5. Design for deconstruction

5.1 Definition

Design for deconstruction (DFD) refers to the design of a building with the intent to manage its end-of-life more efficiently. The process is intended to ensure the easy disassembly of buildings in order to reduce waste generation and maximise the recovery of high value secondary building components and materials for reuse and recycling. This innovative approach encourages designers to incorporate DFD principles at the design stage of construction projects to ensure that the subsequent stages of remodelling, repair and building removal are conducted efficiently (DFD views end-of-life scenarios for building systems, products and services in a holistic manner that includes both asset management and building removal processes). This approach reinforces the need to consider the life cycle of a building as presented in the model for sustainable construction.

A new perspective that is increasingly being debated is that of perceiving buildings as a future resource pool for building materials. Instead of demolishing old buildings and disposing of the C&D waste and extracting virgin materials from finite natural resources to construct new ones, many environmentally inclined construction practitioners are beginning to consider buildings as one of the preferred sources[4] of building materials. The reasons for this include reduced energy and emissions associated with material supply and the conservation of embodied energy contained in secondary materials. When considering buildings as a future source of raw materials DFD[5] is a key element in material retrievability [12].

5.2 Why design for deconstruction

The *longevity* of a building is determined by the building's ability to maintain structural integrity for a long time, as well as its desirability in terms of function and style. The structural integrity of a building is determined by the *durability* of materials and the quality of construction. Desirability is determined by the building's ability to adapt to change over time. Striking a balance between durability and *adaptability* in the design of a building results in building *flexibility* – an important quality in buildings that are constructed according to the principles of sustainable construction.

Bowes and Golton indicate that obsolescence is the dimension that determines the timing of the demolition of a building [13]. Buildings are not demolished only when they have reached the end of their technical design life, quite commonly they are demolished because those who control them have no further use for them. The reasons that lead to buildings having no further use include economic perspectives e.g. financial aspects and location, utility perspectives e.g. function and the environment, social perspectives e.g. style and regulatory control and of course structural perspectives e.g. structural decay [13] and [14].

Designing a building for durability can save costs and reduce the negative environmental impacts related to operation and maintenance i.e. the consumption of materials during renovations and the resultant waste generation. On the other hand, if a decision to demolish a building is made long before the expected end of life, the above can be reversed i.e. the incurred costs of durable materials, which may have cost more, may not be recovered because

[4] Other preferred sources include renewable resources and recyclable waste from other industries.
[5] DFD is used synonymously to refer to design for disassembly.

of the building's short life [15]. This emphasises the salient point that if a building is intended to have longevity, then durability must be balanced with adaptability.

Adaptability in buildings refers to both the shell and interior of a building. Incorporating adaptability in building design enables the building to adapt to changing demands of the intended use as well as the ability to adapt to a different use. This flexibility in building design introduces a fresh perspective of looking at buildings, i.e. as a series of layers that can be configured in various ways to meet the changing demands of the user and the surrounding environment.

5.3 A look at the theory of building layers

Buildings have for a long time been thought of and designed as "eternal entities". Part of the reason for this is that designers and contractors perceive buildings as entities that should last forever (designers are not prepared to invest in structures that will not last and no contractor believes that his structure will be torn down) [12]. Buildings have also generally been perceived to be "complete entities" that are designed to perform as a whole i.e. hence the use of "a building" in singular [6]. Craven *et al* point out that such buildings lack inherent flexibility and are likely to generate more waste when modified, in extreme cases their inflexibility can leave no option but for them to be demolished under the pressures of changing demands that are placed upon them [14].

Crowther takes the argument further by pointing out that the notion of "a building" in the singular may be a misconception resulting from the reading of a building in a limited timeframe [6]. Few, if any buildings actually remain in their initial state for more than a few years or a couple of decades at most. Building remodelling, repair, expansions and maintenance continually change the building. These changes occur both on the exterior and interior of the building in response to the demands of the user and the surrounding environment. This means that the exterior and interior of a building should be able to respond to the criteria determined by the economic, utility, social and structural perspectives mentioned earlier for the building not to be obsolete.

Table 5 gives some of the elements of the building exterior and interior and their estimated lifespans.

Table 5: Lifespan and replacement cycles of building materials and components, source [14]

Building Component/Material	Estimated lifespan (years)	Replacement*
Paint, awnings, solar collectors etc.	15	Replaced 9 times in the average life of a structure
Flooring, plumbing fixtures	30	Replaced 4 times in the average life of a structure
Plaster, windows, piping systems	60	Replaced at least twice in the average life of a structure
Primary structures	150	-

* Replacements according to the estimated life of the primary structures in row 4

Note: A detailed table of building layers and lifespans is shown in Appendix F – adopted directly from [6].

The theory of building layers enables the designer to incorporate flexibility into building design. This allows a building to be easily disassembled into components. It also allows the selective removal and replacement of specific components without affecting the rest of the structure. Without a doubt, this theory will be useful in the design of buildings with intent to deconstruct at the end. However, an understanding of the building design i.e. finite or eternal, material type e.g. virgin, recycled content or composite, reusability, recyclability, the various lifespans of chosen materials, component connectivity and the changes in user and environmental demands will be key to its use.

