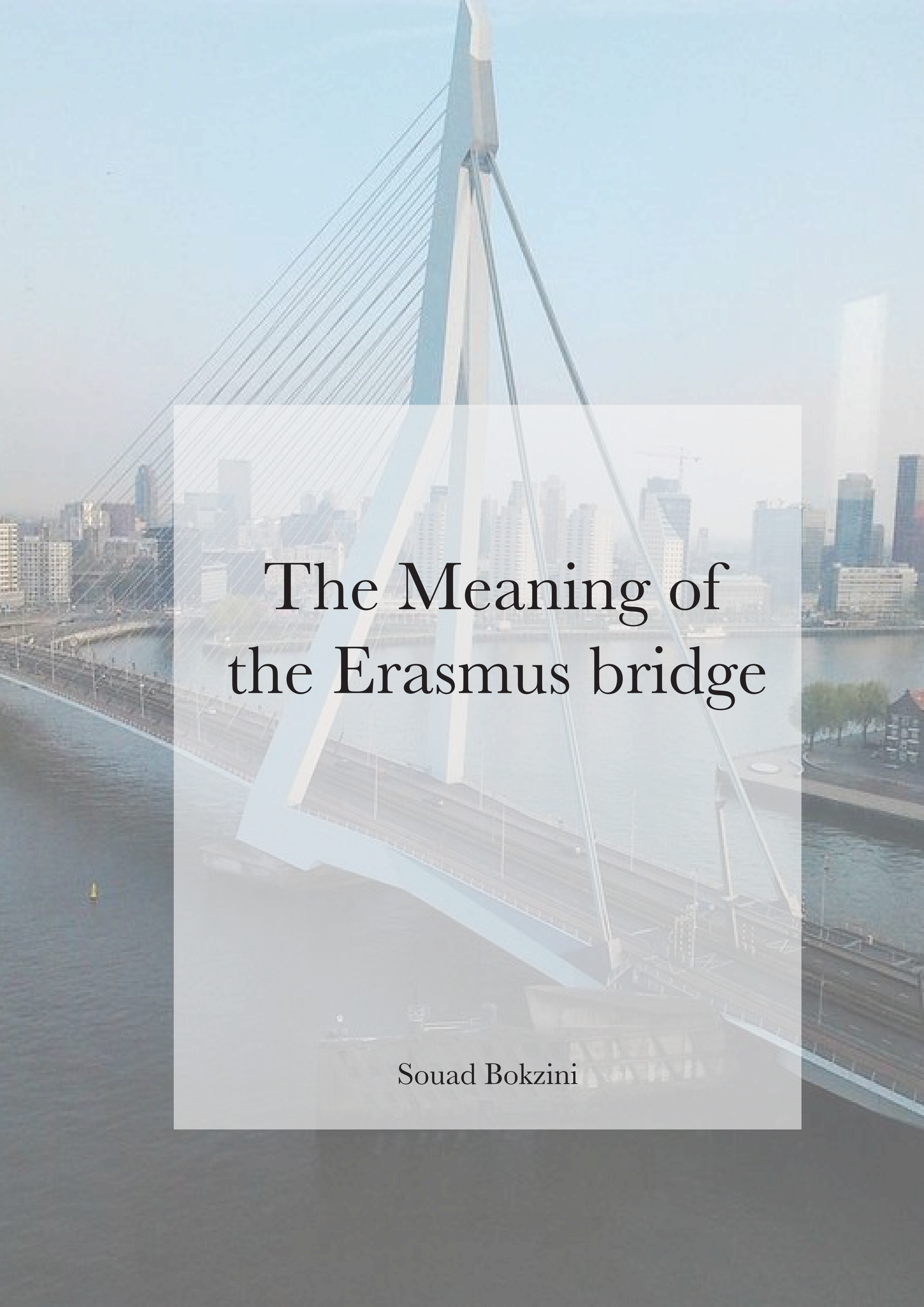

The Meaning of the Erasmus bridge

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Content

Introduction

This paper aims to understand more about the iconic bridge, the Erasmus bridge of Rotterdam, the city that presents itself as the 'Netherlands architectonical city'. Over the years, the built environment of Rotterdam has transformed and the city has made significant steps in terms of architecture and culture. One of the changes is the original harbor area. This was at the south part (Kop van Zuid) and shifted to the west when the harbour became too small. The changes results in implementing an iconic bridge, in Rotterdam.
The bridge was designed by the architect Ben van Berkel and structural engineers in the 80's. It was designed to connect the centrum of Rotterdam to the Kop of Zuid (Rotterdam South). The Erasmus bridge marked this newfound significance of South Rotterdam through a monumental gateway to the south. They solved the complexities by the tools that they had at that time.

This paper aims to study the meaning of the Erasmus bridge for its surroundings and Rotterdam as an entire city within the filed of urban planning, architecture and construction. By looking to those different fields it will be clear what the bridge for impact have for Rotterdam. This will be done to give answer on the following question: "What is the meaning of the Erasmus bridge for its surroundings and Rotterdam as an entire city, within the fields of urban planning, architecture and construction?".

This question will be answered through the three different chapters, urban planning of Rotterdam, the Architectural design of the Erasmus bridge and Construction of the Erasmus bridge.

01

Urban planning

This Chapter will focus on the urban planning of Rotterdam and highlight how the Erasmus bridge is a significant part of the new urban plan developed for the city.

1.1 Rotterdam

Rotterdam is the second largest city after Amsterdam in the Netherlands. It has approximately ca. 600.000 inhabitants and is located in the centre part of the Randstad. For forty years, Rotterdam was known for having the largest port in the world. Even today, Rotterdam's port is the largest in Europe. The port is situated at the Rhine and Maas rivers. In the last four decades, Rotterdam has been faced with a changing economic context, and faces the need to adapt with greater economic strength and diversity. This spurred the need to develop the "Kop van Zuid". This project would develop the south of Rotterdam and connect it more strongly to the northern half of the city. The project is still on-going to this day, with new upcoming developments planned for the near future. (Ungureanu, 2010)

1.2 Port of Rotterdam

The port of Rotterdam was rapidly developed in the late 19th and 20th centuries and became the largest port in the world for a period (Daniels, 1991). The development of Rotterdam port began with by the creation of direct access to the sea. Ships could reach the port directly without the need to pass locks or docks. First, it started with the first access to the sea where every ship could reach Rotterdam directly without the need to pass locks or docks it named the Nieuwe Waterweg in 1872. Secondly, with intensification of global commerce and the rapid industrialization of Europe, there was continuous growth in transportation. Rotterdam port was very well-located and benefited greatly from this worldwide increase in commerce, leading to the expansion of the port. However, between 1880-1920, the ports of Hamburg and Antwerp overtook Rotterdam port in size. In response, Rotterdam opted to compete in terms of speed, concentrating on the mechanization of the handling of goods and on the rapid transit of cargo. Hence, Rotterdam opted to become a transit harbour which made the harbour competitive and successful.(Meurs, 2012)

Until 1872, the harbours of the city were most located on the Northern bank of the river Maas. Along the river bank, there was a mixture of warehouses and luxurious merchant's houses. Stretching along the old city core and beyond, the riverfront was the stager for the harbour activities. Many residents of Rotterdam enjoyed the river and its linear parks and green spaces.
This is the place of the Boompjes. Nowadays the greenery is lesser. However, for the Rotterdam-

mers is the boompjes till a good walking route. (Meurs, 2012)

1.3 Lodewijk Pincoffs

After a few years the southern shores of the River Maas faced a complete makeover. New harbours were created and this was done by public private investment, initiated by the entrepreneur Lodewijk Pincoff. He dug out of the land and creating a functional landscape to live and built on (Meurs, 2012). As a Jewish resident, Lodewijk Pincoff was not welcome in the Rotterdam's chic gentlemen's club, such as the "Arti et Amicitiae". However, his family which immigrated form German, already belonged tot the wealthy class in Rotterdam.

