1528). The landfill tax (Contaminated Land) Order 1996 (SI No 1529) sets out the provisions for exempting waste from the clearance of historically contaminated land.

Adopted Directives to be Implemented by UK Legislation

96/61: Integrated Pollution Prevention And Control (IPPC) (OJ L257 10.10.96)
The purpose of this Directive is "to achieve integrated prevention and control of pollution" arising from the industrial activities listed in Annex I to the Directive, and to "prevent, or where that is not practicable, to reduce emissions in the air, water and land…including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole". It is very similar in concept to the UK's Integrated Pollution Control (IPC) system, and this Directive will therefore have less impact on the UK than on other Member States.

The Landfill Directive 99/31/EC
The Directive defines three classes of landfills: for hazardous, non-hazardous and inert waste. The following wastes are banned from landfill:

- explosive, oxidising or flammable wastes
- infectious clinical waste
- tyres (whether whole or shredded)
- liquid wastes, except those suitable for disposal at an inert waste site.

All hazardous waste is to be treated before landfilling, although the term "treat" can be taken to mean merely sorting, provided the hazardous character of the waste is reduced. The Directive states that hazardous waste may only be landfilled in a hazardous waste site and therefore rules out co-disposal, which must cease by 2004 at hazardous waste sites.
The most significant requirement of the Directive is that each Member State should draw up a strategy for a three-stage reduction in the quantity of "biodegradable municipal solid waste" disposed of to landfill. This must be reduced to:

- 75% of the 1995 figure by 2006
- 50% by 2009
- 35% by 2016.
-

The UK and other Member States that rely on landfill for more than 80% of their municipal solid waste (MSW) have been granted additional four-year extensions to the targets.

Proposed Directives

Draft Commission White Paper on Environmental Liability
The European Commission has been considering the introduction of a Community-wide scheme of environmental liability since 1989, when a draft Directive was issued on civil liability for damage caused by waste. This controversial draft was subsequently dropped, to be replaced by a wider-ranging set of proposals in the 1993 Green Paper on remedying damage to the environment. The current thinking within DGXI is set out in a draft White Paper, the most recent

version of which was produced in October 1998. If the Commission accepts the White Paper it will be reissued as a draft Directive, possibly in the year 2000.

Policy

New Demolition Code of Practice BS 6187: 2000
This British Standard concerns the process of demolition from initiation, through planning, to the execution stages. The new version of BS 6187:1982 is essentially a re-write which takes into account the advances in technology and equipment that are available to the demolition industry. The application of new techniques and the effect of new legislation that has been introduced, particularly health and safety, and environmental legislation, including the Construction Design and Management (CDM) Regulations 1994, the Construction (Health, Safety and Welfare) Regulations 1996 and the Environmental Protection Act 1990 have been taken into account. The document is written for **all** – including Clients - involved in demolition (which include partial demolition) projects and gives emphasis to responsibilities from concept stage to completion, starting with clients. This Standard addresses the safety of both those engaged in the demolition process and also those members of the public who may be affected by the demolition activities.

The new edition of BS 6187 has been expanded to cover project development and management, site assessments, risk assessments, decommissioning procedures, environmental requirements and facade retention. Deconstruction techniques are considered, including activities for re-use and recycling. Principles relating to exclusion zones, their design and application have also been added.

8.4 CHANGING NATURE OF DEMOLITION

The demolition industry has undergone major transformation within the last 20 years. Traditionally it has been a labour intensive, low skill, low technology, and poorly regulated activity, dealing mainly with the deconstruction of simply constructed buildings. It has followed the trend of all major industry and mechanised, replacing labour with machines. This has come about because of the increased complexity in building design, the financial pressures from clients, health and safety issues, regulatory and legal requirements and advances in plant design. The industry now employs fewer, but more highly skilled operators and very expensive specialised equipment. Also traditionally much of the demolition contractors' income was from the sale of salvaged and recycled materials. Today income is generated from the fee - demolishing as quickly and as safely as possible.

Differences in Demolishing Victorian to more Modern Buildings
Older buildings of non-complex construction are generally simpler to demolish, at least until toxic materials like asbestos are found. Their elements also often have an aesthetic or antiquarian value which being greater than their material value results in them being salvaged. As the complexity and size of buildings has risen so have the technical demands placed on contractors taking them down safely.

8.5 CURRENT DEMOLITION TECHNOLOGIES

Research from University of Salford [12] reveal that demolition techniques are now not only numerous but also varied in their technology, application, cost and speed. Traditional methods such as the steel ball are being rapidly replaced by more modern methods as the emphasis changes from masonry and brickwork to concrete and steel structures.

Factoring affecting the choice of demolition method

According to Kasai et al [13] there are eight factors, which affect the choice of demolition method. Any one building will be subject to a unique combination of these factors.

1. *Structural form of the building*. What are the technology and materials involved in its construction?
2. *Scale of construction*. A large building may make a complex method economic, while a small building could be demolished by hand.
3. *Location of the building*. Access for plant can affect the choice of equipment for a demolition. (This is related to point 4.)
4. *Permitted levels of nuisance*. Noise, dust and vibration tolerances will vary from site to site.
5. *Scope of the demolition*. Some methods are not suitable for partial demolition.
6. *Use of the building*. A contaminated structure will be treated differently to an ordinary residential terrace.
7. *Safety*. Both of operatives and environmental.
8. *Time period*. A spokesperson for the National Federation of Demolition Contractors says "……given the time we could recover most things during demolition, but client's want to see a rapid return on their investment [14].

The first six of the above factors are concerned with the physical aspects of the building to be demolished; its technology and materials, size, location, site, use and the scope of the demolition required. The final two factors are an indication that the characteristics of the building are not the sole consideration when deciding on a particular demolition method. The incorporation of the time factor shows that the contractual conditions can have an effect on choice, whilst the inclusion of safety aspects points to the influence of wider issues such as legislation, and the environment.

It is suggested that three more factors should be added to the initial group of eight. The suggested additions are again concerned with issues unrelated to the physical attributes of the building.

9. The proposed fate of the building materials once the structure is demolished will probably affect the choice to some extent. Some of the methods available, for example, explosives, merely reduce a building into manageable size pieces taking little or no account of the separation of materials. Clearly such methods would be unsuitable for a project where a high degree of reuse of individual components was specified.

10. The culture of the demolition firm carrying out the work will to some extent condition their choice of method for dealing with a particular problem. A firm that is familiar with a specific method or equipment is more likely to apply that expertise if possible than

search for another solution. If the problem falls outside the boundaries of their previous knowledge, they could then be forced into examining other options.

11. Monetary cost. If a method would place a heavy burden on the contractor, without presenting any other advantages it is unlikely to be chosen. Similarly a client will probably let a contract on the basis of the least cost option, although this is slowly changing as more clients look for the best value option, which may not always be the cheapest initially.

There will usually be several methods of tackling a demolition, all of which have various merits relating to the factors above. It may not be a case of ‘right’ and ‘wrong’ methods, just alternative options based on different assessment of the relevant factors in a case.

One of the objectives of this report is to identify the factors relevant to the choice of demolition methods in a particular case, and determine the influence that decision has on the eventual recovery of materials.

Methods of Demolition

In the main the demolition process relies on one of eight basic methods, pulling; impact; percussion; abrasion; heating (or freezing); expanding; exploding or bending.

Abraham et al [15] classify the methods of demolition into traditional, explosion and newer methods. In the following pages the various methods are summarised in tabulated form (Tables 4, 5 and 6). Each table includes the equipment required, the type of building the method is suitable for, and the procedure the method entails. The final column provides a commentary on the methods and includes the advantages and disadvantages, just as each building to be demolished has its own characteristics, and these must be considered carefully before any decision is made on the method that would be most suitable for a particular case. “The frequency of application [of a demolition method] is a result of the evaluation from the suitability, performance, and nuisance.” [5] In many cases it is likely that the demolition, which eventually takes place is a combination of methods, which achieve the overall aim of the project.

Table 4: Traditional methods of Demolition

Method	Tools/Equipment required	Application suitability	Preparation /procedure	Comments
By Hand	Portable tools including: crowbars or mattocks pneumatics drills power saws	Now reserved mainly for high and inaccessible areas, or architectural salvage	Demolition proceed in a top-down fashion, floors in buildings are removed prior to demolition to prevent premature collapse due to weight of debris collection	Oldest method Labour intensive and slow Expensive if labour costs are high Debris is easily segregated for salvage purposes Possible safety implications of working at height.
Pulling	Wire Rope Vehicle to provide pulling power	Brick or masonry structures	Remove all stabilising elements eg pipework, beams and lintels Detach from adjacent buildings Set rope around section of brickwork and drag to collapse	Causes dust nuisance Time consuming if uncontrolled collapse occurs Destabilised for a period before demolition – safety implications.
Impact	Demolition ball between 0.5 and 2.0 ton suspended form a crawler crane	Fairly large, brick, masonry, concrete or r.c.	Remove floors as per hand Buildings > 30m high should be reduced by hand before using ball. Detach from adjacent	Widely used in European countries Produces noise, vibration and dust Can be set to drop weight vertically onto floors and foundations
	Pusher arm (extended arm and steel pad fitted to tracked vehicle)	Normally brickwork	Arm is positioned at top of wall and forward motion applied	Popular in late1970s More controllable and versatile then demolition ball Restricted in terms of height of wall to be demolished
Percussion	Hammer: hydraulic or pneumatic: handheld or vehicle mounted	Concrete, brickwork/masonry capable of partial demolition	Involves repeated impact	Pneumatic hammer is smaller and lighter, but noisier than hydraulic Both produce persistent noise

	Hydraulic breaker, four or five types available		Jaw-like attachments break concrete by holding and crushing into sections	Produces small size materials, no need for secondary crushing before use as recycled aggregate Reasonable cost

Table 5: Demolition using Explosives

Method	Application suitability	Preparation /procedure	Comments
Borehole Charges	Concrete, brickwork and masonry, not suitable for narrow members	Place in pre-drilled holes	Shock waves from powerful explosives can be transmitted over great distances by some ground conditions eg clay and by airwaves Risk of flying debris Produces medium sized materials that may require further crushing before use as recycled aggregates
Lay-on charges		Placed in contact with structure and contained with sandbags or clay	
Concussion charges	Enclosed structures eg tanks	Bulk charge placed within structure	

Table 6: Newer Methods of Demolition (cont. on next page)

Method	Tools/Equipment required	Application suitability	Preparation /procedure	Comments
Expansion/ bursting: Static	Buster with wedges	Concrete or masonry	Mechanical wedges forced into pre-drilled holes and expanded by hydraulic pressure	Create noise and dust at drilling stage, otherwise nuisance free. Slow. Good for working in close proximity to other buildings.
	Chemical expansive agent	Cannot be used for narrow structural members, r.c. or pre-stressed concrete	E.g. Injection of unslaked lime composite mixed with water into predrilled hole, hydration of mixture causes expansion which splits surrounding material	
Dynamic	Explosives, high-pressure water, gas pressure		Apply to pre-drilled holes	
	CARDOX		Liquid carbon dioxide in metal tube inserted in pre-drilled hole, heated by electric filament, causes expansion	
Abrasive	Hammer drill, hand operated, or vehicle mounted	General	Reduces concrete to dust using rapidly rotating and hammering bit	Vehicle mounted hammer drill used for the destruction of mass concrete
	Diamond boring machine	Drilling concrete	Diamonds form abrasive interface	Quite slow and expensive
	Diamond disc cutter	Capable of cutting r.c.		
	Diamond wire saw	Cuts around circumference of concrete sections		Noisy, but produces little dust or vibration
	High-pressure water jet	Can be used to cut cement grout to release components	250-300 Mpa water jet forced through small nozzle can cut plain concrete. Addition of particles of steel allows it to cut through r.c.	Expensive in comparison to other methods. Uses large quantities of water
Heating	Thermic lance (metal tube, approx. 3m long containing aluminium alloy or iron alloy rods	Reinforced concrete	Tip of lance heated to 1000C oxygen fed to tip produces flame 2500C, can melt reinforcing rods and concrete	Cutting of some materials can cause toxic fumes

	Fuel Oil Flame		Combustion of mixture of kerosene and oxygen gas produces flame to melt concrete	
	Argon-hydrogen/Argon-nitrogen plasma, and carbon dioxide laser beam		Development stage (Kasai 1998)	Specialist use only
	Heating and peeling using electrical conductors		Drill holes to reveal rebars, attach electrical conductors to induce current through the rebars, causes heating which dries out surrounding concrete so it peels	Little noise or dust after drilling stage. Could use microwaves to dry out concrete, omits use of drilling but expensive
Cryogenic		Reinforced concrete, steel framing	Quick-freezing steel in a restricted area makes it brittle	Time consuming, limited use and expensive
Bending	Jack-up	r.c. horizontal members	Application of point force upwards against floor slab induces bending and shearing forces into slab designed for down loading only	Developed in Japan, rarely used.

8.6 DEMOLITION SURVEY

The following information was collated as part of University of Sheffield PhD research [16] from in-depth exploratory interviews with demolition experts. These experts were members of the National Federation of Demolition Contractors (NFDC), Institute of demolition engineers (IDE), UK Research Organisations, and private consultants. Through interviews, knowledge and opinions where sought about the current state of the industry and potential design changes that would help increase the reuse and recycling potential of buildings, their elements and material components. The conclusions of this in depth study are presented below.

Perception
Demolition is in fact the start not the end of most building projects, particularly on inner city or brown field sites. As such it needs to be fully integrated with the future works program, not as it often seems, perceived as an obstacle to be quickly overcome before building can commence. When presented with a brief to design a building, most architects start with the visualisation of a clear site and end with the newly constructed building. If reuse and recycling is to be encouraged there is a pressing need to change this approach and include the demolition phase. Projects should start with demolition phase and consider its incorporation into the new building and end with the potential for the elements of this building to be included within the next redevelopment.

Time & Money
Time is inextricably linked to money, both in terms of that allowed for the demolition contract as a whole and as the deciding factor as to any material's fate. No time to dismantle re-useable materials simply means no materials for re-use. Due to developer pressure the main emphasis is now on demolishing in as speedily as is safely possible. As such demolition contracts have gone from six months to six weeks duration. If more time was available recycling might increase but the bottom line is economic: labour is expensive and new products are now cheap. In some isolated cases demolition firms have offered two very different tender fees, the difference being due to recycling. The first for say a million pounds and down in six weeks and the second for a hundred thousand pounds and down in six months with the demolition contractor making up the difference from salvaging as many elements and materials as possible.

Information
All interviewees suggested that information should be more prominent. The emphasis here being on the quality not quantity of information available to the demolition contractor. This should include:

- As built drawing records;
- Records of all changes to the building;
- Asset registers showing what is in the building and its recycling potential;
- Identification of potentially hazardous materials;
- If prefabricated elements were used details of these plus fixing and carrying points; and even
- Labelling of materials.

CDM regulations are starting to improve this situation. We live in a society that is increasingly geared towards and driven by information and this is equally relevant to the building profession.

Quality information can speed up both the pre-tender and main demolition contract, and allow pre-determination of waste and recycling routes.

The following points summarise demolition experts' opinion on specific issues regarding their activities. The points reflect a consensus of opinion:

Health & Safety
Health and safety legislation is becoming tighter all the time. It has resulted in safety standards being raised across the industry but possibly has had a detrimental effect on recycling as working practices become more restricted. Working at height or in dangerous places, removing slates from a roof for example now requires full scaffolding and boarding out. This is prohibitively expensive and so most contractors would try and use more remote methods which usually implies less separation and selection of individual materials resulting in less recycled material.

Landfill Tax
The landfill tax has had a mixed response within the industry. Initially its implementation caused contracts to stall as those involved worked out who was to pay. The price differential between inert and non-inert waste has encouraged some additional recycling, with any extra costs being on the whole passed on to the client. The EU Report[Error! Bookmark not defined.] proposes that relying solely on landfill tax or primary aggregate tax would not achieve high recycling rates. It reasons that the taxes would have to be set at politically unacceptable levels before they changed the behaviour of building professional, particularly in areas with easy access to landfills or quarries.

Barriers to Recycling
All interviewee's identified a number of barriers to recycling, these are summarised as follows:

Legislation & Regulation
As discussed above legislation & regulation is not only pressurising the demolition phase of a contract it also appears to be currently inhibiting the amount of material recycled.

Infrastructure, Markets, Quality & Standards
Due to the lack of infrastructure for recycling, the fluctuating price paid for recycled materials and the inconsistent quality of recycled materials, contractors are wary of recycling and using recycled materials and customers are dubious about buying them. There are issues of perception, quality and quantity here.

- Perception. Willingness of client, public etc to accept second hand materials
- Quality. Reliability and safety of second hand materials, and liability in event of failure.
- Quantity. Often, insufficient quantity of any one material at time of use and unreliable markets.
- Standards. The construction industry is traditionally 'conservative' in nature, and has a tendency only to use specifications that have been tried and tested over considerable periods of time. For the use of recycled materials to increase there is a need to move towards more performance-based specifications. This places the emphasis on the identification of the properties and qualities required of materials appropriate to the intended use.

- Definition of Waste. There must be a redefinition of the term Waste. Many materials which nobody intended to discard and, which require little or no processing before re-use, are being treated by Regulators as waste.

