Historic Trends in Building Disassembly

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INTRODUCTION

Disassembly may sound like the opposite of assembly, but in the building industry it is seldom practiced as such. Assembly may be seen a complex sequence of connecting carefully designed components and materials, a process that may involve thousands of people and fleets of machines. Building assembly requires careful control over labour, materials, time and space, all with a grand vision of the creation of the built environment. On the other hand, disassembly, in the building industry, usually involves a few bulldozers or a fist full of explosives. It may last just a few seconds and the results are seldom described as visionary. This destruction does not however have to be so. In fact there are examples, notable for their exception, of buildings in which disassembly is exactly the opposite of the assembly process.

While designing for careful disassembly is not often practiced in the building industry, the principles involved have been used at times to produce buildings that can, in one form or another, be disassembled. In fact some building types are unique for their ability to be dismantled and reassembled or reused. An historic survey of buildings designed for disassembly reveals a number of unique characteristics. While the reasons for disassembly in these examples are varied, the technology employed shows a number of common trends that would suggest the possibility of creating guidelines for designing for disassembly. This often forgotten technology has remarkable potential in an era where concern over reuse and recycling is becoming increasingly important.

THE ANCIENTS

The earliest buildings that were specially designed for disassembly were perhaps very similar to the first buildings that humans made. When people first left the protection of natural caves and built their own shelters they probably built using a frame of timber sticks and coverings of leaves, bark or animal hides. These techniques evolved into the familiar form of the tent that we now see used by nomadic people all over the globe. This tent form, with its light weight compressive frame and its tensioned membrane cover, has proved to be an enduring structure for people who move regularly and must transport their shelters with them.

The light weight of the building components is an important characteristic that facilitates the ease of handling for disassembly, transport and reassembly, and allows for a regular program of maintenance (Hassanain and Harkness 1997).

THE MIDDLE AGES

In more robust buildings, not designed for relocation, the reuse of timber components has been common practice in many parts of the world for many centuries. In Europe, the scarcity of suitable timber in the middle ages lead to the regular reuse of beams and other members from one building to the next. The common practice at the time of using timber pegs to connect members allowed for their easy disassembly for recycling. In the sixteenth century, in the Swiss canton of Appanzell, where the forests were owned by the church, peasants were granted the right to fell timber free of charge for their own house on their own land. This lead to a group of enterprising builders constructing houses on their own land, then disassembling them to be exported and reassembled elsewhere (Peters 1996). While in this case the technique of disassembly in construction was used as a form of medieval capital gains tax avoidance, similar technology was used all over Europe to construct timber buildings that could be taken apart for reuse.

Such technology was not however limited to Europe. Traditional Japanese timber architecture also utilizes a construction technique where members may be disassembled from each other. "Japanese wooden architecture ... is a complete architectural system in which the expansion, remodelling, removal and reconstruction of buildings is possible according to life styles." (Kikutake 1995, p.27)

Traditional Japanese domestic buildings are constructed using a primary frame of major timber members that are placed according to structural requirements of the roof and walls. A secondary frame of timber members is then constructed in accordance with the spatial requirements of the occupants. This secondary frame may be disassembled and remodelled to suit changes in the occupants' requirements without affecting the primary structure and without the wastage of building materials that other techniques produce (Itoh 1972).

The technologies applied in these examples of timber buildings show how mechanical jointing techniques and a hierarchy of structure allows for the efficient disassembly of members for reuse.

THE NINETEENTH CENTURY

The technology of designing for disassembly in timber houses reached its peak in Great Britain in the nineteenth century with the portable colonial cottage. As early as 1624 prefabricated timber cottages were being exported from Britain, and by the nineteenth century, the technology employed in the portable colonial cottage had become quite sophisticated.

One of 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 timber frame of grooved posts set into, and bolted to, a continuous timber floor plate. Between the posts were fitted interchangeable panels of a standard three foot width. The panels were topped with a wall plate which supported the trusses of the roof. The roof itself was generally of canvas which was light weight and compact for transport, but this was often upgraded to a roof of shingles or slate for a more permanent building (Archer 1996). All components were sized for easy handling and the whole structure was held together using bolts which allowed for the easy disassembly and reassembly of the whole building using nothing more than a wrench. This low technology solution allowed the unskilled labour of the owners to carry out the assembly themselves in minimum time. 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 (Herbert 1978, p.11)."