Lodewijk Pincoff was a businessman who had an important role in the the expansion of the port with new harbours. He served on the council of Rotterdam in the Provincial States, and in the Senate. For his various contributions, he received high honours. In 1872, he was the founded of Rotterdamsche Handelsvereening (RHV) in 1872. (Hagendijk, 2013)

Pincoffs was committed to the development of Rotterdam. The expansion of the ports on Feijenoord and the establishment of riverbank connection were significant projects was an important subject on his agenda. These projects could be realised because of the city council's support of public-private partnerships. Mutual relationships between the public and private sectors were established and the tasks and responsibilities of the respective sectors were clearly defined. But these plans did not really get off the ground. However, in 1872 when he was the director he supported this idea with the other RHV plans for public-private partnership is rushed through the city council. Mees supported this by having a large piece placed in the public publicity of NRC. (Hagendijk, 2013)

Task and responsibilities of the public and private parties where precisely specified. Also the mutual relationships are established. It involves the realization of the Noordereiland, the bridges connecting, the Noorderhaven, the Entrepothaven, the Binnenhaven and the Spoorweghaven. Hence, RHV's agenda extended considerably beyond port construction. The company wanted to invest in trade and shipping through a variety of businesses. Unfortunately, Pincoff fell into financial difficulties and fled to America to avoid criminal charges. This led to the subsequent demise of the RHV put an end to the public-private partnership that had been established.

As a result, the municipality decides to take matters into its own hands in order to realise the plans that had already been made. In 1882, the municipality formed "Handels inrichingen", a department that would oversee the construction. The department did not manage any money of its own and would have to request financing for large purchases and investments must always be requested separately from the municipal authorities. (Hagendijk, 2013)

1.4 Master plan for Kop van Zuid

After the harbour became too small to accommodate the increasing traffic, it was shifted to the west of Rotterdam facing the North Seas. As a result, the Kop van Zuid became an abandoned area. In September 1986, the department of city development (stadontwikkeling) asked Teun Koolhaas to design a master plan for the Kop van Zuid. (Rodermond & Tilman, 1993)

In 1987, Koolhaas presented the proposed master plan together with Riet Bakker. Within the plan was the remarkable proposal to construct new bridge that would connect the city centre of Rotterdam to the Kop van Zuid (South part). The plan also proposed the redevelopment of the nearby neighbourhoods – Feyenoord, Afrikaanderwijk and Katendrecht. The proposal was firstly for the needs of business spaces within the Kop van Zuid, and the areas for living came into it. (Rodermond & Tilman, 1993) Quickly, it became clear that social housing the new area of the Kop van Zuid would not be realisable within the proposed development. The vision for the area was that it would be seen as a central part of the new urban plan to attract high quality cultural, recreational and business developments. Especially for high income groups.

In order to realize the plan, collaboration between public and private sectors was vital. Hence, many different market participants were involved in the plans of the Kop. As a result, the traditional roles of the disciplines architect and urban designers changed. They not had the abilities to design a new urban district, but also had to attract investors. (Rodermond & Tilman, 1993)

The goal of the urban plan was not only to make the Kop van Zuid a place for higher income groups. It was also important to connect the Kop van Zuid to the city centre across the Maas River. Apart from creating a cultural and financial centre and connecting this new area to the existing city centre of Rotterdam, it was also important to establish connections to Rotterdam Airport and stadionweg (an important street) in the South of Rotterdam. The development of the Kop van Zuid would make it easy to quickly reach the Airport and Stadionweg from the city centre. This was especially needed for the business sector.

Hence, the government and the municipality of Rotterdam agreed on the above-mentioned visions for the Kop can Zuid and financed the construction of the main infrastructure. Theyimplemented the varkenoord viaduct, the metro station Wilhelminaplein, the tramplus infrastructuur (in English = infrastructure for the tram system) and the Erasmus bridge (Erasmusbrug). Although, the connection of the Willemsbridge is not comparable with the Erasmus bridge, the new bridge created strong physical and symbolic connections form the south of Rotterdam to the city axis (Coolsingel = a street name on the axis in the city centre) centre. The highway of Rotterdam are linked directly to the districts Zestienhoven, Coolsingel waterstad and Kop van Zuid. The connection to the city axis of the centre and other cross axis to other further districts forms the framework of the Kop van Zuid. (Balzer, 1994)

1.5 Allocation plan for Kop van Zuid

The vision and master plan of the Kop van Zuid was linked to the master plan of Rotterdam through the establishment of an allocation plan. The allocation plan demonstrates how the social, planning and qualitative objectives underlying the master plan would be realised. It specifies the parameters for the overall area, as well each sub-area. However, the plan is flexible and can be changed to, to accommodate changing needs as the developments are implemented. (Balzer, 1994)

The project Kop van Zuid consists of much taller developments compared with projects from Europe and specific from the Netherlands. In order to guarantee the quality of these developments, the Q(uality) team was established by the municipality of Rotterdam. The team consists of several architects and urban planners of international fame, from the Netherlands and Europe. The members of this team continue to review upcoming developments till today. Furthermore, the intention of the Q(uality) team is also to reinforce each other as individuals. (Balzer, 1994)

Figure 1. The extensions of the port in Rotterdam in 1898 (Meurs, 2012).

Figure 2. Lodewijk Pincoffs. retrieved from: http://resources.huygens.knaw.nl/bwn1880-2000/lemmata/bwn1/pincoffs

Figure 3. Nieuwe Waterweg in 1872 (Meurs, 2012).

Figure 4. Haringvliet (Meurs, 2012).

Figure 5. Boompjes (Meurs, 2012).