Location
The location of a site affects the demolition contract in a significant way. It basically controls the type of demolition carried out. For inner city or urban sites full protection from the surrounding area must be provided. Strict site operation times, noise, dust, space and transportation guidelines will be placed on the contractor. This usually results in a more controlled slower demolition but one in which the time considerations are paramount and space on site is at a premium.

Client Perception and Risk.
The perception of demolition as a public nuisance does not help the image of recycling. Clients in an effort to minimise adverse publicity will usually desire the demolition phase to be as rapid as possible. For the positive perception of recycling to grow, the benefits of recycling need to be sold to the client, perhaps through green marketing.

Approaching Demolition
Generally the same approach to a demolition contract is adopted across the industry. Demolition is in-effect the reverse of construction and as such you demolish from the inside out; remove hazardous materials, soft strip, and then main frame and finally the foundations. Some contractors do not even bother with the soft strip, demolishing whole buildings and then extracting materials [i.e. metals] at ground level. The cost implications are always first.

The ideal process is as follows:
1. Pre-tender Health and Safety plan as part of CDM regulations, covers hazardous materials, previous uses and as built and modified drawings.
2. Client provides adequate information about life of building.
3. Undertake a site visit with someone who knows the building and is familiar with any changes and the Health and Safety Plan
4. Demolition contractor can then make an informed decision as to method of taking down the building. Of course there are many other partial demotion types in addition to complete end of life total demolition. In this one would identify Hazardous materials [i.e. PCB’s asbestos, solvents], inert and none inert waste
5. Strategy for demolition is then:
    - Isolate and make safe services
    - Remove hazardous materials
    - Soft strip, i.e. all internal finishes, partitions, carpets, services etc
    - Remove none-load-bearing elements
    - Remove load-bearing elements, these two in reverse of construction and in a way that you could reuse or recycle materials.
6. Then from all this information contractor would develop a demolition health and safety plan, which would include reuse and recycling ‘options’.

Soft Strip
Information about the soft strip was hard to come by. Potentially this is the layer with the highest resale value as many items are in a recognised product form. The lack of information about the fate of this layer may indicate that many of the products were already being informally recycled due to their resale value. It is also the layer with possibly the largest environmental impact. Many buildings undergo a number of internal fit-outs through their lifetime, consider the widely reported increasing ‘churn rate’ of office buildings or high street retail stores. In each of these fit outs, highly processed and resource intensive elements, such as light fittings, false ceilings, shelving units and carpets are removed and replaced by similar new products.

Steel and Concrete
Contractors did not foresee any particular problems with steel or concrete buildings, the two materials being easy to separate providing the right machinery is available. These two materials are the basis of most buildings and demolition firms are highly skilled at demolishing and separating them. The main steel elements [beams etc] are removed first and overhead magnets above the concrete crushing plants extract the rest of the steel [reinforcement]. Most of the demolition work is carried out remotely, using the hi-reach hydraulic excavators. These are capable of ‘crunching’ through pre-cast or in-situ concrete slabs and beams or composite slabs and by changing the head to shears they also cut through steel beams. For particularly large beams or difficult access situations hot cutting gear is used with close manual operation, safety concerns though make this the exception. It is rare for beams to be unbolted, although cutting gear may be used to remove the bolts. Pre-cast concrete floor units are often lifted down and crushed at ground level.

The majority of foundations encountered are concrete [90% plus]. Ground bearing slabs, footings and ring-beams are all removed. However this is not the case for bored pile foundations. Here the pile cap will be removed along with possibly the first metre or so of the pile, the rest being left in the ground. Particularly in London this is starting to become a major issue as construction contractors are finding it difficult to sink new piles without crossing old ones.

Particular problem elements
Complex designs, the lack of foresight as to the eventual demolition, the bonding of dissimilar materials and contamination of waste streams were the main issues raised, for example:

- Buildings with pre-stressed and post tensioned beams, cantilevers and undercrofts have all recently been demolished. In all these cases the demolition process was more onerous due to the presence of these complex structural elements.
- Composite materials, loose and bonded insulation particularly in permanent shuttering, cladding panels and large glass curtain walling all make the demolition task more difficult. Polystyrene boards used in foundations and to provide the voids in hollow core concrete beams and floor units make recycling the concrete very arduous. [In the past the voids where formed using bags filled with air.]
- As previously mentioned steel and concrete present no particular problems, and they also have well-established reuse or recycling loops. However contamination in concrete is an issue. Steel mixed with concrete is easily separable with magnets but the likes of timber must be separated first, as it is impossible to do this after crushing as the timber splinters.

- Fire cladding if bonded to the steel makes it more difficult to isolate, most contractors preferring the more jacket types of fire cladding.

8.7 DESIGNING FOR FUTURE REUSE AND RECYCLING.

The environmental impacts and implications of buildings are now recognised as being of prime importance. Increasingly, these are being addressed in both the construction and the operational phase of a building's lifecycle.

The realisation of the environmental importance of the demolition stage of a buildings life has lead to number of notable publications in recent years. These have assessed the 'base line' and the 'state of the art' in demolition practice [6,17,18]. They have then gone on to investigate the potential amount of materials that can be reclaimed by conducting specific case studies of buildings being demolished [19,20,21,22].

The best publicised UK projects are the demolition of the IBM offices at Hursley [10], near Winchester and the demolition of an existing building to construct the BRE's 'Office of the Future' at Garston [11], Watford. In both of these cases an estimated 95% of materials by volume was reclaimed and either reused/recycled at virtually no extra cost to the demolition contract.

Finally, practical guidance for designers, specifiers and clients on ways to minimise waste and increase the uses of reclaimed materials have been produced [23].

8.8 FUTURE OF THE INDUSTRY

Demolition in the UK is likely to follow the lead being taken by the Dutch. Landfill becoming gradually more expensive and in all likelihood disposal of recyclable materials will be banned. This will encourage selective demolition and so increase recycling rates. The innovations within the industry are likely to come from new mechanical plant, which are rapidly becoming more sophisticated and specialised. The next growth market for plant is likely to be in the area of the soft strip, which is still labour intensive.

8.9 CONCLUSIONS

The construction and demolition industry produces vast quantities of waste that for environmental, economical and social reasons is becoming unacceptable. To effectively tackle this waste issue a more proactive approach must be taken. This sees buildings as dynamic systems, operating at a number of physical and time scales, with many changes over their lifetime. Fundamental to this approach is the circularisation of resources, waste should not occur and elements should be readily reusable and recyclable and respond to the changing requirements placed on them.

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CHAPTER 9
IMPLEMENTING DECONSTRUCTION IN THE UNITED STATES

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SUMMARY

Out of 260 million tons of non-industrial waste produced annually in the U.S., 136 million tons are a result of the construction and demolition industry. This equates to approximately 33% of the waste produced nationally. Similarly in the State of Florida, the Florida Department of Environmental Protection (FDEP) reports approximately 22% of the waste produced is a result of construction and demolition activities. In this report, Florida is used as an example of construction waste generation issue in the U.S.

The process of deconstruction (the disassembly of structures for the purpose of reusing components and building materials) can significantly decrease the national solid waste burden the construction industry places on the environment. Through deconstruction, natural resources are saved, employment and training opportunities are created, and local businesses are developed that use the materials diverted from landfills. Deconstruction supplies useful materials to building materials yards, recycling centers, and remanufacturing enterprises, creating additional jobs and community revenue.

This report investigates and analyzes issues related to the feasibility of replacing demolition and landfilling of building materials with deconstruction and reuse in the U.S. The report contains information from an extensive search of case studies throughout the U.S. Case studies are examined and used to develop a list of influence factors affecting the implementation of deconstruction. Factors such as, labor, scheduling and cost, tipping fees at construction and demolition landfills, hazardous materials management, existing markets, value adding and marketing of reused materials, material grading systems, time and economic constraints, contractual agreements, environmental building goals, and public policy are all contributing factors to the successful implementation of deconstruction. These influence factors are further explored to provide insight into successfully implementing deconstruction in the U.S.

The report found that, although the transfer of technology and information about new building materials is important to promote their use, it is also important that research into creating building materials specifically designed for deconstruction becomes a priority. Given that the emphasis on recycling products is only going to increase in the future, it is important that organizations start becoming conscious of the need to design products that are environmentally friendly, despite the belief that this will significantly increase their design and manufacturing costs. The extra effort in designing environmentally friendly products is often not significantly more than designing for other considerations.

9.1 INTRODUCTION

Deconstruction may be defined as the disassembly of structures for the purpose of reusing components and building materials. The primary intent is to divert the maximum amount of building materials from the waste stream. Top priority is placed on the direct reuse of materials in new or existing structures. Immediate reuse allows the materials to retain their current economic value. Materials that are not immediately reused can be recycled, downcycled, or upcycled. An example of immediate reuse is large structural timbers for use as structural members in a new building. Recycling may consist of turning scrap steel into new steel rebar or beams. Downcycling for example, would be turning a concrete slab into road base, and upcycling may consist of salvaging lumber and creating custom cabinetry or other value-added products.

Deconstruction is a new term used to describe an old process – the selective dismantlement or removal of materials from buildings instead of demolition. The common practice in the industry is to cherry pick or strip out highly accessible recyclable, reusable, or historic materials prior to traditional demolition. Traditional demolition usually involves mechanical demolition, often resulting in a pile of mixed debris, which is often sent to the landfill. Deconstruction encompasses a thorough and comprehensive approach to whole building disassembly (versus cherry picking specialty items), allowing the majority of the materials to be salvaged for reuse.

Deconstruction requires the careful disassembly of buildings in the reverse order of construction. Deconstruction, unlike demolition, is labor intensive, low-tech, and environmentally sound. The process of deconstruction can significantly decrease the national solid waste burden the construction industry places on the environment. Through deconstruction, natural resources are saved, employment and training opportunities are created, and local businesses grow are developed that use the materials diverted from the landfill. Deconstruction supplies useful materials to building materials yards, recycling centers, and re-manufacturing enterprises, creating additional jobs and community revenue.

The construction industry's practice of land-filling construction and demolition debris not only results in a large loss of potentially reusable building materials, but also wastes natural resources and landfill space. The effective reuse and recycling of materials requires at least three key elements: knowledge, incentives, and coordination. Deconstruction is considered a new strategy to advance local and regional sustainability and reduce environmental degradation. Deconstruction is a significant advance toward a sustainable environment. The immediate reuse of materials keeps existing materials in circulation and out of landfills.

In looking at the waste management hierarchy (Figure 1) it can be seen that one of the highest levels is reuse. However, the majority of the current practices fall in the lower two levels. The common practice on construction and demolition sites is to simply toss “waste” into the dumpster. This practice often occurs regardless of the potential value of the materials. In less developed areas, debris is burned on site, often without permits or authorization. Efforts are being made to recycle waste materials. However, as discussed later, these efforts alone will not create a sustainable future. Deconstruction assists in moving the construction industry further up the sustainability “food chain”. Not only does deconstruction conserve landfill space, but it can reduce the demand for new materials, decrease the environmental strain caused by the mining of raw materials, and preserve the original energy spent in the creation of building material.

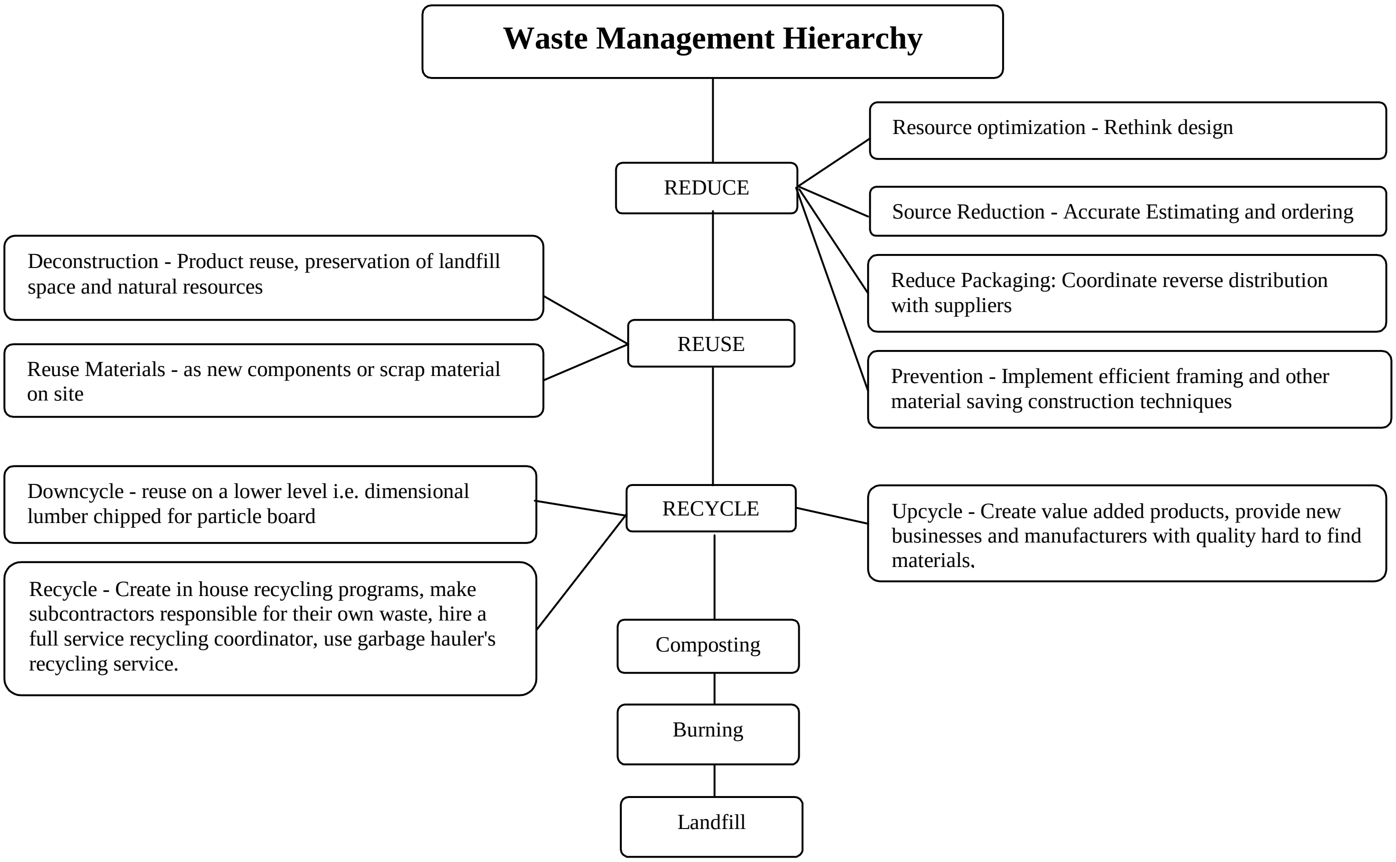

Figure 1 Waste Management Hierarchy

In regions lacking natural resources, it is commonplace to reuse the supplies on hand. Structures such as old homes, barns, and buildings are used to build new or needed facilities. Regions lacking natural resources turn to locally available materials, whether they be new or borrowed materials to sustain their new construction. However the drive to reuse these materials is not limited to the lack of natural resources - it is basic common sense. Reclaimed or salvaged building materials are inherently valuable, based simply on the energy and raw materials used to create them. Dismantling a building into its components keeps the materials in service as long as possible. Keeping materials in service longer results in reduced demolition or restoration waste, which in turn preserves landfill space. There is no additional energy spent mining new resources or manufacturing new products. Immediate reuse of materials also keeps valuable usable materials such as dimensional lumber from being downcycled into items such as oriented strand board, particleboard, or mulch - a less valuable product. Although this is better than land - filling the materials, immediate reuse is the best conservation of materials and energy. In addition to the many environmental benefits, deconstruction also has many positive social and economic implications.

There are many factors that can influence the successful implementation of deconstruction, factors such as labor, scheduling and cost, tipping fees at construction and demolition landfills, hazardous characteristics of demolition waste, markets, material grading systems, time and economic constraints, contractual agreements, and public policy. These conditions affect the potential for deconstruction to develop into a long term, economically viable sector of the construction industry for waste reduction, resource conservation, and job creation.

9.2 WASTE IMPACT OF THE CONSTRUCTION INDUSTRY

General

Buildings have a significant impact on the environment. In the U.S., buildings represent more than 50 percent of the nation's wealth. New construction and renovation account for approximately $800 billion or approximately 13 percent of the Gross Domestic Product and employ over 10 million people [1]. The construction industry uses 40% of all extracted materials. Thirty percent of all energy used is a result of the construction industry and the built environment [2]. Out of the 260 million tons of waste produced nationally, 136 million tons are a result of construction and demolition (C&D) waste. Over one-third of the waste produced in the nation is the result of one giant industry. Approximately 7 pounds of waste is produced for every square foot of new construction. Renovation and demolition produce up to 70 pounds of waste per square foot. It is clear, based on these numbers, that there is significant room for improvement in the way the industry operates. Buildings are constructed, and on average, are demolished twenty-eight years later. Unfortunately traditional demolition is with a wrecking ball, leaving piles of mixed debris [3]. The construction industry lags far behind other industries in efficiency related to materials consumption, reuse, and recycling. For example, a new BMW contains 70 percent recycled content, but a new building probably contains less than 1 percent reclaimed materials [4].

