Technical developments in high-rise building

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***Abstract*- What are the considerations when opting for high-rise building? What construction techniques for the logistics are applied in Europe? What ecological innovations are applied? What are the technical conditions for combined use of high-rise building seen from a vertical point of view? What are the differences in technical aspects of high-rise construction in the world? What are the market differences between the continents?**

***Index Terms*—High-rise building, development, clients, differences between continents, combined use in a vertical way, innovations, ecology.**

I. Introduction

THIS is a report of the results of a large-scale study of technical developments in the construction of high-rise projects. The spread of the world's population is changing and leading to a rise in urbanisation. This increased concentration of the population may result in a rise in the amount of high-rise building. Many developments influence one another and the relationships between them are shown in the diagram (Fig. 1) below.[1]

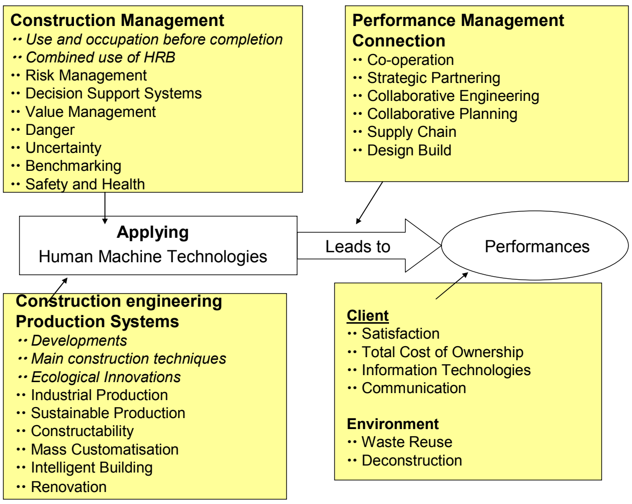

Fig. 1 Relationship between developments in High Rise Building (HRB).

This research was conducted in 2004 and 2005 by the Construction Management and Engineering Research Group of Eindhoven University of Technology [3].

II. Research Questions

The research questions concern:

1) *Necessary changes in the performance of High Rise Building*
2) *Developments in Production Systems*
3) *The Construction Management approach*

According to this categorisation, the various detail questions will be dealt with in Chapter IV.

III. Research Method

The research was conducted between November 2004 and March 2005. It was done in 12 parts by junior researchers of the CM&E Group at Eindhoven University of Technology. To facilitate the proceedings, they carried out extensive research into high-rise building all over the world and performed an analysis of a wide range of exceptional projects:

- Coolsingel Tower, Rotterdam, 187 m
- Millennium Tower, Rotterdam, 149 m
- Montevideo, The Hague, 151 m
- Hof Tower, The Hague, 142 m
- Westpoint, Tilburg, 141 m
- Messe Turm, Frankfurt, 256 m
- Commerzbank Tower, Frankfurt, 300 m
- Skyper, Frankfurt, 151 m
- Freedom Tower, New York, 541 m
- One Bryant Park Building, New York, 366 m
- Sears Tower, Chicago, 442 m
- Bank of America, Atlanta, 312 m
- Petronas Towers, Kuala Lumpur, 452 m
- Turning Torso, Malmö, 190 m
- Landmark Tower, Yokohama, 296 m

Projects in the Netherlands, Germany and Japan were also visited. Users, designers and builders of some of the projects were also polled.

IV. Results

A. General

There is an increasing need for high-rise building due to demographic and economic developments.

Usual designs and construction methods differ greatly from continent to continent, but will all have to be adapted as a result of increasingly stringent requirements in terms of safety, ecology and the varied use of a high-rise building.

B. What are the considerations [6] when opting for high-rise building?

Until now, there has been very little high-rise building in the Netherlands, but the growing population and welfare has led to more and more high-rise construction. As it develops, people have to learn to cope with other critical success factors compared to low-rise building. This study provides an overview of the factors that determine the success of the development of high-rise building projects.

