TRANSFORMABILITY OF CONVENTIONAL AND DYNAMIC LOAD BEARING BUILDING NODES

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Summary

Due to inadequate design many building materials and components are lost whenever a building no longer meets contemporary needs. Those adaptations are labour intensive because disassembly is difficult and not planned. However, by implementing the time dimension in design, a building could be re-build dynamically and could respond to changing requirements of society and individuals, such as changing family composition, changing patterns of life and changing work environment.

The last few decades design strategies and approaches were developed to facilitate change and the reuse of building parts; nevertheless dynamic building is still restricted to a small scale and specific functions, such as temporary buildings. A frequently cited reason of this restriction is the lack of constructional knowledge. Therefore, in the context of this paper it is examined whether there are actually gaps to build in a dynamic way by exploring which load bearing building nodes, based on different building methods (e.g. masonry construction and timber construction), do have a transformable variant and which do not.

Firstly, a summary is given of the mean characteristics which facilitate disassembly and the technical transformability of a structure. Secondly, conventional load bearing structures and their dynamic variants are being verified against those characteristics in order to evaluate the transformability of the load bearing structures.

Keywords: Design for disassembly, reuse, detailing, conventional building methods

1 Dynamic characteristics

The characteristics, which will be used to evaluate the transformability are established by literature of Durmisevic [1], Nordby [2], and Paduart [3].

Firstly, in order to create dynamic buildings it is necessary to disconnect physically the functional parts/ layers with different life spans, otherwise more parts than wonted will be damaged during upgrading processes of a functional part with a shorter life span. Brand differs six building layers: site, structure, skin, services, space plan en stuff [4]. Leupen added a seventh building layer: circulation [5].

Furthermore, a component should have limited dimensions and weight to be handled easily. Another dimensional criterion is the use of generative dimensions, which gives architectural flexibility. By standardizing components and by supplying sufficient assembly

and disassembly tolerances dismantling and reassembly is facilitated. To reduce damage a component has to be physically suitable or durable to be reused repeatedly. [2]

To close the cycle on material level McDonough and Braungart proposed Cradle to Cradle as a solution, whereas the used building materials are upcyclable or biodegradable [6]. In addition Nordby advises to use a minimum of different types of materials in a component, including connections for sub-assemblies, which simplifies sorting [2].

Nevertheless the connections are a main aspect in closing the cycles on the different scale levels of a building. If a joint is not dynamic the materials cannot be recycled, the components cannot be reused and a building cannot be adapted. Morgan and Stevenson classify connections into three categories: infilled (e.g. adhesives and cement mortar), direct (e.g. nails and staples) and indirect (e.g. bolts and dowels) depending on their degree of reversibility [7]. Those connections should be accessible in order to facilitate disassembly. To facilitate (dis)assembly it is necessary to comprehend easily the way components are connected. Minimal skills should be sufficient to (dis)assemble a building.

According to Durmisevic it is important to make independent functional clusters of components to reduce the number of (dis)assembly sequences on site, which is often a bottleneck for disassembly [1]. Paduart translates this principle in a minimum of (different types of) used connections and assemblies and in the application of pre-clustering or pre-assembly [3]. By introducing a base element as an intermediary between different assemblies those clusters become independent. The disassembly sequences are as well influenced by the geometry of a component, the interface design. For example an interpenetrating geometry is less suitable for disassembly, for the reason that disassembly is only possible in one direction. At last, to minimize assembly sequences parallel disassembly of components should be possible. [1]

2 Transformability of conventional and alternative load bearing building nodes

In this section it is explored which conventional load bearing building nodes, based on different building methods (e.g. masonry construction and timber construction), do have a transformable variant and which do not. Moreover, the properties mentioned above are in this section used to compare the characteristics of conventional construction methods and their dynamic alternatives. The properties of the building nodes are based on professional literature and product brochures.

Not for every conventional building method has there a more dynamic alternative been found. Timber element construction has already some dynamic properties, which makes it difficult to find a more dynamic variant. Massive building methods constructed with stones (e.g. loam structure) do not have an alternative yet. This is due to the structural working of such walls, which is based on a monolithic entity. For masonry construction there is an alternative still in the making, namely a smaller variant of Legioblocken®, the Q-bricks (**Fig. 1**). At the moment, research is being done to use the stones for emergency sheltering. The small, standardised stones could be piled up by one person. However, the small dimensions cause a large number of components and connections. This could be improved by the preassembly of components in order to reduce the number of (dis)assembly sequences on site.

