GREEN-LINKING ROTTERDAM ZUID

DESIGN OF A BRIDGE WITH INTEGRATED PARK CROSSING THE MAAS

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Content

Problem statement
Research question
Methodology
Analysis results
Design study
  Design brief
  Context
  Concept
  Design explanation
    Structural simulation and optimisation
Final remarks
Problem statement
Problem statement

Mobility problem
Problem statement

Social problem

Job opportunities

High unemployment rate
Problem statement

Site specific
Research question
What structural feasible solution can be found for a bridge with integrated green crossing the Maas between Feijenoord and de Esch?
Methodology
Methodology
Guidelines and demands

- Future plans
- Visual Impact Plan
  - Rotterdam
  - Urban guidelines
  - Visual guidelines

- Urban context
  - Infrastructure
  - Site specific
  - Technical demands
  - Design study

- Bridging types
  - Moveable systems
  - Landings
  - Bridges
  - Feasibility structural system
Methodology

Design study

- Strategic guidelines
- Technical demands
- Structural guidelines

Urban planning
Bridge type
Moveable system

Landing design
Bridge design

Structural feasibility
Detailing
Analysis results
Analysis results
Urban plans

• Focus on sustainable means of transport

• Easily accessible

• Attractive public spaces with interesting quays

• On the quays, pedestrians will have priority

• Experiencing of water
Analysis results

Visual impact plan

- Bridge contributing to attractive public space
- Sightlines on skyline from bridge and city quays
- Autonomic volume in greater ensemble
- Connection to current city bridges
Analysis results

Technical demands

• Vertical clearance: 12.5m
• Passage width: Moveable part: 50m
                  Static: 200m
• Bicycles: Maximum ideal slope 2%
• Tram: Maximum slope 4%
• Flexible design: Future plans for transport may change
Analysis results

Site specific

• Prominent location in the city

• East entrance of city
Analysis results

Site specific

- Green character of area
• Green route with tidal parks along shores of Maas
• Two unique nature areas in Rotterdam
Analysis results

Site specific

• Location part of green cluster
Analysis results

Site specific

- Raised dyke
Analysis results

Site specific

- Social netwerk needs connecting
- Opportunity of connecting green areas
• All types of transport on the south bank

• Small road in the north, dead end of tram nearby
Design study

Context

Concept

Design explanation
Design study

Context

Concept

Design explanation
Context

Possible locations
Context

Possible locations
Context

Chosen location
Design study

Context

Concept

Design explanation
Concept

- Split deck
- Park integration
- Superstructure
Concept
Split deck

- Separate traffic flows:
  - Public transport + car ("Fast traffic")
  - Cyclists and pedestrians ("Slow traffic")
Concept
Split deck

- Different slope %:
  - Fast traffic max 4%
  - Slow traffic max 2.5%
• Integration of green connection with slow traffic
- Super structure + moveable structure have same character
• Connection to current city bridges
Design study

Context

Concept

Design explanation
Design explanation
Design explanation

Plan/landings
Design explanation

Plan/landings

- Connection to different context
• Connection North:
  
  Fast deck: at Nesserdijk
  Slow deck: at new dyke, stairs to quay
Design explanation

Plan/landings

• Connection South:
  
  Fast deck: to urban infrastructure
  
  Slow deck: flat escalator to quay
Design explanation

Superstructure

- Reacting on difference in context
Design explanation

Superstructure

- Interaction with split deck
Design explanation

Arch
• Principle of tied arch bridge
Design explanation
Arch

- Principle of applied tie
• Tie visible between decks
Influence single support on cable layout
Design explanation

Arch
Design explanation

Arch

- Influence single support on cable layout
• Influence single support on cable layout
Design explanation
Arch
• Asymmetry arch
Design explanation

Arch section

- Architectural idea
Design explanation

Arch section

- Compression forces in arch
Design explanation

Arch section

- Change of section over the arch
- Diamond shaped section: play of light and shadows
Design explanation

