The development of a concept for a Dutch construction system for high-rise buildings

Frans van Gassel

Abstract— **During the eighties, the construction industry in Japan was in trouble. The image was bad, too many fatal accidents happened on the construction sites and craftsmen preferred to work in other industries. In addition, the space for constructing high-rise buildings was minimal, especially in the big cities. This is why in the nineties, the leading Japanese construction firms started to develop and use mechanised and even automated construction systems for high-rise buildings. In the Netherlands, only one experiment (Delftse Poort) with a comparable construction system is known to exist.**

Dutch contracting company Ballast Nedam has built a residential building called Westpoint, which is 111 meters high. It was built in a traditional way. This was a chance to erect this building using particular a construction system, but in the preparation phase, the process designers had too little insight into the costs, production time and risks, so they decided to build it in a traditional way. Now the building is ready, a simulation has been made of the production process involving the use of an automated construction system. This paper provides the results of this study.

Index Terms—**Construction Systems, High-rise Buildings, Process Design, Process Simulation**

I. Introduction

IN 2005, the Netherlands has about 120 buildings higher than 70 metres in the study phase or under development (www.hoogbouw.nl 2005). This means that for the coming years, there is a need for production capacity and an opportunity to innovate production processes. Time to think about how high-rise buildings can be constructed in an efficient and safe way.

Most of the high-rise buildings were built using traditional working methods and had logistics problems in the busy inner cities. In the Netherlands, only one case is known where a construction system was used for a 150-metre office building called Delftse Poort, which was built in 1991.

The big Japanese contractors have been using efficient and safe production methods for the last fifteen years. They have developed several construction systems for this purpose and completed a lot of high-rise buildings with success. Considering the Japanese experience with construction systems for high-rise buildings, we could ask ourselves why we do not use such construction systems in the Netherlands and what we can learn from the Japanese experiences.

Author is assistant professor at the Technische Universiteit Eindhoven, Department of Architecture, Building and Planning. The Netherlands. e-mail: f.j.m.v.gassel@bwk.tue.nl

II. Problem

When Dutch contractors want to develop a construction plan for a high-rise building, they are mostly interested in using a construction system. They know a little bit about the existing Japanese construction systems but are not aware of the benefits and risks of using such a system. One of the problems is that they do not know how many times such a construction system can be used and over how many years the investment has to be written down. Experiences are only available for one Dutch case. Because of this uncertainty, the contractors decide to use the traditional production methods.

In the following section, we will describe a construction system, the experiences with the Dutch construction system Delftse Poort, and the characteristics of a Japanese construction system.

III. Construction Systems

First two descriptions of the terms mechanisation and automation. People, equipment, computers and telecommunication devices are involved in the production of a building object. Everything performs physical and control tasks. Mechanisation is then defined as to shift physical tasks from people to equipment, and automation is a shift of control tasks from people to computers and communication devices (Van Gassel 1995).

According to Van Gassel (2002), a construction system is a technical installation, assembling building parts into a building. An installation is a collection of equipment, computers, telecommunication devices and people working alone or together. Construction systems can be classified into four groups: traditional, mechanised, mechatronised and automated. The category the systems are classified into depends on who will be performing the physical and planning tasks. See Table 1.

Table 1. Typology of construction systems (Van Gassel 2002)

Type of construction system	**Physical tasks**	**Control tasks in execution**	**Control tasks in management**
Traditional	• People • Equipment	People	People
Mechanised	Equipment	People	People
Mechatronised	Equipment	• Computers • Telecommunication devices	People
Automated	Equipment	• Computers • Telecommunication devices	• Computers • Telecommunication devices

A. Delftse Poort

As we have already mentioned, the Delftse Poort building in Rotterdam was erected using a construction system. The reasons to opt for a mechanised construction system were that the weights of the prefab concrete floor and façade elements were too heavy for the tower crane and that the influence of the wind on the hoist loads was too great. This made the production schedule too uncertain.

Afterwards, it proved that the use of the construction system was no more expensive than the use of a tower crane and that construction time was within the schedule. The self-climbing hoist shed was only used for this project and was dismantled afterwards. See fig. 1.

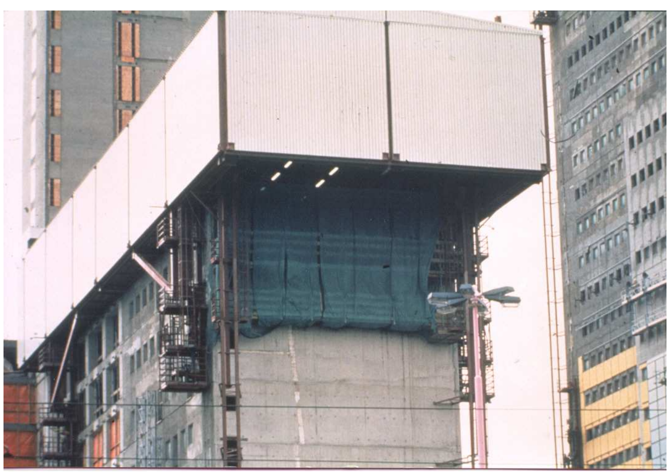

Fig. 1. Delftse Poort Mechanised Construction System

B. Big Canopy

In Japan, there are several construction systems such Automated Building Construction System (ABCS), Shimizu Manufacturing System by Automated Robotics Technology (SMART) and Automated Construction System for Reinforce Concrete Building 'Big Canopy'. For this case study, we opted for the Big Canopy construction system because of the following features:

