Tailor Made Concrete Structures – Walraven & Stoelhorst (eds)

New Amsterdam Public Library (Openbare Bibliotheek Amsterdam)

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ABSTRACT: The new Amsterdam Library is the largest library in Europe. Arup provided structural, MEP and lighting design services. Through an integrated approach to architecture and engineering it was possible to create a stunning building. The building is equipped with energy saving measures such as long term energy storage and the use of the structural frame as thermal mass. The plenums underneath the raised floors and the large vertical atrium are used to distribute and extract air. By integrating structural and MEP elements, height could be reduced, making it possible to add one extra floor within the building envelope. A carefully designed grid, compatible with both the below ground car park and the library building, and the theater box, which is situated on the top floors of the building, prevented the need for transfer structures. This allowed for a further reduction in height. By placing cores outside the building, the use of spectacular sculptural columns and suspending structural elements such as walls and columns, an exciting dynamic design was achieved.

1 INTRODUCTION

1.1 *Largest library in Europe*

On 7 July 2007 the new Amsterdam Public Library opened its doors to the public, officially becoming the largest library in Europe. Designed by architect Jo Coenen & Co, the 28 000 m^2 building includes 7 collection floors and provides storage area for books, a theatre, a readers' cafe and a restaurant overlooking the city of Amsterdam.

The new library looks into the future, clearing its name from being a subdued dusty book warehouse, and creating a place to meet, interact and get smart: seven days a week from ten in the morning till ten at night!

Enjoying spectacular views over Amsterdam's Central Station and the large open waters of the 'IJ', nine stories of offices are situated at the back of the library.

Figure 1. South façade with external cores clad in natural stone.

Figures:

- 8 kilometres of bookshelves
- 25 kilometres of storage shelves
- 1000 library seats of which 600 equipped with PC and free internet connection

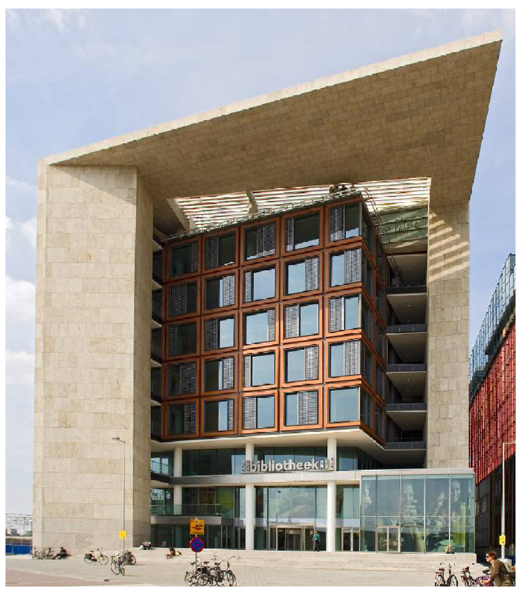

Figure 2. South façade with external cores clad in natural stone.

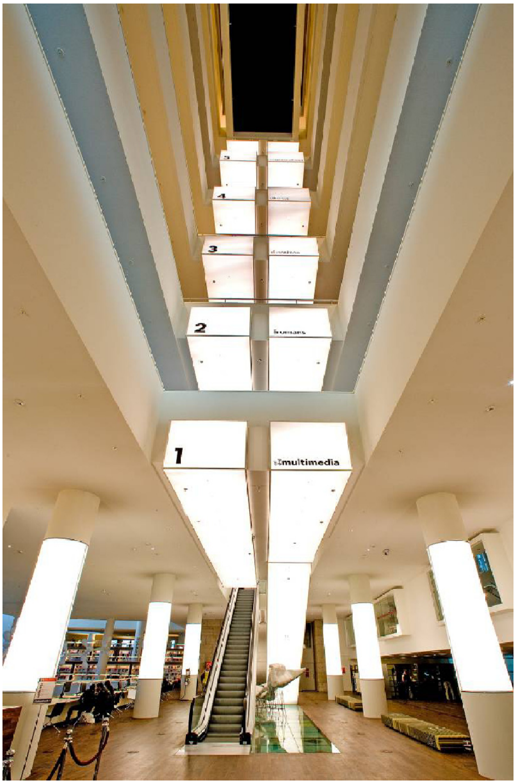

Figure 3. Atrium.

- 3 conference rooms with 100 seats each
- 300 seat auditorium

1.2 *Space and light*

The architect's vision was to create a building where space and light are central to the users' experience. To help achieve this, Amsterdam Public Library has various terraces and squares situated in a very high atrium, reached by inviting, luminous escalators that guide visitors upstairs.