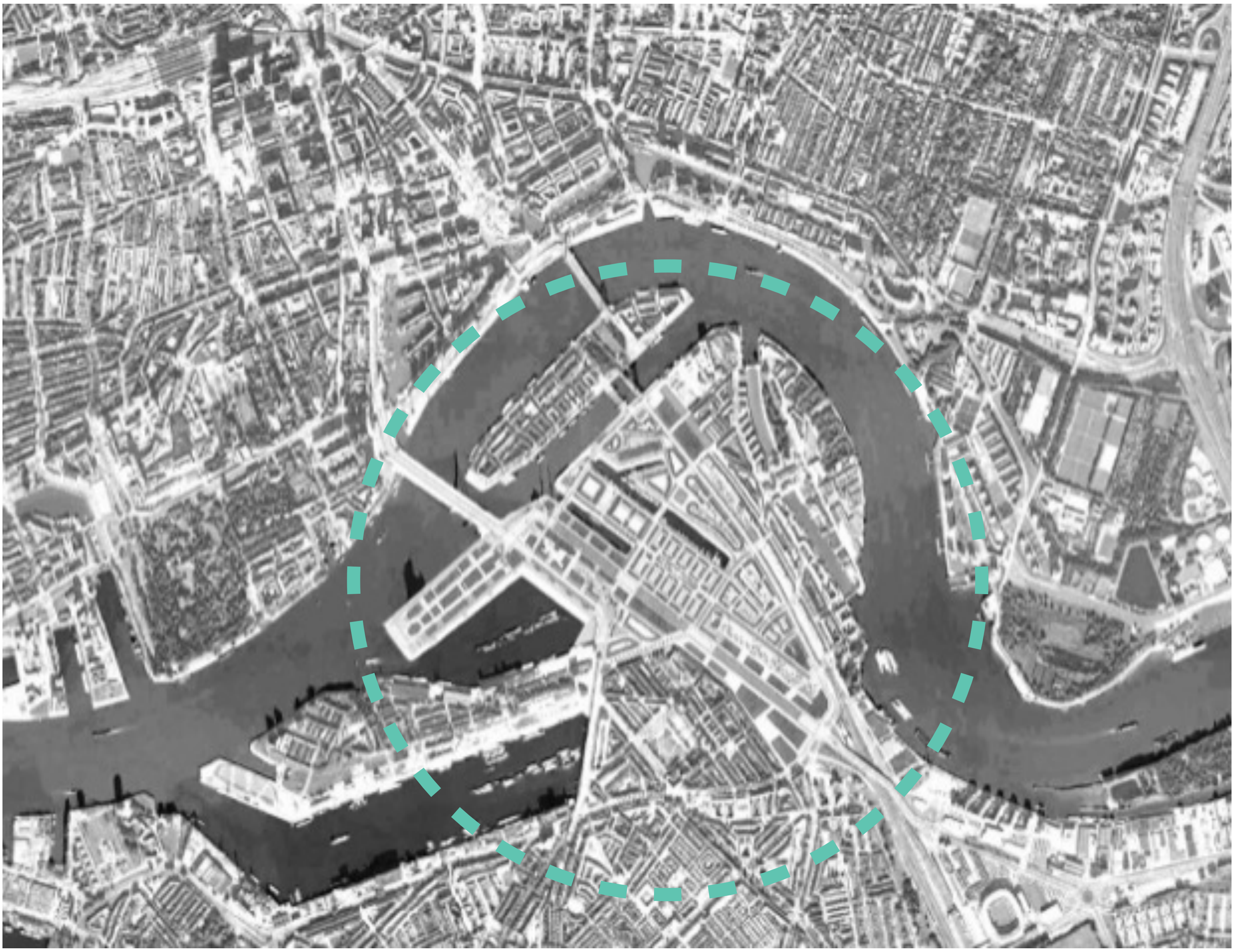

Figure 6. Allocation plan. retrieved from: https://theportandthecity.wordpress.com/tag/kop-van-zuid/

02

Architectural design of the Erasmus bridge

The second chapter will look more closely at the design of the Erasmus bridge. It will explore the motivations behind choosing a more expensive design over a cheaper one.

2.1 Iconic value

In the first century BC, architect, engineer and roman soldier Vitruvius has described that the architectural value of a structure was based on firmitas (firmness), utilitas (usefulness) and venustas (beauty) (Verheul, 2012). Throughout history, literature about iconic architecture has described, similar concepts. Iconic value is used in a variety of contexts to assess the qualities of a project. Often, iconic architecture symbolising important events in history and hence intrigue people who are curious to know more about the narrative behind such projects. Such projects can be recognised by an aesthetic characteristic that distinguishes them from other artefacts. As Verheul states, iconic architecture is famous, at least for a certain population, and it distinguishes itself due to symbolic or aesthetic meanings ascribed to it. (Heijnsdijk & Mouter, 2015)

Looking at infrastructure projects around the world, many projects aim to create iconic value above and beyond their functional value. Such examples include the Golden Gate Bridge in San Francisco and the Oresund Bridge connecting Copenhagen (Denmark) to Malmö (Sweden) (Verheul, 2012).While the functional goal of many infrastructure projects is to improve traffic flow in an area, iconic projects are often designed to stand out in a certain way. In the context of Rotterdam, an iconic bridge was needed to symbolise the redevelopment of the Southern part especially the Kop de Zuid, which was economically lagging behind the rest of the city in the '90s of the previous century (Dammers, Hornis, & de Vries, 2005). Hence, the proposed bridge connecting the redeveloped Kop de Zuid to the city centre of Rotterdam would also be a symbolic connection between the flourishing centre of Rotterdam and the southern part of Rotterdam which was much more deprived.

2.2 The design phases

During the planning of the Kop van Zuid, the idea arose to construct a bridge that would connect the south of Rotterdam to the city centre. This connection need to be both functional and symbolic, in order to create an iconic landmark for Rotterdam. The municipality of Rotterdam asked an structural engineer, to lead the design team and to explore the limits of what possible was on the site (Melet, 1997). Arie Krijgsman was chosen as he was a structural engineer with creative capacity. He soon realised that it was not the structural design, but the architectural design of the bridge which was most important. Hence, he approached the architects Wim Quist and Ben van Berkel to join the team as aesthetic consultants. Finally, van Berkel took over the lead for the design of the bridge and Krijgsman was the structural engineer in the team. In that time, it was from a structural point of view, a major concern that an architect, instead of an engineer, designed the Erasmus bridge (Reusink & Kuijpers, 2018).

During 1991, the concept phase of the design, several alternative bridge designs were proposed during the concept design stage for the bridge. It was a real battle of different designs. Finally, the council chose a design that they felt had the most charisma, even though the chosen design was approximately 18 million euro more expensive than the more restrained design proposed by the city architect Maarten Struijs. While both proposals had similar infrastructure capacity, the main reason for selecting van Berkel's design was that it would create a spectacular icon for the citizens of Rotterdam. The slender design and the dramatic heights of the pylon made the design striking and were symbolic of the high ambitions for the Kop van Zuid. Hence, it was the symbolic value of the design which was the deciding factor in the city council's decision. (Balzer, 1994)

Originally, the bridge was named "Harp Bridge" due to the harp-like shape of the bridge and the string-like cables connected to the tall pylons (Annema & de Jong, 2010). The pylon with cables referenced the harbour cranes that were frequently seen at the Kop van Zuid when the harbour was there. Later the bridge was renamed to Erasmus bridge.