5.4 Useful hints for design for deconstruction

Design for deconstruction is still not used extensively in practice. There are a number of reasons for this, the two of which are:

- The benefits of using the principles of design for deconstruction take anything between 30 to 150 years before they are realised. This means that the designers may not live to see the benefits of their designs, which is not a good incentive.
- There are no official guidelines yet on how to design buildings for deconstruction.

Not much can be done about the first constraint, except for the construction industry to target the services of environmentally inclined designers, “the converted” or “green designers”, for construction projects. The second constraint limits the use of DFD principles during building design.

A number of researchers in the field of building deconstruction internationally have realised this among other shortcomings and are currently dedicating their efforts into the integration and consolidation of recurring themes, principles and experiences that have come out of previous research efforts and deconstruction projects. It is expected that some of these efforts will contribute to the formulation of a set of ‘guidelines for building deconstruction’ that can be used by building designers. In addition, other industries e.g. the automotive industry are more advanced in terms of design for disassembly and lessons could be learned from their experiences and adopted to the construction industry.

Table 6 presents a list of principles that can be used as a guide when considering design for deconstruction in projects.

Table 6: Principles of design for deconstruction, references [4], [6], [15], [16]

Item	Principle
Information	- Keep the records of all information relating to the design and construction of a structure, for example: Architectural plans Engineering designs Components used Materials used Photographs of connections, location of wiring system etc.
Building design	- Incorporate flexibility into the design (durability, adaptability and

	building layers), for example: Consider using modular design (standardisation, prefabrication) Consider preparing designs for the disassembly of the building Design buildings that can be easily converted to a different use Consider designing demountable buildings Choose materials based on life cycle costs and salvageability (not just capital cost)
Materials	- Use a minimum of different materials - Reuse secondary materials - Use renewable, recyclable and recycled content materials - Avoid materials containing hazardous substances - Choose materials with low embodied energy - Avoid composite materials
Connections	- Use a minimum of connections - Use a minimum of different types of connections - Avoid adhesives and nails - Use standardised connections i.e. connection points, connectors and building components - Use easily removable, reusable connectors - Use building components designed for repeated use
Material salvage	- Always consider the end-use hierarchy when designing for deconstruction, i.e.: **Reuse** – Building Components Materials **Recycling** – Upcycling Recycling Downcycling **Incineration** – Energy recovery Volume reduction **Disposal** – Landfill

Note: A detailed table of principles of design for deconstruction and the hierarchy of recycling is included in Appendix G – adopted directly from [6]

5.5 Building component considerations

When designing buildings for deconstruction, care should be taken in the selection of building materials. The material selection process should be guided by the principles of sustainable construction (see Figure 1). The quality of each building component and the performance of the structure, as a whole, should not be compromised.

In some cases, conflict will be inevitable for example:
The use of "green" materials *vs.* their usefulness at deconstruction stage
Cost and embodied energy *vs.* durability

In such cases decisions will have to be made by evaluating the priorities of the project e.g. resource reuse *or* renewable resources and by analysing the life cycle costs of the project e.g. using expensive durable materials *or* cheap replaceable materials.

The main aim of designing buildings for deconstruction is to ensure that at the end-of-life the building can be disassembled relatively easily, the waste generated is minimised and the salvaged materials are maximised. Thus for buildings to be the resource pool of the future, designers should use materials and construction methods that will yield a high percentage of salvaged materials that are fit for reuse and recycling.

Table 7 gives a summary of some building component considerations for design for deconstruction.

Table 7: Building component considerations for design for deconstruction, references [12] and [16]

Component	Elements	Materials	Comment
Foundation and floor	Foundation Floor bed Floor finish	Concrete Timber Ceramics Carpets	Concrete – cannot be reused immediately, but can be recycled into secondary materials Timber – can be reused immediately and recycled into various products Ceramics – durable, cannot be reused immediately, but can be recycled Carpets – recyclable, but process complicated, small market
Walls	Frame Siding Wall finish	Timber Steel Concrete Brick Gypsum drywall	Timber *as above* Steel – needs extra care if immediate reuse is considered, most recycled material Concrete *as above* Brick – high reuse potential, can be recycled into secondary materials Gypsum drywall – highest percentage of generated construction waste, recyclable if not contaminated, small market
Roof	Frame Sheeting Ceiling	Timber Metal Asphalt Concrete Polymers Gypsum	Timber – *as above* Metal – durable, costly initially but cheaper in long term, most recycled category of materials, established secondary market Asphalt – affordable, not reusable initially, can be recycled to road materials depending on prevailing policy Concrete *as above* Polymers – usually composite, not reusable or recyclable Gypsum *as above*

5.6 Conclusions

Design for deconstruction can contribute to the construction industry's quest to achieve sustainable construction, particularly through natural resource conservation, waste reduction and waste recovery for reuse and recycling. It is important that designers learn to consider design for deconstruction during building design because the decisions made during design influence the deconstructability of a building at its end-of-life.

The main elements to consider when designing for deconstruction are:

- Using the model for sustainable construction as a guide during design
- Designing for flexibility i.e. balancing durability and adaptability and using building layers
- Using principles of design for deconstruction
- Selecting the right materials for building components