Technical equipment, mechanical and electrical services are cleverly hidden from view to create the perception of space, while studio and reading rooms are situated next to a large auditorium, which seats 300 people.

1.3 *Masterplan*

The Oosterdokseiland is a brownfield redevelopment site east of Amsterdam's Central station, knicknamed the 'Island of Knowledge'. The new development consists of a two-storey deep parking deck on top of which the Public Library, the Royal School of Music, a hotel, shops and apartments are being built.

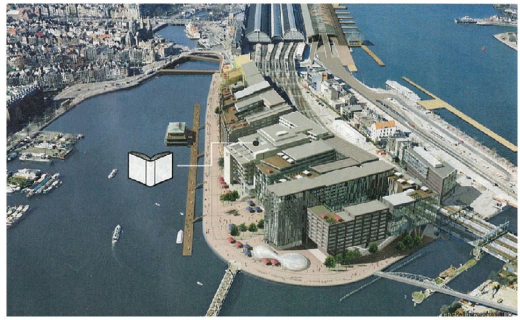

Figure 4. Redevelopment of the Oosterdokseiland.

1.4 *Total design*

Arup was instrumental to the project from the very early stages, providing structural and building services design and specialist lighting advice. Arup collaborated with other experts, including Deerns on engineering services for central energy supply and LEDexpert on the lighting design for the book shelves.

As a result of an integrated approach to architecture and engineering, it was possible to equip the library with a well-balanced energy system. Energy saving measures such as long term underground energy storage and the use of the structural frame of the building as thermal mass, are an example of how this integrated design approach has lead to a limited use of fossil fuels and an energy saving of 35% on the Energy Performance Buildings Directive.

The plenums beneath the raised floors are used to distribute fresh air to the terraces and squares that are situated around the atrium. In its turn, the atrium is used to extract the air. In order to provide for future flexibility, the space beneath the raised floors is also used to install sprinkler ducts and data and electrical cabling.

By thinking laterally, across the disciplines, it was possible to create a slim total package of structural and MEP elements. This enabled the addition of 1 extra floor within the building envelope.

This paper focuses on the structural design of the New Amsterdam Public Library.

2 STRUCTURAL DESIGN

As the structural design of the library and the offices is fundamentally different, the two designs will be treated separately in paragraphs 2.1 and 2.2. Paragraph 2.3 will be about the design of the special structures, like the sculptural columns, the theatre, the high-strength columns, the stability cores and the hanging structures.

2.1 *Structural design library*

The structural frame of the library mainly consists of in-situ concrete. Flat floor slabs are supported by a column structure on a grid of 8.4 m by 8.4 m, which is compatible with the parking deck below. The floor slabs are pre-stressed without bonding. The reasons for the use of this type of floor are that a considerable saving on the use of reinforcement could be made and that the floor thickness could be reduced.

The floors consist of a structural 280 mm monolithic flat slab with a raised floor on top. Starting point is that the undersides of the floors are level

The floor voids that create the atrium are staggered. This is why the edges of the floors are not coinciding with the column grid. In order to build the floors, the lower floors are often hung to the floors above. These above floors are strengthened on the top side of the structural floor within the space of the raised/technical floor.

Locally, the floors have been folded between the columns to form different levels around the central atrium.

All columns have been cast in-situ. The standard diameter is 800 mm and the length of the columns varies from 4 m to 12 m.

Around the freely formed voids, the floor edges are supported by walls and columns that are hung to the floors above.

A theatre has been built on the top floor of the library. Paragraph 3.2 will elaborate on this special structure.

Three cores, mainly situated outside the structure, provide for the stability of the library. Slender connection bridges transfer forces from the floors to the cores. The most northern core provides for the stability of both the library and the office building.

2.2 *Structural design offices*

The concrete structural frame of the offices is prefabricated. The offices are supported by seven prefabricated sculptural concrete columns which are placed eccentrically and under an angle. These columns are each made of three transportable elements of anthracite coloured concrete. The inner-façade is placed on top of these columns.

A pre-cast floor plank forms the first floor at a height of 8.5 m. The reason for choosing this type of floor is the need for sufficient diaphragm working to transfer the horizontal loads, resulting from the leaning columns below, to the in-situ cores. The planks are supported by a narrow sharp concrete bracket.

