SLIMBOUWEN® A STRATEGY FOR INNOVATION

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Slimbouwen® (SLIM in Dutch stands for both smart and lean, BOUWEN is the Dutch word for ‘to build’) starts from the appointment that the traditional way of building does not fit the today’s requirements anymore. Building does substantially affect the environment in many ways and the building process became quite complex. In the last century 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 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.

Keywords: building strategy, industrial, efficiency, flexibility, innovation, product development.

INTRODUCTION

This contribution is about a vision on innovation or maybe 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 been maintained. It is remarkable that unless a substantial change of the market requirements, the building industry is still 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 in the Netherlands it has already been proven to be a successful approach since the first Slimbouwen® products are already developed and applied in the building market. Still there is a lot to be done in order to achieve further efficiency and to adapt the anchored routines.

STRUCTURAL BUILDING INNOVATION UP TO 1900 AD

The traditional building process is also nowadays strongly based on ancient lines. Often it seems that certain phenomena in building are invented at a certain point, but in many cases they evolved slowly and remained through the ages. Sometimes they

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even were forgotten and had to be reinvented, not to speak about the never reinvented values which might still be hidden for us in our era.

The ancient Romans applied the stacked construction method (building with stone or brick) 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), theatres as the Colosseum, baths and other civil works. Also the Pantheon is a memorable structure. The span of the dome construction (43 m) was only exceeded in the 20e century in concrete. And of course also the Roman heating system (floor and wall heating by distributing heated air) is generally considered as 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 government and 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 and distributors, casted taps, pumps, valves etc. Water was considered to be very important in those days. Compared to our era the water consumption was about 3 times higher. 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 build up with masonry till the third floor and from there one continued with light weight timber frame structures. 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 70 pes[1] (approx. 21 meters), but

[1] One pes = 296 mm

about the year 100 AD under Emperor Trajanus this limitation was brought back to 60 pes (approx. 18 meters). 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 and for efficiency reasons they contagiously developed a kind of poured concrete method. A double row of Bricks or tiles, anchored by stone or wooden connections, served as a permanent formwork for the concrete to be poured in between. This method was named ‘Opus Caementitium’ (fig 2).

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 does, a misrepresentative impression remains. Timber frame with an infill with boards, wattle-and-daube or straw armed loam, was already applied for many centuries before the Roman empire. Thus apart from the stacked stony construction method, also the timber frame building method was already widely known.

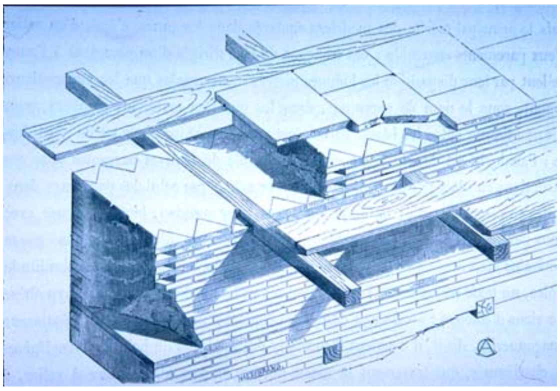

Figure 2: Opus Caementitium

With the fall of the Roman Empire also the know how of stacked construction technique with cement faded away. During the ages up to the 18th century, 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 very modest. Amoung the incidents are the construction of cathedrals, castles and ramps and of course the work of Brunellesschi, Leonardo Davinci and Michelangelo. Through them and a number of contemporaries, about 1500 AD an innovation wave in construction passed. Still wood and Stone remained also in that time as main construction materials and also the building process was not fundamentally changed. We even lost a lot of Roman know how. For example cement technology disappeared completely and was finally reinvented in the 19th century.

In the 18e en19e century cast iron and steel was introduced as a new construction material. Cast iron already existed, but Abraham Darby discovered in 1709 in Coalbrooksdale that by using cokes as a fuel, 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 Coalbrooksdale 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 frame 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 example of building in glass and steel. One of the examples of disintegration of structure and fill in.

> Around 1900 in the United States the first 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 (fig. 4).

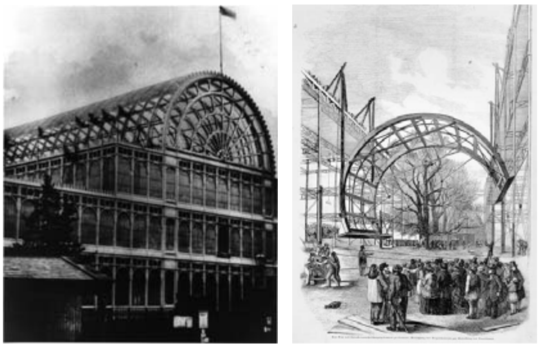

Figure 3: Crystal Palace (1851), an early example of industrial and demountable building.