The proposed design did face criticism from the public for a number of reasons. Firstly, the municipality had approved the design although it exceeded the budget. As the Dutch government financed a large part of the construction of the Erasmus Bridge, some saw this as an irresponsible use of public funds (Annema & de Jong, 2010). Secondly, van Berkel was accused of plagiarism. As he has earlier worked for Calatrava, he was accused of copying the design of Seville bridge. While both bridges used backward-sloping pylons, Calatrava's bridge did not have cables attached to the pylon. Furthermore, the weight of the pylon in Calatrava's bridge spanned horizontally. In contrast, the pylons in van Berkel's design spanned vertically. The span of the Erasmus bridge is also almost twice as long as the span of Seville bridge. Hence, if the design of Erasmus bridge was identical to that of Seville bridge and did not have ropes attached to the pylons, the pylons would have to be over 250m high, which would not have been structurally feasible. (Melet, 1997)

2.3 Pylon fixation

The Erasmus bridge is the second bridge to cross over the New Maas River. It has a 239-meter-high asymmetrical kinked steel pylon. The bridge was initially nicknamed "The Swan", because of their shape. Between the Kop van Zuid and the place of the pylon (back of the bridge) there is a 89 meter long bascule bridge for ships. This was added in the design for shipping that cannot pass under the cable-stayed bridge. This bascule bridge is the largest and heaviest bascule bridge in Western Europe. (Balzer, 1994)

The manner in which the pylon was fixed to the bridge is fascinating. The pylon itself was assembled in Vlissingen by Heerema, a contractor that specialises in heavy construction. They were the only contractor that was capable of bringing the pylon onto the site in one piece (Gannon, 2004). Doing so helped to save twenty million guilders in construction cost. One of the largest crane ships of the world was used to place the pylon on the back. When the pylon arrived on site in April 1995, more than ten thousand spectators gathered to watch the assembly of the bridge. Public interest had been raised through discussion between international specialists due to the complex shape forces of the pylon. This had lead to both concerns and interest in the constructability of the bridge. This had mostly to due with the fact that there was a lot of discussion about the pylon bend by international specialist. They believed that the shape forces were complex and complicated. Hence, they concern about the constructability of the bridge. (Heijnsdijk & Mouter 2015).

After its completion in 1996, the bridge became famous for its exceptional design and was deemed a success by residents and visitors (Verheul, 2012). Various significant events like the Tour the France and the Red Bull Air Race are organized around the bridge.

The Erasmus bridge made the Kop van Zuid easily accessible, by walking and through public transport. By bus, it takes 10 minutes to reach the Kop van Zuid from Rotterdam Central Station. The city tram service, know as RET, also uses the Erasmus bridge. In 1997, the metro was also introduced at the Kop van Zuid, leading to even greater connectivity to the station Wilheminaplein. (Melet, 1997)

2.4 Ben van Berkel

Most bridges are typically designed by engineers instead of architect. However, the design of the Erasmus bridge challenged this practice. Ben van Berkel, was an architect without any engineering background. He has studied at the Rietveld Academie in Amsterdam and at the Architectural Association in London. In London, he met his partner Caroline Bos, which is an art historian. (Kunstbus, 2016)

It was characteristic of him to create designs that appeared gravity-defying, as seen in the design of the Erasmus bridge. He was also known for designing asymmetrical forms and for his distinct use of materials. The streamlined shapes, sharp angles and sloping surfaces seen in his designs are reminiscent of current-day parametric designs. (Kunstbus, 2016)

During the academic year of 2001-2002 the student of facility of the Knowlton School of Architecture had conversation with Ben van Berkel and Caroline Bos. The following was extracted from a series interactions of the book “Source Books in Architecture, UN Studio Erasmus Bridge”.

Designing the Erasmus Bridge

During interviews, Ben van Berkel mentioned that the architects were not happy with their jobs. He felt that there was a hierarchical tradition within the practice and he wanted to distance himself from this. He felt that this could be done by introducing new ways of working. For example, he asked the following questions:

> *“How could an architect operate in our culture? How could one be experimental?”*

He shared these thoughts with his friends and colleagues, such as architects Greg Lynn, Alejandro Zaera-Polo, and American architectural criticus Jeff Kipnis. They were also interested in new techniques and new opportunities these techniques would bring. They wanted to integrated different discipline in the design process as the architect and engineers.

Throughout the 1990s, many practitioners were talking about the computer and the kinds of designs that would be possible through the use of computers. Hence, van Berkel looked at contemporary techniques and explored how those techniques could work in the architectural field. He hoped to discover the essence of architecture through the exploration of such technique. This was explored during the design process for the Erasmus bridge. There were many discussions between architects and engineers and they together attempted to push the limits of architectural design by “developing new design techniques in pursuit of new architectural effects". The main intention was to create an architecture that was inclusive and in van Berkerl's words, "this was the greatest lesso he learned while he was working on the Erasmus Bridge". He mentioned:

"We devoted ourselves to developing new design techniques in pursuit of new architectural effects. Perhaps most importantly, we strove toward greater inclusiveness. This was the great lesson we learned working on the Erasmus Bridge".

The design process undertaken for the Erasmus bridge demonstrated that the computer was able to eliminate the traditional fragmentation of architectural practice.

By using the computer, many more design options could be explored. Hence, they knew that they needed to change the way of working, because the effect was positive. This was a positive change in the design process and reaffirmed van Berkel's thinking that the process of architectural design should be changed for the better through the inclusion of computers. The computer allowed the designer to "see everything at once. Geometry, materials, structural forces, effects of light, paths of movement, and more were explored within the framework of that single machine." While this new tool helped to better organise and intensity the design process, it did not create new forms. Hence, the main advantage of using computers was that it made the design process more efficient and allowed "conceptual and material concerns to come together simultaneously." By using these new methods in the design of Erasmus bridge, the bridge become both "manifesto and its proof" for van Berkel.

"With the computer, we could see everything at once. Geometry, materials, structural forces, effects of light, paths of movement, and more were explored within the framework of that single machine" van Berkel

During the design process of the bridge, the architects decided to do it differently in this case. Ben van Berkel had worked with Calatrava and was impressed with his work, particularly in the way he expressed structural forces in his designs. Hence, van Berkl also tried to imbue the design of the Erasmus bridge with this character. However, van Berkel was also critical of Calatrava's projects. He felt that Calatrava's projects "existed as discreet objects" that were "conceptually removed from the life of the city." For van Berkel, it was important that the project "insinuates itself deeply into the fabric of the city." Hence, he felt that the design of the Erasmus bridge should be such that it would be integrated into the fabric of the city. This meant that the design of the bridge should "derive from the distinct character of Rotterdam." Distinct from the "administrative formality of the Hague" or the "picturesque quality of Amsterdam", Rotterdam has always been a city with "an industrial character". To van Berkel's wife, who was also working in the UN studio, this made Rotterdam "by farthe most modern of the three cities, owing largely to the fact that it was horribly bombed during the Second World War." Hence, the design team felt that the Erasmus bridge should have a subtle industrial character as that would befit an iconic project within Rotterdam. This was reflected in the pylon and cables. It was also important for van Berkel that the visual continuity of the river and the view from North Island would be preserved. Hence, the iconic pylon was placed in such a way that is was seen from the city center and the north Island.

It was clearly that the design was a great example of a design approach which integrated the fields of construction, urbanism and architecture. About every step was considered by the different disciplines. It was an educational project for van Berkel's office, the UN studio, as they were able to practice the ideas they had been building up over the years. The Erasmus bridge was a projects whit a lot of challenge and complexity.

Caroline: "We felt the bridge should derive from the distinct character of Rotterdam. Rotterdam has always had an industrial character, quite different from the administrative formality of The Hague or the picturesque quality of Amsterdam. Rotterdam is by far the most modern of the three cities, owing largely to the fact that it was horribly bombed during the Second World War".