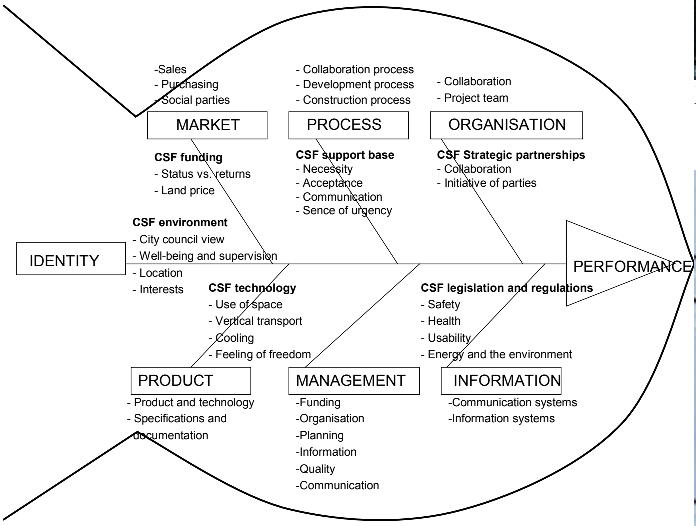

Fig. 2 Critical success factors

C. What logistics [2] are applied in Europe?

An important aspect that keeps turning up on all high-rise projects is the logistical bottleneck. These are the cranes and platform hoists. A crane is used to transport material and a platform hoist is used for transporting personnel. If one of either breaks down, it has direct consequences for the building process. It is, therefore, essential to plan and include these consequences in the preliminary schedule.

A monorail system was used for the frontage renovation of the Main Tower in Frankfurt. The system is not susceptible to the weather. At the same time, it saved work for the cranes, because the system is totally independent of them, except for the top five floors.

The monorail was attached to the top edge of a floor. The cladding element was attached to the monorail with a hook and cable and placed between the floors. This took 15 to 20 minutes for each element. This meant that two floors could be finished a week. The system can finish 15 floors without being moved.

Fig. 3 Main Tower, Frankfurt

Fig. 4 Main Tower, Frankfurt

Fig. 5 Main Tower, Frankfurt

Fig. 3 shows the Main Tower. The monorail is attached halfway up the tower. Fig. 4 shows a cladding element hanging from the cables of the monorail. Fig. 5 shows workers taking in and positioning an element from inside.

D. What are the differences in the technical aspects [5] of high-rise construction in the world?

Technical differences usually originate from the location and decades of tradition in the use of materials.
The table below provides an indication of characteristic aspects that determine the techniques used in high-rise construction work in Europe (the Netherlands/Germany), Japan and the USA.

	Supporting structure	Construction methods of supporting structures	Major structural forces
The Netherlands	In the Netherlands, concrete has been used as a construction material since the 1970s. Framework constructions and rigid construction cores are usually used.	Because of the wide experience of building with concrete (mainly due to the traditional ways of building), the fabrication of concrete cores in the Netherlands is done in situ, as well as in precast concrete.	In the Netherlands, the bearing capacities of the soil have to be considered. Because of the poor soil quality, the structure of the building has to be chosen carefully.
Germany *(the city of Frankfurt is best known for high-rise buildings and will therefore serve as a reference)*	In Frankfurt, the same aspects apply as in the Netherlands. Most high-rise structures are built with a concrete main structure.	The Germans mostly build with in situ concrete. There is much less experience with precast concrete than there is in the Netherlands.	In Frankfurt, the main structural forces are the more regular ones. Wind, the weight of people and the interior are the aspects that have to be taken into consideration.
Japan	The number of high-rise structures in Japan with a steel frame is increasing by the year. Because of the flexibility of a steel structure (earthquake resistant) and the capability of building extremely quickly, steel frames tend to be preferred.	The steel frames are fabricated in giant production robots, which are developed by the large construction companies in Japan. Concrete buildings are built with in situ concrete.	The major structural forces that high-rise buildings encounter in Japan are those of earthquakes and wind (typhoons). For centuries, these have influenced Japanese construction methods. The poor soil conditions add to the difficult task of constructing the foundation and structural frame.
USA	The vast majority of high-rise structures are built with a steel frame. There is a lot of experience in construction with steel.	The steel structures are welded together on the construction site. The prefabrication of steel structures as well as concrete structures is not developed at all. The reason for this is the power of the Unions to determine the way of constructing the buildings' frame. They prefer 'in situ concrete' because they can then provide their members with much more work.	Especially in the west of the USA, constructions have to cope with earthquakes. Although less severe than in Japan, earthquake hazards have to be considered.