The total economic and environmental impact of the construction industry begins with raw material extraction and continues to product manufacturing, product transportation, building design and construction, operations and maintenance, and building reuse or disposal. Each building product alone contains vast quantities of energy - energy used to extract raw materials, are process and create a marketable product. Extraction of these natural resources, especially through mining and smelting, is one of the most wasteful, energy intensive, and polluting industries on earth. Reusing and recycling building materials prevents this pollution by reducing the need for virgin natural resources to be mined and harvested, while saving already threatened forests and natural areas from further degradation. When you consider the combined energy required to transport materials and the labor required to design and construct buildings, demolishing a structure is simply throwing away valuable resources. Reusing building materials conserves this energy "embodied" in the products, meaning we are conserving the energy originally used in the manufacturing and transportation of these materials. Deconstruction is a huge step toward sustainability. Salvaging the materials from structures reduces waste, preserves the energy originally used to create the materials, and lessens the need for virgin materials. For example, reusing wood eliminates the harvesting, transporting, processing, and other energy intensive steps that would be needed to produce new dimensional lumber. Rather than destroying the value of these salvageable materials and burying them in a landfill, reuse and recycling keeps this value within the local economy where it can continue to produce financial benefits as it is remanufactured and used again.

Current Practices

In the movement toward sustainability there are several changes occurring in the construction industry. There is a movement toward using "green" materials, more energy efficient structures, managing construction waste, and implementing reuse and deconstruction. Unfortunately, the construction industry, as is the case with most industries, is driven by money. This industry is well-established and, for the most part, highly resistant to change. The industry as a whole feels comfortable and confident in their tried and true methods. When it comes to “debris” or “waste” the industry prefers the easiest, fastest, and cheapest option, which in most parts of the nation is landfilling. The industry also perceives materials that are delivered to the site not wrapped in visqueen® and on wooden pallets to be substandard. These are the perceptions that must be changed – there are other waste management options and there are other sources of materials. Although the focus of this report is reuse and deconstruction, it is important to mention these sustainable factors, as they are an integral part of the construction industry is operations.

Landfilling
The current practice in industry is to landfill most materials perceived as waste. The large quantities of debris also contribute greatly to the costs of solid waste management. Landfills have limited space and therefore can only receive a limited amount of trash. When a single landfill fills, it must be replaced by another landfill, which is generally more expensive to operate and maintain. The higher cost is a result of complying with environmental regulations, higher expenses in siting a new location, buying or allocating land, constructing the landfill, operating expenses, and long term maintenance costs after the landfill is closed. Additionally, the new landfill may be further away than the old landfill, increasing transportation cost.

In general, new landfills cost more than old ones. Paying the higher cost at a new landfill and paying the increasing cost of closing a landfill are avoided by keeping the old landfill open. Under new Federal regulations governing landfill closure, landfills must be monitored, inspected, and maintained for at least 30 years following the facility closure. This includes operation of the leachate collection system, extensive ground water monitoring, inspection and repairs as needed of the cap and other protective systems, and the maintenance of a financial assurance bond or other security. Closing landfills and the costs associated with this process are extraordinary. For example, the West Marin Sanitary Landfill in California expects its closing cost alone to be upward of $2.5 million.

The bottom line is that landfills are becoming increasingly expensive. In some way, society is paying these costs – through tipping fees or taxes. No neighborhood welcomes the thought of having a new landfill built in their backyard. Keeping existing landfills operating as long as possible benefits both the environment and society. To extend the longevity of the landfills, increasing waste reduction and recycling efforts are a must and deconstruction can significantly reduce the amount of usable materials sent to landfills.

Renovation
Longevity is central to environmentally responsible building design [5]. Longevity can relate to a building as a whole by adaptive reuse rather than new construction, or longevity can relate to the building components through increased recycling and the use of salvaged materials. The common aim of each is to keep materials within the materials cycle as long as possible without the need for further processing. Renovation provides longevity of the structure itself if designed properly. Although the interior is often completely lost, the potential to reuse the skeleton of the building exists. Consideration of longevity points to the importance of distinguishing between strategies that result in immediate environmental benefits from those when the benefits are deferred to the future. Significant waste savings can result from reusing the structure of a

building. Designing for adaptability of interior spaces could reduce the need for complete renovation of the interior of structures.

The cost of renovation is 15-20 percent higher than the cost of new construction. For example, on a typical commercial project, the cost of new construction is approximately $100/sf while the cost of renovating a structure is approximately $118/sf. It is possible, however, to design a more adaptable building. This would reduce the cost of renovating buildings and make it more appealing than simply demolishing a structure for the needed land. Renovating is the ultimate reuse of a space. If done properly, fewer new materials are needed and the bulk of the structure remains intact.

Refurbishing older buildings involves both the residential and commercial sectors. Large-scale renovations and adaptive reuse conversions are common in Canada. For example; in Quebec City, a church has been converted into condominiums; in Ottawa, a school into a regional building; in Toronto, the Bank of Montreal into the Hockey Hall of Fame; in Winnipeg, industrial buildings into seniors' housing; in Edmonton, the former Lieutenant Governor's mansion turned into a museum; and in Vancouver, offices were refitted for use by the University of British Columbia [6]. In many cases the adaptive reuse conversion option presents the most cost-effective and practical means to preserve historical buildings. Although restoration created a potentially significant waste stream from the typical "gutting" of the interior of a building, if deconstruction were implemented many materials would be salvaged, reused and diverted from the waste stream. More importantly, considerably less demolition type waste is created from renovating since the shell of the building is retained.

Green Building Materials

On an environmental level, there is a choice between using "green" materials in the construction of buildings and designing buildings as potential sources of future resources (raw materials) for new buildings. One must address the issue that green building materials are not always the best choice when designing a building for deconstruction. The ideal choices for deconstructable building materials are those with the greatest service life, and those materials which are desirable or hold historical value. In order for the concept of deconstruction to be effective, it is necessary to use materials that will be in great demand in the future.   For example, linoleum floor such as Marmoleum®, is made from renewable raw materials. The flooring contains linseed oil, wood and cork flours, natural rosins, crushed limestone, and non-toxic pigment [7]. This flooring is a much "greener" product than a traditional vinyl floor covering. However it has little future value. If a traditional solid wood tongue and groove floor was installed, not only will it last much longer, the floor would retain its value over time. The tongue and groove floor is worth salvaging, whereas the linoleum floor is basically disposable.

Use of suitable building materials can offer financial benefits and positive environmental results. Consideration must be given to energy and water efficiency, waste reduction, construction cost, building maintenance and management savings, insurance and liability, employee health and productivity, and building value. In addition, it is important to consider the local economic development potential of green building initiatives and present a methodology for environmental life-cycle assessment and its application to green buildings.

The movement to "green" materials has begun as consumers find themselves more informed about environmental degradation. One may assume that economic and regulatory issues will create changes within the material industries. However the creative design which makes the best possible use of materials both individually and in combination, will remain the domain of the architect and builder.

Demolition

The primary reasoning for demolishing structures is based upon society's needs, and supply and demand. There may be a need for the land an existing building occupies, the building may no longer serve any of society's needs, (for example old mill type factories), or the building may no longer be structurally sound. These are all opportunities to salvage existing resources.

Deconstruction

Some deconstruction exists in today's market and deconstruction for the reuse of lumber is fairly common. Nationally, deconstruction (as opposed to demolition) occurs to some extent on approximately 40% of all demolition sites over 20,000 square feet [8]. Although this figure includes buildings that are only partially deconstructed, the shift towards salvage and reuse is beginning. There is only one true reason for the shift – money. Although we would like to believe that society and industry is changing purely to benefit and preserve the environment, this is not the reality. Demolition contractors have made money from used wood in ways that were not possible ten to fifteen years ago. In some regions, tipping fees are rising rapidly enough that contractors notice the cost of waste disposal. Unfortunately, increasing the disposal cost is the only way to force the industry to look for alternatives such as deconstruction.

Waste Statistics

Constructing, renovating, and tearing down commercial buildings nationwide produced approximately 136 million tons of waste in 1996 (Franklin Associates 1998). Figure 2 shows the component breakdown of the construction and demolition waste stream while Table 1 lists the breakdown. It is estimated that 65 million tons (48 percent) of the 136 million tons were a product of the demolition of structures. The remaining 71 million tons of the C&D waste stream is comprised of approximately 60 million tons (44 percent) renovation waste and 11 million tons (8 percent) new construction waste. Further analysis of the demolition portion of the waste stream reveals that 45 million tons (69 percent) of the 65 million tons is a result of the demolition of residential structures. The remaining 20 million (31 percent) of the 65 million is a result of the demolition of non-residential structures.

Table 1 Tons produced by each waste category

WASTE CATEGORY	MILLIONS OF TONS
Renovation	60 million tons
Residential demolition	45 million tons
Non residential demolition	20 million tons
New construction	11 million tons

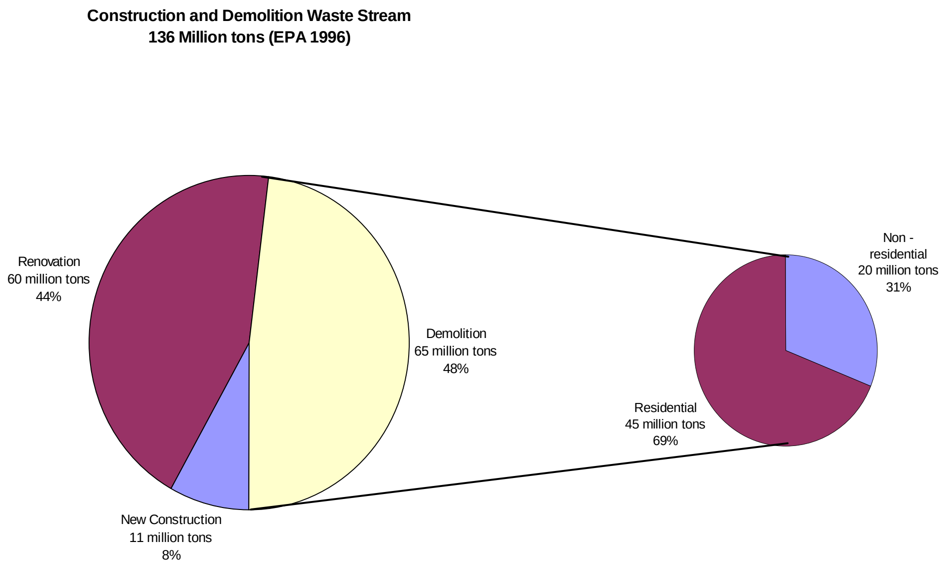

Figure 2   Construction and Demolition Waste Categories

These numbers indicate the majority of the C&D waste stream is a result of demolition and renovation (92%) - 125 million tons of waste - and not new construction. This significant percentage of the waste stream can be directly impacted, that is reduced by deconstruction. Renovation requires partial or complete removal of the interior and possibly exterior of the structure prior to the new construction that occurs to renew the structure. During the "rip out" stage of renovation, deconstruction could significantly reduce waste. Targeting the demolition and renovation waste stream provides the greatest potential impact for reducing the amount of usable building materials that are commonly sent to landfills. Since these activities account for the majority of the C&D waste, the focus should be on providing alternatives to traditional demolition. Both demolition and renovation provide opportunities for material recovery, reuse, and recycling by means of deconstruction.

Deconstruction substantially increases the amount of demolition material reused or recycled by placing priority on recovering materials for use in new construction and manufacturing enterprises. Several case studies have shown the average rate of materials recovery for deconstructed buildings is 80%. The case studies reported findings of recovery rates varying between a minimum of 50% to a maximum of 90%.

Several deconstruction demonstration projects have been completed and showing that high diversion rates may be achieved. The NAHB Research Center completed the deconstruction of a two-story, four-unit apartment building in Maryland [9]. The Research Center measured the volume and the weight of all materials on site, whether salvaged, recycled, or landfilled. The diversion rate was 76 percent by weight and 70 percent by volume.

Potential Building Stock for Deconstruction

Every year as many as 300,000 buildings are demolished in the U.S. Over 100 million housing units exist in the U.S., most of which are wood-framed. Since the turn of the century, over 3 trillion board feet of lumber and timber have been sawn in the U.S., much of it still resides in existing structures [10]. Nationally, 7,000 units of public housing and over 100,000 privately owned homes are demolished each year. Many of these structures could be deconstructed, creating a supply of building materials for reuse/recycling versus adding of tonnage to the C&D waste stream. Opportunities for deconstruction exist in practically every community in the U.S. Virtually all houses constructed prior to World War II are candidates for deconstruction due to the quality of materials used and the methods used to construct them. [11].

Recycling Limitations - The Need for Deconstruction

In an effort to reduce the solid waste management burden, there have been attempts to increase the recovery rate of C&D debris for recycling. The major barriers to increased recovery rates at this time are:

- The cost of collecting, sorting, and processing
- The low value of the recycled-content material in relation to the cost of virgin-based materials
- The low cost of C&D debris landfill disposal

Collecting, Sorting, and Processing

When debris is delivered mixed to a disposal facility, the current method of collecting, sorting and processing construction waste materials leaves little room for improvement. Debris in the mixed state requires tedious and labor intensive separation. The best way to combat this sorting barrier is to separate out the usable material prior to them reaching the landfill, meaning the materials should not be mixed or lumped together only to have to be separated again. Deconstructing allows for each material to be separated at the source, eliminating dump trucks of mixed debris. Not only does deconstruction eliminate mixed debris, it allows for the immediate reuse of materials and facilitates easier recycling because you can see exactly what materials are present.

Perception of Low Value

The perceived low value of recycled content materials is social, incentive, and subsidy driven. Without a change in societal attitude, recycled materials will continue to be viewed by the majority of society as substandard but environmentally friendly. The nation’s economy is, and always will be directed by regulated incentives and subsidies. Subsidies for recycling efforts pale in comparison to the hundreds of billions of dollars in subsidies provided to virgin-resource processors over the past century and which continue today. The virgin-based forest products, mining, and energy industries all benefit from both direct and indirect subsidies and tax breaks. Some examples of these tax breaks and subsidies include percentage-depletion allowances, which are intended to promote resource exploration and below-cost timber sales from Federal lands. Other subsidies include U.S. Forest Service research donated to industry, write-offs for timber management and reforestation costs, and below-cost mining leases based on an 1872 law. These subsidies do not include the many exemptions from environmental laws that the virgin-resource industries enjoy, allowing them to externalize costly burdens to the environment.

The Drive for Change - Landfill Information

The largest number of C&D recycling facilities was reported to be in the Western states (28 percent) and the Mid-Atlantic states (27 percent). The Southwest and Rocky Mountain States each have only three percent of the total recycling facilities and the Southeastern, Upper Midwestern, and New England states have 12, 13, and 14 percent of the facilities, respectively. As stated in Waste Spec, Model Specifications for Construction Waste Reduction, Reuse, and Recycling there is a correlation between disposal costs (tipping fees) and the construction industry finding alternative outlets for their waste. The turning point for tipping fees lies around the fifty-dollar mark. In regions where tipping fees have approached the $50 per ton mark the contractors, workers, developers and owners are not only more open to waste disposal alternative, but businesses exist to offer alternatives. For example, in the San Francisco Bay area, there is an extensive network of businesses to support deconstruction activities. In this region tipping fees can be as high as $110.00 per ton [12]. An integral network of businesses exists to support the salvage, sale, and reuse of lumber. In addition, due to this network structure, several businesses have developed which use these salvaged materials to create value-added products. This structure is explained further in the Implementing Deconstruction section. This section also contains a comparison of regional influences.

A large fraction of C&D debris generated in the U.S. ends up in C&D landfills. Since much of this waste stream is inert, solid waste rules in most states do not require the landfills to provide the same level of environmental protection (liners, leachate collection, etc.) at C&D landfills as is required at landfills licensed to receive municipal solid waste (MSW). Therefore, C&D landfills generally have lower tipping fees, and handle the majority of the C&D debris. Shown below in Table 2 are the average regional tipping fees throughout the nation.

Table 2 National Regional Tipping Fees (shown in $/ton)

Region	1985	1986	1987	1988	1990	1992	1994	1996	% of recycling facilities
Northeast	12.66	17.11	52.41	61.11	64.76	65.83	66.92	68.02	14%
Mid-Atlantic	16.99	22.08	26.32	33.84	40.75	47.94	56.39	66.34	27%
South	3.24	5.76	13.13	16.46	16.92	22.48	29.83	39.59	12%
Mid-West	7.23	11.75	16.42	17.70	23.15	27.10	34.32	37.13	13%
West Central	5.36	6.21	7.23	8.50	11.06	12.62	14.40	16.43	3%
South Central	7.24	7.61	10.17	11.28	12.50	12.53	12.56	12.59	3%
West	10.96	11.10	13.92	19.45	25.63	27.92	30.41	33.13	28%
National Average	9.09	11.66	20.37	24.04	27.82	30.91	35.11	38.60	

The regions contain the following states:

Northeast - Connecticut, Maine, Mass., New Hampshire, New York, Rhode Island, Vermont
Mid-Atlantic - Delaware, Maryland, New Jersey, Penn., Virginia, West Virginia
South - Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tenn.
Mid-west - Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin
West Central - Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah Wyoming
South Central -Arizona, Arkansas, Louisiana, New Mexico, Oklahoma, Texas
West - California, Idaho, Nevada, Oregon, Washington

A few conclusions can be drawn when comparing regional tipping fees and the percentages of recycling facilities. There tends to be a movement toward looking at alternative ways to handle waste when tipping fees approach $50.00. We first looked at the region with the highest percentage of recycling facilities – the West – with 28%. When comparing this 28% to the average tipping fees in the region we see the tipping fees are in the $30.00 range. With this region containing the most recycling facilities, we would expect the tipping fees to be much higher. However, in many areas on the West Coast, the tipping fees are above the $50.00 range and in these regions we see a concentration of recycling facilities. The states inland from the West Coast have reduced the tipping fee average. The West Coast is also traditionally known for its natural environment and remains at the forefront of environmental preservation. In the next region – the mid-Atlantic region – there are 27% of the recycling facilities. In this region, we note the tipping fees are in the $60.00 range. This correlates exactly with the expectation. We look next at the Northeast, which also fits this prediction. Regions also following this trend are the Central region – which combined contain only 6% of the recycling facilities with tipping fees well under the $20.00 mark.