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 galvanizing in 1837, portable iron cottages became a common way of dealing with the building shortage in British colonies. The sheet metal's light weight made it ideal for transportable buildings and it was soon used for everything from cottages to churches and from warehouses to hotels. Cottages sent to Australia at the time were sold as complete buildings with timber floors and timber linings to the walls and ceilings. The buildings were supplied with all internal finishes including wallpaper, carpets, and furniture, and with instructions on how to assemble them (Reuber 1998). The idea of providing assembly and disassembly instruction was also evident in buildings imported into Australia from Asian countries. Examples of such houses had Chinese characters marked onto each of the timber beams, most likely as instructions for the assembly of the building (Lewis 1993).

This whole collection of portable buildings exhibits a number of important new characteristics, as well as the ones already discussed, that enhance the disassembly of the structures. These are the separation of structure and enclosure, the use of low technology solutions, providing permanent instructions on assembly, and having a complete system with integral finishes and services.

We now move from some of the smallest prefabricated buildings to one of the largest. In 1851 Britain hosted "The Great Exhibition of the Works of Industry of All Nations." This international trade and technology fair took place in London's Hyde Park in a temporary building, designed my Joseph Paxton, which came to be known as the "Crystal Palace." This entire building, over 560m long, was based on a structural grid that was generated from the maximum size of a piece of 16oz. glass available at the time. This 49in. length, when set on an angle in the roof, produced an 8ft. roof module which in turn produced the 24ft. standard structural grid (Strike 1991). Cast iron columns, assembled from a standard kit of parts that were bolted together, were set out on the grid. Columns were linked with standard trusses that were fitted into flanges on the columns and locked into place with wedges of cast iron or timber (Peters 1996). This skeletal frame of columns and trusses was then clad and roofed using panels of timber, iron and glass. These factory-produced panels allowed for the quick assembly and disassembly of the building, and its eventual relocation after the exhibition had closed. By 1854 the building had been transported and reassembled on a new site in Sydenham. The building on this new site was not however exactly the same as the original. It was in fact considerably larger and taller and included a cellar (Peters 1996).

The lessons to be learned from this example are the use of a standard module of construction and an open system that allows for alternate arrangements of the parts, and the use of a limited number of standard components.

THE TWENTIETH CENTURY

Some of the most demanding applications of buildings designed for disassembly have been building projects associated with war. The First World War saw the development of numerous types of mass produced prefabricated buildings that were designed for quick assembly, disassembly, transportation and reassembly. One of the most successful designs was the Nissen Hut, and the larger Nissen Hospital Hut.

This hut was based on a six foot, nine inch grid, with a floor of four foot wide timber panels. A Tsection iron frame supported the semi-circular roof which was made from corrugated sheet iron. The hut was originally lined with tongue and groove timber boards, but later designs used corrugated sheet iron internally as well. The complete hut weighed only one ton and each component was light enough to be handled by only two men. The entire hut, measuring twenty seven feet by sixteen feet, could be assembled by four men in four hours using nothing more than a spanner (Mallory and Ottar 1973). The Nissen hut illustrates a number of characteristics that make it a good example of designing for disassembly. The system was comprised of simple components, it had a small number of components, the components were interchangeable, they were mass produced, and they were assemblable using simple, everyday tools and technology (Kronenburg 1995). Similar techniques were used during the Second World War to produce portable temporary buildings, and the characteristic of mass production enhanced the standardisation of materials and components.

The architect, Buckminster Fuller, who had designed small portable shelters for military use, had a plan for utilising this technology of mass production in peace time. His proposal was to use the production line technology of aircraft manufacturing, to mass produce prefabricated housing. His early scheme for the Dymaxion house was never realised but the Dymaxion Bathroom module was built in very limited numbers. It was a self-contained unit that could be disconnected and relocated into a new house when the owners moved (McHale 1962). Fuller's later design for the Wichita House, which was in many ways similar to the Dymaxion House, shows most of the same characteristics of portable military buildings. It was to be mass produced of standard components, each of which weighed no more than five kilograms. The house would arrive at its site, packaged in a singe steel cylinder, and could be assembled by six people in just one day (Kronenburg 1995). Fuller also proposed in his Dymaxion house project that the buildings should be rented to the users like a product that would be serviced, repaired and replaced by the supplier. This would allow materials to be easily returned to the manufacturer for eventual reuse and recycling (McHale 1962).