Traditional massive timber solid construction, for example the northern European log work (**Fig. 2**), is already quite transformable and is more adaptable on many levels than for

example the so called dynamic building system Holz100 (**Fig. 3**). The wooden elements are mostly connected with dowels, making them not easy to dismantle. The Holz100-elements can have all possible dimensions without being based on a generative system, while the trunks used for log work are sawed in more or less standardized dimensions. On the other hand, the Holz100 elements are pre-assembled, which reduces the number of (dis)assembly sequences on site. Furthermore, parallel (dis)assembly of the elements is possible. The downside of prefabricated elements is the size; they are too big and too heavy to be assembled by only two persons.

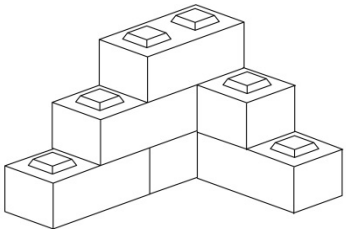

Fig. 1 *Building node of Legioblock® building system*

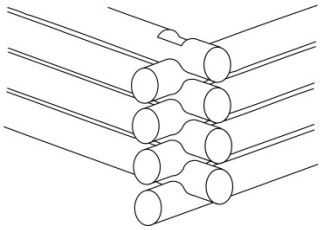

Fig. 2 *Building node of traditional log work*

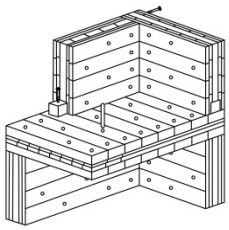

Fig. 3 *Building node of Holz100 building system*

The CD20 building system is an example of a satisfactorily dynamic alternative of concrete plate construction and concrete skeleton (**Fig. 4**). The elements are standardized and are reversible connected with the use of steel pens. There exist for wood-frame construction dynamic alternatives too, for example the Lukaslang® building kit (**Fig. 5**). The parts are standardised and are reversible connected, but, in contrast to traditional timber element construction, not in a labour intensive way.

Steel standardized columns and beams are already regularly demountable constructed with the aid of standardized bolts. Therefore, it is difficult to find a more transformable variant of steel skeleton. Quincon® is an option (**Fig. 6**), but it uses its own bolt system. This is a common problem with the dynamic systems, the skills and tools needed to demount the components are more sophisticated and the connections have less (dis)assembly tolerances. On the other hand, dynamic systems have more accessible connections; they also often have a base element and a good interface geometry.

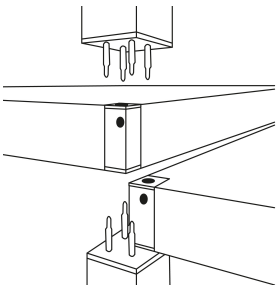

Fig. 4 *Building node of CD20-building system*

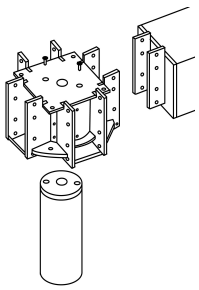

Fig. 5 *Building node of the Lukaslang® building system*

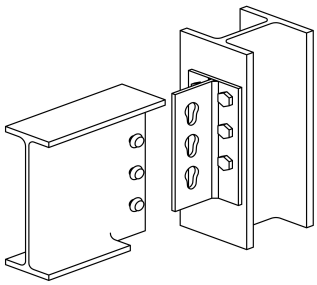

Fig. 6 *Building node of Quicon® building system*

The degree of interference of the structure on the other building layers is linked to the building method. For instance the structure of massive building methods will influence all other layers, except the furnishing; in contrast to the other extreme, skeleton structures.

There are some other properties that depend on the construction method, such as the size of the components and the recyclability of the materials. For example steel and clay can

be recycled in a high quality way, and unprocessed wood can be composted. The amount of different materials used in all those construction methods is limited to a maximum of two, which is good and the components are durable enough to be reused repeatedly. To conclude parallel disassembly of components is not possible with stack work, but it is possible with skeleton structures.

3 Conclusions

At present, there exist various transformable load bearing building systems; even some conventional building methods are already quite transformable (e.g. steel skeleton connected with bolts). Nevertheless, there is no dynamic alternative yet for a few conventional building methods, for example masonry.

The dynamic alternatives can be perfectly used in contemporary construction work in order to respond to changing requirements of society and individuals. The variants score better on some dynamic properties (e.g. reversibility and standardisation), however they are not an improvement over the entire line (e.g. minimal (dis)assembly skills). For both groups (conventional and alternative) certain properties can be improved in order to be more transformable, other properties are specific to the building method (e.g. functional decomposition).

Acknowledgement

This research is funded by IWT, Agency for Innovation by Science and Technology in Flanders.

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