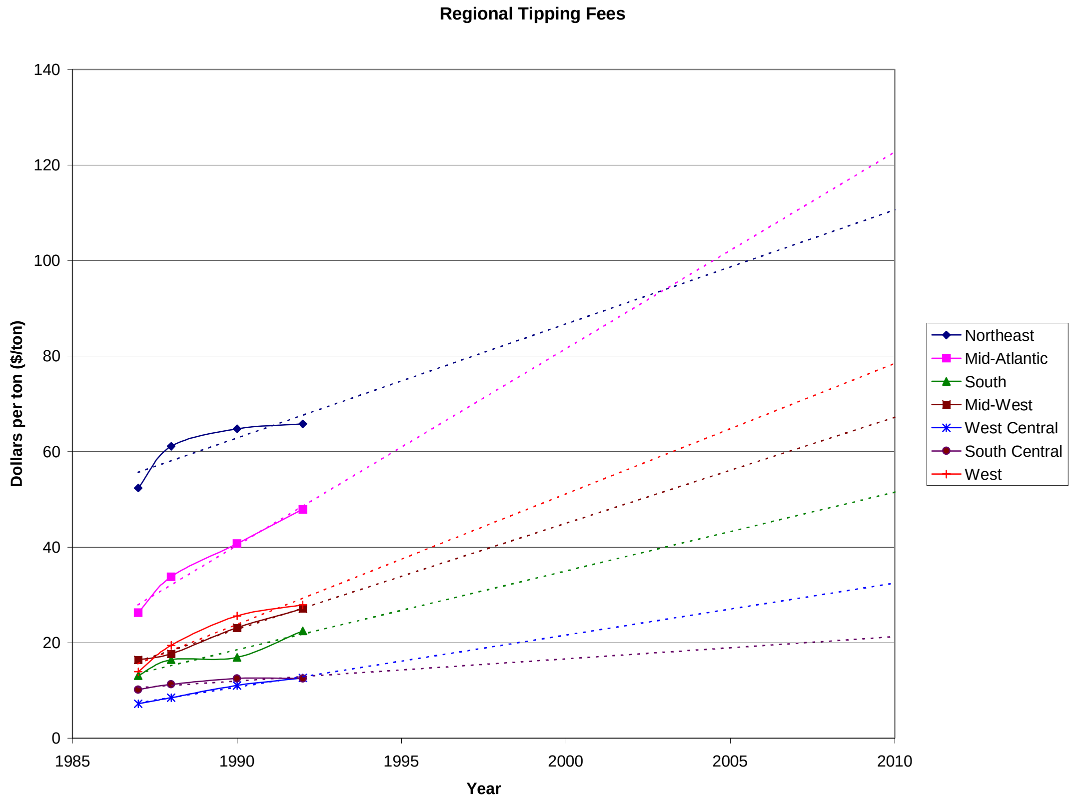

Figure 3 National Tipping Fee Trends

The tipping fee trends shown if Figure 3 provides a graphical representation of the tipping fees throughout the nation. All regions of the nation are experiencing increasing tipping fees.

The most obvious observation from this graph is that the tipping fees are indeed rising nationwide. One EPA report indicates that tipping fees are rising at a rate greater than that of inflation. The report indicates a 7% rate of increase in tipping fees as compared to the general inflation rate that hovers around the 2% range. The tipping fees are rising fastest in the most populated areas - the Northeast, East Coast, and the West Coast. As would be expected, these regions have begun looking for alternatives to traditional waste disposal. We note that the majority of the case studies have occurred in California, Connecticut, Maryland, and Oregon.

Some sample tipping fees from several regions are shown in Table 3.

Table 3 Sample tipping fees

City	Material Disposal Costs
Binghamton, New York	$60/ton
Los Angeles, California	$25-$50/ton
Spokane, Washington	$97/ton
Santa Fe, New Mexico	$60/ton
Austin, Texas	$6.10 /cubic yard

The next regions approaching the fifty-dollar mark are the Mid-West and the South followed by the West and South central states. Again, in the areas where the tipping fees have approached or exceeded the $50 mark, alternatives to traditional demolition have been identified and are being implemented. There is an underlying incentive for demolition contractors to identify other outlets for their waste. It is important to note here however, that although tipping fees are a significant driving factor, they are not the only influence factor on implementing change. Other influence factors are regional issues, historical value, land scarcity and labor are discussed later in this report.

The cost of landfilling debris is an important factor as is the location of landfills available for use. A 1994 survey done for the EPA identified about 1,900 active C&D landfills in the U.S. [13]. It would be expected that regions with many acres available for new landfills and large numbers of existing landfills could offer lower tipping fees. This is indeed the case in Florida. Florida had the largest number (280) of the 1,900 landfills reported in 1994. This number has dropped to 163 as of November 1998. The decreasing number of C&D landfills is not a Florida specific phenomenon, but a result of increasing national regulations. The dropping number of open landfills should not be taken lightly. The regulations will continue to increase, Florida's population will continue to rise, and land will continue to be in demand. All of these factors can assist in the implementation of deconstruction since deconstruction reduces the amount of waste sent to landfills, slowing the rate at which landfills will fill and prolonging their lives. This also means less land will be needed for future landfills.

Florida

In 1980, Florida had approximately 500 open dumps. During this time period, it was a common practice to either burn or use one of these open dumps in order to dispose of solid waste. Not one of these landfills contained any methods to prevent toxics from leaching into the groundwater. The state of Florida in addition to the Municipal Solid Waste Landfills has 163 active construction and demolition (C&D) debris disposal facilities. The table below shows their locations within the state. Of these facilities, 97 are permitted as active C&D disposal facilities and 71 are permitted as land clearing facilities. Five facilities are permitted as both C&D and land clearing facilities. Prior to 1996 Florida experienced a steady growth in the number of C&D facilities. Since 1996 there has been a significant drop in the total number of permitted C&D disposal facilities partially due to new C&D regulations.

The regional locations within the state of Florida are shown in Table 4. For simplicity the state was divided into divisions used by the Florida Department of Environmental Protection (FDEP). These numbers show that the majority of Florida’s landfills are located in the northwest section of the state. The northwest section is closely followed in numbers by the central region with respect to C&D debris facilities. However, if the land clearing (LC) debris facilities are included, the northwest region contains approximately 2 ½ times the landfills contained in any other region of the state. The concentration of the landfills in the northwest and central portions of the state are primarily due to the mining industry. In addition to the mining industry, these sections of the state have a less dense population than coastal and southern areas of Florida. The mining industry left many open pits which the industry calls abandoned quarries. These quarries lend themselves to becoming landfills.

Table 4 Florida landfill regional locations

DISTRICT	Number of C&D Disposal Facilities	Number of Land Clearing Debris Disposal Facilities	TOTAL Number of Facilities per DISTRICT
Northwest	30	56	86
Northeast	11	7	18
Central	27	7	34
Southwest	17	1	18
Southeast	10	0	10
South	2	0	2
TOTALS	97	71	168
Total Facilities	163	Five are both C&D and LC Facilities	

Although the average tipping fees throughout the state are fairly constant, some variation may be noted. Average tipping fees based in Florida regions are presented in Table 5. In general the highest tipping fees are in the southern portion of the state, which tends to be the most populated area. Tipping fees are somewhat lower in the north and central regions of the state where the cost of purchasing land for landfills tends to be less than that in the more metropolitan areas to the south.

Table 5 Florida regional average tipping fees (shown in $/ton)

Region	1997	1998	1999
South	$36.91	$36.91	$31.68
Southeast	$31.28	$31.14	$30.35
Southwest	$33.03	$31.51	$31.51
Central	$28.05	$26.62	$29.36
Northeast	$32.38	$31.36	$34.50
Northwest	$28.38	$33.06	$31.28
Average	$31.67	$31.76	$31.44

The highest tipping fee was found in Monroe County in the south region of the state with tipping fees of $92.00 per ton. The lowest tipping fee was found in Hendry County where the fees are $5.00 per ton [14]. Figure 4 identifies these counties and shows the regional average tipping fees.

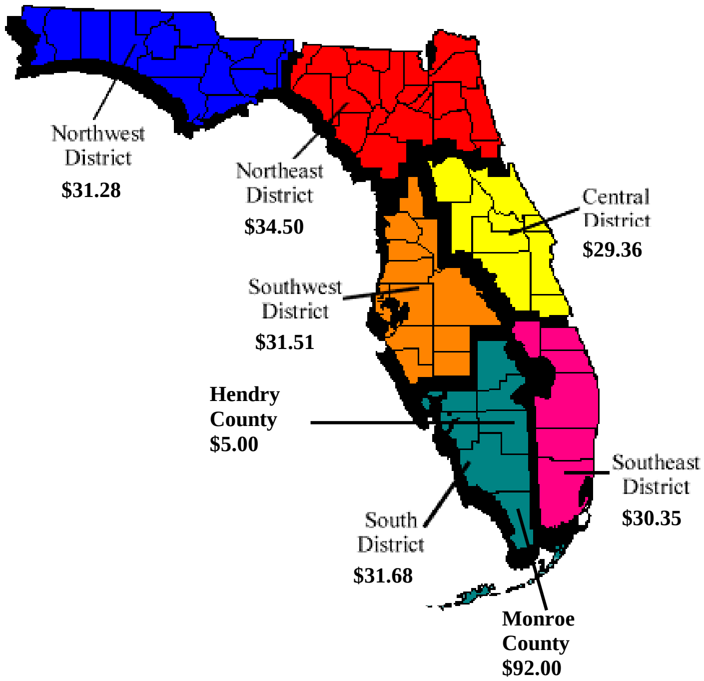

Figure 4 Florida map containing average tipping fees

Although there are regions in the state where the tipping fees are higher than the nation's average (approximately $44.50), for the most part the tipping fees throughout the state are low. As long as tipping fees remain low, there is little incentive for the construction industry to alter their traditional form of disposal – landfilling. In the counties with the highest tipping fees, we would expect to see alternatives, such as recycling facilities. When looking at the recycling facilities listed for the state [14] there appears to be no correlation between tipping fees and location of recycling centers. This could be a product of the recycling industry's volatility. As listed in the FDEP report there are a total of 51 recycling facilities in the state that accept construction and demolition debris. However, not all of these recycling facilities accept all types of C&D debris. Table 6 shown below lists the counties with tipping fees approaching or exceeding the $50.00 mark and the corresponding number of recycling facilities.

Table 6 Florida counties with high tipping fees and corresponding numbers of recycling facilities

County	Tipping Fee (per ton)	Number of Recycling Facilities
Monroe	$92.00	2
Putnam	$57.00	0
Dade	$45.00 - $59.00	3
Wakulla	$50.00	3
Pasco	$47.49	0
Clay	$47.00	0
Franklin	$45.00	0

Only eight of the states' 51 recycling facilities are located in the counties with the highest tipping fees. It would be expected that the recycling facilities would be focused in these areas. Instead, the state has a fairly consistent spread of recycling facilities throughout its regions.

Population and Waste Comparison

When comparing the national waste stream and the Florida waste stream, several differences are noted. There are differing methodologies between classifications for the U.S. Environmental Protection Agency (EPA) (national waste stream) and the FDEP (Florida waste stream). The EPA does not consider C&D debris part of the municipal solid waste whole FDEP does. As reported earlier, the EPA states that approximately 52% of the waste stream is C&D waste. The FDEP information indicates that the C&D portion of the waste stream is approximately 23%. In the FDEP 1998 Solid Waste Management in Florida report it states "Three types of waste dominate Florida's MSW stream: paper, yard waste, and construction and demolition debris". These three components comprise an estimated 62% of the State's MSW collected during 1996 on a weight basis. When compared to national waste consumption data, Florida's MSW exhibits a relatively higher percentage of C&D debris and a significantly lower relative percentage of total paper. Historic waste composition data indicates that the percentage of each type of waste component has remained fairly constant with the exceptions of C&D debris and yard waste, both of which have increased (FDEP Solid Waste Management Report). This statement seems to indicate the primary discrepancy between the C&D national and Florida numbers are a result of waste category classifications and methodologies. Although no direct conclusive relation can be drawn, we can look at Florida's population growth, total waste and C&D waste as shown in Table 7. The total waste in the table shows the MSW and C&D waste combined. The Solid Waste Management Report does not specify if industrial waste is included.

Table 7 Population and Waste, Florida

Year	Population	Total Waste MSW + C&D (in tons)	C&D Waste (tons)	C&D Waste as a percentage of the Total Waste
1995	14,149,327	23,007,330	5,201,795	22.6%
1996	14,411,563	23,745,911	5,489,514	23.1%
1997	14,712,922	23,776,302	5,492,557	23.1%
2017*	17,586,397	34,976,554	7,927,934	22.7%
Growth rate per year	1.9712%	1.6574%	2.7568%	

Note the above years are calendar years - this information was provided in the 1997, 1998 and 1999 FDEP Annual Report on Solid Waste Management in Florida.

*Predictions for Population calculated based on a 1.9 % rate of increase per year. Total Waste and C&D waste figures provided by the FDEP.

The current population of the state of Florida ranks the state as the 4th most populous state. Florida is projected to be the 3rd most populous state by the year 2025. The growth rate of the state of Florida is approaching 2% per year while the national growth hovers around 1%. To sustain Florida's population growth – new infrastructure – schools, homes, roadways and other common amenities are needed. The growth of the state itself is forcing the construction industry to provide additional built environment, which increases C&D waste. As seen in Table 7, the rate of increase or growth rate of the population and the C&D waste do not correspond. The rate of increase of the C&D waste is significantly higher than the population growth rate. However when looking at the total growth of waste, the rate of increase is slightly less than the population growth rate. These numbers indicate the great influence that the construction industry has on the waste stream produced in the State.

According to the FDEP, C&D waste was 22.6, 23.1, and 23.1 percent of the total waste stream in 1995, 1996, and 1997 respectively. The FDEP has predicted that in 2017 the C&D waste stream will remain approximately 22.67 percent of the total waste stream. However when looking at these figures and using the calculated growth rate from the figures provided by the FDEP, the total waste expected in 2017 would be 41,225,601 tons and the corresponding C&D waste for the year 2017 would be 10,405,567. This indicates that approximately 25.24% of the total waste would be a result of construction industry activities. It is necessary to target this significant portion of the waste stream for reduction since the majority of the waste stream is recoverable, reusable and recyclable.

Florida's rapid population growth is not uniform throughout the state. Popular coastal regions of the state are becoming more densely populated and land is being sold at a premium. As virgin property disappears, developers will look to demolition and renovation of outdated structures to support the influx of new residents. Implementing deconstruction prior to this need will provide deconstructors the time needed to master the task and beat the learning curve prior to a statewide shortage of landfill space.

Summary of Construction Industry Waste Impacts

Acceptance of structures as non-permanent fixtures in society is a key to changing the waste produced by the industry. The construction industry in this nation produces over 136 million tons of waste each year. Based on the nation's growth, the C&D waste quantities will continue to rise. Relatively speaking, the majority of waste produced is a result of the demolition and renovation sectors of the construction industries. While tipping fees remain low, financially there is little incentive for the construction industry to change the traditional practices of landfilling what the industry perceives to be waste. Unfortunately, with few financial incentives, a heavy burden is placed on government agencies to enact policy and implement regulations that will require the industry to change current wasteful practices.

9.3 DECONSTRUCTION BENEFITS

The benefits of deconstruction span many areas. Deconstruction offers advantage historically, socially, economically, and environmentally. Older buildings often contain craftsmanship, which has significant historical value to collectors. Deconstruction can carefully salvage these important historical architectural features because materials are preserved during removal. Deconstruction is more time consuming and requires more skill than simply demolishing a structure. Although the extra time required could act as a deterrent, the additional jobs that can be created benefit the community. Deconstruction provides a market for labor and sales of salvaged material [15]. More importantly, deconstruction puts back into circulation item, which may be directly used in other building applications, reducing the amount of waste sent to landfills. Currently there are few incentives to break the historical mold of landfilling debris. The occasionally higher cost of selected demolition or deconstruction can be offset by the increased income from salvaged materials, decreased disposal costs, and decreased costs from avoided time and expense needed to bring heavy equipment to a job site.

Deconstruction produces a flow of good quality, low-cost building materials into a community. Deconstruction also provides opportunities for the creation of value-added products made from salvaged building materials. The implementation of deconstruction results in new economic development since several businesses are needed to support a deconstruction infrastructure. Used building material associations provide outlets for salvaged reusable materials. Jobs are created due to deconstruction. Business growth is experienced by demolition contractors since those who regularly demolish usually practice some form of deconstruction such as cherry picking. In addition to used building material stores, value adding manufacturing, and the preservation of landfill space, deconstruction develops a long term, economically viable sector of the construction industry for waste reduction, resource conservation, and job creation.