Another innovative thinker who was interested in the architectural application of industrial technology to achieve flexibility and portability was Cedric Price. His scheme of 1961 for the Fun Palace was an inspirational work in the realm of adaptable buildings. Price's design consisted of a steel-framed structure that contained hanging auditoria with movable floors, walls, ceilings and walkways. The whole building had been designed with obsolescence in mind and was serviced by cranes on the top of the structure which allowed the component parts of the building to be manipulated and relocated to suit various proposed activities (Landau 1985). The influence, a decade later, on the Pompidou Centre by Rogers and Piano is obvious.

Although the Fun Palace was not realized, the Inter-action community centre in Kentish Town was built in the 1970's following many of the same principles. This multi purpose community centre, of approximately 2000 square metres floor area, was designed with unlimited permutations of flexible space to house continually changing uses. It consisted of a major steel structure set out on a regular grid with a series of flexible enclosed spaces that were independent of the main structure and could be disassembled and reassembled into new configurations. Separate self contained modules, that housed service zones such as toilets, could be plugged into the frame where ever they were required. A strong hierarchy of structure allowed the building to expand or contract in the future without interrupting the existing building. The Inter-action centre was actually classified by the council as a "temporary" structure and the architect prepared complete instructions for the buildings disassembly (Inter-action Centre 1977).

Many architects were influenced by the work of Price. One such group of British architects, calling themselves Archigram, produced an almost endless stream of designs for portable, adaptable and temporary buildings during the late 1960s and early 1970s. Of the more buildable schemes, the Plug-in City displays some interesting technology in its ways of dealing with disassembly. The Plug-in City, in which "the whole urban environment can be programmed and structured for change" (Cook et al. 1972, p.36), was based on a steel mega-structure that contained the major transport corridors and services. This structure supported a series of detachable living and working units than could be manoeuvred by cranes fixed to the main structure. The units responded to a hierarchy of obsolescence where those parts of the building that would need to be serviced or replaced most frequently were most accessible. For example the living modules and shopping areas, that had a three year to eight year rating, were nearer the top of the structure, and the heavy elements such as railways and roads, with a twenty year life expectancy, were nearer the bottom (Cook et al. 1972). Archigram also proposed a scheme that illustrated the ultimate step in disassembly, the Walking City. This was a design for a forty story building that could literally disconnect itself from its site and move to a new location.

At the same time as Archigram were investigating high tech portable architecture in Britain, the Metabolism Group in Japan were pursuing similar idealised environments. They took the principles of adaptability in traditional timber dwellings and applied them to modern high tech architecture. The key to the work of the Metabolists was a philosophy of allowing for replaceability and changeability of components in such a way as to not disturb the remainder of the building. This designing for disassembly was evident in early works such as the Mova-house system, which, in a similar design to the Plug-in City, used housing modules, with a life expectancy of twenty five years, that were attached to a mega-structure support system (The Approach of Kiyonori Kikutake 1964). Although much of the Metabolist Group's work was unrealised, the 1970 World Exposition in Japan did allow for some of the disassembly technology to be tested in full scale.

The Capsule House in the Theme Pavilion of Expo '70 was meant to represent the city of the future. It was a cluster of individual pods that could be disassembled from each other, and from the mega-structure supporting them, such that individual changes in the use of the house could be accommodated. Another realised work was the Takara Pavilion, whose design was based on a standard modular structure that could be added to and expanded in any direction. In this building approximately 200 six pointed steel crosses were bolted together on site to produce a structure that supported thirty stainless steel habitable capsules (Kurokawa 1977). This construction system used a repetitive structural module that could be assembled and disassembled easily. It would allow the building to be altered over time in such a way that components and materials could be easily reused to expand the building in other areas, or be used on other buildings using the same system.