Following the design process, the construction of the Erasmus bridge went very slowly. The construction of the bridge took ca. two years and it was officially opened in 1996. After the opening, the bridge faced issues. The cables moved violently whenever there was rain or heavy wind speeds between 10 and 18 m/s (Melet, 1997). To address these issues, the bridge had to be closed. This caused a media scandal and was used by many Dutch political campaigns to criticise the ruling party. However, upon inspection, it appeared that the issues were caused by a minor technical oversight. It was easily solved by modifying the position of the shock absorber. The media had made a mountain out of a molehill. In the words of Caroline Bos, "Perhaps any project must go through that sort of thing to achieve success. Nevertheless, the citizen of Rotterdam did embrace the bridge. It was a symbol of pride for residents and was used in the long-standing competition between the cities or Rotterdam and Amsterdam. Despite the minor technical issues, the iconic form andww advanced techniques used in the construction of the Erasmus bridge put Rotterdam on the map (Melet, 1997).

Figure 7. The Pylon. (Oorthuys et al, 1996)

Figure 8. Building the Erasmus bridge (Oorthuys et al, 1996)

Figure 9. Model Plan Kop of Zuid (Gannon, 2004).

Figure 10. The Erasmus bridge (Communicatie-team Kop van Zuid, 1993)

03

Construction of the Erasmus bridge

The third chapter will focus on the construction of the Erasmus bridge. The bridge's pylon gave the design a lot of complexity and led to design challenges that the engineers and architects had to tackle.

3.1 Overview of the bridge

The design of the Erasmus bridge needed to solve two distinct functional requirements. Firstly, the bridge needed to allow ships to pass under it without creating any obstacles that would delay the flow of ships. Secondly, the slope of the bridge needed to be gentle enough to allow for public transportation, cars and bicycles. In order to achieve both of these requirements, the engineers and architects combined two different bridge principles within one bridge. The front of the bridge (Northn part) is based on the principles of a cable bridge while the end (south part) of the bridge is based on the principles of a bascule (i.e. movable) bridge.

As the cable bridge has a many suspension points, the bridge deck needed to be 2.30m thick. As for the bascule (movable) bridge, it needed a vertical passage of 50m under the bridge. The resulting vertical passage under the Erasmus bridge is 12.50m +NAP over a width of 200m. In the middle of the bridge, there is a lane reserved for public transportation (i.e. Rotterdam's tram system). On either side of this lane, there are other lanes for cars, cycling and pedestrians. To accommodate these uses, the maximum slope of the ramp is 1:28.

The properties of the bridge are shown in table 1

3.1 Urban bridges

With its 139m tall pylon, the design of the Erasmus bridge is striking and can be seen from many parts of Rotterdam. As an urban bridge, the Erasmus bridges could not just meet functional requirements. Most urban bridges are also landmarks for cities. Hence, the Erasmus bridge had to meet the aesthetics, socio- cultural expressions and technological developments of the times. In order to achieve this, construction issues had to be considered in the initial stages of the design. In the design of most urban bridges, the engineers proposed short to medium spans in order to allow for more complex design elements that would create an iconic bridge. The complexity in the design of most urban bridges comes from creating an appropriate design for the context, as it is important for the scale of the bridge to be in harmony with its surroundings.

To meet the transportation requirements of the Erasmus bridge, it was important to integrate the bridge with other existing structures associated with Rotterdam's transportation system. Traffic maintenance requirements also played a decisive role in the design options that could be considered. The existing transportation system had to remain operational during the construction phase of the bridge. Construction schemes that used steel-concrete composite decks or prestressed concrete decks were considered to be the most convenient.

During the design process of the Erasmus bridge, the architects explored various creative ideas and these were proposed to the engineers for their assessment. Some of the ideas were very complex and the computer proved to be an invaluable tool for visualising complex details such as the pylon and calculate some parts of the structural parts. The architects conveyed their ideas to the engineers through simple illustrations and photographs. The photograph in **Fig XX** shows that when compressive forces are applied to a vertical element, a bend naturally occurs. Horizontal forces are not desirable for bridges in the Netherlands because the soil is weak. If the horizontal forces became to high, the bridge would not stand. When the team where analyze the bending moments they saw that a straight pylon with uniformly distributed stay cables has the biggest bending moment at the middle. However, the loads decreased when the pylon bend in the other direction. The bent pylon produces more forces with smaller loads compared of the the big moment of the straight pylon. Hence, the team chose for a short bended pylon, which give the benefit of more economical construction of less material. (Gannon, 2004)

The original intention was to construct the pylon out of concrete. However, the architects and engineers realised that using steel was more advantageous as the superstructure could be constructed indoors in a remote location before being brought to site. This could save time and construction cost.(Gannon, 2004)

3.2 The Pylon

The pylon is slender, with a modern look. It is 139 metre in height and 3 metre wide. It has been fabricated of thermomechanical rolled high strength steel S46OML, which was unique for its time. The plate thickness could be reduced significantly because the fatigue and plate stability were not governing factors. Hence. the dead weight and the amount of welding could be reduced. Since, the thermomechanical rolled steel has a very low carbon equivalent, the thick plates could be welded without pre-heating. Hence, it saved money. It is painted in four layers of white to protect it against weather conditions. (Communicatie-team Kop van Zuid, 1993).

The top of the pylon can be raised mechanically over a vertical distance of 2 m. The platform used for inspections hangs on cantilevered beams. By using the rail system, the platform can hang out and the entire perimeter of the pylon can be reached. During operation, fastening points along the wall of the pylon prevents the platform from moving horizontally in the wind. (Reusink & Kuijpers 2018).

The final shape of the pylon came about from the following construction challenges:

1. How can the cantilever of the upper front cables at the top of the pylon be minimised?
2. How can the bending forces be minimised?

These questions can be answered by understanding how the bridge works in terms of deflection, strength, forces, balance and loads.

Balance

There are two plans of 16 cables at the front of the bridge. Altogether, the Erasmus bridge is balanced by 32 cables that are connected to the pylon. The pylon is made of high quality thermal galvanized steel - S46OML - which is five times stronger than regular steel. To ensure that the cables do not pull the pylon forward, two thick cables are connected to the pylon. These two cables are anchored deep into the foundation in order to bring the bridge in balance (Den Adel & & Noorlander, 1995). When the loaded condition is at its maximum, the tension in the cables is 60 kgf/mm2. Each of the 16 cables is composed of secondary cables which consist of a core surrounded by six cables. These secondary cables are protected with preservatives and are coated by polyethylene to protect it from weather conditions. However, this is not enough the pylon is kinked asymmetrically. Hence, to ensure balance, a large clamping moment is placed in the foundation. As the 32 cables cannot carry the entire weight of the pylon on their own, more support is provide by another four points under the bridge. Two of these points are paced on both shores. The third is placed under the pylon and acts as an anchor for the cables at the back. It is also used as a support point for the bascule bridge. The counterweight of the bascule bridge is also involved in this support point. After the vibration of the cables that occurred after the opening of the bridge (Melet,1997), additional stability was added by, installing hydraulic dampers at the attachment points. (Den Adel & & Noorlander, 1995)

Deflection

The deflection takes place at the kinked asymmetrical point of the pylon. After the opening of the Erasmus bridge it appeared that distortion could occur because the wind and rain caused the cables to vibrate. The vibration occurred because a small water jet ran over the cables, causing the profile of the cables to change into a wing profile. Hence, this profile caused the cables to swing and the water jet moved further. This effect could be reinforced by weather conditions that can cause an amplitude of up to one meter. (Reusink, 1997)

Strength

Strength is an important property of any bridge. For the Erasmus bridge, strength is more important at some points than others. The first important point is where the cables are attached to the pylon. The cables must be anchored well to the road surface at the top of the pylon. To ensure that the cables do not get damaged by vandalism or traffic accidents, tubes are attached to the bottom of the cables to protect them. The second important point of strength is within the cables itself as they should not break or bend. The large moments in the foundation are important as they results in extra clamping that prevents the cables from rotating. (Den Adel & & Noorlander, 1995)

The pylon was internally strengthened by horizontal partitions that also as floor elements. The two anchorages at the back of the pylon were the most complex part of the pylon design. Each anchorages consist int total of four cables and have a combined weight of 45000 kN. Each pylon leg supports vertical forces with a load of more than 40000 kN (Reusink & Kuijpers 2018). As mentioned before, the architect and engineers chose to have only vertical instead of horizontal forces. At each pylon leg, there are 1x2 m rubber that operate as support for the load transfer. In addition, both anchorages have internal stairs, ladders and platforms. The western anchorage also has an elevator. As a result, all internal positions, especially the cable anchorages, were made accessible.