One example of the benefits of deconstruction is the removal of sound materials from the waste stream, eliminating the need to harvest and mill new lumber and manufacture new household basics. Even when building codes prevent the use of old, ungraded wood directly in a new home, they can be used for concrete forms, walkways, and equipment sheds at the construction site. Deconstruction also provides low income and thrifty people with cheap building materials and potential tax incentives.

Social Benefits

The basic skills needed for deconstruction can be easily learned and transferred to the construction trades. Unskilled and low-skilled workers can receive on-the-job training in the use of basic tools and techniques for carpentry, construction, and materials recovery. Training individuals can also foster community oriented enterprises such as deconstruction service companies, used building materials stores, and small manufacturing centers while protecting the community's environmental health.

A review of deconstruction case studies show deconstruction requires significantly more labor than traditional demolition methods. As a result of the labor intensity, deconstruction provides a significant amount of employment opportunities. In 1997, The Center for Economic Conversion estimated that there are ten resource recovery jobs for every one landfill job. Deconstruction can supply useful materials to building materials yards, recycling centers, and re-manufacturing enterprises that create additional jobs and revenue within a community.

Case Study: Public Housing
Location: Hartford, Ct

Since 1993, the U.S. Department of Housing and Urban Development's (HUD) HOPE VI program has disbursed approximately $500 million per year to local housing authorities for demolition, construction, or rehabilitation of public housing, as well as for planning and technical assistance. In FY 1998, the Hope VI budget included $550 million, of which $26 million was allocated for demolition and for revitalization of public housing designed to meet the special need and physical requirements of the elderly. A secondary goal of HOPE VI is to move public housing residents from the welfare rolls to living-wage employment. In addition, HUD's Section 3 requirements promote job creation and business development for public housing residents.

Recognizing that deconstruction provides communities with a unique opportunity to combine removal of structures with job training/employment, the Hartford Housing Authority (HHA) is the first housing authority in the nation to require a deconstruction program as part of its HOPE VI program. In 1998 HUD agreed to allow recipients of HOPE VI grants to re-invest demolition funds for deconstruction projects. If deconstruction were employed in conjunction with demolition to remove public housing across the country, as well as other public and private sector structures, communities could reap substantial environmental, economic and social benefits for their residents.

Cities can look to deconstruction as a way to address their abandoned housing problems while creating job training. The city of Hartford, Connecticut has set aside funding from the state to deconstruct 350 abandoned buildings as part of a program to develop deconstruction service companies that train workers for skilled employment.

Economical Benefits

Economic benefits can result from the sale of salvaged materials. There are markets and demands for materials that can only be created from salvage operations. Regions of California have experienced favorable revenues and business growth from deconstruction operations.

Case Study: Reclaimed Lumber Sales / Business Revenue
Location: Berkeley, California

EcoTimber of Berkeley expects revenues from its reclaimed timber sales to climb from about $100,000 last year to $500,000 this year. In 1992, the company started importing hardwood from certified well-managed forests. Because that market was small they branched into selling salvaged timber in their product lines. This year reclaimed timber will account for about 15% of the company's anticipated $4 million revenues. EcoTimber is now re-milling and marketing more than 2 million board feet of timber including old-growth redwoods and Douglas fir.

Case Study: Material Revenue
Location: California

Reclaimed wood from deconstructed Military warehouses such as hand hewn barn beams sell for as much as $15 per linear foot. Old oak flooring goes for $6 a square foot, compared to $3.50 for new oak.

Traditional demolition contractors can expand their business to include deconstruction. By expanding their businesses, increased revenues may be realized. The sale of salvaged materials will increase salvaged material company revenue while providing low cost building materials to the public. Although mentioned before, but difficult to quantify, are the social benefits resulting from creating jobs and training opportunities for low-skilled workers. These community and personal benefits are invaluable.

Case Study: Create Business
Location: Minneapolis, Minnesota

The Green Institute of Minneapolis launched its DeConstruction Services in 1997 to improve the quality and quantity of inventory at the ReUse Center, its 26,000 square foot store that since 1995 has offered salvaged, reusable building materials. Now DeConstruction Services has four crews trained and insured to salvage reusable materials from buildings scheduled for demolition. About 60 percent of the salvaged materials are sold at the deconstruction work sites or from the program's warehouse. The ReUse Center and DeConstruciton Services expect more than $800,000 in sales this year.

Environmental Benefits

Since construction and demolition sites are one of the largest sources of waste headed for landfills, deconstruction will help communities reach their recycling and landfill diversion goals. The Riverdale project report notes that potential environmental benefits of deconstruction are not reflected in the cost comparisons. These benefits include decreased disturbance to the site, conserved landfill space, the energy saved by reused materials replacing new building materials, and decreased airborne lead, asbestos and nuisance dust at and around the job site. This means that when most companies or researchers look at deconstruction, items that do not have a price tag printed on them are ignored. Often benefits to the environment can far outweigh any costs to the industry or business. Although difficult to quantify, environmental considerations must play a major role in the full cost accounting of structures. Every day companies place price tags on the environment, for example the money paid out to Alaska by Exxon or fines collected by the EPA. These monies often are paid after the damage has occurred. With the amount of usable materials that can be recovered and diverted from landfills implementing deconstruction is one of the most environmentally sound alternatives available. This process closes the loop in the construction material cycle, keeping construction materials in circulation as long as possible.

Recovery Rates

The following recovery rates listed in Table 8 are from different case studies. These rates show how much of an affect deconstruction can have on the waste stream. The recovery rates range from 50 to 90 percent. Although at first glance these numbers seem high, this is the total amount of waste diverted from the landfill.

Table 8 Deconstruction project recovery rates

Location	**Case Study**	**Reuse/Recycling Rate**
San Francisco, CA	Presidio	87%
Fort McCoy, WI	U.S. Army barracks	85%
San Diego, CA	U.S. Navy Motor Pool building	84%
Marina, CA	Fort Ord	80-90%
Twin Cities, MN	Army ammunition plant	60-80%
Baltimore, MD	Four unit residential housing	76%
Port of Oakland, CA	Warehouse	70%
Minneapolis, MN	Residential building	50-75%

Landfill Preservation

One of the key environmental benefits of deconstruction is the preservation of landfill space. Deconstruction reduces the waste stream and extends the landfills’ potential service life. Materials are separated at the source during deconstruction, allowing materials that cannot be used immediately to be recycled.

Case Study: Landfill Preservation
Location: De Moines, Iowa

Facing dwindling capacity, Landfill of Des Moines has extended the life of its construction and demolition debris landfill by recycling an extensive list of materials. A grant from the Iowa Department of Natural Resources helped the company - now Central Construction and Demolition Recycling, Inc. - shift its business toward recycling. With five of its 23 acres dedicated to recycling, Central recycled 43% of the 87,038 tons of material it received last year.

Hazardous Materials

Deconstruction, by its nature, forces the proper removal and handling of hazardous materials before the remainder of the building's parts can be salvaged. Due to the hands on, non-mechanical nature of deconstruction human exposure to potentially hazardous materials is elevated. With traditional demolition, worker exposure is limited. Structures often are not thoroughly examined for potential hazards since most workers do not deal directly with the structures' components. Potentially hazardous materials often end up in the landfill simply because they were undetected prior to demolition. Due to the thorough examination and exploration of structures during the deconstruction process, hazardous materials are identified and disposed of properly.

Summary of Deconstruction Benefits

Deconstruction has social, economical and environmental benefits. Deconstruction can assist in the rebuilding of dilapidated neighborhoods, provide employment for relatively unskilled workers, provide low cost building materials, and greatly reduce the amount of waste send to landfills. As a result, landfill space is preserved, ultimately saving the local governments the cost associated with closing existing landfills. In reality there are many valuable building materials that can be and are salvaged from buildings slated for demolition. Deconstruction provides an environmentally friendly alternative to recapture the value of theses materials for reuse.

9.4 ESTABLISHING DECONSTRUCTION

General

Implementing deconstruction is not a simple task. Successful implementation cannot occur without a support structure of government, regulations, and businesses working together toward a joint goal. Deconstruction can result in environmentally sound community economic development through the formation of partnerships between non-profit social service and environmental organizations, government agencies, and the private sector. It is necessary to first educate and train those who are potential deconstructors. Individuals working in the field of demolition are primary targets. In addition to education and training, outlets for the salvaged materials must be created. Deconstruction can supply useful materials to building materials yards, recycling centers and remanufacturing enterprises, which in turn can create additional jobs and community revenues.

Successful Implementation

There are several areas in the U.S. where deconstruction has been implemented. As indicated throughout this document, there are case studies spanning from the east to the west coast. However, the majority of these deconstruction projects received grant money to perform studies for research. This factor makes an accurate determination regarding the success of actual implementation very difficult. Full scale successful implementations of deconstruction are concentrated on the west coast, from the San Francisco area north to the Pacific Northwest. Other cities scattered throughout the nation are achieving local success with deconstruction. By far the region proving to be most successful is the west coast. This region has turned deconstruction into a highly profitable alternative.

Influence Factors

Although the optimal solution for the environment is to salvage all materials, this is not the optimal economic solution for most starting deconstructors. The optimal economic solution results from many factors. Each of these factors change based on location, building types, and regional markets. The overall economic situation plays a key role in implementation. The economics of the region, economics of the people in the region, and the economics of businesses are all contributing factors. Following money, the influences most often heard by business are regulations, mandates, laws, and incentives. Without a legal or an economic push to reduce, reuse, and recycle, the effort is often ignored. The construction industry, comprised mostly of midsize construction firms, operates under a tight profit margin (usually around 5%). As in most industries, the construction and demolition companies are not willing to jeopardize this profit margin by implementing reuse programs or expanding their demolition practices to deconstruct if the company will not realize an immediate and significant profit. Most businesses feel it is simply not worth the financial risk to be environmentally friendly.

National Availability of Buildings - In looking at the demolition and deconstruction industry it is important to identify the feedstock for this industry. Nationally, regionally and locally building types vary drastically. The building stock also varies based on classification - i.e. industrial, residential, or commercial. Availability of buildings is not the issue so to speak, it is the availability of buildings worth being deconstructed. Currently it is necessary to be extremely choosy in the selection of a building for deconstruction. Contractors still rely on their old cherry picking rule of thumb to deconstruct only those buildings that appear to have historically high value materials.

Public Housing - Across the nation, an estimated 200,000 public housing unit will be demolished as a result of HOPE VI. For example, the city of Chicago plans to demolish 11,000 apartments, nearly 40 percent of its public housing stock for families, over the next 15 years.

U.S. Military Bases - Hundreds of military bases across the country are being closed or realigned and converted to civilian uses. Redeveloping these properties often requires buildings to be removed because they are obsolete or inconsistent with reuse plans. Many structures on military bases do not meet standard building codes and must therefore be removed or rehabilitated to protect public safety. Deconstruction, which has already begun on some military bases, can help the military reach a 40% solid waste reduction goal. The 40% goal was introduced by the Department of Defense in 1999. The military is encouraging deconstruction, salvage, and reuse.

Recent military base deconstruction efforts demonstrate real world improvement in economic efficiency. Contractor bids to demolish and landfill the Presidio and Port of Oakland buildings came in substantially lower than salvage bids. However, when the profit from sale of materials is added, the numbers favor salvaging. Estimated costs for demolishing, $150,000; estimated cost for deconstructing, $330,000; however, the income from lumber sales, $280,000 resulted in a net cost of only $50,000 if the buildings were deconstructed [25].

> Case Study: Presidio
> Location: San Francisco, California
>
> On the Presidio project the government required as many materials as possible form the project be salvaged, reused or recycled in order to minimize the impact of construction waste in landfills and to minimize the expenditure of energy and cost – benefit analysis for recycling. Buildings were offered intact for removal and reuse but there were no takers.
>
> Two buildings were ultimately deconstructed, one by a consortium and one by a general contractor. The deconstruction by the general contractor was not documented, however the deconstruction by the consortium took six weeks and provided time full time jobs. Over 90% of the wood in the building was recovered for reuse. Most of the costs were for labor. Workers were paid a total of $33,000. Equipment and administrative costs brought the total project cost to $55,000. Revenues from the sale of lumber were estimated at $43,000. The project also received a donation from the National Science Foundation (NSF) and a credit for avoided demolition costs that enabled it to turn a small profit.

The Building #733 project in Oakland showed the benefits of combining deconstructable building stock, at-risk youth and experienced personnel.

> Case Study: Building D-733
> Location: Oakland (across the San Francisco Bay)

The Youth Employment Partnership (YEP), a job training organization for high risk, low income youth worked with Beyond Waste Inc. to deconstruct Building D-733 at the U.S. Navy's format Fleet Industrial Supply Center. Four supervisors and fifteen youths (who were paid $6.50 to $9.00 per hour) diverted over 425 tons of material from the local landfill and salvaged 315,000 board feet of lumber. The project's overall recovery rate was 70 percent, not including the 110 tons of wood that was chipped for mulch and fuel.

Florida Building Stock - The majority of Florida structures are not built of old growth timbers and, if so, they are some of the few historic structures. Although Florida has few historic structures, there is a large quantity of smaller dimensional lumber that could be salvaged. In addition to the dimensional lumber, a common building material is the concrete masonry unit (cmu). These units could be salvaged and used as road base or aggregate to support the growing need for road expansion in the state. The bottom line with deconstruction is each structure must be examined individually to determine what materials that structure will produce.

The population trends for Florida help to determine what the influx of new residents may be and how the past influxes have affected the state. In looking at the Florida Building stock - the majority of the state's growth occurred in the 1950's. According to Pete Hendricks, a veteran deconstructor, buildings built before WWII provide excellent building stock for deconstruction. However we note that the growth spurt for the State of Florida occurred after WWII. There is a mix of construction styles and categories throughout the state. Wood frame and concrete structures dominate the state. Although it may not appear that the state is ideal for salvaging and resale of materials, these are not the only benefits resulting from deconstruction. The state should focus on the environment through lessening virgin land development, conservation of resources, and extending the service lives of landfills.

Tipping Fees - As discussed previously, there is a correlation between regional tipping fees and the efforts of industry to find alternative waste disposal methods. As tipping fees rise, the cost of doing business related to demolition, renovation, and new construction also rises. Inflation and markets also affect tipping fee prices.

While higher tipping fees create more incentives for earth friendly waste disposal alternatives, they are not the only driving factor. There are many areas throughout the nation that experience high tipping fees but show no signs of implementing deconstruction or mandating reuse or recycling. In these regions the tipping fees are simply considered the cost of doing business. As landfills close and tipping fees rise, the construction industry passes the increased expense of waste disposal to the owner of the construction project who in turn passes the extra expense along to society in the form of rent or the new purchase price. Society needs to decide where the money should be spent, either in preserving the environment now or footing a higher bill later.

Feasibility and Market

Determining the feasibility and market for deconstruction plays a key role in its success. A network of businesses must be created to allow for the smooth flow of goods. The product flow of deconstructed materials mimics the traditional flow of materials. Traditionally, materials follow resource extraction, to manufacturing, to marketing and distribution. Deconstructed materials must follow a similar pattern, however in this case, the definition of the stages of flow change. Traditional resource extraction, what we think of as mining, for example, is now changed to physically removing materials - deconstructing - to acquire the valuable resources. When thinking of manufacturing, we think of changing raw materials into desirable products. The new definition of manufacturing in this case is taking the salvaged items and performing repairs, rectification, or adaptation to what society needs. Marketing at this stage is similar to that for new products. A clientele must be established to facilitate the flow of these products back into circulation. Marketing requires not only a supply of these products, but also a need, if not demand, for these deconstructed materials.

Builders must make tradeoffs when it comes to reusing "older" materials. Use of salvaged materials can be both beneficial and detrimental. On the positive side, for example, salvagers may have the option of deconstructing an old factory floor made of solid old growth wood. This product is not only in demand, but valuable and difficult to find in today's market. At the other end of the spectrum, old plumbing fixtures, such as toilets, may be salvaged. When considering their reuse, it is important to consider the tradeoff of not selecting a newer low flush toilet. Examining at these choices - saving landfill space or saving water - forcing us to determine the primary concerns of society: How will society choose to allocate its limited resources? How many years of potable water remain? What technological advances may be made that may change society's conservation focus?

Florida Versus San Francisco - The current market climate in the greater San Francisco Bay Area is perfect for the expansion of existing reclaimed lumber markets and the creation of new ones. The economic downturn that stalled housing starts several years ago has lifted, creating a steady growth rate in the building industry. In addition, the metropolitan areas that make up this region have very promising mix of positive indicators. The Bay area ranks high above the national average in disposable income, average education level, average per capita income, and has a very high percentage of people in the age bracket between 20 and 60, the bracket when people build houses. In addition, the level of environmental awareness and demonstrated financial commitment to environmental change is high.

San Francisco has an extensive network of businesses established to support a successful deconstruction infrastructure. For example, the Wood Reuse Working Group was formed in 1996 to assist non-profit organizations and their for-profit partners in the development of value-added markets for wood reclaimed through deconstruction of wooden structures.

