DECONSTRUCTION: HELPING TO FOSTER A SUSTAINABLE CONCRETE INDUSTRY

Morten Gjerde[1]

ABSTRACT

As the construction industry generates a significant proportion of the waste going to landfill it is becoming increasingly important that it begins to consider ways of reducing this total. An approach to dealing with this challenge has been to deconstruct and recycle buildings, a concept that is gaining favour in those countries with the most urgent need to reduce waste going to landfill. Recently the Victoria University School of Architecture researched and prepared a national report of deconstruction activities in New Zealand. The concrete industry can claim several highlights in this report and should consider opportunities identified in it to further enhance its reputation as a sustainable building material.

The paper gives a brief overview of the principles of deconstruction in the context of developing more sustainable building practices. Several case study examples that demonstrate opportunities for concrete and concrete buildings to be recycled are presented. The paper concludes that the concrete industry should embrace the principles of deconstruction to further enhance the reputation of concrete as a sustainable building material.

Keywords: Deconstruction, Sustainability, Lifecycle Assessment

INTRODUCTION

Sustainability is a measure of the degree to which society lives 'within its means'. In order to foster sustainable development of the built environment the construction industry must consider a wide range of issues. These issues can be grouped under three broad headings; cultural, economic and environmental. This paper presents three important environmental sustainability factors as background to an overview of deconstruction and recycling of the built environment.

Waste Disposal

The disposal of waste is a problem of significant proportion in most countries in the world. The statistics are alarming. About four billion tonnes of waste material is generated globally each year. Of that total, the construction industry accounts for close to half [1]. The majority of waste is put into landfill, a practice that is now being challenged in many parts of the world. In New Zealand, the government published a strategy document in 2002 which, among other goals, targets a reduction of the construction and demolition waste going to landfills by 50% by 2008. Over half of the territorial authorities in the country have gone on to declare their intentions to reduce waste to zero by 2015 [2].

Energy

The energy used to construct the built environment, including everything from the sourcing of raw materials to completion on site, or 'embodied energy', represents a significant proportion of the total energy used worldwide. When buildings and infrastructure are viewed in this way, it can be argued that it is in the best interests of society to maximise the return on that investment through maximising the length of time it is in service.

Natural Resources

In the past 40 years society has consumed more material resources than in the entire preceding period of human history and the pace continues to accelerate [1]. The built environment accounts for a considerable proportion of the resources

[1] *Senior Lecturer & Cement and Concrete Association of New Zealand Fellow, Victoria University School of Architecture*

that are used and it is unfortunate that most of these resources are converted to waste once the building has reached the end of its useful life. If reclaimed or recycled materials are derived from demolition or construction waste (e.g. demolition rubble, architectural features or surplus construction materials), then not only is waste taken out of the waste stream before it goes to landfill but also the equivalent use of primary materials is avoided [3]. Like embodied energy, the embodied resource value of the built environment must be considered in lifecycle cost analysis.

It is generally acknowledged that sustainable building practices will require a significant reduction in waste being generated and the development of methods to increase the return on the investment of resources tied up in the built environment. Like others, the construction industry is looking for ways to recycle and reuse what was once thrown away. As the primary construction material worldwide, concrete will undoubtedly come under closer scrutiny as the environmental impact of construction activities is researched and understood.

DISSASSEMBLY AND REUSE OF CONCRETE STRUCTURES

Deconstruction, or disassembly and reuse of buildings and materials of construction can be seen as a way of increasing the sustainability of our built environment and of the construction industry. Attitudes toward deconstruction have however, been mixed. Researchers have identified many benefits that can be derived through deconstruction, but the construction industry has been slow to take it up. In most places the cost to demolish an existing building and cart the refuse to landfills and then to procure a new building from virgin materials is less than the systematic demolition, storage and reuse of materials in one or more new construction projects. Notwithstanding the current level of uptake, experience in other parts of the world and in other industries suggests that deconstruction will become more important in the future.

Deconstruction can be considered at various scales and each presents opportunities for concrete to be seen as a sustainable building material. Following is a brief overview of several scales at which disassembly and reuse of buildings can be approached. Broad reference is made to the potential for concrete buildings and construction systems to be recycled.

