slimbouwen©,  
a rethinking of building,  
a strategy for product development

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ABSTRACT: Slimbouwen© (Slimbuilding in Dutch means both smart and slim) starts from the appointment that the traditional way of building does not fit the today’s requirements. Building does substantially affect the environment in many ways and the building process became quite complex. Step by step services were added to the already known building structure, without re-evaluating the building tradition. Slimbouwen© is based on a skeleton structure and the separation of services from the building structure. A crucial development for this approach is a floor system which enables the installers to mount their prepared and prefabricated services practically as a whole. The separation of services facilitates a simplification of the process and a substantial gain of time. Slimbouwen© is a new approach and source for research in the frame of the chair ‘product development’ at the Technische Universiteit Eindhoven.

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INTRODUCTION

This contribution is about a vision on innovation or perhaps the lack of innovation in the building market. The last two centuries indeed interesting attempts have been made to change construction in a structural way, but in spite of these attempts it has to be concluded that the bulk market also today is still based on very old building traditions. There surely is innovation, but it is predominantly based on additions on component level. The historical given basics of construction however have maintained. In order to explain this statement a short historical view on construction principles is given. Unless a substantial change of the market requirements the building industry is extremely sticking to traditional building technology.

Twelve eye-openers, strongly related to sustainable, economical and social items, are presented to prove the need for fundamental change.

Slimbouwen© is presented as a conceptual solution for accelerating innovation and product development. In fact it has already been proven to be a successful approach since the first Slimbouwen© products are already developed and applied in the building market.

2. INNOVATION HISTORY

The ancient Romans applied the stacked construction method, the building with stone, on a large scale. Building with stone was already well known for centuries, but the techniques were revolutionary developed and exploited by the Romans.

The Roman highlights are of course the works for water distribution a.o. many tunnels and aqua ducts, the theatres as the Colosseum, baths and other civil works and also the Pantheon is a memorable structure. The span of the dome construction (43 m) was only exceeded in the 20e century in concrete. Also the Roman heating systems (floor and wall heating) is quite spectacular technology.

Apart from the highlights it is also interesting to know how the citizens of Rome were accommodated. Through writings (A.o. Tacitus and Vitrivius), remainders and archaeology the situation can be reconstructed quite well. At the beginning of the era, Rome had about one million inhabitants, most of them being member of the working class or the Roman army. Shelter was arranged in so-called insulae (fig. 1), a kind of apartment buildings that mostly were planned in quadrants round a central court space.

Figure 1: Reconstruction of an ancient Roman apartment building (insula).
The insulae were buildings of three up to five storeys high. Ground level was normally filled-in with commercial activities. The floor plans of the other storeys were divided in rooms. Each room was in fact a house. Access to the houses was provided by a central stairwell. Through wall openings either on the courtyard side, either on the street side, daylight and fresh air was let in. Sometimes in the window openings mica or even glass was applied as a transparent separation, but mostly there was only the opening, that could be closed by shutters. The Romans are praised for their sanitary facilities including (plumb) pipes, valves etc. Nevertheless in the insulae was no water supply. One had to get water from a well or fountain in the central court. Also for the toilet one had to go outside to a public facility. Limited cooking was performed on charcoal fire in the house.

The insulae were built up with masonry till the third floor and from there one continued with light weight timber construction. The quality was poor and regularly buildings collapsed. In the first century under August a regulation existed by which the maximum building height was limited on 21 meters (70 foot), but about the year 100 AD under Emperor Trajanus this limitation was brought back to 18 meters (60 foot). Insulae were build in each Roman city, but remainders are still to find especially in Ostia, the harbour area of Rome.

In the Roman building technique the development of the masonry in particular is of great importance. The Romans already invented cement mortar. Later on they developed for efficiency reasons a kind of poured concrete method. A double row of Bricks or tiles served as a permanent formwork. This method was named Opus Caementicium (fig 2).

