

# Surgical Quay-wall Renovation

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*This paper describes an innovative approach towards quay wall renovation design. In the “RDM Kraanbaan 13” project in Rotterdam, significant cost savings were made and environmental impact was minimised, while on a tight schedule and with limited information about the structure and its future use. Essential were a very practical and flexible team of engineers, quick decision making, performing field tests to support design calculations and commitment towards saving the structure.*

**Keywords:** Quay-wall, Deck-on-piles, Renovation, Rejuvenation, Innovation, Sustainability, Field Testing, Brownfield.

## 1. Introduction

The “Kraanbaan 13” quay-wall in Rotterdam is being renovated. The approach followed in that renovation is new and has advantages. This paper describes the approach and those advantages. It also summarizes the lessons that we learned in the process, which may be of use for anyone trying the approach. The paper does not intend to describe all technical details of the project.

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## 2. Background

### 2.1 History

Use of space and infrastructure often changes as a result of redevelopment of areas, or simply as a result of a change in user. Functions of existing structures may then also change. In the past, these structures were then all too often simply demolished, leading to excessive investments and an environmental impact higher than required.

At the premises of the former Rotterdamsche Droogdok Maatschappij (RDM or Rotterdam Dockyard) shipyards in Rotterdam Heijplaat, a case as the above occurred. A deck on piles was no longer in regular use and appeared in bad technical state. This quay-wall, called “kraanbaan 13” (in Dutch) or crane track 13, had originally been in use as ship repair facility. After bankruptcy of the shipyards in the mid 1990s, the terrain was largely dismantled. During this time, the quay was used by a demolition company to ship off heavy steel structures, and it was specifically this use that caused damage to the deck and piles.



*Figure 1. “Kraanbaan 13” with crane vessel during the early 80s.*

## **2.2 Rejuvenation**

As part of the overall rejuvenation of the area into a light maritime industrial area that was to be a high profile “campus for innovation and sustainability” the structure was now to be renovated to allow continued light industrial use. Rejuvenation of the area is part of a deal between PoR and the municipality of Rotterdam to revive several port areas near the city center.

## **2.3 Technical details**

The quay-wall consists of 2 sections, each being a concrete deck on piles with a water depth of 10.65m to NAP, but having a different structural design. The North section originates from 1955 and has a length of 216 meter and a width of 12.0 meter. The structure consists of a continued, concrete, wide U-shaped structure, on top of a large number of concrete piles. The U-shape was filled with sand, and originally covered with pavement. The South section originates from 1966 and has a length of 166 meter and a width of 12.5m. This part of the quay-wall is built up as a series of concrete trestles, 9.0m apart, each side supported on 6 concrete piles. On top of the trestles is a deck, consisting of prestressed concrete I-beams,

with a concrete deck on top. The two designs are illustrated in below Figure 2 and Figure 3. Behind the entire length of the quay-wall, a sheetpile wall serves as retaining wall.

The South section needed the majority of the works. The approach for the renovation of the South section is the subject of this paper. The renovation of the North section will be discussed, but in less detail.

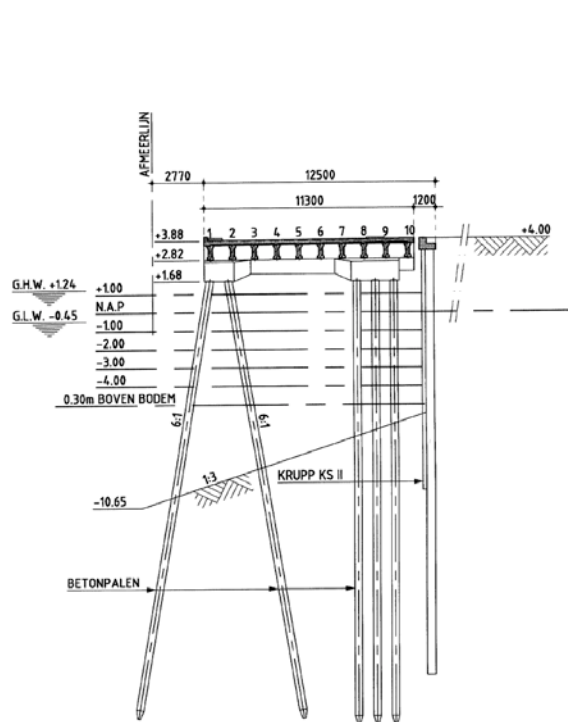


Figure 2. South section design (cross section, not to scale)