Building reuse

The greatest recovery of the energy and material resources embedded in a building can come through reuse of the complete structure. Adaptive reuse fits one or more new uses into a building that is no longer required for the use it was originally designed. A contemporary example of this strategy is the conversion of existing inner city commercial buildings to apartments. Buildings with recognised historic merit or architectural character are those most often selected for adaptive reuse. It can be noted that developers are quick to recognise the value in buildings with these attributes. We should also be able to value the material and energy value embodied in many buildings that are otherwise targeted for demolition and look for ways to exploit that value through adaptive reuse.

Concrete buildings, especially those that employ frame structural systems, are well suited to conversion. Frame structures allow maximum flexibility of planning, being without the restrictions imposed by structural walls. The inherent durability of concrete should give developers the confidence that the converted building will be a sound investment and last at least a ‘second lifetime’. Concrete structures may be easier to convert, in most cases not requiring secondary fireproofing or acoustic treatment. One of the common complaints about converted buildings in the inner city (other than those constructed in concrete) is that they do not provide adequate sound separation between living units or to the outside [4]. A concrete building has an inherent benefit over one built using other construction materials in this regard, and can be seen as an ideal candidate for adaptive reuse.

Component reuse

Building components can also be reused in alterations to existing or in the construction of new buildings. Following whole building reuse, component recycling ranks second in terms of preserving the embodied materials and energy of the original construction. The potential to reuse components is often directly related to the methods used in constructing the original building. Methods that enhance the buildability of a project can also lead to enhanced deconstruction potential. Prefabrication of modular components with assembly on site is a method that is increasingly specified as designers and builders seek to improve construction quality and reduce timeframes.

Precast concrete systems have been an important part of the construction industry for some time, and have been particularly well developed in New Zealand. Precast concrete buildings are ideal candidates for deconstruction and component salvage. The stumbling block to reuse of precast concrete components is often the 'wet' methods of making the joint between components to achieve permanence and to transfer structural loads efficiently [5]. This must be overcome when exploring ways to recycle concrete buildings that haven't been designed with deconstruction in mind. In the design of new buildings for deconstruction efforts should be made to ensure 'dry' and easily reversible connections, such as those using bolts or welded plates, are used.

Material Reuse

Another way of recycling buildings is to reuse the materials as a substitute for materials that would otherwise be sourced or manufactured from virgin supplies. To determine the embodied energy that is being saved it is necessary to account for all the extra energy used in converting the material and comparing it against the energy that would be used to extract/manufacture the new material from other sources. There is no doubt that reusing materials in this way will preserve raw materials and reduce the amount of waste going to landfill.

Concrete lends itself to use in this manner two important ways. Concrete structures that cannot be reused either as whole buildings or as components can be systematically ground to create aggregate. The ground concrete can be used to substitute for all or part of the aggregate requirement in new construction. After all, concrete is nothing more than cast stone. Some demolition concrete waste is being crushed back into an alternative high grade aggregate and base course for roading following the issue of Transit New Zealand guidelines. [1]. The recycled aggregates can also be used in new concrete. Research confirms that there are no technical reasons why recycled concrete should not be used in this way. Lack of certainty of supply and perceptions of the resultant concrete being inferior have slowed the uptake of concrete reused in new concrete. Guidelines for the reuse of aggregates, such as those being developed in Norway, will help to give specifiers the confidence to specify.

Concrete can also be used to effectively 'bind' other waste materials. The use of fly ash, a waste product from coal fired power stations, is an example of this. This successful synergy between a waste product and concrete suggests that other opportunities should be investigated.

Recycling concrete buildings must be approached from two directions. Existing building stock has more than likely not been designed with deconstruction in mind. When these buildings are presented for demolition the options that can be considered are in most cases limited to whole building reuse or recycling of the material. In some circumstances the original method of construction will lend itself to being taken apart easily to facilitate the components being salvaged. Evaluation of existing buildings and specification of recycling strategies for these can be a creative exercise.

New buildings should be designed with future recycling in mind. In this regard, the construction industry could look to other industries for motivation. The German government requires that all motor vehicles manufactured in that country be at least 80% recyclable as part of their extended producer responsibility obligation.

EXAMPLES OF DECONSTRUCTION

Many successful building projects incorporating deconstruction have been documented by other researchers. These projects serve to demonstrate the varied approaches to the reuse of building components and how deconstruction can be planned for when designing without compromise in the performance of the building being designed.