A remark has to be made on what remained from the Roman building technique is not representative for the reality. Also the ancient Romans constructed a lot with timber, but since wood did not stand the time of ages as well as stone, a misrepresentative impression remains. Constructing with timber, already many centuries before the Roman empire, has been based on a timber frame with an infill with boards, wattle-and-daub or straw armed loam. Thus apart from the stacked construction method with stone, also the timber frame building method was already widely known.

With the fall of the Roman Empire also the know how of stacked construction technique with cement faded away. During almost 18 centuries there was hardly any basic innovation. Naturally incidents are to be reported, but in general and considering the time span (we are almost 15 centuries ahead) the progress in construction have to be considered as small step innovations. One of these incidents are the construction of gothic cathedrals and of course the phenomenon Leonardo Davinci. Through him and a number of contemporaries, about 1500 AD an innovation wave in construction passed. Wood and Stone however remained also in that time as main construction materials.

The industrial revolution brought in the 18e en19e century cast iron and steel as a new construction material. Cast iron existed already, but Abraham Darby discovered in 1709 in Coalbrookdsdale that by using cokes higher temperatures could be achieved. This discovery facilitated the realization of larger foundries, larger casting-ladles and thus larger parts. His grandson Abraham Darby III produced and built in 1779 near Coalbrookdsdale an iron bridge over the river Severn. The bridge consists of five arched trusses with a span of 33 meters. Each arch is assembled out of two main parts. The technology is to be considered as a break-through. Yet it lasted up to almost 20 years for this new technology concurred a broader basis. After that it became clear that a basis was created for the industrial approach of building and especially steel skeleton construction methods.

A famous example is Crystal Palace (fig. 3) of architect Joseph Paxton, a world exhibitions building in short time erected in 1851 in Hydepark London and designed on the necessity of moving the building. It has been demounted and rebuilt in 1853 in Sydenham London where it functioned for many years. Unfortunately in 1936 it was destroyed by fire. Crystal Palace was an early examples of building in glass and steel.

Figure 2: Opus Caementicium

Figure 3: Crystal Palace (1851), an early example of industrial and demountable building.

Around 1900 in the United States the first examples of high-rise buildings were erected. Lack of space and European examples especially the Eiffel
tower (1889) opened the way to new steel based building techniques.

Figure 4: Early high-rise. The Reliance building, Chicago, 1895.

Why so much attention to building history? Well, in my conviction only by this approach one can become aware of the fact that in spite of 20 centuries of building evolution we after all are still dealing with the very same two mainstream building methods: Stacked construction and timber frame.

3. INNOVATION BY ADDITION

One might be touched by the Roman technology level. The fact that we are, also tells us something about the present level of technology. Surely there was innovation. Especially in the past century the quality level increased substantially. Sound insulation and fire protection were improved, energy consumption for heating houses was reduced, communication techniques and domotics were introduced, etc. Only all this innovation has not caused a fundamental other building approach. We maintained the building technique and we only added lots of technology. That is what is meant by 'Innovation by addition'.

Through that approach, we finally created a moloch.

This moloch mainly is caused by adding lots of installations and services.

In 1900 the installation technique was limited to a sewerage system, water supply and a chimney. Now, 100 years later, the installation technique is about 35 - 40% of the total building budget. For vertical transport shafts were added to the building. For the horizontal transport (piping and wiring) there was hardly any solution but to hung it under the floor. Electrical services and water supply were fixed on walls.

In the second half of the 20e century, services in sight were not accepted any longer. Nowadays we use to hide them in walls in milled chases, being covered afterwards or we hide them into poured concrete constructions. Or we still hang them under floors covering it with suspended ceilings. In fact the ceiling is also an addition. A complication of this solution is the bypass sound to neighbour rooms through the ceiling cavity. One of the possible solutions is to let the partition wall penetrate through the ceiling and connect it on the solid floor above the ceiling. However with that solution the flexibility of the partition walls is very poor. That conclusion has initiated the development of a ceiling grit and barriers above this grit. Again an addition, but the story is not finished since services have to pass these barriers. Anticipating on that problem sleeved joints were developed. In this case therefore addition on addition.

The interweaving of services with the building parts has in general become very high (fig. 5).