Arch section

- Concept of section
  - Follows angle of cables
  - Coloured
Design explanation

Arch colour
Design explanation

Arch colour
Design explanation

Arch colour
Design explanation

Arch bracing

- Optimised positioning
- Diamond shaped
Design explanation

Arch
Design explanation

Arch
Design explanation

Arch
Design explanation

Arch
Design explanation

Arch
Design explanation

Arch
Design explanation

Deck
Design explanation

Deck
Design explanation

Deck

- Fast deck; flexible in use
Design explanation

Deck

- Fast deck
Design explanation

Deck

- Slow deck; different filling of lanes
• Slow deck
• Two orthotropic box girder connected with crossbeams
Bending moments in deck
Design explanation

Deck

• Sightlines from deck
Design explanation

Deck

- Crossbeams and deck visually attractive from below
Design explanation

Green integration

Tree requirements:

• Strong against wind

• Semi ‘open’ crown

• Class 3 tree: smaller than 6m
Design explanation

Green integration

• Chinese elm
Design explanation

Green integration

- Tree boxes in deck
Design explanation

Green integration

• Permavoid system
Design explanation

Moveable bridge
Design explanation

Moveable bridge

Equilibrium: $z_w a_1 = z_d b_1$

$z_w a_2 = z_d b_2$

- Bascule principle
Design explanation

Moveable bridge

• Structural principle
Design explanation

Moveable bridge

- Mirrored arch of main span
- No cables
Design explanation

Moveable bridge

- Continuation of deck main span
Design explanation

Moveable bridge

• Same concept for arch section
Design explanation

Moveable bridge

- Counterweight drops in bascule cellar
Design explanation

Moveable bridge

• Separate counterweights and hydraulic cylinders
Design explanation

Supports
Design explanation

Supports
Design explanation

Supports
Design explanation

Supports
Structural simulation and optimisation
Structural simulation and optimisation

Design process

- Architectural idea
- Structural concept
- Optimisation process
- Final design

- Design space + Boundary conditions
- New design space
- Optimisation
- FEA
- Analyzed shape
- FEM
Structural simulation and optimisation

Structural model

- Deck and arch sections simplified to box sections with same properties
Structural simulation and optimisation

Boundary conditions

- Loads according to Eurocode
• Variables
Boundary check: clearance
Boundary check: clearance
• Maximum stresses vs Deformation vs Total mass
• Stresses in arch
• Stresses in arch
Structural simulation and optimisation

Shape optimisation

- High stresses at beginning of arch and at position of links
- Aesthetically not satisfying

Stresses: 160.8 N/mm²
Deformation: 0.25 m
            0.36 m
Mass: 8.91*10⁶ kg
Structural simulation and optimisation

Topology optimisation

- Dead load deformation before tensioning cables
• Dead load deformation after tensioning cables
Structural simulation and optimisation

Topology optimisation

<table>
<thead>
<tr>
<th></th>
<th>Before pretension</th>
<th>After pretension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast deck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead load</td>
<td>17.3 cm</td>
<td>9.2 cm</td>
</tr>
<tr>
<td>Max. load</td>
<td>25.7 cm</td>
<td>17.8 cm</td>
</tr>
<tr>
<td>Slow deck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead load</td>
<td>33.2 cm</td>
<td>17.2 cm</td>
</tr>
<tr>
<td>Max. load</td>
<td>36.4 cm</td>
<td>21.5 cm</td>
</tr>
</tbody>
</table>
Structural simulation and optimisation

Topology optimisation

- Normal forces in cables
Structural simulation and optimisation

Topology optimisation

Stresses:
- 177.8 N/mm²
- 148 N/mm²

- Change of position of bracing
Larger sections needed at endings of arch
Design explanation

Arch
Final remarks
Final remarks

Conclusion

- A new bridge can partly solve the infrastructural challenge of Rotterdam
- The chosen location is very interesting for connection of multiple networks
- Integration of park on bridge can increase its value for the city
- Parametric model as a tool for integration of aesthetics and structural feasibility
Final remarks

Recommendations

- Material research

- Green integration

- Integration green on moveable bridge
Questions?