The Netherlands

Deconstruction in the Netherlands has been stimulated by government policy. In 1997 the Dutch government imposed a landfill ban which prohibits the landfilling of reusable or burnable demolition and construction waste [5]. The effect of this legislation is that all waste is processed and reusable materials are put back into the built environment rather than lost in landfills. The Dutch government is progressive in a number of social areas and this demonstrates their commitment to sustainable construction. The legislation has been effective in reducing the volume of waste going to landfill. Recycled concrete and mixed granulates have proven to be cost competitive in the marketplace, largely because the processing takes place as a matter

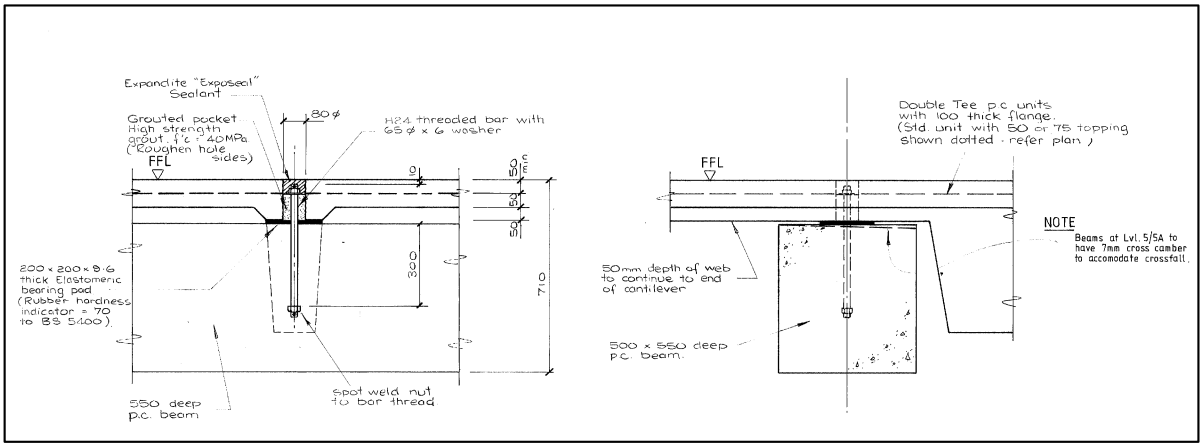

Figure 0: Construction Details of Flooring Beam Connection

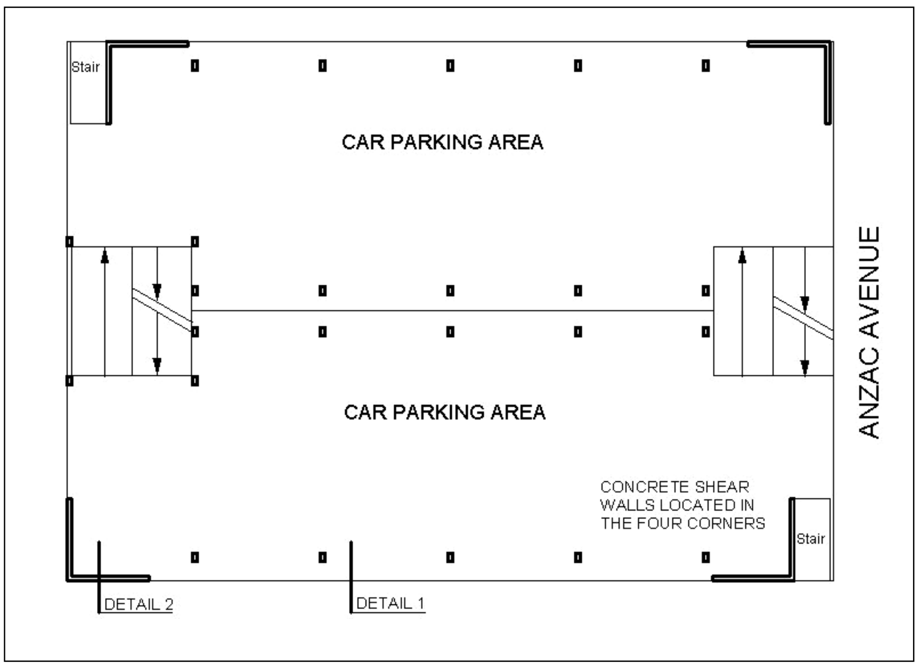

Figure 1: Plan of Anzac Avenue Carparking Building

of course and it is in the interest of the industry to find alternative uses to comply with the legislation. These and other drivers have led to the Netherlands being able to recycle 80% of the construction and demolition waste generated in the country. Most other countries are able to recycle in the order of 20-30% of C&D waste. It is estimated that the New Zealand industry is recycling at about the same level, although the research has not been done to confirm these figures.