Figure 5: Services to hide into poured concrete

This is an important conclusion since this has caused an inefficient building process. For one thing, the consequence is that the finishing process has become very complicated and is carried out by many disciplines with a high rate of mutual interdependency.

To illustrate this phenomenon: Around 1900 with the realizing of the structure and shell, the building was almost ready. These days, with the completion of the structure and shell, only 20-30 % of the building process has been established.

All in all it is remarkable that the building method as a whole never was rethought.

4. COMPLEX BUILDING SUPPLY CHAIN

It is quite explicable why innovations in the building industry only slowly are adopted and why they have been based on the principle of 'innovation by addition'. The main explanation is hidden in the complex structure of the supply chain.

The building supply chain is rather complex. The chasm between on one side the large resource related multinationals and on the other the end consumer, for instance a tenant of a building, is quite impressive. Another phenomenon is that in the building process some participants can be important decision makers without being a direct customer. Especially the designing and engineering group and the authorities on all sorts of levels are important players. Moreover the industry consists of relatively
small-scale businesses that all represent only a partial interest. Explicit market leaders are missing in most of the sectors. The consequence is that in building business nobody consider himself as an initiator and product champion.

5. WHEN IS CHANGE TO COME?

In this paragraph, a number of eye-openers is presented, showing that the traditional way of building in the contemporary context is no longer tenable. The statements are based on the Dutch situation, however the effect is probably quite similar in other Western and industrialized countries.

1. For the realization of 1 m² net floor surface 1,000 up to 1,500 kg of building material is applied. To compare: A mobile home weighs about 80 kg per m²;
2. The building industry generates 35% of all waste. In the Netherlands annually about 65 millions of tons of waste is produced. With more than 22 millions of tons the building industry is a major part of the waste problem;
3. 25% of all road transport of goods is building related;
4. 25% of a building volume is packaging. Customers rent or by gross space of which a quarter is taken in by construction or hollow cores.
5. The price of houses is compared to consumer goods considerably risen. Since 1970 the price of a house is risen four to five times. Cars, washing machines and refrigerators have only been risen only two times over the same period;
6. Buildings are built with a technical life span of 100 year or more, but often they are demolished already within 35 year. The market and users are obviously significant more dynamic than the flexibility of buildings permit;
7. With 65,000 houses each year, the existing stock (in the Netherlands 6,500,000 houses) will be totally replaced in 100 years. A substantial part of the number of new houses is however meant as expansion of the stock. Taking this into account we come to a replacements period of 150-200 years. Therefore we should nourish the stock and at the same time new building volume should be realized as flexible as possible;
8. Flexibility counts also for energetic and sound insulating measures. Improvements afterwards are in general not economic feasible, yet we keep building with the standards of today and not with those of tomorrow.
9. The traditional building process requires a lot of building site personnel and expertise that is not sufficiently available. Being a building worker is not socially accepted and because of that the inflow rate is low (fig 6);
10. In the building industry cost of failure are within the range of 5-15% of the turn over. This is far more than what is accepted in an industrial environment;
11. The progress in the early stage of the building process (structure and shell) is experienced as rather fast. The top of the building is generally reached quite soon after the foundation ceremony. After that it looks like there is no progress at all.

Figure 6: The decreasing of the number of bricklayers in the Netherlands

12. De profits in the construction industry are estimated on about only 1 %. In innovation theory a structural low efficiency is to be considered as an indication that the product has reached the end of its life cycle;

The eye-openers can be considered as symptoms that support the theorem that rethinking the building industry is unavoidable. The building industry, including technique, process as well as organization has, by the addition of many incremental innovations, evolved to the present moloch, by which the participants have become so much part of it, that they do not percept it as a moloch. Only for this reason there is a barrier to concur. The society is ready for change.

6. SLIMBOUWEN©

Slimbouwen© is to be considered as a strategy that reacts to the problems as described. It is an open view. Slimbouwen© will result in concrete products that facilitate its realization and in fact it already has generated some new products. In itself Slimbouwen© is certainly not a building system. It is more like a shareware platform. Only the name is protected to avoid devaluation of the conception by commercial misuse.