Forces and loads.

Different loads are exerted on the bridge. These include, the weight of the traffic that runs on the bridge, natural elements like the wind, and the load from the pylon itself. To ensure that the bridge will not be disturbed by these forces, different calculations were made by structural engineers. In the calculation, the load of the forces attributed due to traffic flow were based on a traffic jam in both directions, consisting of cars and trucks carrying loads of 60 ton each.

The bending forces were minimized by the vertical position of the backstay anchorage and also by the bends and angles of the lower and upper legs. They limited the cantilever of the upper front cable at the top of the pylon by attaching the back stay cables at the minimal height of the third front stay.

Total length	802	metres
Length cable bridge	410	metres
Bascule bridge. Inc basement	89	metres
Free passage below the cable bridge	260	metres
Minimal 12.5m + NAP	200	metres
Passage below the bascule bridge	50	metres
Top of the pylon	139	metres
Height bend of the pylon	79	metres
Height of bascule valve	63	metres
Maximum height of road deck	17	metres
Construction height of the deck	2.3	metres
Maximum ramp of the deck	1:28	metres
Width of the road deck cable bridge	30.80	metres
Width of the road deck bascule valve	33.10	metres
Sidewalk	2 x 2.45	metres
Bicycle path	2 x 2.60	metres
Roadway automobile traffic	2 x 5.60	metres
Path Public transport	2 x 3.15	metres
Total weight cable bridge	6.800	ton
Pylon	1.800	ton
Cables	600	ton
Total length cables	6.180	metres
Total length strings	515.000	metres

Table 1. Overview Erasmusbridge

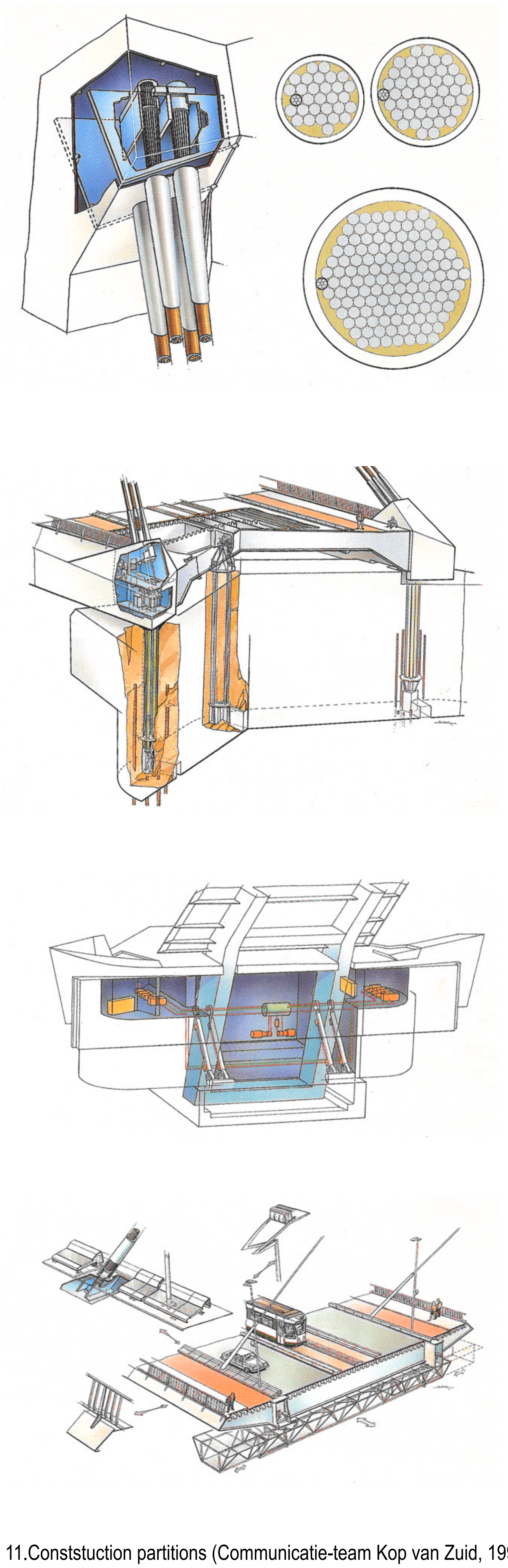

Figure 11.Conststuction partitions (Communicatie-team Kop van Zuid, 1993)

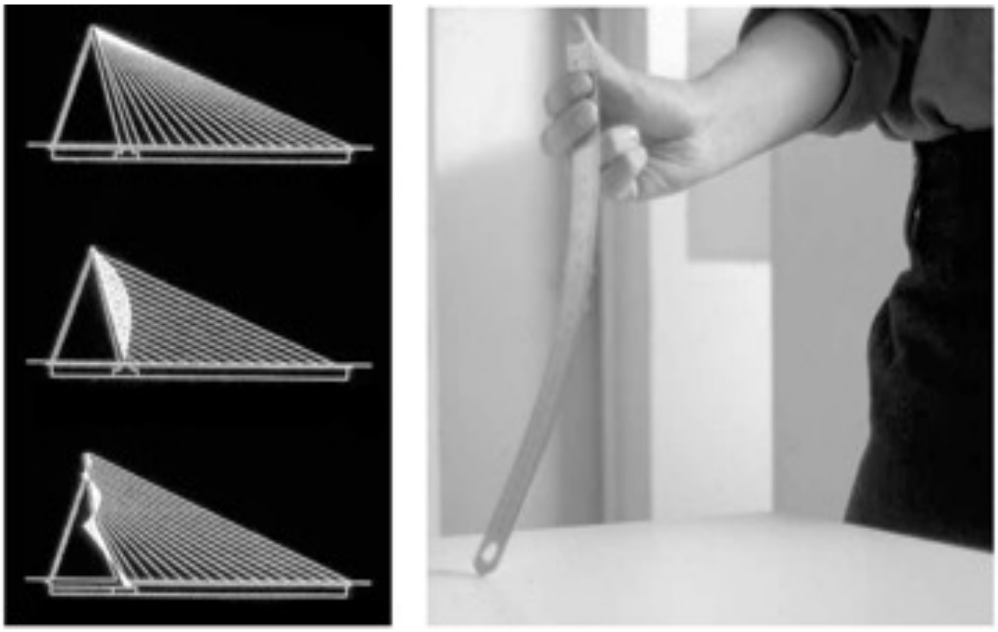

Figure 12. Bending forces. (Oorthuys et al, 1996)