These visionary projects, many of them unrealised, all exhibit a common practice of utilising technology from outside the building industry to enhance the construction systems and processes. This characteristic utilises the best of common practice in other areas to enhance disassembly. These projects also show concern for access to the components and solutions for the sequencing of disassembly such that parallel disassembly is possible rather than only sequential disassembly.

CONTEMPORARY

More recently there have been several built works, mostly factories, by Nicholas Grimshaw that have exhibited certain characteristics of disassembly. The Herman Miller furniture factory has been designed for disassembly to accommodate future changes in many ways. The building's steel structure is set out on a grid that orders all of the elements of the building. The cladding consists of panels, 3m by 1.25m, that may be opaque plastic, glass, louvred panels or glazed doors. These panels are all interchangeable and cane be easily changed by just two people. This allows the buildings cladding to be altered to suit the internal uses as they are changed to suit different production runs. Similarly the services system inside the building has been designed for flexibility with catwalks that are designed to accommodate new service systems as they are required. The toilets are housed in a standard Portakabin module that can be detached from the services, moved using one of the factory's own fork lifts, and reconnected in any one of fifteen different locations (Action Factory 1977). This means that when alterations are needed in the planning of the factory, the changes can be made quickly with no waste of materials as would normally be experienced in building renovations.

Grimshaw's later factory building for the IGUS company also exhibits many of these same characteristics in response to similar client demands. It has detachable cladding, relocatable toilet and office modules, and if required, the whole building can be converted with minimal effort into a supermarket or office building (Bryden 1993).

Grimshaw's expertise in disassembly is not limited to factories though. The British pavilion for the 1992 World Exposition in Seville was also designed to be fully disassembled after the event. In this pavilion Grimshaw uses technology from outside the normal building industry to create a building that can have a second life. Many of the components of the building, such as water tanks, pumps and solar cells, were designed to be disassembled for later use in Third World countries. Connections between elements of the main structure were simple pin joints such that the building could be disassembled for relocation after the six month expo (Brookes 1992).

In these buildings we see all of the same principles that were employed in the design of the portable colonial cottages of 150 years earlier, as well as some new characteristics of disassembly. Components should be designed to withstand repeated handling for repeated reuse, and disassembly should be possible at all scales to allow for material separation for recycling as well as total building relocation.

CONCLUSION

One of the major drawbacks in the recovery of building materials for reuse is the problem of separation of various base materials and components from each other. This survey of historic examples of building disassembly highlights a number of forgotten technological strategies that can enhance the possibilities of separating materials, components and whole buildings for reuse and recycling. Analysis of these, and other, examples of designing for disassembly, results in a list of recurring technological characteristics that have been used as construction strategies. Such a list includes the following:

- Use light weight materials to facilitate easy handling of components.
- Size components to suit the proposed means of handling.
- Separate structure from cladding to allow changes to the building envelope.
- Provide access to all parts of the building that are to be disassembled.
- Arrange components in a hierarch of access related to life expectancy.
- Allow for parallel disassembly rather than just sequential disassembly.
- Use a modular system that is compatible with existing standards.
- Use low technology solutions and standard tools and practices.
- Minimise the number of different components and connectors.

- Use mechanical connections not chemical ones.
- Provide a means of identification of components and assembly instructions.
- Design using an open system that allows for structural alternatives.
- Avoid deformation of components due to repeated assembly process.
- Allow for disassembly at all scales from materials to whole buildings.

This list is not yet complete, but represents the current state of ongoing research into building disassembly technology. Such a list of performance guidelines could be used by architects and engineers to assist in designing buildings that take full advantage of the economic and environmental advantages of reusing and recycling materials.

As the problems of environmental degradation increase, designers will come under increasing pressure to provide solutions to reduce energy and materials consumption, and reduce waste and pollution production. Designing for disassembly is one possible solution in which a building can be truly deconstructed in a reversal of the construction sequence. This technology has been in existence for many centuries but remains to be fully embraced by the contemporary building industry as a strategy for better building practice.

As Robert Kronenburg (1995, p.7) said, "Very few make much use of knowledge from designs that have gone before and the sometimes more advanced technology available in unrelated applications."

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