Several demountable concrete systems have been developed in the Netherlands and research in this area has been supported by the government. A government report has suggested that the successful use of demountable systems is highly dependent on discussions between all stakeholders, including the designers and builders. This would help ensure appropriate attention is given to buildability issues and maintain the dry construction jointing methods that in turn will help ensure the ability to dismantle in the future.

An interesting project, designed for deconstruction, demonstrates the potential for the concrete industry. The upper seven levels of a twelve storey residential building were removed as the housing needs in the area changed. The components salvaged were then combined on new building sites in the surrounding area to form 114 new low rise residential units. The project demonstrates the flexibility of concrete systems and should encourage them to be specified for new construction [5].

Figure 2: View of Concrete Panels Relocated to Form Extension

Anzac Avenue Carpark

The Anzac Avenue Carparking Building was developed in Auckland in 1990 following a period of economic uncertainty. The owners of the site required a new building which would provide an income until economic conditions were right to carry out their long term development aims, yet would not compromise their long term plans. A reinforced concrete car parking building was therefore designed that was capable of being disassembled and re-erected on a different site at a future date.

Good quality precast concrete structural units are widely used and readily available in New Zealand. The challenge is to minimise or eliminate the use of cast-in-situ concrete to join the pre-cast concrete elements of a building. In this case, lateral bracing of the structure is provided by four 'L' shaped cast-in-situ concrete shear walls at the outside corners of the plan (see Figure 1). The design strategy of resisting the lateral loads at these corners allowed the structural frame to take the gravity loading only, and as a consequence allow beam to column joints to be pin jointed.

The three main pre-cast concrete elements in the structure are pre-cast concrete flooring units, the pre-cast concrete columns cast to their full height of four floors with corbels to support the beams. The pinned beam to column joints were made by welded, freely accessible connections, able to be cut at the time of disassembly. With each floor designed as a seismic diaphragm a sturdy connection was required between pre-cast flooring units. This was achieved by joining the flanges of adjoining double-tees using bolts in preformed pockets cast in the flange, freely accessible for disassembly.

The flooring and mechanical connections between units provide the structural capacity that is necessary for a floor, however without a topping, the concrete floor is not perfectly level or true. The connection between each floor unit and supporting beams was made by threaded rods, easily removable at a later date (see Figure 2). The vertical stepping between flooring units is not enough to be of concern for foot or vehicle traffic in a car park but would not be suitable for most other building types, where it would be necessary to employ a raised floor or a form of mechanically fixed modular leveling overlay to achieve a level floor while still allowing for disassembly.

The project demonstrates that it is feasible to design for deconstruction in a seismic zone without significant increase in cost; however the strategy has not been widely adopted in New Zealand for this building type or indeed any others.

While much of this building can be deconstructed, the cast-in-situ shear walls will require demolition. If an alternative structural system, such as a steel eccentrically braced frame had been used, it could have been bolted to both the foundations and to the superstructure, increasing the extent of structural reuse.

The International Antarctic Centre

A project that was specifically designed for partial deconstruction to facilitate a planned expansion is the Antarctic Visitors' Centre in Christchurch. Due to budget constraints and uncertainty about the market opportunity for a 'Snow and Ice

Experience' when the Visitors' Centre was being planned, allowance was made for this facility to be added at a later time. The planning of the project was done to allow the construction to take place with minimal disruption to the operation of the Visitors' Centre and detailing of the construction addressed demolition and reuse of components. The construction of the Centre included the use of modular pre-cast concrete panels as the exterior structure and cladding. The design allowed for the panels, approximately 8 metres tall, to be unbolted from the foundations, the roof framing and from each other when the time was right for the extension to be undertaken. These panels could then be relocated in their new positions with new panels manufactured in between (see Figure 3).

The expansion was undertaken in 1995 and completed successfully. The owner was able to engage services of the original contractor for the Visitors' Centre. Armitage Williams Construction had important knowledge about the construction methods used originally and access to the original formwork which could be used to cast the new makeup concrete panels. This gave the firm a competitive edge in both time and cost; however there would have been no reason another contractor could not have undertaken the expansion work. The project as completed successfully with very little disruption to the operation of the Centre.