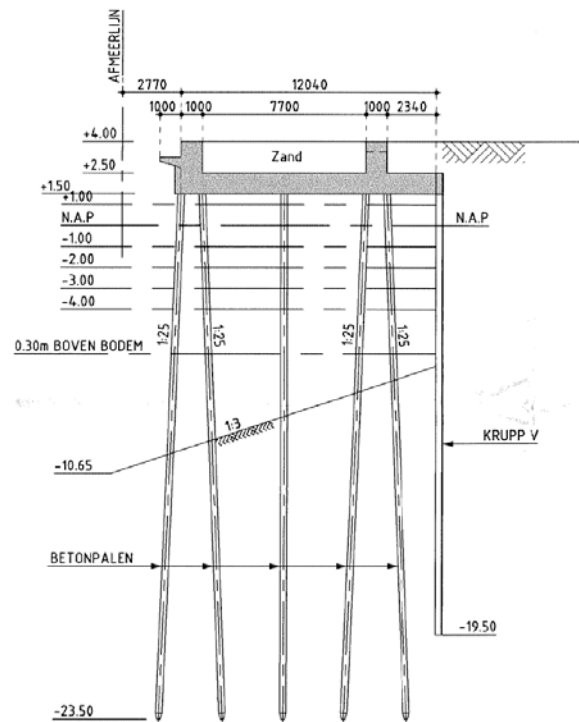


Figure 3. North section design (cross section, not to scale)

## 2.4 Invitation To Bid

In August 2009, the Port of Rotterdam Authority (PoR), as owner of the quay-wall, issued an invitation to bid (ITB) for the renovation design and tender documents. With this ITB, Royal Haskoning's (RH) involvement commenced. Prior to the ITB, 2 other engineering consultancy firms had recently been involved: one for technical inspections and one for (amongst other) a sketch design for the renovation.

## 3. Objective and Challenges

### 3.1 Objective

In short: the objective was to make a renovation design and tender documents for a concrete deck-on-piles structure. The only 2 requirements were 1) distributed variable load of 20kN/m<sup>2</sup> on entire deck, and 2) tender award before 31st December 2009.

Section of the ITB (translated into English):

*“Important drivers in the RDM area are sustainability and innovation, but these aspects have not been made concrete in the sketch design. In your offer, we would like to see concisely demonstrated how you envisage materializing the opportunities related to sustainability and innovation in this project.”*

### **3.2 Challenges**

Challenge is any renovation project is combining new parts with the old structure. In this project, added challenges were:

1. A very tight time schedule; deadline for tender award was 31 December 2009, less than 4 months after envisaged start of design. The schedule was driven by the absolute requirement to award construction in 2009, to secure 100% subsidised funding of the project. The schedule was considered short for a traditional approach, but extremely tight for a project using an innovative approach;
2. Very limited information was available about the structure. Reporting on recent (visual) inspections were available, but no drawings (certainly not as-built) and no design calculations. There was evidence of overloading of the structure, but no previous users could be approached to obtain information about use;
3. The future users of the structure were yet unknown. Operational requirements were not known. Priorities could not been discussed;
4. The overall plans for the RDM area were not fixed, leading to varying requirements during design, tender and even construction;
5. PoR challenged the bidders in the ITB to “make sustainability concrete”. See Figure 4;
6. PoR challenged the bidders in the ITB to come up with an innovative approach that aligned with the philosophy of the overall RDM rejuvenation project. See figure 4.

## **4. Approach**

### **4.1 Alternative Approach**

The sketch design (by others) proposed a full replacement of the deck at the South side, whilst the substructure was kept in place with no measures being proposed. For the North section, several options for new pavement were described.

In the proposal stage, time was invested to consider the existing sketch design and the envisaged process, as described in the ITB. It was realized that “if the South section’s substructure is 100% OK and does not need any repairs, then it is unrealistic that the top structure would need 100% replacement? And vice versa.” Instead, an alternative approach was proposed.

### **4.2 Guidelines**

Governing in the project approach were the following guidelines:

1. Perform an in-depth technical inspection of all parts of the structure, aimed at determining which parts of the structure may be maintained within a renovation design;
2. Keep all parts in place that are still functional. Minimize the volumes of materials to be demolished and constructed;
3. Restore the structure to its original capabilities, and maintain the design principles of the old structure in any new part;
4. Make the renovated structure robust and simple.