- freedom of design
- weather-independent
- application of steel or concrete
- working conditions
- the need for a construction site
- construction time
- the amount of work

(De Kruyff 2004)

The Big Canopy construction system can be divided into the following subsystems:

- a roof supported by four tower crane posts, which are situated outside the building
- a complex hoist system with three cranes mounted against the roof
- a jib crane on the roof to mount and to dismantle the tower crane posts
- a high-speed construction lift to all floors
- all components bar-coded for easy identification
- a material management system to manage the flow of materials and components

(www.bca.gov.sg 2005) See fig 2.

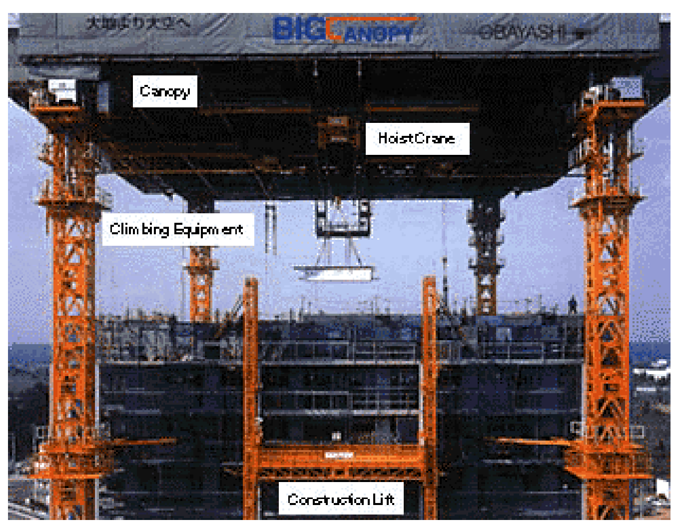

Fig. 2. Big Canopy automated construction system

The Big Canopy automated construction system ensures good working and environmental conditions, shorter construction time, less waste and improved overall productivity. (Wakisaka et al. 2000)

IV. Aim, Question and Method

The aim of this case study is to gain a better understanding of the benefits and risks of the construction of a high-rise building by comparing the traditional method with a mechanised, mechatronised or automated one.

The case involves the high-rise building project Westpoint in Tilburg, which was built in a traditional way. For the sake of comparison, Westpoint was built virtually using the Big Canopy automated construction system.

The research question was: what are the differences between the two methods with regard to such aspects as construction time, cost and working conditions?

In his master's degree study, De Kruyff (2004) conducted a comparative study of the above-mentioned aspects. The sources for this study were the Westpoint production reports compiled by contracting company Ballast Nedam and a literature survey of the characteristics of the Big Canopy system.

Fig. 3. Westpoint 'under construction'.

V. Westpoint

In 2004, contracting company Ballast Nedam completed a 142-metre high-rise building with 75 floors, the highest apartment building in the Netherlands at the time. The body of the building consists of poured concrete floor and walls using tunnel moulds and a number of concrete prefab walls. The front facade is made of a poured inner wall and the outer wall is a prefabricated concrete element. The side façades consist of plastic elements and the inner walls are built up with lime stone blocks. The materials were transported by tower crane, concrete pump and special assembly equipment for the façades. See fig. 3.

VI. Results

Using the Big Canopy construction system for Westpoint will reduce production time by 65 working days, which is 13% shorter than construction with the traditional method. This system reduces construction costs by 312,000 euros, a percentage of 0.9%. Use of the Big Canopy system improves working conditions because the weather (low and high temperature, rain and wind) has less of an influence on the comfort of site workers.

The Big Canopy installation has a depreciation period of 12 years, an utilisation degree of 71% and an interest rate of 5%.

VII. Conclusions

In the future, a number high-rise buildings will have to be erected in the Netherlands. If there is no certainty that a number of buildings can be built using a construction system within the next few years, no contractor will invest in a particular construction system.

The study was carried out on the assumptions of a depreciation of 12 years and an utilisation degree of 71%. These two assumptions are not enough to conclude that there is no market for construction systems in the Netherlands.

VII Next Steps

A lot of suitable production technologies are available. To decide on the best possible combination of technologies is difficult. The process designers have hardly any insight into the performance of the new technologies such as cost, production time and risks.

A computer simulation may help to choose the best combination of technologies. A simulation program such as ARENA could be very useful (www.arenasimulation.com 2005). Arena simulation software can handle complex, large-scale projects involving highly sensitive changes related to supply chain, manufacturing, processes and logistics.

In the coming period, we intend to repeat the case study with the help of simulation modelling and analysing software.

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