De Bolder, an unusual example of off-site construction

by

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ABSTRACT:

De Bolder ("The Bollard") is a 42.5 metre-high building with a circular cross-section of 30 metres and a weight of 25,000 KN. It was built in an industrial plant, transported a considerable distance across water, subsequently put ashore and placed on a foundation.

This study focuses on the differences in construction methods and the consequences of these differences.

Research aim: How can the De Bolder study results be used to improve traditional construction techniques?

Research questions: What are the differences between construction of De Bolder and construction on a traditional site? Where do these differences stem from? To what extent do these differences impact the actual construction period?

Results: use of this method depends on the characteristics of the object (volume, design and weight) and circumstantial attributes (transportability). The dynamics of transport determine the building's design; planning of an off-site construction process entails other dependencies, such as blurring of the distinction between structural works and finishing works.

KEY WORDS:

Building systems, industrialised construction, integrated product and process design, transport of building.

1. INTRODUCTION:

1.1 The initiators

This is a project involving the construction of a new Headquarters for the Mammoet Van Seumerengroep in Schiedam, the Netherlands, an organisation known throughout the world for its unique achievements in the offshore industry and the associated heavy transport operations. In 2001, the company successfully raised the Russian submarine Kursk, an operation considered impossible by many.

1.2 The design

The building was to be designed in the form of a bollard. It was to be a compact, tenstorey construction with a cylinder-shaped building volume, which, by reason of its constricted shape, resembled a bollard. The building is situated on the axis of the Benelux tunnel, the route of the A4 motorway under the river Meuse (the Rotterdam harbour), which makes it visible from a long way off by the 150,000 motorists who travel along this motorway each day.

The building's compact bollard shape made it ideal for transporting. Because of the production capacity at Grootint Zwijndrecht – one of the subsidiaries of the Seumerengroep where oil platforms are made – the idea was conceived of constructing this building in the industrial plant in Zwijndrecht and transporting it by water to its ultimate location in Schiedam.

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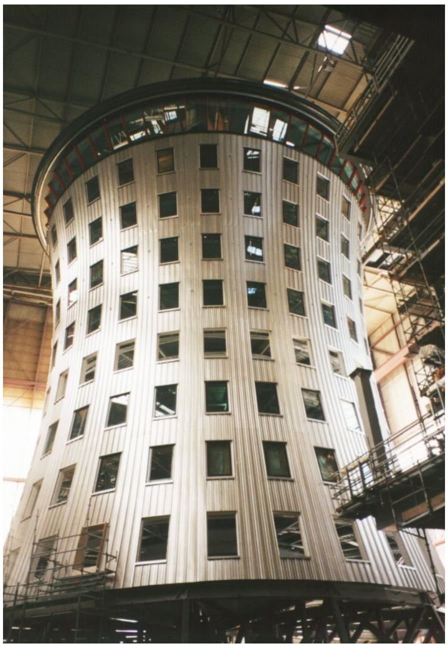


Figure 1 De Bolder under construction in the industrial plant

The project has the following characteristics: diameter: approx. 30 metres; height: 42.5 metres; mass: 25,000 KN; transport distance by water: 25 km; over land: 300 metres; method of transport: self-driven platform trailers and seagoing pontoons; largest obstacle: the Botlekbrug bridge with a maximum headroom of 45.7 metres at lowest possible water level; construction period (superstructure): mid-July 2001 to 29 January 2002.

As there was no experience with the prefabrication of this type of office building, the decision was taken to develop this innovative industrialised construction method parallel to a building to be constructed using traditional techniques.

This meant that it had to be possible to build the structure along traditional lines and also in such a way that it could be transported. This applied to all aspects of the construction, i.e. functional and spatial development, intended constructional and installation technologies, as well as other specific structural details and dimensioning.

As a result, the building differs only slightly from traditional structures, with the exception of a few components. It may be assumed that it is possible to optimise the construction yet further if the transportable variant is opted for at an earlier stage. On the other hand, limiting the project by allowing for both options did result in an explicit focus on specific aspects such as planning effects and specific circumstances on the construction site, without these aspects being related to a very different building concept. To all intents and purposes, De Bolder is a traditional structure, but one built under industrialised circumstances in a factory setting, and one that could be transported.

2. RESEARCH QUESTIONS

- What are the differences between construction of De Bolder and construction on a traditional site?
- Where do these differences stem from?
- To what extent do these differences impact construction time?
- How do the separate building activities relate to one another?
- How can the results of the research into this type of conditioned construction work be used to improve current construction processes?

3. RESEARCH METHOD

3.1 Research limitations

Research work was carried out between November 2001 and June 2002.

When the study started, the project was already at its final completion stage. Apart from the fact that the outside walls had not yet been sealed off, it was not immediately possible to see that this building had been factory-built. Nor was it possible during construction to identify and measure productivity or failure costs and to compare these with standard times or costs of traditional structures cited in the relevant literature.