In general, Florida does not mimic the existing environment of San Francisco. Florida on average has a lower lever of disposable income, lower education level, and lower per capita income, general environmental awareness is lower, and the state has a significantly higher percentage of retirees. Although it is not accurate to compare the state as a whole to one specific region or city on the west coast, for the most part the regional atmosphere of Florida acts as a whole.

Some regions in the state show conditions very similar to that of San Francisco. For example, three South Florida coastal metro areas rank in the top 20 nationally in per capita income. The West Palm Beach - Boca Raton metropolitan area, ranks the highest in Florida and third in the nation behind San Francisco and the Connecticut metropolitan area. The Naples area ranks seventh nationally and the Sarasota-Bradenton area is 16th. With similar incomes, these regions also experiences high growth rates and have a higher density than non-coastal regions of the state. However, the disadvantage Florida exhibits is the lack of older buildings.

9.5 Environmental Policy and Incentives - National

There are very few policies in place on a national level that mandate environmentally friendly construction, buildings, designs, and materials. Without policy favouring sustainability, researchers look to the governments to offer incentives that will begin to sway the construction industry when designing and building for the future. Currently there are few incentives, and those that are offered are not nearly enough to persuade business to invest the extra money in designing for the environment. The U.S. EPA runs a program that started in 1992 called Design for the Environment. This program forms voluntary partnerships with industry, universities, research institutions, public interest groups, and other government agencies. The program attempts to change current business practices and to reach people and industries that have the power to make major design and engineering changes. Their ultimate goal is to incorporate environmental considerations into the traditional business decision-making process.

The U.S. Department of Energy, Office of Pollution Prevention, has begun a Pollution Prevention by Design project in an attempt to help engineers, designers, and planners incorporate pollution prevention strategies into the design of new products, processes, and facilities. The problem facing the industry is not the invention, or innovation, but the education and implementation of new techniques and concepts.

Existing Federal Laws and Executive Orders, which pertain to the construction industry, are primarily focused on energy conservation. The following is a listing of these regulations in place [18]:

- Energy Policy and Conservation Act (EPCA of 1975)
- Resource Conservation and Recovery Act (RCRA of 1976)
- National Energy Conservation Policy Act (NECPA of 1978)
- Comprehensive Omnibus Budget Reconciliation Act (COBRA of 1985)
- Federal Energy Management Improvement Act (FEMIA of 1988)
- Energy Policy Act (EPACT of 1992)
- Executive Memorandum ("Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds")
- 10CFR435
- 10CFR436
- Executive Orders: 12759, 12843, 12844, 12845, 12856, 12873, 12902

Over the past two decades, public concern and support for the environmental protection have risen significantly, spurring the development of an expansive array of new policies that substantially increased the government's responsibilities for the environment and natural resources [26]. The implementation of these policies, however, has been far more difficult and controversial. Government is an important player in the environmental arena, but it cannot pursue forceful initiatives unless the public supports such action. Ultimately, society's values will fuel the government's response to a rapidly changing world environment that will involve severe economic and social dislocations in the future. Environmental policy is difficult to predict, the U.S. is moving from a nation that exploited resources without concern for the future to one that must shift to sustainability if it is to maintain the quality of life for present and future generation. If green plans were proposed in the U.S., they would survive the political process [27]. Several states have already implemented their own progressive environmental policies that are stricter than Federal regulations.

Incentives - Two major changes in federal policy are also creating major opportunities for deconstruction: the demolition of public housing under the HOPE VI programs and the conversion of closed military bases across the U.S. If deconstruction were employed in conjunction with demolition to remove public housing across the country, as well as other public and private sector structures, communities could reap substantial environmental, economic, and social benefits for their residents, at little or no additional cost compared to traditional demolition.

Forty-four states and the District of Columbia have set solid waste diversion and/or recycling goals. Several states are beginning to insist on environmental preservation. Blatant disregard for the environment is no longer tolerated. One example is the California Resource Recovery Association, which is actively pursuing manufacturer responsibility legislation.

<u>The California Resource Recovery Association</u>

- If it can't be assimilated into the environment, then it can only be leased
- Anything not biodegradable/recyclable is tagged with its constituents and manufacturer
- Mandated deposit laws for certain materials
- Mandatory separation of wastes
- Mandatory procurement of recycling products for public projects
- Product disposal borne at manufacturer level, "advanced disposal fees" for manufacturer wastes
- Advanced fees means that disposal is calculated upfront as part of the costs of producing the product and is internalized by company.
- This is like pollution permits, whereby quotas could be traded between those with product stewardship and those without, this would be called a "processing fee"
- Eco-labeling and materials labeling is consistent.
- Product made with minimum recycled content requirements.

Federal Government Support

Several federal government agencies demonstrated support for deconstruction by providing financial and technical assistance to pilot projects across the country. The U.S. EPA supported the Riverdale Housing Project. The EPA provided grant funding to the National Association of Home Builders Research Center, the Green Institute, and the Materials for the Future Foundation. In addition to the financial support, the EPA has also provided technical assistance on deconstruction projects. The Department of Health and Human Services' (HHS), Office of Community Services, The Department of Defense, Office of Economic Adjustment, and the U.S. Department of Agriculture's Forest Products Lab (FPL) have all contributed to the deconstruction research effort. The FPL has been evaluating the grades and strength characteristics of used lumber and timber. They are working cooperatively with lumber grading agencies to develop grading criteria and grade stamps for used lumber.

Case Study: Implementation
Location: Hartford, Connecticut

The City of Hartford, Connecticut, has set aside funding from a state demolition grant to deconstruct 350 abandoned buildings as part of a program to develop deconstruction service companies that train workers for skilled employment.

Barriers to Implementation
The use of salvaged materials can only be successfully implemented if there are not lower cost new materials that will serve the same purpose. Currently the sale of antique or historical materials is successful. However, the sale of salvaged windows, for example, which may not have the same energy efficiency of new windows may carry other detrimental environmental affects. The bottom line is that the salvaged materials either need to be less expensive than the new materials or have some characteristic that makes them unique to and interesting to the buyer.

As stated previously, it is necessary to have knowledge, incentives, and coordination. The main problem is the transfer of knowledge. To facilitate this transfer of knowledge, researchers must move slowly to determine the feasibility of existing alternatives. Many environmental strategies are not possible, either as a result of existing regulatory barriers, economic constraints, or lack of public acceptance. Currently, the largest barriers to non-traditional construction and demolition techniques are cost and attitude. The primary concern of business is to make a profit. At the present time, in most regions, it is not cost effective to alter traditional, tried and true techniques. Another challenge is changing the industry's attitude, or more to the point, grabbing the attention of industry long enough to provide them with the appropriate tools to make an educated decision about their building options.

Project time requirements
Project time constraints can limit options with respect to deconstruction. Often by the time the demolition contractor is contacted, the project owner is under a time constraint requiring construction to begin in a matter of days. This time constraint will not allow for the deconstruction process to occur. The deconstruction process requires significantly more time than traditional demolition. Possible alternatives such as mandatory waiting periods for demolition in addition to public announcement/ advertisements and or direct contact with demolition/ deconstruction contractors to increase their awareness of the opportunity could be an invaluable incentive to increase deconstruction.
Salvage Material and Market Variation
Due to the wide variety of buildings available for deconstruction there is a variety of materials produced from this disassembly. The uncertain quality and quantity of this used building materials feedstock means that users cannot rely on a constant and consistent supply. For those willing to use these materials, this inconsistency is a great disincentive.

Market Demand

The market demand for old growth high quality large timbers will always exist, however there is very little existing demand for denailed standard dimensional lumber. The cost of new materials is simply too low to drive the consumer to venture to other markets for building materials - markets such as salvaged materials. It is possible that the new material supply could be subject to a future disposal cost fee as in Europe where manufacturers of products are charged the disposal cost of their packaging materials. In the German automotive industry, the manufacturer is required to "take-back" and properly dispose of the vehicle after use. The major problem with assigning responsibility for product disposal is the change in ownership of building and the rate at which construction companies go out of business.

Land Value
Land value often dictates redevelopment or new development. These efforts should be concentrated in areas where land is scarce and costly, where people are more likely to redevelop than simply develop. Emphasis can also be placed on areas where land is relatively inexpensive. Developing new land results in an infrastructure burden and the unnecessary development of pristine undisturbed land.

Mechanical Properties of Reclaimed Materials
Although public interest in utilizing recycled wood resources is increasing, several technical constraints hinder widespread acceptance. These technical obstacles hinder general acceptance in the marketplace and more specifically, acceptance by building officials at the jobsite. Existing grading rules can be used to grade recycled lumber using the general requirements for sizing, grading, and marking of softwood lumber established in the American Softwood Lumber Standard. Neither rules nor standards specifically address the use of recycled lumber or the characteristics that distinguish it from new lumber.

Summary – Establishing Deconstruction

Several key factors influence the successful establishment of deconstruction. In general, European countries, governments, and individuals have some level of environmental literacy. These countries also lack the land needed to simply landfill mass quantities of waste. The lack of space for waste results in high disposal costs and therefore alternatives to traditional disposal are readily accepted. These alternatives tend to be progressive and inventive simply out of financial need and environmental awareness. Unfortunately, these conditions are not present in the U.S. Many factors, in addition to those previously stated, influence the establishment of a successful deconstruction market sector. Factors such as population, tipping fees, existing supporting infrastructure, and building feedstock for deconstruction process all influence the potential for deconstruction.

9.6 DESIGNING FOR DECONSTRUCTION

With existing buildings containing so many useful materials it is important that these materials be accessible for reuse after the building has exceeded its service life. When considering buildings as a future source of raw materials designing for disassembly is a key element in material retrievability. Additional issues are material durability, desirability and longevity. Materials must be durable if they are to be used over several service lives.

By definition deconstruction is an age-old concept of reusing existing structure components to create new facilities. However, designing for deconstruction from a practical standpoint is a difficult concept to grasp. Designers conceptualize their buildings as being timeless and no designer intends on spending intensive labor creating a building only to be torn down. The designer's perception is that the building will stand forever. Similarly, no contractor believes that their structures will be torn down. Designing and building structures to be taken apart run counter to these professionals' principals. Marketability is always a concern in construction. Many products today are not produced with recycling in mind, just the selling cost. Manufacturers today focus on generating the least expensive product for the short term. A return to traditional materials and methods means incorporating products and building techniques, which have stood the test of time and are still preferred by home buyers. For example, a vinyl window specified at the time of deconstruction may not be worth reusing or recycling.

Design for Disassembly has been used most frequently in Europe in response to Extended Producer Responsibility (EPR) laws that require companies to take back and recycle their products. The automotive industry pioneered techniques for disassembly that the construction industry can employ. There are currently no EPR laws in the U.S., but private industry may be forced to change its practices as landfills overflow and tipping fees rise.

Case study – Dibros Corporation
For an example of potential design changes that could facilitate disassembly a Florida builder was interviewed regarding designing for deconstruction. Dibros principals Miguel Diaz and his son Luis A. Diaz are among many builders in the Gainesville, Florida location. Dibros, in order to make their development more attractive to potential homebuilders, has committed to developing a "neighborhood" using the concepts of New Urbanism. New Urbanism also stresses "traffic calming" through street design and takes the focus away from the automobile and puts the focus on the people. This concept also mixes retail and light commercial businesses with housing.

Dibros began planning their community as most builders do, by surveying the land and then planning roads and lots accordingly. However, Luis Diaz decided that instead of having the design dictate the layout, he would let the land dictate the design. Dibros created a Computer Aided Drafting (CAD) plan of the land and marked trees, which ultimately determined the layout of roads, lots and common parks. From the start, this community was developed in a non-traditional manner. Additionally Dibros is interested in new, innovative, environmentally friendly construction materials as well innovative construction techniques.

Components of a Dibros Home
For the purposes of deconstruction, it is important to look at the typical components of a home built by Dibros. Listed in Table 10 are the highest cost items in a typical Dibros home.

Table 10 Highest cost items in a typical Dibros home.

Description	Total Cost ($)	Description	Total Cost ($)
Roof and Floor Truss System	7826	Building Panels	2064
Lumber	6939	Welded Steel Railing / handrail	1920
Wall Covering	5733	Appliances	1901
Stem Wall Concrete	2888	Roofing	1562
Siding	2846	Paint	1357
Drywall	2428	Interior Doors	1226
Framing Hardware	2262	Plaster Stucco	1196

After reviewing this list for items, which warranted further research we eliminated items such as paint and stucco which from a deconstruction standpoint have little value. Further investigation of these components shows the highest cost item, the Roof and Floor Truss System, to be the most expensive item. The trusses are constructed of engineered wood in Melbourne, Florida. The builder agrees that purchasing from a local producer would be less costly. However, Space Coast Truss provides them with excellent quality control. Lumber is the next highest cost category. These components will be further investigated to determine the feasibility of reuse or recommendations for an alternative material.

Foundation Systems and Flooring

The foundation system is a concrete slab and for the house that was examined the finished floor was Hartco wood flooring. Hartco Flooring is a 3/8" glue down laminated wood flooring with true wood layers. It should be noted that flooring and floor covering are subject to physical abuse from feet and heavy objects, and, as the lowest spot in a room, they tend to collect dirt, moisture, and other contaminants. A good flooring material should be highly durable to reduce the frequency with which it must be replaced, and it should be easy to clean. At the same time, softer surfaces may be preferred for reasons of comfort, noise absorption, and style, setting up a potential conflict for the designer. There are also raw material and manufacturing impacts to be considered with many types of carpeting and other floor coverings.

Concrete Slab

The acceptance of concrete slabs comes from a purely marketability standpoint. It takes less time and cost to install. After the service life of the home, the concrete slabs may be reprocessed. The broken concrete can be sent to a ready mix concrete plant that can incorporate crushed concrete (used as aggregate) back into the concrete manufacturing process. The crushed concrete is most often not immediately reused except when it is crushed on site and used as a temporary road base.

Alternative flooring methods are addressed below as to their deconstructibility.

- Carpet systems, including carpet pads and carpet adhesive, have been identified by the EPA as a potential source of indoor air pollution. Although carpet recycling is technologically difficult due to the contaminants and multiple components of used carpet, some companies now have extensive recycling programs. Carpet padding has long been made of recycled materials and is extremely recyclable. One problem with carpet is that it will hold dirt and pesticides, creating a unhealthy environment. The life expectancy of carpet on slab is reduced due to the harsh backing concrete offers.
- Thin wood flooring composites are glued down. Any attempt to remove it will lessen the quality of the material, making it less desirable for reuse. It is essential to ensure the adhesive is not toxic or in any way harmful to the environment for disposal purposes. These products do not take excessive abuse and will not permit numerous resurfacings.
- Ceramic and porcelain tiles have high embodied energy but their durability makes them environmentally sound in the long run. Some high quality ceramic tile incorporates recycled glass from automobile windshields. As a floor covering, tile is durable and recyclable.
- Linoleum cannot be reused and does not contain any recycled content.

Concrete is less forgiving to both the human body and the materials that cover the slab. Concrete slabs can have other problems: cracking from settling and major demolition is required to repair utilities under the slab.

Crawl Space

In comparison to the concrete slab on grade, a crawl space provides many deconstruction options. The construction time and cost are higher but it may provide less maintenance concerns compared to a concrete slab. The alternatives for coverings are the same as for a concrete slab except the following:

- Wood flooring over a crowd space is a return to traditional tongue and groove wood that has always stood the test of time. It does not require excessive resurfacing, provides a cleaner surface, and is more forgiving to the human body and other materials. The quality of floor temperature is also easier to control.
- Area rugs can be incorporated which protect the wood and provide a more favorable environment. Wall-to-wall carpeting can be used with an extended life expectancy.

Crawl spaces provide easier and cleaner coordination of utilities, not to mention easier access for maintenance. The space can also be incorporated into a passive cooling system throughout the facility reducing consumed energy.

Framing

Dibros currently uses southern yellow pine framing. Using wood versus steel framing in structures depends on personal preference can benefit either side. From a deconstruction standpoint wood and steel both have advantages and disadvantages.

Wood

Wood is a renewable resource if it is purchased from a sustainably managed forest. This is more difficult than it may initially appear. The process of following the lumber from forest to mill to manufacturer is not easy and is costly. It should be noted that it takes approximately 40 to 50 trees to construct a 2000 square foot house [7]. From a deconstruction standpoint there is a potential to immediately reuse some of the wood salvaged from the site. The wood that cannot be immediately reused may be recycled.

Steel

Although steel is manufactured using a finite resource, it is the most recycled material in North America. Steel framing members contain at least 28% recycled content and generate as little as one cubic yard of recyclable scrap [20]. Steel framing requires approximately 30% more labor to construct than a typical wood framed homes. To immediately reuse steel framing members, they must be deconstructed with great care to avoid warping, twisting, or bending during disassembly. Even though the steel may not be available for immediate reuse, all of the steel can be recycled.

Wall Finishes

Dibros currently uses gypsum drywall in 4’*12’*½” sheets with a texture finish veneer plaster. A disadvantage of drywall is the large amount of waste generated during construction. Drywall generates about 15% of all construction waste and represents the highest percentage by weight of waste in residential construction. For a typical 2000 square feet home, 2000 pounds or five cubic yards of waste is generated. This equates to one pound of waste per square foot of building. Recycled gypsum drywall is available and is becoming more prevalent in the U.S. Specific types of drywall for fire rating and moisture resistance contain products, which can prevent recycling. In addition to the large quantities of waste created in the construction process, drywall has little to no value with respect to material recovery. The drywall acts more as a barrier to the materials that deconstructors are trying to retrieve.