Fig. 6 Technical aspects world-wide

E. What are the technical conditions for vertical combination of uses in high-rise building? [3]

Many cities are confronted by a shortage of space, a lack of diversity and too much mobility, particularly in the city centre. This study examined the technical complexity of combining functions. This is evident from the following:

- When the building plans include vertical combination of uses, the choice of building method and techniques will not differ greatly from high-rise building with a single function. A separate construction method will be chosen for each specific function, however. Where one function runs over into another, special attention has to be paid to the transitional construction.
- If the functions of living and working have to be combined, the transition from the 'beams and pillars' method to the 'supporting walls' method calls for highly complex function transitions. If there are another twenty floors above this function transition, enormous forces have to be transferred, requiring a lot of calculation work and innovative ideas and a long time to prepare. All the more so because homes have a completely different force distribution than offices; they have a different nave size and the cladding is usually completely different to that on an office building. It should be noted that partition walls for offices hardly affect the dimensions of the structure, but walls that separate dwellings do.
- Another problem with the complex transitions is that they are usually built with sections that have to be embedded, thus increasing the risk of error. Due to the complexity and difficulty, these transitional floors take two to three times longer to build than standard floors. The first few weeks will also generate more costs due to teething problems.
- Apart from the function transitions, the combination of living and working functions require every feature to be built twice: lifts, stairwells, entrances, etc., but this also applies to the fire safety regulations such as fire escapes, fire brigade lifts, etc. This all detracts from the amount of floor space available for rent and hence the ratio between free floor space/gross floor space and the return on the project.

F. Are there market differences between the various continents?[4]

The continents of Asia, America and Europe that were studied have a number of similarities which are important in terms of attractiveness when developing high-rise building projects. The first requirement – lack of space – is present on each continent due to the high density of their populations. Other aspects such as economic conditions and strict regulations make Europe a highly unattractive continent for high-rise building projects compared to Asia and America.

With China as its growth market, Asia is an excellent place to develop high-rise projects. Office space is inexpensive, citizens are not bothered about living high up and planning procedures are faster than in Europe. America is the second most suitable continent for developing high-rise projects. The economy is recovering and the costs per working area are relatively low.

The final aspect, somewhat less important than those outlined above, is the environment. The stricter requirements in Europe with regard to the environment makes it less attractive to investors to develop high-rise projects here. At the same time, America regards environmental issues in a different light, which is evidenced in their refusal to participate in the Kyoto treaty. But the stricter rules in Europe make it more ecologically sound to build high-rise projects there.

G. What ecological innovations are applied?[7]

The ecological features applied in 1998 in the Commerzbank in Frankfurt still meet current requirements seven years on. However, in the future, developments in the area of ecological features will be needed to meet environmental requirements, particular those regarding CO_2 emissions.

The following is a list of specific recommendations:

- the development of ecological systems
- large-scale use of ecological systems in high-rise buildings to cut costs
- the construction of green zones in high-rise buildings
- stimulation of public transport to and from high-rise buildings so employees can leave the car at home
- the combination of wind and solar power
- stimulation of further development of solar panels and the construction of solar power storage facilities
- use of subterranean energy to cool and heat buildings (heat pump)
- stimulation of further development of the double cladding system
- give users of ecological high-rise buildings more information about the building they work in

V. CONCLUSION

- High-rise construction merits a new approach to enable it to meet the required performance following expected developments.
- This new approach should improve techniques and logistics.
- Ecology can shed a new light on design, production and user satisfaction.

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