3.2 Research approach

This study was conducted by reconstructing the preparation and construction processes as faithfully as possible. By collecting data and conducting interviews with people directly involved in the construction work, it was possible to paint a picture of the way in which preparations and actual construction work had been carried out. Of particular interest were the decisions taken and the criteria and considerations leading up to them. This reconstruction was compared to the common Dutch construction methods. Traditionally prefabrication is limited to certain sections of a building.

4. THE RESULTS

4.1 Planning

4.1.1 Introduction

An important difference between traditional techniques and those used in the construction of De Bolder is the drastic reduction in building time. Despite the time required for transport, a net time gain of 22 weeks was made. The difference in construction time is made up as follows:

1. Work under industrial circumstances (- 6 weeks)
2. Changes in planning (order and sequence of building activities) (-20 weeks)
3. Preparations for transport, transporting and unloading (+ 4 weeks)

4.1.2 Work under industrial circumstances

The fact that works could continue irrespective of the weather resulted in a direct time gain. A standard of 29 days on which work is held up on account of weather conditions applies to this region of the Netherlands for the duration of any construction work. This downtime includes seven working days due to frost, nine due to rain and eleven due to wind.

Although deviations will, in practice, occur as regards actual weather conditions and there will be workable days on which weather does hold up work but only to a certain extent, these 29 days are a generally observed rule. Eliminating downtime not only shortens the construction period but also does away with the unpredictability of work during the winter. Work can be carried out under all circumstances, irrespective of the weather, so that the work itself and the link between the project as a whole and the various individual activities involved (sequence and drying times, for instance) can be far more strictly planned.

4.1.3 Changes in planning

If we compare the planning work of this construction project with those of traditional projects of the same type and scope, three aspects among the various activities stand out most.

Firstly, the erection of the supporting structure can start without prior work on the foundations. The floors in industrial plants where oil platforms and offshore installations are built have sufficient load-bearing capacity to support a building of this size. The building of the eventual foundation for the building can run parallel to the construction of the upper structure at the final location, generating a time gain of eight weeks in this case.

A second difference is the direct succession of structural work and finishing work. At the completion stage, materials are used that are susceptible to weathering. The building has to be fully glazed before most of the finishing work can be started, which is why it is usually not worthwhile starting finishing work immediately after the structural work. In the case of De Bolder, the entire project was both water and wind ‘resistant’ from the onset and conditioned construction was, therefore, possible. This allows for a direct start of the finishing work immediately following the structural work, storey by storey (by tradition, the building was built up from the bottom). Although, as far as safety was concerned, various incompatible activities were being conducted at the same time, conditioned circumstances on the construction site made it possible to keep this under control by working with two separate construction teams in different shifts throughout the critical period.

The third difference lies in the timely installation of costly equipment. As a rule, the building should be appropriately sealed off before costly equipment such as air conditioning and telecommunication systems and ICT networks are installed. Especially users equipment is often put off until after final acceptance. The result is that shafts and ceilings have to be reopened. In the case of De Bolder, facilities such as those mentioned above were assembled and installed in good time, seeing as the risk of theft or vandalism was virtually eliminated. The above two differences resulted in a time gain of twelve weeks; this does not include the time gained after completion once the end users started moving in. The total time gain of the three mentioned differences is 8 + 12 = 20 months.

4.1.4 Productivity

Finally, we must mention a further key factor, which we have not been able to explore in greater detail: actual productivity during construction work. Various factors play a part, for instance the extent to which activities can be planned, whether they can be physically prepared, the logistic advantages of an industrial setting (both material advantages and advantages as regards the information flow), and matters relating to motivation of the employees on the job.

Previous analyses have shown that improvements to circumstances on the construction site can lead to a dramatic increase in the productivity of construction workers, from 50% to 75% of the available working hours. This may be even more in an industrial production setting such as the one used for De Bolder. On the other hand, the consequence of adapting this kind of building structure to an industrial setting in which high safety requirements and stricter procedures apply for working on offshore installations may also have a decelerating effect.

We recommend that further case studies investigate productivity more thoroughly, as this can lead to new findings of practical use to more traditional building methods.

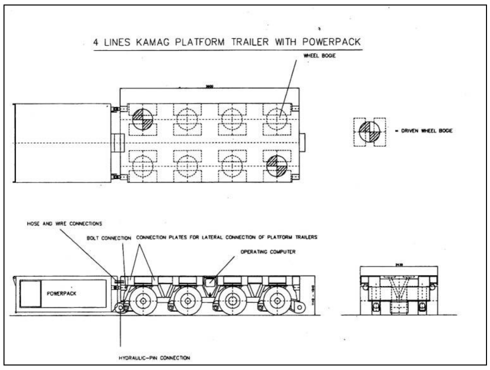
Figure 2 De Bolder on the transition structure

4.2 Design and choice of materials

Design requirements, weight and deformations have to be taken into account to make the transport of a structure possible, in fact the specific transport modalities have to be taken into account as early as the initial design stage. Vehicles bear the weight of the structure during transport; in the case of De Bolder these were what are known as self-steering platform trailers commonly used in the offshore industry.