Concrete hollow core slabs, with a thickness between 260 mm and 400 mm are used to form the remaining floors. A reinforced structural screed is used to act as a diaphragm on these floors.

Figure 5. Column with narrow sharp concrete bracket.

There where the span between the load bearing facades is greater than 16 m, the floors are supported by type of steel integrated floor beam. In their turn these beams are supported by round prefab concrete columns.

The stability of the offices is derived from two in-situ cast cores and a core wall. The biggest of these two cores is also one of the library's stability cores.

3 STRUCTURAL DESIGN SPECIALS

3.1 *Sculptural columns*

The sculptural columns that support the offices are composed of anthracite colored prefab concrete.

Each of the columns consists of three elements that have been cast in a supporting formwork. To ensure that the three elements fit together seamlessly, the top and bottom part have been cast first. After removal of the top/bottom shutter, the bottom side of the upper element and the top side of the lower element were treated with a thin layer of wax after which the third, middle, element was cast in between.

Steel sections and starter bars take care of the connection between the elements. The sole task of the steel sections is to take up shear forces. After placing the elements on top of each other on site, the connection was injected.

Figure 6. Compilation of the sculptural columns.

3.2 *Theatre*

The theatre is situated on the top floors of the library. Concrete folded walls that form the long side of this box-structure, span a good 25 m from concrete walls in the west façade to a steel built-up girder that has been integrated in the structure and that is supported by two columns.

The steel built-up girder consists of two I sections that were factory welded and positioned next to each other. On site, a steel plate was used to connect the top and bottom flanges of the two I sections. The steel plate was fixed by injecting pre-stressed bolts.

By dividing the steel sections into 2 elements of 20 metric tons each, they became manageable and could be lifted. The sleeve formed built-up steel girder rests on top of two columns and is integrated in the structural floor of the theatre box. The ends of the steel built-up girder support the folded side walls of the theatre box.

The concrete structure of the theatre box consists of a partly pre-stressed reinforced concrete floor with traditionally reinforced concrete walls on top. The roof of the box consists of 20 m long pre-stressed prefab concrete beams and 14 m spanning concrete hollow core slabs.

The structure could only support itself once the reinforced compression layer on top of the concrete hollow core slabs was strong enough. During construction, the structure had to be supported by A-frames as relatively large spans had to be achieved and as the walls don't directly transfer load to the columns, which the A-frames did. The temporary support system (A-frames) could not be removed without a changing load transfer and resulting deformations. To control the deformations and the accompanying stresses, hydraulic jackets were placed below the steel girder. This way, it was possible to manage the changing load transfers, the deformations and the stresses throughout the construction of the theatre box structure.

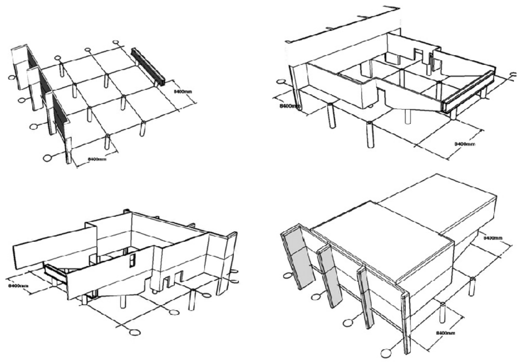

Figure 7. Construction sequence of the theatre box.

3.3 *High-strength columns*

The standard diameter of the columns is 800 mm. Despite the integrated lighting and the fact that some columns go unsupported for several floors, the columns are very slender. Through the application of local light fittings, the diameter of the columns had to be reduced to 700 mm while the load bearing capacity had to be around 20000 kN.

In order to achieve this slenderness, to support the high loads and to comply with the fire resistance requirements, the columns have partly been made of high strength concrete, B105. Columns higher than 12m have also been made of this type of concrete.

To ensure that the columns are fire resistant up to 90 minutes, additional reinforcement was used between the cover and the main steel bars.

3.4 *Stability cores*

The schematic below shows that both the southern and eastern cores are placed outside or at the edge of the floors. Only the northern core has been placed centrally between the office and the library building.

Structurally, the function of the southern and eastern cores is to provide the structure with sufficient stiffness and resistance to rotation. Slender connection bridges transfer the shear forces, which are caused by rotation, from the floors to the cores. The greatest part of the stability of the structure is provided by the northern core.

As the eastern and southern cores do not support any floors, there are less axial forces on the cores. This is why the cores are only reinforced to deal with tension.

Climbing formwork was used to erect the cores. Once the connection bridges, at a height of 8.4 m, were constructed, the cores could climb up freely.