Slimbouwen© in this function offers also a basis for development strategy for the industry and by this to provide for an infrastructure and coherence to the fragmented development efforts.

One of the main thoughts is to rearrange the building process from a parallel process into a serial process existing of only a few main steps. This has to be explained.

The traditional building process and especially the finishing process, can be characterized as a complicated process in which the participants do carry out activities with a high rate of interdependency to other participants. The result is a lot of overlap, inefficiency, failure costs, complex coordination, lack of mutual respect, etc. Participants do have to return on site several times since the proceeding is dependant of other participants. In fact this process is a kind of parallel process (fig 7).
Figure 7: The traditional parallel building process

A sequential process containing only a few major sub-activities, can only be obtained by a separation of services from the rest of the process. In the traditional process the services are interwoven with almost all building parts and in a new approach this has to be avoided. Only then it will be possible to divide the building process into a limited number of sub-processes with a low interdependency rate.

The participants are responsible for preparation, production, mounting, guarantees, etc. for the total sub-system. This is similar to other industrial branches. For example in the car-industry, the electric wiring is installed in one course. This is facilitated by the car-design where in details the process of wiring has taken into account. The one course installation also enables the development of a cable-tree. Actually this is where an industrial process is all about.

Industrial and flexible building has been subject for analysis and developments for a long period. In 1914 Le Corbusier came up with the domino concept. It was based on separation of structure and fill in. However in those days Le Corbusier hardly had to deal with services. In 1969 Professor John Habraken published his book “De dragers en de mensen, het einde van de massa woningbouw” (In English translated under the title: Supports, An alternative to mass housing, the Architectural Press, London, 1972, ISBN 0 85139 225 3). In that book he made statements about a separation of structure and fill in. However in those days Le Corbusier hardly had to deal with services. In 1969 Professor John Habraken published his book “De dragers en de mensen, het einde van de massa woningbouw” (In English translated under the title: Supports, An alternative to mass housing, the Architectural Press, London, 1972, ISBN 0 85139 225 3). In that book he made statements about a separation of structure and fill in as well and in his further development, he, together with Professor Age van Randen, already generated solutions for the separation of services (fig 8).

Figure 8: Separation of services by the Matura system (top floor)

In the eighties and ninetieth, at Eindhoven university, experience with the separation of services was embodied in a research and development project, the so called ISB project (fig. 9).

Figure 9: The ISB project

I was involved in that project as a development team manager. One of the problems with this system was the industrial realization as well as the adoption by the market.

As a follow up, a development team of A+ created the so called Infra+ concept (fig 10). Infra+ is a hollow core floor system suitable for horizontal distribution and access of services in the structural zone (no additional space upon or beneath the floor required). After positioning the services the floor is covered on the upper side. Meanwhile this product has found already many application and is by the success already followed by various interpretations by other producers.

Infra+ is an example of product development that was initiated by the Slimbouwen® strategy.

Figure 10: The infra+ floor concept
The natural solution for the sequential building process is a division in:

- Foundation, skeleton and floors;
- Skin (Outer walls + roof);
- Services (vertical through shafts, horizontally through hollow floors);
- In fill (top floor and partition walls).

user obtains a flexible solution in which future changes are feasible.

7. RESEARCH

The research in the frame of Slimbouwen© in the future will focus on the consequences and possibilities for both new product and market development. Right now the University obtained a grant to proceed together with industrial companies. Examples of research topics are:

- Vibration control in lightweight structures;
- Sound insulation;
- Comfort control in lightweight buildings (a.o.: low temperature heating and building activation);
- Development of Slimbouwen© strategies for the refurbishment market;
- Development of flexible installation technology, floors, structural systems, and other parts;
- Adaptability for sustainable energy;

CONCLUSION

This paper has shown that there is hardly any development on a fundamental level in the building market. As an answer a feasible strategy for innovation and product development in the construction market was introduced. This building strategy (Slimbouwen©) is based on separation of services from the structural parts. As a deliverable already some products were initiated and applied in the market. Also future research in the frame of the chair product development will be based on this strategy.

REFERENCES