Roofing
Dibros currently uses asphalt roofing shingles. Roofing provides one of the most fundamental functions of the building, shelter. Roofs must endure drastic temperature swings and experience long term exposure to ultraviolet light, high winds, and extreme precipitation. Durability is critical in roofing because a failure can mean serious damage not just to the roofing itself, but to the entire roofing system, building, and its contents. This type of damage multiplies the economic and environmental cost of less reliable roofing materials. Roofing can also have a significant impact on cooling loads. The use of lighter colored, low-solar absorbency roofing surfaces is one of the key measures in life cycle energy costing associated with a home. All roofing options do not allow for immediate reuse and comparisons of the various options are listed below.

Asphalt
Asphalt roofing is the most affordable initial cost option for roofing. Its service life can range from 10 to 30 years depending upon the grade of tile purchased. As far as deconstruction is concerned, the tile may not be immediately reused nor is it readily recycled. Manufacturers publicize the recycling of asphalt roofing in road mix designs, however, the Florida Department of Transportation does not use asphalt roofing in their paving operations. Research is being conducted to incorporate asphalt roofing into mix designs. However the roofing the FDOT is using is waste from the manufacturing process, not waste from the roofs of homes. FDOT reports there is simply too much contamination and inconsistency in the “take-offs” to use this waste when trying to create a predictable mix design.

Metal
Options for metal roofing include galvanized steel, aluminum, and copper. Metal roofing is an alternative to the common problems experienced with traditional roofing shingles. Metal roofing does cost more initially than a typical shingle or tile roof, but it is actually cheaper because of its longer service life, approximately 3 times that of a shingle roof. In addition to the longer service life, metal roofs have fewer maintenance requirements, provide a better appearance, and a greater value for homes [21]. Because of their low maintenance and long life, steel roofing systems can ultimately be one of the lowest cost roofing materials [22]. The benefit related to deconstructibility of metal roofs is the well-established metal scrap market. Even in regions of the U.S. where there is no deconstruction infrastructure there will often be scrap metal dealers. Aluminum is also one of the most valuable materials to recycle.

Wood
Wood shingles may not be immediately reused, but may be readily recycled. The expected life of a wood shingle roof, however, is only 15 to 20 years. Building codes require that wood shingles carry a specific fire rating which affects their make up and recyclability.

Polymer Materials
There are a variety of new products on the market made from recycled polymers. One product is made from asphalt and recycled baby diapers, which has the appearance of slate and includes a 50 year warranty. With this composite type material, reuse or re-recycling will be very difficult.
Tile / Concrete

Clay and concrete tiles are also an option where hail is not a serious threat. Both of these roofing options offer excellent service lives. Local availability of these products is an issue due to their relatively high weight, which could result in higher transportation costs. Tile and concrete roof tiles can be deconstructed and the material can be crushed and used in new concrete as aggregate or as roadbase.

Slate
Slate is one of the most durable roofing options with an expected lifespan of over 100 years. This roofing material is also very expensive yet desirable. Slate is reusable if it is not cracked. Pre-manufactured nail holes reduce the amount of waste created.

Siding
Dibros currently uses a combination of Hardiplank and concrete stone, depending upon the customer's specifications.

Vinyl
Vinyl siding has a 20 year warranty because of its innate durability and flexibility. It is installed with nails or other fasteners that increase the labor associated with deconstruction. Vinyl offers low maintenance and it does not need to be painted or stained. However its recyclability is questionable since heating of vinyl produces hydrochloric acid (HCl). Recycling of vinyl results in downcycling, meaning that existing vinyl siding will not be recycled into vinyl siding again, but a product lower on the product cycle chain.

Wood
Wood is a traditional material, just like brick, but unlike brick, it will require more maintenance and has a shorter life. Life expectancy is shorter because of the possibility of termites and weathering. In addition, wood requires continuous upkeep, maintenance, and painting. If wood is properly maintained it may be removed and reused. Removal could be facilitated through the use of screws versus nails.

Hardiplank™
Hardiplank™ is an extremely durable composite made of portland cement, ground sand, and cellulose wood fiber. This product offers a 50-year warranty and is resistant to humidity, rain, and termites. Hardiplank™ is potentially 100% recyclable. However, there is no current recycling process in place.

Brick
Brick offers the best immediate re-use potential. Locally produced brick and stone are long lasting, low maintenance finishes that reduce transportation costs and environmental impacts. Molded cementitious stone replaces the environmental impact of quarrying and transport of natural stone with the impacts of producing cement.

Design for Deconstruction – Some Recommendations
There are four elements in designing for deconstruction:

1. Reuse existing buildings and materials – It is possible for new buildings to be designed to facilitate the reuse of existing materials from existing structures

2. Design for durability and adaptability – Longevity is determined by the durability of materials, quality of construction, and by the buildings adaptability to changing needs. Durability needs to be properly balanced with adaptability. Different material life spans must be factored into the design.
3. Design for disassembly
4. Use less material to realize the design

9.7 CONCLUSIONS

Buildings must be thought of as integrated systems. Environmentally responsible building design covers a broad range of considerations, some of which are difficult to quantify. It is necessary to judge overall building performance and cost-effectiveness while linking them to environmental issues. However, environmental information is not equally accessible to all parties: the owners, designers, builders, and users.

Increasing awareness of the importance of natural resource depletion and environmental degradation influence long-term economic growth. The main problem we face as a society is an attitude against change. It is ultimately the general public who will demand and drive change in the construction industry. By informing the public and owners in general, they will ultimately drive the market, which will force industry to change. The public also has the power to drive policy toward further environmental preservation.

Past environmental problems have been highly visible and politically charged. Protection of the environment has been a result of remediation, that is, dealing with the problem after the damage has benn done. Environmental degradation is not the problem but a symptom of an attitudinal and value system premised on consumerism and excess. The environmental crisis is a human problem and the solution depends on major changes in human values and actions. Environmental degradation is derived from a combination of conscious choices made within a societal context, which has different priorities and ignores the environmental effects of design decisions. Even with the current cost and regulatory constraints, architects and builders can design more environmentally responsively and responsibly. However, it is still necessary to consider different design priorities. The attitudes, commitment, and priorities of the design team will ultimately dictate the rate of progress in environmentally responsible building design and construction.

Currently the largest barriers to non-traditional construction and demolition techniques are cost and attitude. The primary concern of business is to make a profit. At the present time, it is not cost effective to alter traditional, tried and true techniques. Another challenge is changing the industry's attitude, or more to the point, grabbing the attention of industry long enough to provide them with the appropriate tools to make an educated decision about their building options.

The implementation of deconstruction requires not only a change in traditional material flows, but also a change in mindset. Instead of considering used building materials as a waste product, they should be considered as raw materials. Instead of these valuable and usable materials being landfilled reusing these the materials can result in the creation of businesses to sell, supply or manufacturer new products.

As products are more widely used, the price is reduced. However, as time advances on new technologies create improved products that carry with them a high price tag. In order for deconstruction to work, structures must be built out of materials that last and are worth recycling. Currently, many high quality products can make the building too costly in today's economy.

“Durability is the hallmark of sustainability” – it is important to focus on lifecycle costing and quality.

There is an obvious environmental hierarchy when it comes to deconstructing structures. First, we want to immediately reuse any building components possible. This has the highest priority from an environmental point of view because all resources (material and energy) invested in the product during manufacturing are preserved. This often provides economic advantages as well. The negative aspect of deconstruction for reuse is that it requires non-destructive disassembly and additional inspection operations that may increase cost [24]. Material recycling is the next best action. It is important to rethink the practices that have generated waste and to develop new means of diverting construction materials from the traditional waste stream.

With no constraints, construction industry will simply continue to operate in a business as usual mode. They will offset their increased disposal costs by charging more for their services. Labor costs in States such as Florida are low and this is one of the primary incentives to deconstruct. With low wages, contractors may find it is easier to allocate funds to crews of workers to perform the deconstruction. Although this is a driving factor where tipping fees remain low, which is an incentive to landfill debris versus salvaging items. Without a significant rise in tipping fees, it is simply too easy for contractors to continue landfilling potentially reusable materials. For deconstruction to work, disposal costs must be significantly increased.

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9.9 APPENDIX A

LUMBER RECYCLED FROM RESIDENTIAL BUILDINGS - A CASE STUDY

INTRODUCTION

Wood, the raw material from which lumber and timber is produced has for many centuries remained the principal building material for the construction industry. Wood is a natural material and the only renewable construction material in use today. Lumber production in the United States increased by 34 percent from 81.7 million cubic meters in1970 to 109.5 million cubic meters in 1994. The first European settlers in the U.S. found half of the land covered by forests. Unchecked harvesting and fire ravaged the forest for many years until the first decades of the twentieth century when replanting of trees was undertaken on a massive scale to avoid depletion of the forests. Today the forest area has been reduced to 32 percent with the volume of wood 25 percent more than what it was in 1952. Harvesting of wood has increased by 40 percent since 1952 [1].

One source of readily useable lumber and timber for building construction, which remains untapped, is the 7.3 billion cubic meters (3 trillion board feet) of lumber and timber sawn in the United States since the turn of the twentieth century and still residing in structures [2]. When these buildings are decommissioned, the lumber and timber can be salvaged and put to reusable form utilizing little energy. This will conserve the forest resources and reduce the waste deposited in landfills.

Most of the lumber and timbers salvaged from old buildings are tight grained, dense and in most situations free of knots. They are dry and dimensionally stable and devoid of the many distortions, which characterize new lumber due to moisture changes when used in construction. Large timbers salvaged from old buildings have found some limited use in new construction as structural components, however, without knowledge of their mechanical properties, they have been used over conservatively with an assumption of a lower strength due to its age and previous use. Lumber which is 50 mm (2 inches) thick and salvaged from old buildings as studs, rafters, joists, have had very limited reuse value as structural components for new construction. A major factor accounting for this is the lack of engineering knowledge about their engineering properties and grading rules for the old lumber taking into consideration the defects and distinct physical characteristics.

To the natural defects found in virgin lumber such as knots, checks, shakes are added a new class of damage from the construction, usage and during the deconstruction process. Damage to the lumber during the construction stage includes nail holes, boltholes, saw cuts and notches. Lumber in use is subject to drying defects as warping, decay and termite attack. Deconstruction damage includes edge splitting, edge damage and gouges. The lack of tests on salvaged lumber to determine the effect of age and damage on the strength has not been determined and this greatly limits its use as a structural component. While some salvaged lumbers have grade stamps on them, these have been invalidated by the change in condition and damage done to the lumber.

CASE STUDY

The following is a summary of the steps and processes used to deconstruct a home in Gainesville Florida. Reference [3] provides a detailed description of this deconstruction project. Two areas of the home were contaminated by asbestos: the siding and the interior tile. The owner abated these areas prior to the following occurrences.

Site Map

Figure 1 shows the site set up for deconstruction. When materials are removed from the structure the determination must be made on what to do with the specific material. Based on the material type and condition, they may be immediately reused, processed further or disposed of. For this reason it is important to have the storage space, processing space, and dumpsters close to the structure. Having the processing station between these two stations allows for an easy flow of materials. If processing destroys the material or if it is determined that it is not cost effective to further salvage the material it can be easily put into the dumpster.

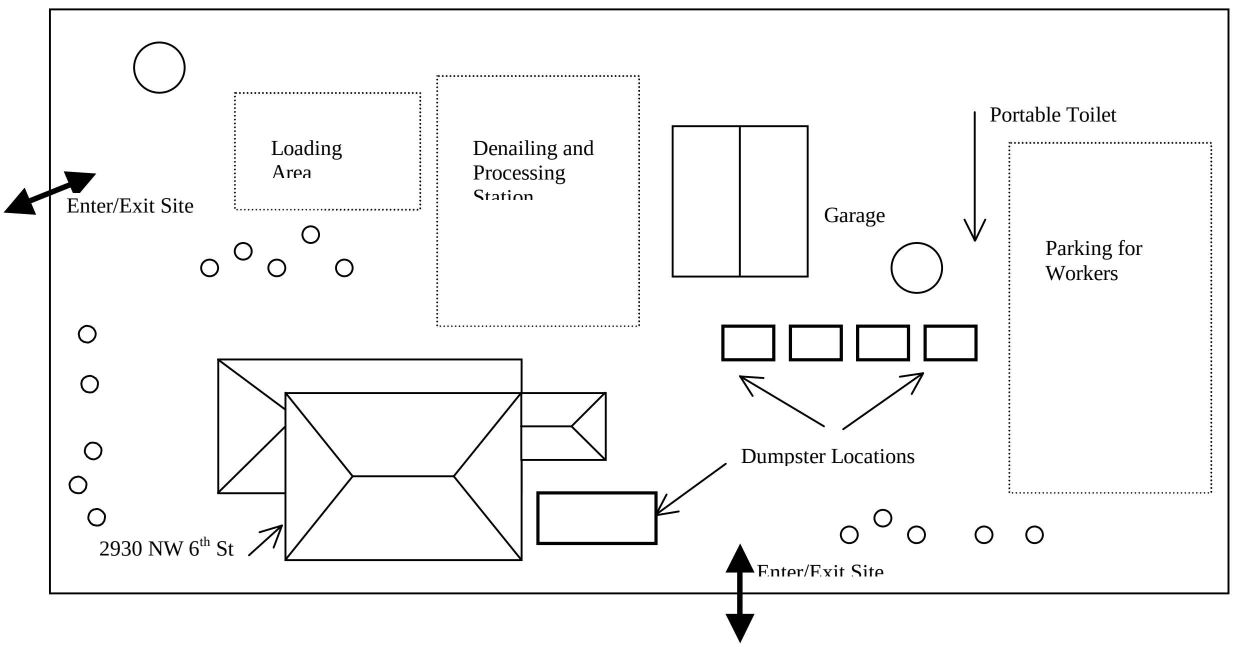

Figure 1 Diagram of deconstruction field organization

Scheduling

Deconstruction in almost all cases requires significantly more time than demolition. For a property owner with plans to redevelop after building removal, time constraints is an important consideration.

Day 1: Site Cleanup and House Cleaning

The location was scattered with debris since the house was abandoned. The yard was cleaned allowing adequate space for the dumpsters and the denailing/processing station to be established. In addition, No Trespassing signs and job-site signs were posted.

Day 2: Abatement of Asbestos Tile
A certified abatement contractor abated asbestos tiles.

Day 3: Doors, Windows, Trim, Exterior Awnings
Removed all doors and windows with frame and associated trim. Doors and windows will be sold as a complete package

Deconstruction begun in the reverse order of construction, the first few days of activities included removing interior materials such as baseboards and trim.

Day 4: Oak floor
The oak floor was laid on top of original pine floor. Baseboards were removed before plaster and lathe. Experiments in demolition of plaster and lathe indicated that it is better to loosen the plaster and scrape it from the lathe. The plaster and lathe were separated for disposal.

Day 5: Plaster, Floor Felt, Lathe
Wall plaster was removed with lathe left in place as best as possible. Lathe is easiest to push out from behind rather than rip out and away from the stud nailing surface. Floor felt under oak floor was peeled up as it was adhered with a water based glue.

Day 6: Sheet Metal Roofing
Sheet metal roofing was difficult to remove due to the 10:12 pitch of the original structure. Roofing material was removal is shown in Figure 2.

Figure 2 Removal of roofing material

Day 7: 1 x 8 roof deck, double layer of asphalt shingles

1 x 8 roof deck on the 10:12 original roof was punched out from behind by crews of 3 to 4 standing on plywood decking. The plywood was positioned to make a continuous work surface on top of the ceiling joists. A secondary roof of two layers of asphalt shingles was left on the 1 x 8's as they easily shattered when punched out. The shingles proved easier to remove at the processing station than up on the rafters. Roofing material and sheathing were removed to expose the roofing structure shown in Figure 3.

Day 8: 2 x 4 rafters, 1 x 8 roof deck

2 x 4 roof rafters were removed from 10:12 roof. Rest of 1 x 8 roof deck was removed. After removal of the roof structure, the stud walls can be dropped to the ground level for disassembly (see Figure 4).

Figure 3   Exposed roofing structure

Figure 4 Stud wall skeleton after removal of roof

Day 9: 1 x 4 roof deck, top of chimney
Small amounts of 1 x 4 roof deck was removed from 10:12 original roof. Top of the chimney was deconstructed. All accumulated processed wood was transferred to storage.

Day 10: Ceiling plaster and lathe, 2 x 4 rafters
Ceiling plaster was removed by standing on plywood deck on top of the ceiling joists and pushing down between joists with a sledge hammer.

Day 11: Remove Kitchen addition to the floor deck
Take kitchen addition was knocked down. Roof, ceiling, and walls were removed.

Day 12: Porch Roof Tin, asphalt shingles, mixed type wood roof deck

Metal roof of the west porch addition was removed. Asphalt shingles were removed using shingle shovels. 1 x 6's and 1 x 3's roof deck were also removed.

Day 13: No Work on Site

Day 14: Porch Rafters, 2 x 4 Studs, 1 x 6 Novelty Siding
West Porch rafters and walls were deconstructed. Sections of the original exterior wall were laid down and the top plate and studs were recovered as seen in Figure 5.