CHALLENGES AND OPPORTUNITIES FOR THE CONCRETE INDUSTRY IN NEW ZEALAND

Many barriers exist in the construction industry, and in particular the concrete industry, to the uptake of building disassembly and reuse. One of the greatest barriers to deconstruction is the feared consequential reduction in the sale of new materials around which the industry is now based. Sales of cement and new concrete will reduce in accordance the number of buildings being reused or components recycled [3]. Virgin aggregate sales will also diminish with each tonne of concrete recycled as aggregate. A strategy to overcome the potential loss of sales is to grow the market. The industry could highlight the sustainability of concrete, not only as a material that can effectively be recycled but also as a material that has inherent durability, can reduce the need for heating and cooling in buildings and is locally produced. There should be no reduction in cement sales attributable to the use of recycled aggregates in new concrete as research suggests that concrete using recycled aggregates will require higher cement content to achieve results similar to those of virgin concrete.

Recycling of materials will no doubt add to the cost of building and, understandably, this is a barrier. In New Zealand, where the cost to dump waste to landfill is low and not in proportion with the real cost to the environment, this difference is pronounced. In countries where the problems associated with landfill overuse are recognised and waste going to landfill is highly taxed or restricted, the recycling cost is comparable so consequently cannot be attributed to increases in construction cost. It will only be a matter of time before similar legislation is enacted in New Zealand. Some territorial authorities are contemplating the introduction of a clean fill tax, which will raise the cost of putting materials such as unreinforced concrete to landfill. The growth of recycling industries in most countries has resulted in job creation which may at a societal level help to offset any potential increases in the cost of construction.

Simpson [6] argues that the greatest restriction to the use of recycled aggregates is uncertainty of supply to meet the demand. Technical issues are understood and can be designed for, even when used in structural concrete. Guidance documents are imminent and demand will be created by political will, although this may be longer in coming in New Zealand than elsewhere. High demand levels and the sporadic availability demolition material will require stockpiles to be created near urban areas. Overcoming this dilemma in an economically sustainable way will require close co-operation between specifiers, suppliers and the demolition industry.

A long term opportunity for the concrete industry is to embrace the concepts of disassembly and reuse to further enhance its reputation as a sustainable material. Because concrete buildings and structures can be seen to be highly recyclable as complete buildings, as building components and as a material, concrete should be specified for use in buildings designed to facilitate future disassembly and reuse. To restate a point made earlier, the concrete industry should target growth of market share of new construction now and into the future rather than concern itself with potential loss of sales due to the recycling of buildings.

CONCLUSIONS

Sustainable development of the built environment is a complex puzzle to solve and must address issues of cultural, economic and environmental sustainability. Concern about the increasing generation of waste going to landfill, high levels of non-renewable natural resource processing into construction materials and high levels of energy embodied in the construction of the built environment has led to consideration of disassembly and reuse of buildings as a way of reversing these trends and be more sustainable.

Concrete buildings can be considered for deconstruction at a variety of scales; that of whole building, that of components and that of material. In each of these categories concrete has been demonstrated through a variety of successful projects and through various research projects to be highly recyclable. There are clear concerns about the negative impact that recycling and reuse of buildings will have on the economic growth of the concrete industry in the future. It has been argued that the industry should embrace the concepts of disassembly and reuse to further enhance the reputation of concrete as a sustainable building material and in turn to help grow the market share of the overall construction spend to offset any reductions in future sales that may be attributed to new construction being avoided through recycling.

REFERENCES

1 Storey, J. Gjerde, M. Charleson, A. & Pedersen, M. *The state of deconstruction in New Zealand*, Centre for Building Performance Research, Wellington, May 2003

2 Storey, J. *De-Constructing our built environment*, Build, Jan. – March 2002, pp. 40 – 42.

3 Guthrie, P. Coventry, S. Woolveridge, C. Hillier, S. & Collins, R., *The reclaimed & recycled construction materials handbook*, CIRIA, 1999, pp 1-6.

4 Pringle, T., *Regulations for change of use*, Build, Jan-March 2002, pp. 33-35.

5 Van Dijk, K Boedianto, P. te Dorsthorst, B. & Kowalczyk, A. State of the art deconstruction in the Netherlands, In overview of deconstruction in selected countries; Kibert, C. & Chini, A. eds, August 2000, 95 – 143.

6 Simpson, D. Recycled aggregates in concrete - a realists perspective, Concrete, 33(6), 1999, pp 17.

7 Crowther, P., *Design for disassembly: an architectural paradigm for sustainability*, PhD thesis at Queensland University of Technology, 2002, 366 p

8 Glucina, M, *Reclaiming value from building industry waste*, Build, March – April, 2001, pp.32 – 34.