The design philosophy thus was to restore the structure to its original capabilities, to design very invasive but local repairs, and keep the overall structure as is. Surgical renovation. Further, several measures were taken to increase durability and robustness. Complicating factor in such an approach is that “old” structures generally do not meet structural safety criteria of modern guidelines. Not always because of lower safety, but sometimes because of different design philosophy or different calculation methods. Key in the approach was a transparent attempt to save the structure; looking for possibilities rather than obstructions, without taking shortcuts with structural safety.

Concretely, the project was to consist of the following parts: documents review, on site inspections, preliminary design, final design and tender documents.

## **5. Description of the Project**

### **5.1 Time schedule**

The activities carried out in the project are discussed individually below. Considerations and activities irrelevant for this paper have been left out. Because of the short time schedule, most activities ran at least partially in parallel. As stated above, at the start of the project, the project was to consist of the following activities: documents review, on site inspections, preliminary design, final design and tender documents. During the course of the project the following were added: field tests of I-beams, cone penetration tests (CPT's), post-award contract negotiations, construction design, construction management & supervision & back-office support.

Project status at time of paper: design finished, tender awarded, construction started Q1-2010.

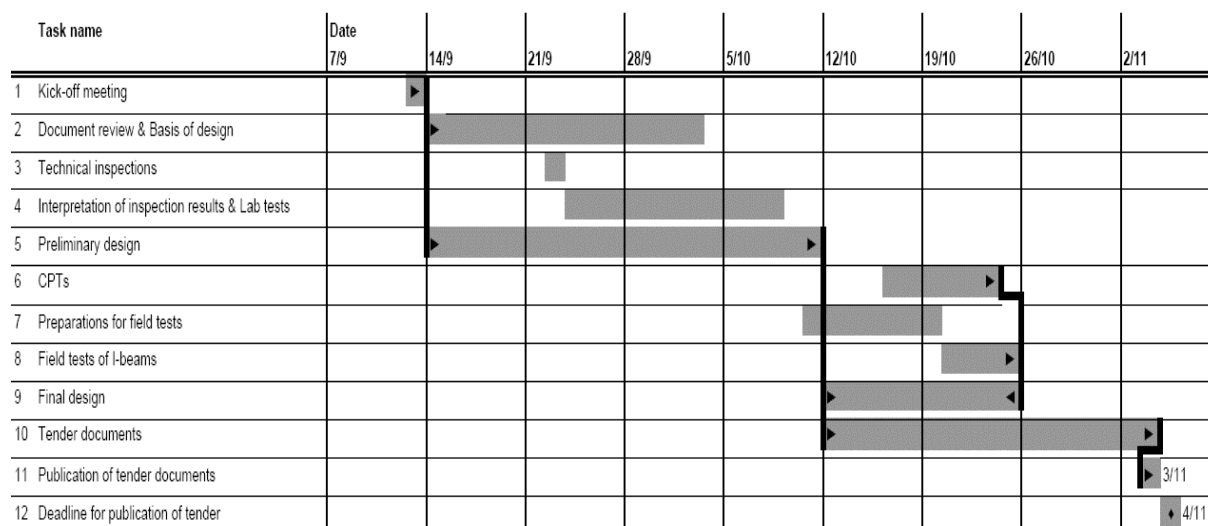


Figure 4. Time schedule, as performed

## 5.2 Documents Review

The project started by studying the documents made available by the PoR, as well as a search of the municipality archives. Only very limited information was available about the structure, as is illustrated in table 1 below. This emphasized the need for further inspections.

Table 1. Available information at start of project

Document	Review
Drawings of outer dimensions	✓
Reinforcement drawings	✗
Concrete Quality	✗
Reinforcement steel quality	✗
Information on prestressing	✗
Concrete cover on reinforcement	✓
Technical state of structure & materials <sup>1</sup>	✗
Foundation piles design	✗
Soil parameters	✗
Loads	✓
Overall design principles	✓

## 5.3 On Site Inspections

Inspections by RH and subcontractors showed that a number of very serious local damages was present in the structure (both substructure and top structure), but that in general, considering age and general previous use, the structure was in reasonably good condition.

Main conclusions:

<sup>1</sup> Recent visual inspection reports of the structure were available. However, more detailed information on the technical state of the structure including e.g. intrusion of chemicals into the concrete was not available.