Figure 5 Exterior stud wall

Day 15: 2 x 4 Studs, Porch Rafters, 1 x 6 Novelty Siding, Front porch canopy
Continued deconstructing porch additions down to floor deck. Experiment in deconstructing front porch canopy as one unit resulted in destruction of salvageable material. After the wall was taken down, the studs were retrieved.

Day 16: Floor Deck, 2 x 8 Floor Joists
1 x 3 porch floor deck was removed. Rains have caused the flooring to cup and pull up from the floor joists around the house. Cupping however makes pulling up the 1 x 3's extremely easy as it could be accomplished without tools.

Day 17: 2 x 4 Studs, 2 x 4 Ceiling Joists
Removed original structure ceiling 2 x 4 rafters and then 2 x 4 studs. The original house was divided in four equal quadrants by the stud walls. The 2 x 4 ceiling joists were removed in one quadrant leaving the next to brace the exterior wall. Next the surrounding exterior stud wall in the quadrant was cut with a skill saw. The stud wall could then be easily pushed over for deconstruction on the ground.

Day 18: 1 x 3 Floor Deck, 2 x 6 Floor Joists, 4 x 6 Floor Beams
Continued removal of 1 x 3 floor deck of porch and support joists. Brick foundation pillars were left in place.

Day 19: 1 x 3 Floor Deck, 2 x 8 Floor Joists, 3 x 10 and 6 x 8 floor Beams
1 x 3 floor deck of original structure was removed along with floor support beams. 1 x 3 decking appeared to cup more when there was less resin in the wood. Every other board of 1 x 3 was cupped due to water damage from rain

Due to nailing, the floor joist had to be cut free for retrieval. In this instance non destructive removal could have been accomplished if the joists were bolted versus being nailed. Planning for disassembly greatly increases the ease of recovery (see Figure 6).

Figure 6 Cutting floor joist free for recovery

Day 20: Foundation and Chimney Brick, Garage Removal
Pushed remaining chimney over with 2 x 4's. Picked up as many bricks from chimney and foundation as possible. The rest of the brick were left to the community to harvest. Tin of garage roof was blown out from underneath with 2 x 4's. 1 x 4 purlins and 2 x 6's were deconstructed. Garage doors were given away on site.

Day 21: Demolish Concrete Block Walls and Concrete Pad
Demolish subcontractor crushed concrete block walls and concrete pad. Figures 7 and 8 show quantities of reclaimed lumber.

Figure 7 Reclaimed dimensional lumber

Figure 8   Reclaimed larger dimensional lumber

Dismantling Technique

One of the greatest barriers to deconstruction is the concept behind dismantling buildings that were never meant to be dismantled, nor were they designed to allow for reusing elements or components. The key is finding methods to disassemble the structures that do not damage the potentially reusable elements. Technical constraints have been designed into each structure simply because no architect or builder designs and constructs a structure thinking it is going to be removed. In other words, the structures are not designed to be disassembled.

MECHANICAL TEST OF SALVAGED LUMBER

Deconstructed lumber from two buildings in Gainesville Florida was tested to determine the bending and shear stresses at failure. Building 1 was constructed in 1915 and located at 2930 NW 6th Street. This was a single story timber framed building. At the time of deconstruction, the oldest piece of lumber was 85 years and there were no grade stamps on the pieces. Building 2 was constructed in 1900 and located at 14 NE 4th Street. This was a two-story timber framed building. The oldest piece of lumber from this building was aged 100 years and none of the pieces had any grade stamps on them. The species of lumber in both cases were found to be southern pine. Some new pieces of southern pine were tested to provide a basis for comparing the values from the old lumber.

Test samples were classified according to usage in the old building as studs or rafters. Selected lumber from both buildings was cut into lengths of 600 mm (24 inches) for the tests. 8 pieces from each category were selected for testing. To determine the cross-sectional dimensions of the samples, measurements were taken at three points, both ends and in the middle. Table 1 shows the dimensions and number of samples for each group.

TEST SAMPLES					
Lumber source	**Description**	**Average Dimensions (mm)**			**Number**
		Width	Depth	Length	
Building 1	Studs	45	92	600	8
	Rafters	56	110	600	8
Building 2	Studs	45	93	600	8
	Rafters	54	102	600	8
New lumber	Studs	38	89	600	8

Table 1: Test Samples old and new lumber

Tests to determine the bending strength of the samples.

The bending tests were performed based on the three point bending and the distance between supports was 47 mm. The tests were conducted based on procedures outlined in the ASTM D 198 [3]. A Tinius Olsen machine of 270 kN capacity was used for the test. The load was applied through a load cell and a computer recorded the load and deflection throughout the tests. The load was applied through a 12-mm thick steel plate to avoid exceeding the sample's bearing stress. The samples were supported on 12-mm steel plate. The actual setup for the bending tests is shown in Figure 9. Failure of the test samples during the bending tests occurred at the middle and was characterized by either a tension failure at the bottom of the piece or compression failure at the top of the specimen. Figure 10 shows tension failure in a test specimen. Some of the samples in building 2 had low values due to the presence of 6-mm holes in the center bottom of the beam.

1-inch pieces were cut off each piece after testing and used to determine the moisture content and specific gravity. The moisture content was determined in accordance with procedures of ASTM D 4442 [4] method A and the specific gravity was determined in accordance with procedures of ASTM D 2395 [5] method A. Table 2 shows the calculated bending stresses of the bending tests as well as density and moisture content of each specimen.

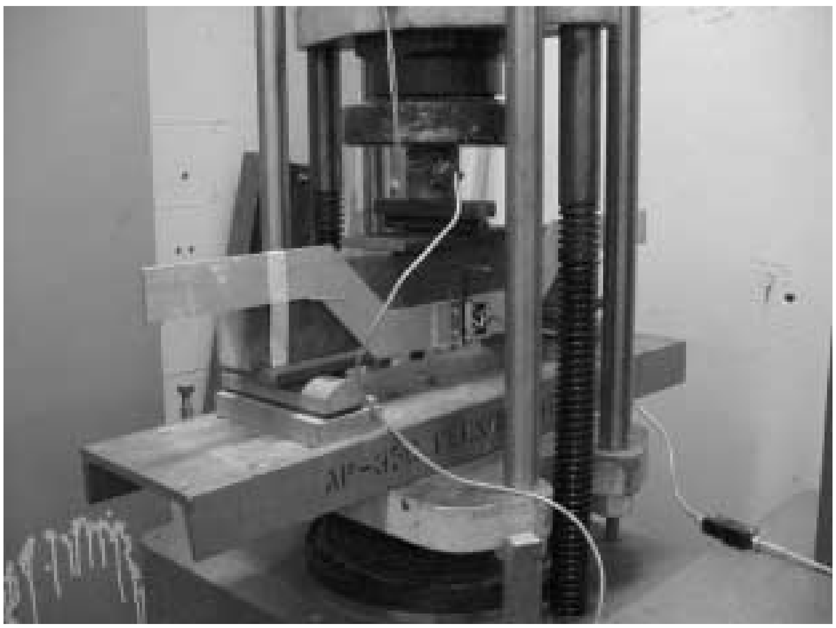

Figure 9: Three-point bending test assembly

A 5% exclusion limit for the average bending values was obtained for each set of specimens. These values were then divided by an adjustment factor of 2.1 to give the allowable bending stress. The factor includes an adjustment for normal duration of load and a factor of safety. The calculated allowable bending stresses were highest for the studs in building 2.

RESULTS OF BENDING TESTS							
Member	**Building**	**BENDING TESTS**			**Density (kN/m^3)**		**Moisture Content (%)**
		Bending stress (MPa)					
		average	σ	**F_b (allow)**	average	σ	
Studs	1	68.7	18.4	**24.8**	6.6	0.6	9.8
	2	64.4	3.7	**33.5**	6.7	1.3	10.6
	New	68.1	15.5	**26.8**	4.1	0.1	10.1
Rafters	1	68.2	17.2	**19.1**	6.2	0.4	10.5
	2	82.7	17.6	**25.6**	6.0	0.2	9.1

Table 2: Results from bending tests

Shear tests performed to determine the shear stresses parallel to grain.

Shear block specimens were made according to procedures of ASTM 143 [6] except that the thickness for the studs was on the average 45 mm (1.75 inches) and those from the new lumber was 38 mm (1.5 inches) since they were cut from nominal 2 by 4. The thickness for specimens from the rafters was 50 mm (2 inches). In all tests, the shear plane was 50 by 50 mm (2 by 2 inches) (see Table 3).

building	description	specimen dimension (mm)			area of shear plane		no of samples
		length	thickness	height	length (mm)	width (mm)	
1	studs	50	45	64	50	50	8
	rafters	50	50	64	50	50	8
2	studs	50	45	64	50	50	8
	rafters	50	50	64	50	50	8
new	studs	50	45	64	50	50	8

Table 3: Shear test samples

The shear specimens were tested with a 270 kN (60,000 lbs) Tinius Olsen universal testing machine. The specimens were placed in the shear tool with the crossbar adjusted so that the ends rested evenly on the support over the contact area as shown n Figure 11. The maximum load at failure was recorded. The portion of the specimen sheared off during testing was used to determine the moisture content. The moisture content was determined according to procedures of ASTM D 4442 method A.

A 5% exclusion limit for the average shear values was obtained for each set of specimens. These values were then divided by an adjustment factor of 4.1 to obtain the allowable shear stress. The factor includes an adjustment for normal duration of load and a factor of safety. The results of shear tests shown in Table 4 showed that the allowable stresses for the samples tested were highest for the new lumber.

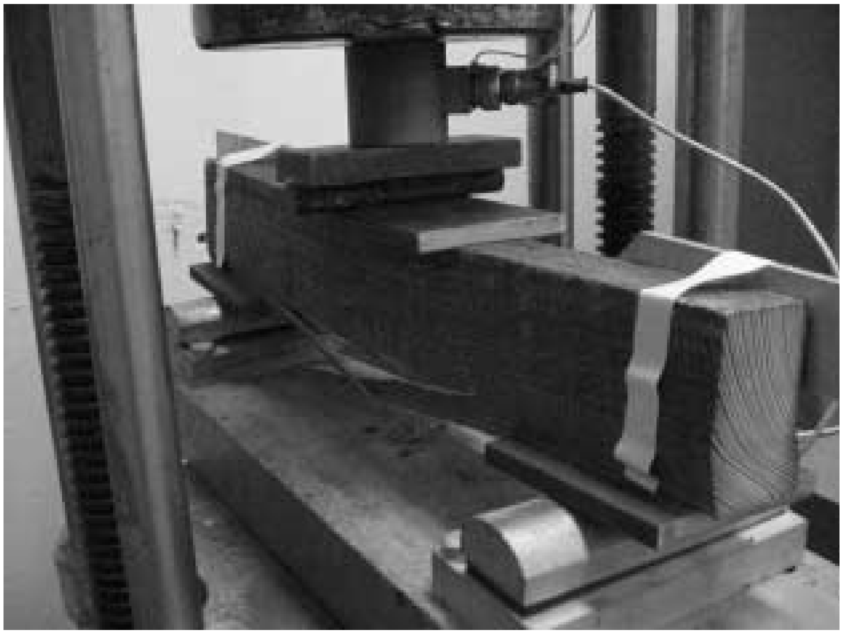

Figure 10: Tension failure at the bottom of a sample during the test

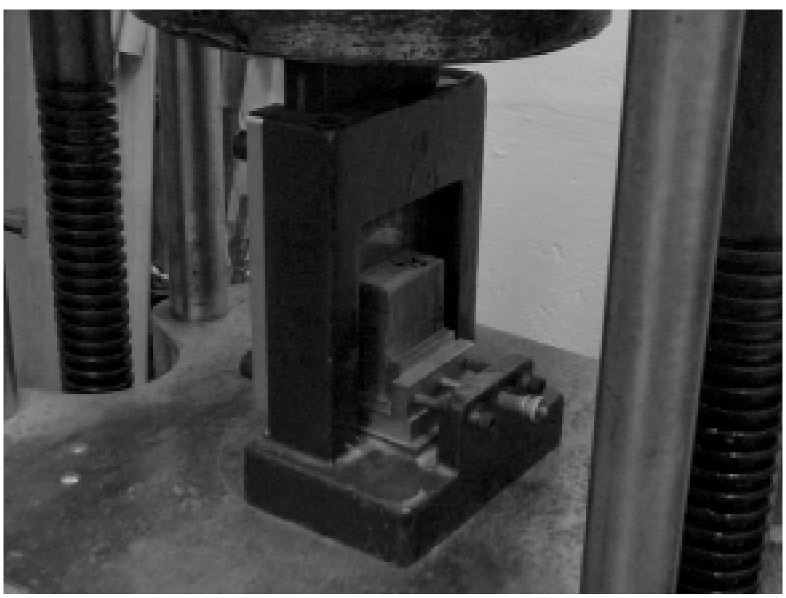

Figure 11: Shear parallel-to-grain Test Assembly

RESULTS OF SHEAR TESTS				
Member	Building	SHEAR TESTS		
		Shear stress (psi)		
		average	σ	**F_v (allow)**
Studs				
	1	7.3	2.5	**0.76**
	2	8.4	1.5	**1.45**
	New	7.5	0.8	**1.52**
Rafters				
	1	7.2	1.4	**1.20**
	2	7.1	1.5	**1.12**

Table 4: Results of shear tests

Salvaged Wood Re-Grading

One of the main barriers to the widespread reuse of smaller dimensional lumber is the lack of up to date grading or certification stamps. Without these stamps the reuse of the salvaged materials is done often not within code. Inspectors simply will not sign off on materials that are not properly graded. Currently the re-grading of salvaged wood is not common. Often consumers are hesitant in purchasing wood for structural applications that lacks certification. Salvaged lumber can be used in non-structural applications, however, a grading system for this salvaged wood would increase its usability. Framing lumber salvaged from older buildings may have either a lumber grade stamp that is no longer accepted by local building inspectors or lack any lumber grade stamp at all. Grade stamps on salvaged lumber may be invalidated by alterations to the lumber, (drilled holes, notches, checking, through-nail penetrations, etc.) or simply by age. It is unclear when, if at all, lumber grade stamps can expire. Many lumber graders have been reluctant to re-grade salvaged lumber because they feel they lack background information and a methodology to follow on the structural performance of lumber that has been under load for an extended period of time. The United States Department of Agriculture (USDA) forest Products Laboratory is currently performing structural tests of salvaged lumber in an effort to provide guidance on this issue.

Evaluating recycled lumber with existing grading rules may not result in the most efficient use of this resource. Existing grading limitations for certain characteristics - checks and splits - were developed for freshly sawn lumber. It is not clear to what extent these defects affect recycled lumber engineering properties and subsequent reuse options.

The Southern Pine Inspection Bureau has general specifications on re-grading lumber that have not been revised in seven years. The wood re-grading is a visual inspection - studies are underway using mechanical testing means to determine if the properties of the wood have statistically changed during the loading period. The Southern Pine Inspection Bureau has several disclaimers regarding the re-grading process. Their standard disclaimer is "they do not re-grade wood to be sold and used for structural lumber." However, the popularity of reusing lumber is rising and the agency is being pushed to comply with consumer demands.

In addition to getting the lumber re-graded, using the lumber falls under the jurisdiction of local building code inspectors. Their acceptance of the material may or may not allow for its use. The inspection bureaus and the local building code inspectors both fear the liability associated with certifying the strength of salvaged or reclaimed lumber. If the lumber has a certification stamp, liability is held by that agency, however if no certification exists and the local inspector approves of the usage, the local government agency is liable for any potential problems that result from the lumber's use.

Trends

For the past thirty years the wood products industry has been retooling to use smaller, lower quality log stock as smaller younger trees replace the old growth supply. The lumber market today is a combination of wood particle products, laminates, composites and engineered wood products. The current trends in the new wood products industry strongly dictate both the markets and manufacturing opportunities available to the reclaimed wood products industry. These trends also provide some interesting marketing opportunities for reclaimed lumber. Glue laminate beams and engineered truss joists also often take the place of reclaimed lumber products because of their superior strength, performance and lower overall cost. Alternately, the new markets for large timbers and beams, dense grain material, and heart redwood, clear grades of pine and Douglas fir are struggling due to lack of supply. These are the markets to which reclaimed lumber has easy entry and traditional success.

The sustainably harvested industry relates to the reclaimed industry in many ways. First, outlets that sell sustainably harvested wood are often interested in offering reclaimed wood to augment their softwood products. The sustainably harvested industry also helps to spread awareness about the importance of buying wood that is ecologically low impact. At times the two products compete with each other and sustainably harvested wood does offer the customer the advantage of a long term source for ongoing projects and products and unblemished with fastener marks. However, since sustainably harvested wood is often second-growth, the overall quality of reclaimed lumber is usually superior.

CONCLUSIONS

Based on the results of the bending and shear tests of the salvaged and new lumber in this study, the following observations were made

- Properties of salvaged lumber tested compared very well with those of new lumber tested.
- The old lumber was denser than the new lumber. The density of the old lumber was approximately 50 percent higher than that of the new lumber.
- The allowable bending stresses of the studs salvaged from buildings 1 and 2 were 93% and 125% of that of the new lumber, respectively.

- The calculated allowable shear stresses were highest in the new lumber. The allowable calculated shear stresses parallel to the grain for the lumber salvaged from buildings 1 and 2 were 95% and 50% of that of the new lumber, respectively.

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