Complete oil platforms and complex installations are built in factory sheds and transported to the wharf on such vehicles. This was also done with De Bolder. The number of vehicles is, in theory, infinite – the weight to be carried is limited only by the axle load-bearing capacity.

Figure 3 The platform trailers



The ground plan of De Bolder specified a maximum weight of 2,5000 KN. This meant that, compared to the usual construction method, the weight of this building with its nine office levels had to be reduced. Monolithic inner leaves and floors are generally used in buildings such as these, the decisive factors being ease of realisation as well as cost reduction. By opting for more expensive composite floor slabs and inner leaves with a wood frame construction, it was possible to reduce the weight of the building by 20%.

Design factors are likewise important, which is why the office-dividing partitions were not erected until after transport. Although weight can be distributed across several platform trailers, the structure should be such that it is possible to transport it without running the risk of major deformations. For the offshore industry this means that the load is always grouped in such a way that three ultimate bearings are created, so that deformations and leaning during transport can be checked and managed.

Traditional structures always transfer their own weight and utilisation load to the foundation construction, following a logical grid. In the case of a building that is to be transported, that load has first to be redirected to three bearings and then redistributed over the several axles.

In practice, therefore, this means that a transition structure is required for the substructure of the building, something not usually found in traditional structures.The transition construction can be part of the building's own structural framework or made as a temporary structure; the latter was opted for in the case of De Bolder.

It is, in any case, evident that both the transportable designs of the structure and the structural features this requires have to be taken into account as early as the initial design stage.

4.3 Costs

De Bolder has been built at a cost akin to that of a traditional building. This does require some comment, however. There was access to an industrial plant of sufficient size and load-bearing capacity and with all the necessary amenities. Transport facilities were also available and hardly any equipment needed to be bought specially for this project.

Given the overall cost of the project, the transport costs were by no means the heaviest. These amounted to EUR 113,250 i.e. the sum of the costs for the platform trailers plus the seagoing pontoon.

The costs for the temporary load-bearing construction, i.e. the transition construction that made it possible to carry and transport the building on the platform trailers, were significantly higher, viz. EUR 1,250,000. In addition, the wharf at the building's final destination had to be reinforced to receive the platform trailers, the costs for which came to EUR 50,700.

These excess costs were eventually compensated by the savings made on construction time, the reduced risk of theft and wilful destruction, as well as other economies.

As both the industrial plant and the final location are by the waterside, making transport over land difficult, we investigated to what extent circumstantial factors have an impact on the transportability of such buildings. Using an abridged sensitivity analysis, we found that transport distances, be they by water or over land, had no profound effect, provided no cost-raising obstacles had to be overcome. Given the flatness of the land and the abundance of waterways in the Netherlands, this concept opens up possibilities for future use.

4.4 Social effects

Cutting back construction times has been an issue in the Netherlands for some time now. This can be achieved in a number of ways. Optimising conditions on construction sites is in itself one way of improving the predictability and planability of construction work, thus also avoiding interruptions, loss and downtime. In that sense, much can learnt from the factory-based approach used in the construction of De Bolder. However, there is no need to opt for total prefabrication or transport of an entire structure.

Yet it would seem that in the Netherlands there is an increasing shift in the characteristics of the surroundings in which construction work is carried out, from erecting new buildings in 'green field' sites, i.e. within perimeters, to embedding construction works in existing urban settings, adapted to existing daily operational activities. Such construction projects are found in the ever more densely built-up inner cities, near airports, railway stations and large complexes such as exhibition sites, educational institutes and health care institutes. Studies of the effect that the surroundings have on building work in 'revitalisation' areas have shown that disruptions should be kept to a minimum. Not only that, the nature and duration of such inconveniences, as well as their predictability are also crucial. The traditional construction process 'within the perimeters' is not geared to that and numerous practices and sector-specific improvements in traditional building projects are inconsistent with environmental requirements.

It is for that reason in particular that the De Bolder project has attracted so much attention from the construction industry as a whole.

5. CONCLUSIONS/LESSONS:

- If a design is suited for off-site production and transport, there are many advantages to be gained from alternative construction process dependencies resulting in disruption-free building with shorter interfaces and a blurring of the distinction between structural work and finishing work.
- The success of De Bolder has established the efficacy of this technology; its application depends on the volume, design and weight (object attributes) of the structure and its transportation capacity (circumstantial attributes).
- The design of such structures depends largely on dynamic aspects (unusual for buildings), which implies that there are other construction problems that need to be addressed at an earlier stage in the development process.

6.

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