Architectural concrete

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NSP Arnhem Central Transfer hall

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ABSTRACT: This paper discusses the current design status of the NSP Arnhem Central Transfer hall project in Arnhem, The Netherlands. The project involves a complex geometrical, double-curved concrete shell roof design by UN Studio architects for a project in which many functions are combined, the Transfer hall being a merging point of passenger, commercial and social interchanges, a multi-use development integrating programme and flows of people and vehicles. The paper will introduce the project and will discuss the design methods applied to convert a complex geometrical vision to a feasible structural design.

1 INTRODUCTION

1.1 *Entrance to the city of Arnhem*

The Arnhem station area is a junction of several different modes of public transport including trains, buses, trolley-buses and taxis. Half of the city centre's visitors come from outside Arnhem. For most bus commuters the station area fulfils a central role in their daily local or regional journey, and the planned underground parking facility will form the most important entrance to the city for those arriving by car. By locating this demanding program on a small area, the need for multiple competition for space had to be addressed. This led to a unique structural design and vertical transport solution commissioned by the clients, the Ministery of Housing, Planning and Environment (min.VROM), the Minstery of Water- and Traffic management (min.VWS) and the City of Arnhem.

1.2 *Design concept*

In the Transfer hall the different transport modalities are connected by inclined surfaces, while the underground parking facility users are directed to a big V-shaped area where stairs will take them to the transfer hall. With the design of the Transfer hall the team created a space without columns where pedestrians find the right way on their intuition without following a marked-out route. The elegant scale shaped concrete roof of the hall is supported by twisted concrete elements with a double curvature and high geometrical complexity. Parts of the structure are supported by walls on the position of the V-walls in the ready build parking garage. The architectural and structural design requires a very high level of integration of the Transfer hall and the underground bike park with finished structures like the parking garage, the NS tunnel, finished

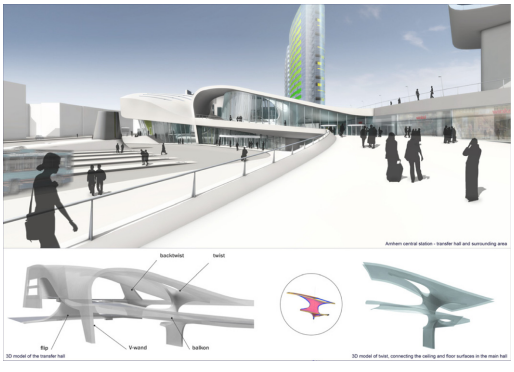

Figure 1. The architectural design by UN Studio.

offices and parts of the bus deck with offices on top of that deck. Part of the Transfer hall is a raised building for offices (K5 building) with a steel structure of trusses with large spans and cantilevers.

2 DESIGN OF A COMPLEX PROJECT

2.1 *Master plan*

Since 1996 the Arnhem station master plan is under development and has resulted in as a core an intensively multi-use buildings with diverse program of 160.000 m2 which has been design on a plot of only 40.000 m2. The building combines many functions, offices, commerce, tunnel, tracks, station, bus, trolley bus, parking, bikes, a cable tunnel, taxi and public square, through an innovative architectural and structural design, which have been integrated to one concept. In the initial design stage the vertical integration of the program was made possible through the simple diagram of the V-walls. This model acts

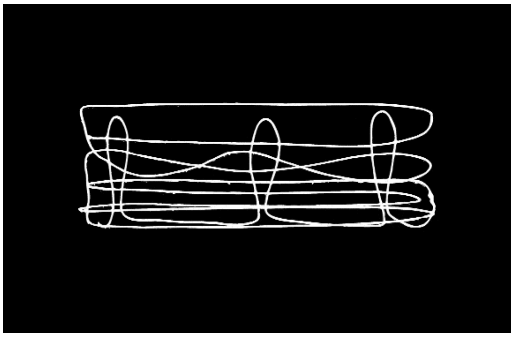

Figure 2. Concept of the V-wall emerging from a sketch.

as the principal tectonic organised device. The long V-walls become a "collector" of people, natural light, ventilation, circulation zones and views across the site; merging the towers and offices with the car park through its folding plates. The Arnhem project has received the Schreuder prize in 2005 for this design. Open and equal communication in a far reaching cooperation in the design team across had to be employed to create a high-level project for the city.

2.2 *Design tools*

For the structural design of the Transfer hall a combination of traditional and sophisticated computational design strategies has been employed.

During the early stages of the various techniques were employed to analysis and shape the building, such as computational form finding, fabric modelling and three-dimensional wax printing.

During the later stages of the design, the concrete shell-like roof has been modelled by making use of custom-built geometrical software tools which translate the architect's design into a controllable structural model to analyse. The structure has been analysed by making use of advanced finite element analysis software which is able to model the complex non-linear behaviour of the cracked concrete double-curved shell. Furthermore, various strategies had to be devised to investigate support and foundation stiffness, buckling and construction influence.

2.3 *Total design for concrete technology*

Arnhem is truly an integrated project where each piece of concrete has multiple functions: architectural, structural, lighting design, building services, etc. This results in the fact that a lot of the concrete will be executed as architectural concrete by making use of seamless formwork without connections going through the concrete. Where seams are allowed, they will have been designed on special seam drawings.

The project can be split up in several levels of geometrical complexity, which each have their influence

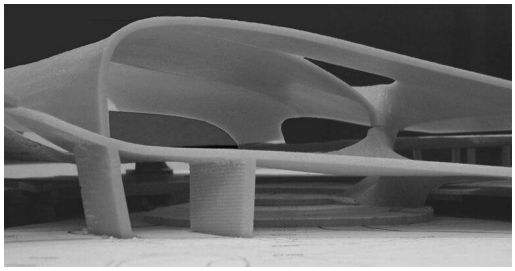

Figure 3. Computer-milled wax model of the roof.

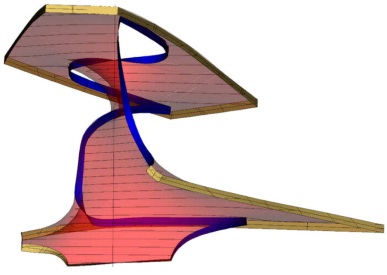

Figure 4. Computational model of the Twist.

on the construction (form work) and reinforcement detailing. Areas with a low curvature or single curvature and which are horizontal have a low complexity. Areas with low or single curvature and which are vertical have been classified as medium complex. Finally, the double-curved, mostly vertical, parts, like the column-like shape under the roof, called the Twist, have been classified as high complexity areas.

3 DISCUSSION

The NSP Arnhem Transfer hall project is planned to start execution in 2008 and will last until 2010. Current and future design activities mainly focus on investigation of the construction process and construction stages of the project as well as the integration with existing parts of the project.

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