- At the South section, 13 foundation piles were found to be broken or completely missing, with another 9 piles damaged (of total 226 piles). 17 I-beams were broken or severely damaged, with another 6 damaged (of total 187 beams). The bituminous deck wear layer was severely damaged. The concrete underneath the wear layer however, was in good state. Chloride intrusion into the concrete was limited throughout the structure. Deck, I-beams, supports and piles generally were in good condition. No polycyclic aromatic hydrocarbons were found in the bituminous wear layer. The presence of asbestos was not suspected, after an inspection by others;
- At the North section, the pavement was almost entirely missing. Steel railings were in very bad technical state. But although a lot of local damage was visible to the concrete, in general the North section appeared in good condition;
- The breasting dolphins in front of the structure were in very bad technical state.



*Figure 5. Photo of south section, 3 piles missing underneath single trestle*

The findings of the inspections supported the originally proposed approach. However, the inspections had not provided conclusive information about the I-beams design, hence their remaining capacity. Mainly the lack of information about the level of prestressing of the beams hampered structural calculations. Secondly, the inspections indicated that the substructure of the South section needed renovation as well. This led to both increased design effort as well as the need for site investigations.

#### **5.4 Field tests of I-beams**

Due to the lack of information on dimensions, loads, material characteristics, etc, making detailed structural calculations was complicated, and would most probably not lead to complete and positive results. Moreover, applying modern rules and guidelines to an old structure, it is very easy to prove the structure does not comply (especially when forced to use conservative assumptions due to the lack of data).

NEN EN 1990 states that, under strict conditions, the design for the I-beams in the deck can be based on a combination of calculations and tests. To support the design philosophy and

reuse of the existing deck, the capacity of the deck I-beams was thus to be proven and field tests of the I-beams up to breaking load were designed and commissioned.



*Figure 6. Photo of field test*



*Figure 7. Photo of field test*

The tests showed that indeed, the beams had been prestressed, and that no reinforcement for shear forces had been applied in the beams. Overall conclusion of the tests was that the bearing capacity of the I-beams was still there. In fact, in time due to continued curing of the



concrete, the capacity of the concrete had increased. The deck was suitable to cope with the required loads.

Needless to say that having the team present at the successful tests, was good for moral.

### **5.5 Site investigations (CPTs)**

CPTs were necessary for the design of the new foundation piles. These site investigations (SI) were performed with land based SI-equipment through drilled holes in the deck, which was to be renovated at those locations anyway. This has led to significantly quicker mobilization of the SI, as well as some cost savings, compared to waterborne SI-equipment. To facilitate this technique, a casing had to be used around the cone, to provide support to the cone over the approximately 4 meter air gap and 10 meter water depth.

### **5.6 Preliminary & final design**

In chapter “6. Summary of Renovation Design”, a concise description of the renovation final design is provided. Below, the design activity is being described.

During the preliminary design, in parallel with the on site inspections, the need for field tests of the I-beams and for CPTs was identified. Scoping, contracting, preparing, executing, interpreting and reporting of these tests took time. The field tests of the I-beams and the CPTs thus ran in parallel with the final design of the deck, the final design of the foundation piles, the drawing works, the writing of the tender documents and the tender preparations. The (preliminary) results of the tests were only available a short period before the moment the tender documents had to be published. The tests therefore served to confirm the design, rather than being available as basis for the design works.

This drove PoR and RH to not only deploy a large number of staff, but mainly to make very quick design decisions, including some last-minute (radical) changes. Of course, this introduced some risks to the project. Should the I-beams have insufficient remaining capacity, then a new deck design would have been urgently required. During the project it became very clear that the quick decisions by Client PoR and the flexibility of the RH staff would probably not be the showstoppers. Therefore, to mitigate the project risks, parallel to the main renovation design, the feasibility (both technical and financial feasibility, as well as practicality given time constraints) of such alternative design including a new deck was investigated. Thus, at all times a fall back scenario was available, providing the team sufficient confidence to proceed with the innovative approach.

### **5.7 Permitting**

Because of the overall approach of the renovation, permitting authority DCMR considered the renovation of the South section as maintenance works rather than a construction project. Therefore, a construction permit was not necessary for this part of the works. Of course, this eliminated a liability from the project. For other parts of the renovation, permits for demolition works and construction works have been applied for and awarded.

## **5.8 Tender documents.**

The tender was performed based on RAW standard. Tender was based on lowest construction costs only, because of time constraints for the tender evaluation over Christmas 2009. Selection on lowest price only is however not preferred for this type of work.

## **6. Summary of Renovation Design**

Below, the main characteristics of the renovation design are given, for reference.