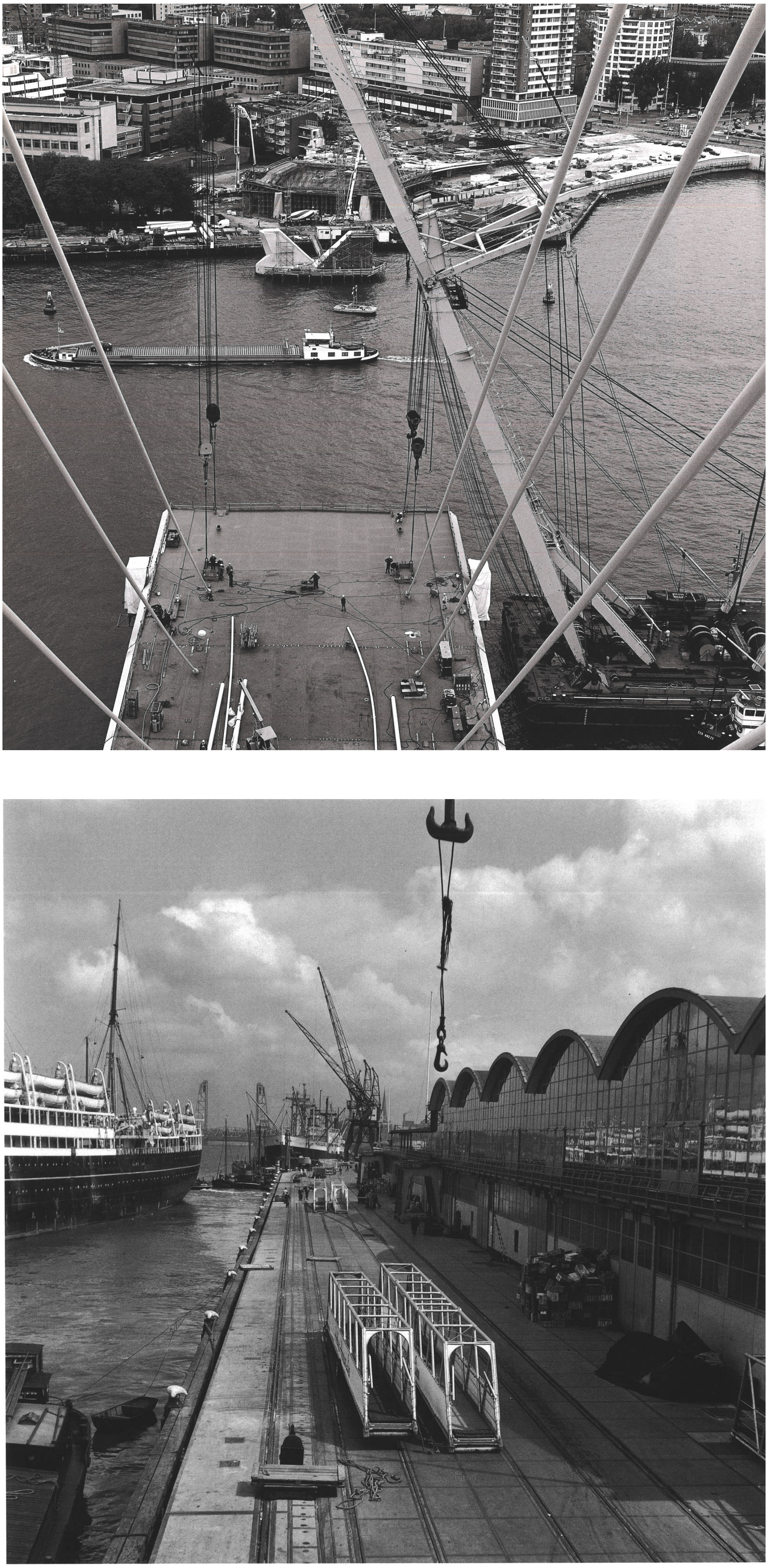

Figure 13. Construction of the Erasmus bridge (Oorthuys et al, 1996)

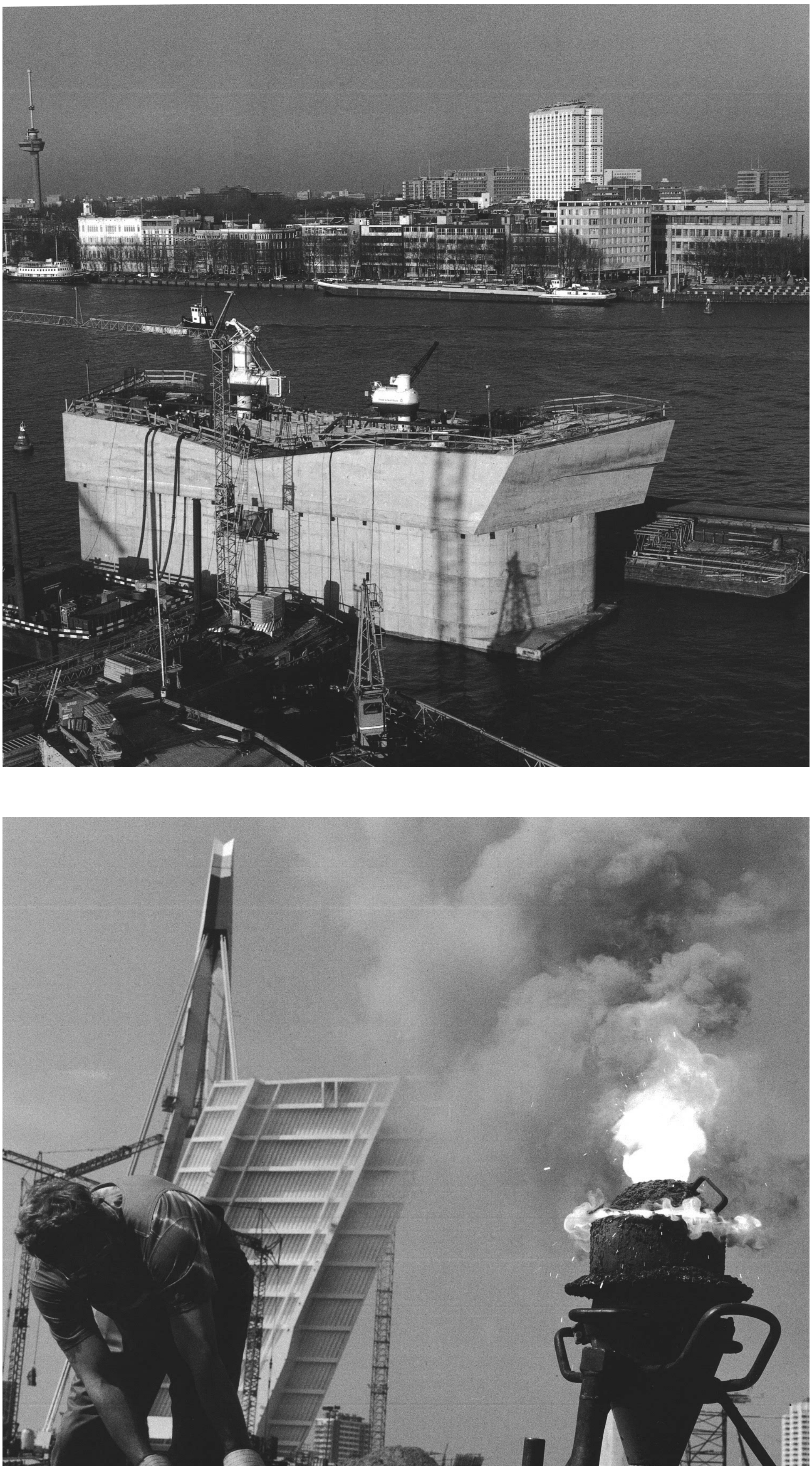

Figure 14. Construction of the Pylon (Oorthuys et al, 1996)