3.5 *Suspended structures*

As shown on the cross section of the library, floors of different levels have been suspended from higher parts

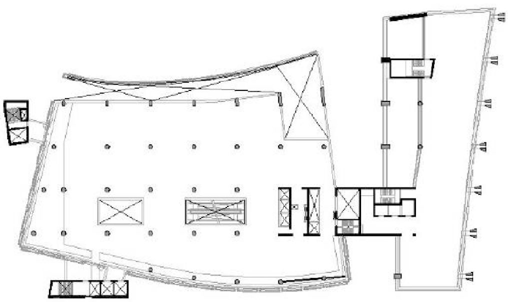

Figure 8. Schematic showing the stability cores.

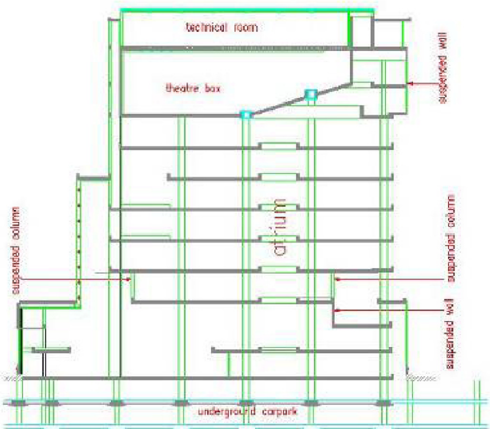

Figure 9. Cross section of the library.

of the construction. Suspension of the floors has been achieved by using suspended walls and suspended columns. The suspended walls are there to transfer the loads through the length of the walls to support points. These support points are suspended columns or cantilevering beams.

As construction was phased, computer calculations were made to simulate the deformations that were inherent to the different stages of construction. These simulations took into account shrinkage and creep. None of the structural elements were post fixed. The floors were pre-cambered in such a way that they would be level once the furniture was placed onto the floors.

Unique Features

MEP

- Raised floors with plenums for fresh air distribution
- Return air by vertical atrium
- Low use of energy through measures such as long term underground energy storage

Structural

- Grid suitable for library and car park
- Cores outside building
- Suspended structures
- Auditorium at top of building

Multidisciplinary

- Low total package of structural and MEP elements adding one extra floor within the building envelope

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Client
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End user
Openbare Bibliotheek Amsterdam
Architect
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Architectural detailing
Arcadis Maastricht
Structural Engineer
Arup (for Aronsohn-Arcadis Oosterdokseiland vof)
Mechanical & lectrical Engineer
Arup (for Deerns raadgevende Ingenieurs)
Lighting Designer
Arup
Building Physics
Cauberg Huygen
Contractor
Bouwcombinatie Hillen & Roosen – De Nijs
Prefab Concrete Factory
Hurksbeton Veldhoven

5 ARUP

Arup is a leading global firm of consulting engineers, providing world class engineering design, planning project management and specialist consulting services in all areas of the built environment. Formed in 1946, the firm now has over 9000 staff based in 82 offices in 34 countries, and our projects have taken us to more than 100 countries.

Our people use technical excellence, quality design and creativity to achieve innovative solutions and lasting value for our clients

We provide the engineering and related consultancy services necessary at every stage of the project, from inception to completion and after. These are available to clients singly or in combination, to suit the particular circumstance of the job. We aim to help our clients meet their business needs by adding value

Figure 10. The library under construction.

through technical excellence, efficient organisation and personal service.

We work in multi-disciplinary teams to ensure co-ordination between the disciplines.

5.1 *Arup Amsterdam*

With more than 15 years of project experience in the Netherlands, Arup established a permanent presence in Amsterdam in 2001. The Amsterdam office has grown to more than 50 qualified engineers and staff who provide multi-disciplinary design of building, bridge and urban projects. The office also works in partnership with other Arup offices around the world to deliver the full range of Arup services to clients in the Netherlands.

Our local staff is fluent in Dutch and English, and speaks a number of other European languages. This allows us to deliver our services in the language most appropriate to each specific client and project.

We are designers and engineers. We strive to integrate architecture, engineering, creativity and innovation into one single solution.

We work for many architects, project developers, owners and the government. We see these relations as cooperative, and we think beyond the typical boundaries of the engineering disciplines.

But we do more. Our Dutch staff provides lectures at the Universities of Eindhoven and Delft, and we frequently publish and lecture about innovations and the development of our profession. We're passionate about what we do.