South section:

- Replace front I-beam over entire length with new beam, and repair deck behind it;
- Replace limited number of damaged I-beams in the deck, and repair deck around these;
- Add supports of steel tubular piles and bracings to the trestles with damaged/missing piles;
- Local concrete repairs after carbonatation / chloride initiated corrosion of reinforcement;
- Remove bituminous wear layer on deck. Apply antiskid epoxy coating directly on concrete.

North section:

- Replace (former) pavement by continuous concrete slab, supported by original structure and intermediate masonry walls;
- Remove soil from U-shaped box structure;
- Local concrete repairs after carbonatation / chloride initiated corrosion of reinforcement;
- Remove protruding walkway at front of structure;
- Apply antiskid epoxy coating.

## **7. Advantages of the approach**

### **7.1 Key advantages**

The approach has three key advantages. Primarily, construction costs are lower, because of minimized volumes of destruction works and new construction materials. Construction cost savings are estimated at around 600k – 750k euro, for the deck of the South section only (compared to 1.25M euro initial estimate sketch design). Because the original sketch design and costs estimate were incomplete, an exact amount cannot be provided. The cost savings for the deck have been reinvested in other elements within the project, to achieve an overall more durable design.

The second advantage of the approach is also related to minimized volumes of rubble and construction materials. The environmental impact of the project is thereby significantly reduced.

Third advantage is that the upfront technical inspection will, in most renovation projects, reveal unexpected aspects or features of the structure, or unknown considerations from the

original design. This may provide valuable input to the renovation design, adding value to the renovated structure, and reducing unknowns hence risks.

## **7.2 Disadvantages**

Disadvantage of the approach are that higher costs have to be made in the project preparation, to achieve the savings in overall project costs later. When from the initial inspections and tests it follows that the structure is indeed heavily damaged, and replacement is required, the initial higher preparation costs are lost, leading to (slightly) higher overall project costs. With regards to higher initial effort in the project preparation: more effort either leads to more time being required in the preparation phase, or leads to activities running in parallel thus introducing risks into the project, when unexpected events occur. These project risks mainly relate to delays due to amending designs, with associated cost overrun.

## **8. Conclusions, Recommendations & Lessons Learned**

### **8.1 Conclusions**

1. Main conclusion is that in renovation projects, by investing in detailed inspections and testing upfront, significant savings can be made in construction costs and environmental impact, without necessarily leading to longer project duration.
2. The south section consisted of separate elements (deck on beams on trestles on piles), which were easy to disassemble. Changing only selected parts, thereby giving the entire structure a second life, was relatively easy. The benefits of this principle related to renovation, which align very well with the Cradle-2-Cradle® principle, should be considered in the design of any new structure.

### **8.2 Recommendations & lessons learned**

Main recommendation is to start any renovation project with a detailed inspection, aimed at determining potential for reuse.

Practical recommendations for anyone intending to try the described approach, are listed below:

1. Decide to apply the described approach of surgical renovation based on concrete indications that savings can actually be materialized in your project. Perform a good technical inspection, after which a choice can be made between full renovation or the above approach;
2. Make sure a very flexible and practical engineering team with ample capacity is present, especially when the project faces a tight time schedule. Unexpected features will be found in any inspection, and uncertainty and changes will occur in any renovation project;
3. Good communication between Client and Consultant, and quick decision making by the Client, are key to preventing that the higher preparation effort leads to longer preparation time;
4. Acknowledge that the project can be stressful and somewhat chaotic, at the moment when the information from the tests becomes available, and the design and tender documents need to be finalized. Many scope changes and design changes occur,

which impact other parts of the design, drawings, reports, tender documents, etc. Good communication within the team is vital to keep progress on schedule and prevent mistakes;

5. Applying modern rules and guidelines to an old structure, it is very easy to prove the structure does not comply. It is vital to have an experienced structural engineer on the team, who is aware of the background of guidelines rather than only applying the formulas, and who is committed towards the attempt to save the structure. An open mind and creativity do not necessarily lead to compromises on structural safety;
6. As fall-back scenario, have an alternative (traditional) design concept available and checked for feasibility. Should, late in the design process, the laboratory tests and field tests prove surgical renovation is not an option, the alternative design can be quickly elaborated;
7. Follow the original design considerations, in any part that is replaced. That allows you to keep the replacements local, rather than one repair causing the next part to need repairing or modification;
8. After tendering, communicate the original design considerations with the construction supervision team. On site many small changes are often made. These changes should also be aligned with the original design considerations. For the Client this means that on top of regular supervision, increased back-office support by the Consultant is needed during construction.