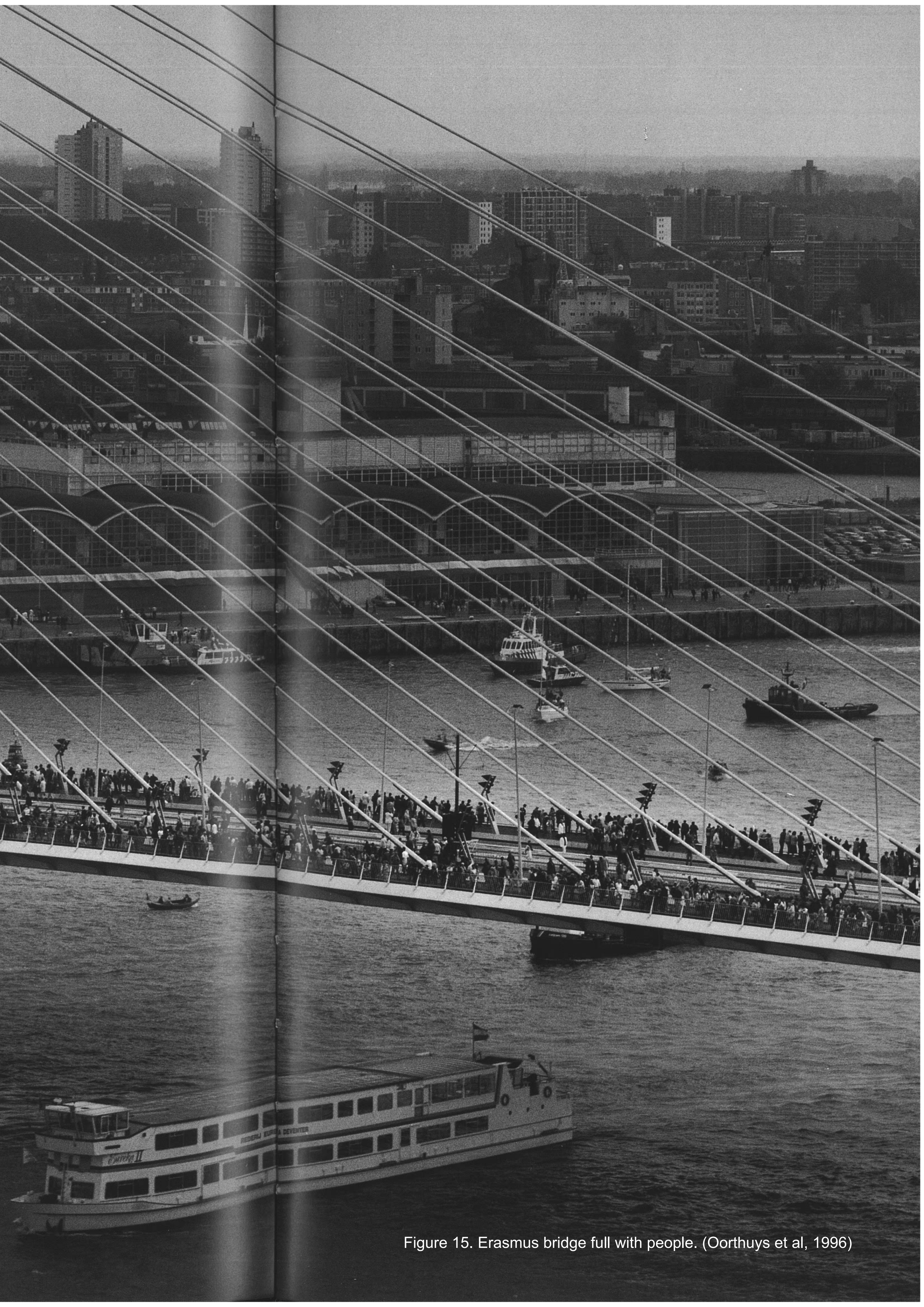

Figure 15. Erasmus bridge full with people. (Oorthuys et al, 1996)

04

Conclusion

The conclusion will give answer op the main question of the thesis: “What is the meaning of the Erasmus bridge for its surroundings and Rotterdam as an entire city, within the fields of urban planning, architecture and construction?”.

For forty years, Rotterdam was known for having the largest port at the Rhine and Maas river in the world. After the grow of the ports in Antwerpen and Hamburg, Rotterdam became a transit harbour 1879, pioneerd bij Lodewijk Pincoffs. The first harbour area on the southern bank became too small to accommodate the increasing traffic, it was shifted to the west of Rotterdam facing the North Seas. As a result, the south part of Rottedam became an abandoned area, basically after 1945.

The municipality of Rotterdam planned to erase the harbour ares of Pincoffs during the seventies. However, insights about heritage changed and the Kop of Zuid was prioritized on the agenda. During this process it went clear that the South part needs to integrate more in the city centre of Rotterdam and needed to be seen as a central part of the new urban plan to attract high quality cultural, recreational and business developments. Looking at infrastructural needs of the early nineties, the bridge was not indispensable because the Willemsbrug and the Maastunnel were well-functioning connection between north and south part.

Koolhaas and Riet Bakker proposed the master plan together. This plan represents the remarkable proposal to construct a new bridge that would connect the city centre (North part) of Rotterdam to the Kop van Zuid (South part). Very consciously after a small competition the municipality of Rotterdam chose the most expensive design of Ben van Berkel to be built, aiming for the highest quality of architecture. This was continued at Kop van Zuid, where a Quality Team was formed. As a result the bridge became an iconic symbol of the urban (re)development of Rotterdam, across the river Maas. Now, the spine of Rotterdam in the 21st century.

The connection of the city center and de Kop van Zuid was also considered in the architectural design of the Erasmus bridge by the architect Ben van Berkel. In that time, it was from a structural point of view, a major concern that an architect, instead of an engineer, designed the Erasmus bridge. However, the case of the Erasmus bridge shows that design of the Erasmus bridge challenged this practice and made it an icon for Rotterdam. The design of the Erasmus Bridge paved the way for the imagery of the architecture at Kop van Zuid: modern with some abstract symbolism (a swan floating on the water). This is especially reflected by the slender pylon, which refers to the cranes of the harbour in the past. To meet the transportation requirements of the Erasmus bridge, it was important to integrate the bridge with other existing structures associated with Rotterdam's transportation system. Traffic maintenance requirements also played a decisive role in the design options that considered.

The Erasmus bridge sealed the upgrading of Kop van Zuid and other neighborhoods at the southern river bank. It can be interpreted as a shake hands symbol of North and South, and expressing the river Maas as the heartline for all future developments.

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