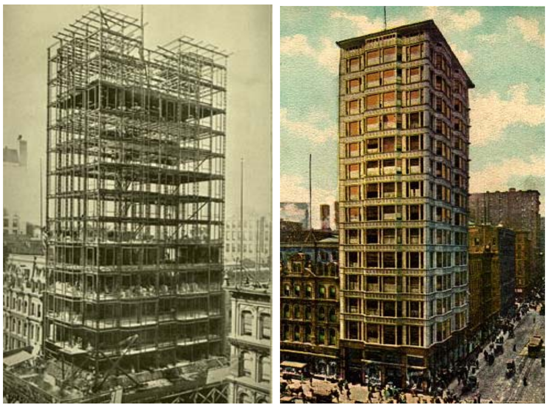

Figure 4: Early high-rise. The Reliance building, Chicago, 1895.

INNOVATION BY ADDITION IN THE 20TH CENTURY

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 existing building technique and we only added lots of technology on a component level. That is what is meant by ‘Innovation by addition’.

Adding to the existing creates inefficiency at the end and that is exactly what happened in the construction industry.

The inefficiency mainly is caused by adding lots of installations and services during the last century. 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 30-40% 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. We still hang them under floors covering it with suspended ceilings. In fact the ceiling is also to be considered as 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 even addition on addition.

Through this way of stacked innovation the interweaving of services with the building parts has become very high.

This is an important conclusion since it 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.

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 do not exist in most of the sectors. The consequence is that in building business nobody consider himself as an initiator for total change.

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 quite similar in other Western and industrialized countries.

1. For the realization of 1 m^2 net floor surface 1,000 up to 1,500 kg of building material is applied. To compare: A mobile home weighs 80-100 kg per m^2;
2. The building industry is responsible for 35% of the total waste production. 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. The production of building materials represent 8-10% of the total energy consumption;
5. 25% of a building volume is packaging. Customers rent or buy gross volume of which about 25% is taken in by building structures or hollow cores.
6. The price of houses is compared to consumer goods considerably risen. Since 1970 the price of a house is multiplied with about 400%. In the same period consumables like cars, washing machines and refrigerators have only been multiplied by 250%;
7. 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;
8. With 65,000 houses each year, the existing stock (in the Netherlands 6,800,000 houses) will be totally replaced in about 100 years. A substantial part of the number of new houses is however meant for 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;
9. Flexibility counts also for energetic and sound insulating measures. Improvements afterwards are in general not economic feasible, yet we design buildings with the standards of today and not with those of tomorrow or with facilities serving future improvements.
10. The traditional building process requires a lot of building site personnel and expertise that is not sufficiently available. Being a building worker is not very popular anymore and because of that the inflow rate of youngsters is very low;
11. In an industrial environment profits are in the range of 10% of the turn over and falure costs in the range of 1-2%. In the building industry (contractors) it is the other way around. Average cost of failure are approx. 10% of the turn over. Profits in the range of only 1-2%. In innovation theory this is a strong indication for an end of life situation;

12. 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 realised quite soon after the foundation ceremony. After that it looks like there is no progress at all;

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 mayor inefficiency and source for environmental damage. Nevertheless the participants in the building process have become so much part of it, that they do not percept it as a problem. For this reason there is a barrier to concur and this will be a drag for progress. However the society is ready for change and the consciousness of social effects will continuously raise the pressure on the supply chain. Related to the mayor effects even governmental intervention is very conceivable and this might change this process from evolution to revolution.

SLIMBOUWEN®

Slimbouwen® is to be considered as a strategy that reacts to the problems as described. It is an open view. The trademark is only to prevent devaluation of the concept by commercial misuse treasured by a foundation under the same name. Slimbouwen® will result in concepts and 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.

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 objectives is to rearrange the building process from an on site parallel process into a serial process existing of only a few main steps with a minimum of interdependency.

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 the progress of other participants. In fact this process is a complex process, where facades, roof, services and infill more or less are shaped in parallel (fig. 8, left scheme)

A sequential process containing limited number of 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 than it will be possible to divide the building process into a limited number of sub processes with a low interdependency rate.

Each main participant is responsible for preparation, production, mounting, guaranties, 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 only one course. This is facilitated by the design and engineering where the process of wiring has taken into account. The one course installation also enables the development of a cable-tree.

Actually this is basically where an industrial process is all about. At first a proper division into sub processes and next comes the prefabrication and then the automation.

Industrial and flexible building has been subject for analysis and developments for a long period. In 1914 Le Corbusier came up with the Dom-Ino concept. It was based on separation of structure and fill in. However in those days Le Corbusier hardly had to deal with services. In 1972 Professor John Habraken published his book “Supports, an alternative to mass housing” (already published in 1961 in the Dutch language). In that book he made statements about a separation of structure and infill and later he was also involved in developing technical solutions for the separation of services.

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. 6) that has lead to 2 prototype houses and a broad discussion about how to build with breakthrough results.

Figure 5: The ISB project

One of the problems with the ISB system was the industrial realization as well as the adoption by the market.

As a breakthrough follow up, a development team of A+ created the so called Infra+ concept (fig 6). 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.

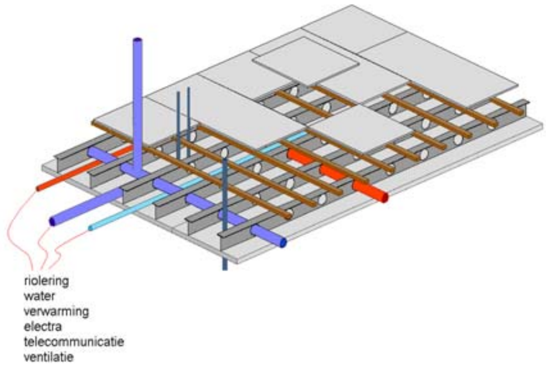

Figure 6: The infra+ floor concept

Figure 7: Example of application of Infra+ in a housing project in Etten Leur (Netherlands)

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)

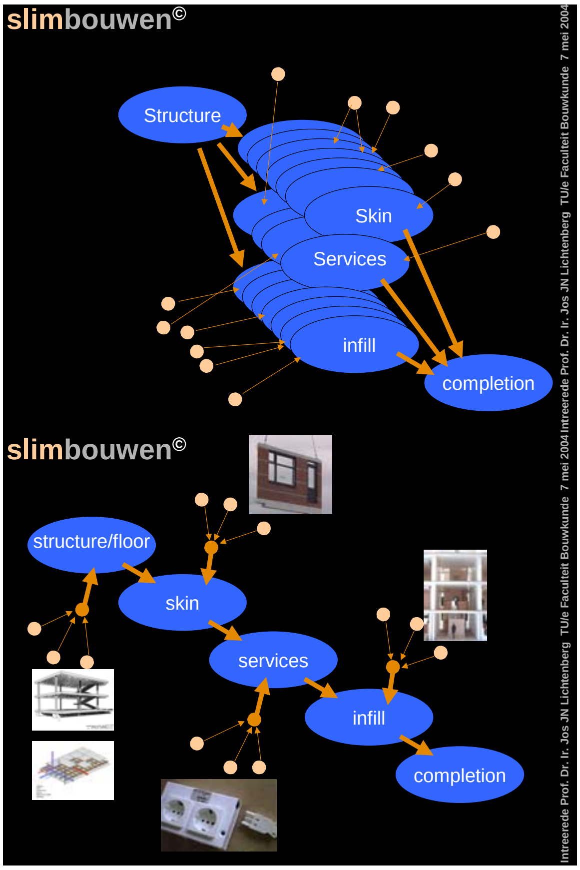

Figure 8: The traditional parallel process (left) and the sequential building process (right)

By this approach the building process time will be substantially reduced and therefore competitive, it will be possible to construct considerably lighter at a much higher and predictable quality level and the user obtains a flexible solution in which future changes are feasible.

The above strongly emphasized on the process aspects of the Slimbouwen® concept. It is to be expected and also already brought in practice, that this approach brings mayor economical advantages.

A second value of the concept is the flexibility which enables owners to adapt buildings to users and market developments. The division of services is a basis for obtaining flexibility and adaptability. For exploiting the building this is an essential aspect, but since it is not in every market equally valued it is to be considered as an additional quality.

A third aim in relation to Slimbouwen® is the reduction of materials and volume. Also this has already been brought in practice. The already shown dwellings in fig. 7 (36 houses in Etten-Leur, Netherlands) only weigh about 50% of comparable traditional build houses.

In fact the reduction of weight, material and volume were the main drivers to apply Slimbouwen® in a multi-storey apartment building in the town centre of The Hague (Netherlands). The project is called La Fenêtre and about to be delivered.

Figure 9: La Fenêtre, The Hague the Netherlands

BRIDGING SCIENCE AND PRACTICE

One of the important aspects of Slimbouwen® is also that it acts as a language between practice and science. And by that to a better focussing of research subjects. The research in the frame of Slimbouwen® in the future will focus on the consequences and possibilities for both new product and market development.

As a result of the communication between market and university some research topics have been identified:

- 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;

The Slimbouwen® programme only started last year. Yet on basis of the natural interest of the market, the already mentioned foundation Slimbouwen®, involved companies, market platforms (s.a. for the healthcare market) and grants provide for a growing financial basis to carry out the necessary research.

CONCLUSION

In the buildingmarket there is hardly any development on a fundamental level. 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 and focuses on:

- Process efficiency
- Flexibility
- Material and volume reduction.

As a deliverable already some products were developed and some are initiated. Also future research in the frame of the chair ‘product development’ will be based on this strategy. Meanwhile the concept is applied in the market on a growing scale.

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