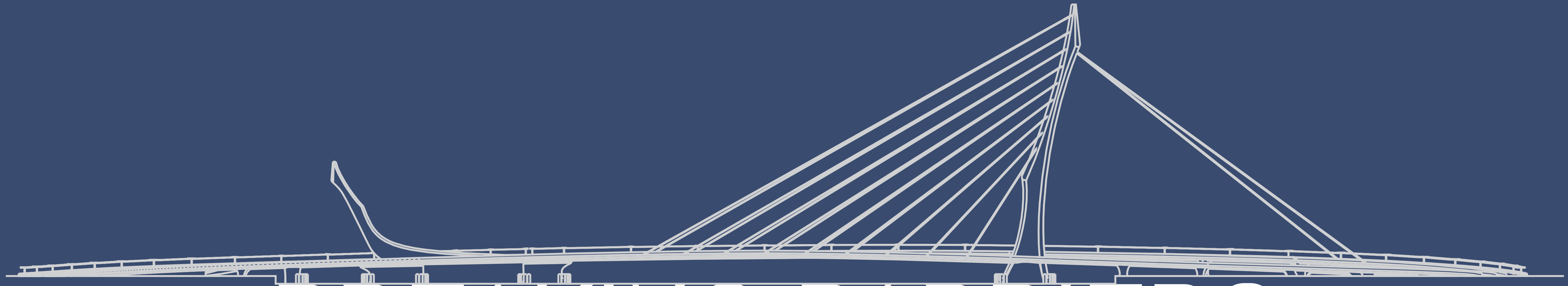


BREAKING BARRIERS

A PARAMETRICALLY OPTIMISED DESIGN CROSSING THE NIEUWE MAAS

Merijn de Leur

Content

Problem Statement

Problem Statement

Practical mobility problem

Problem Statement

Social problem

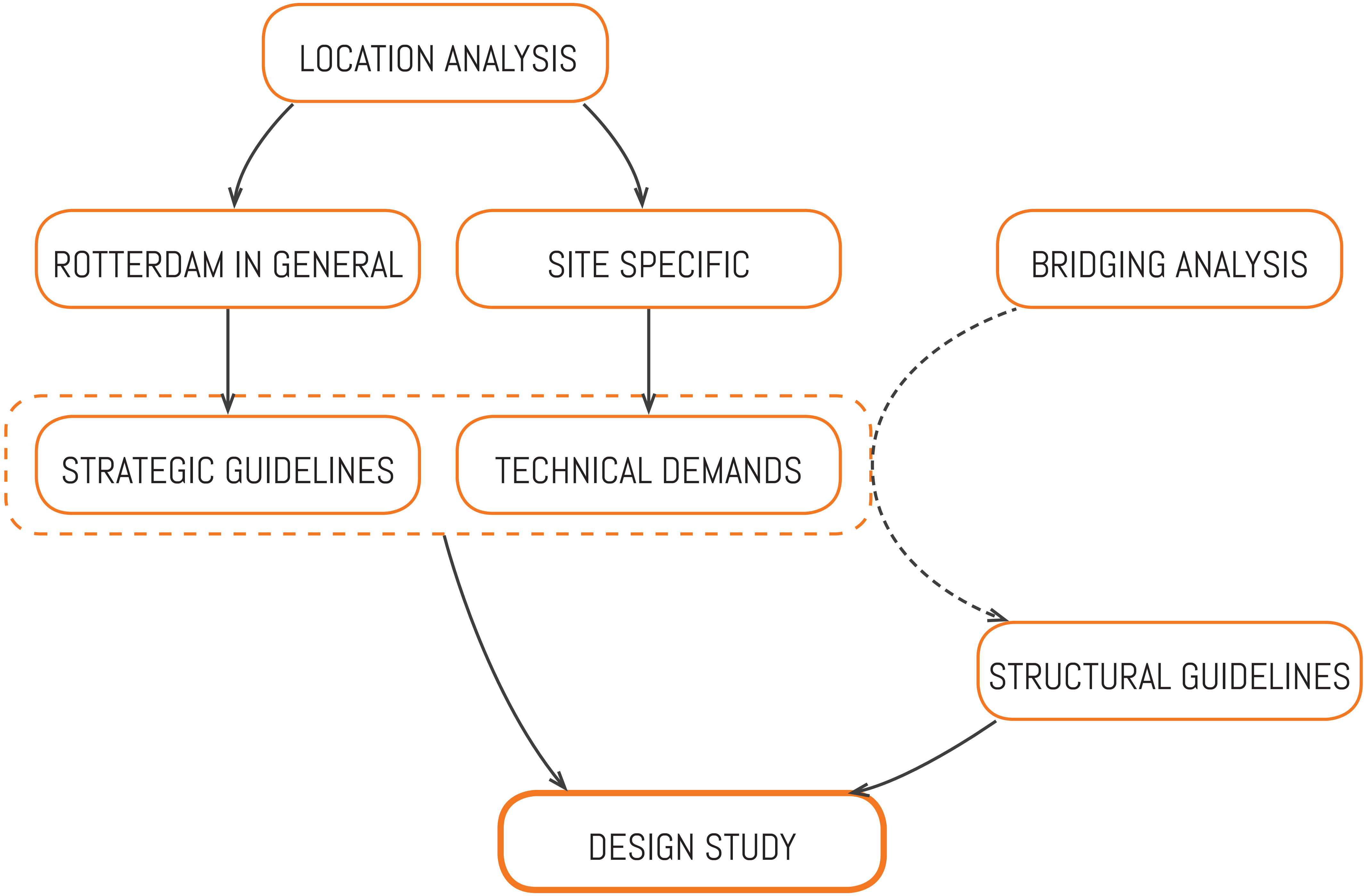
Research question

Can the current social and practical problems be solved using a bridge and how can this bridge be **designed** and **optimised**?

Methodology

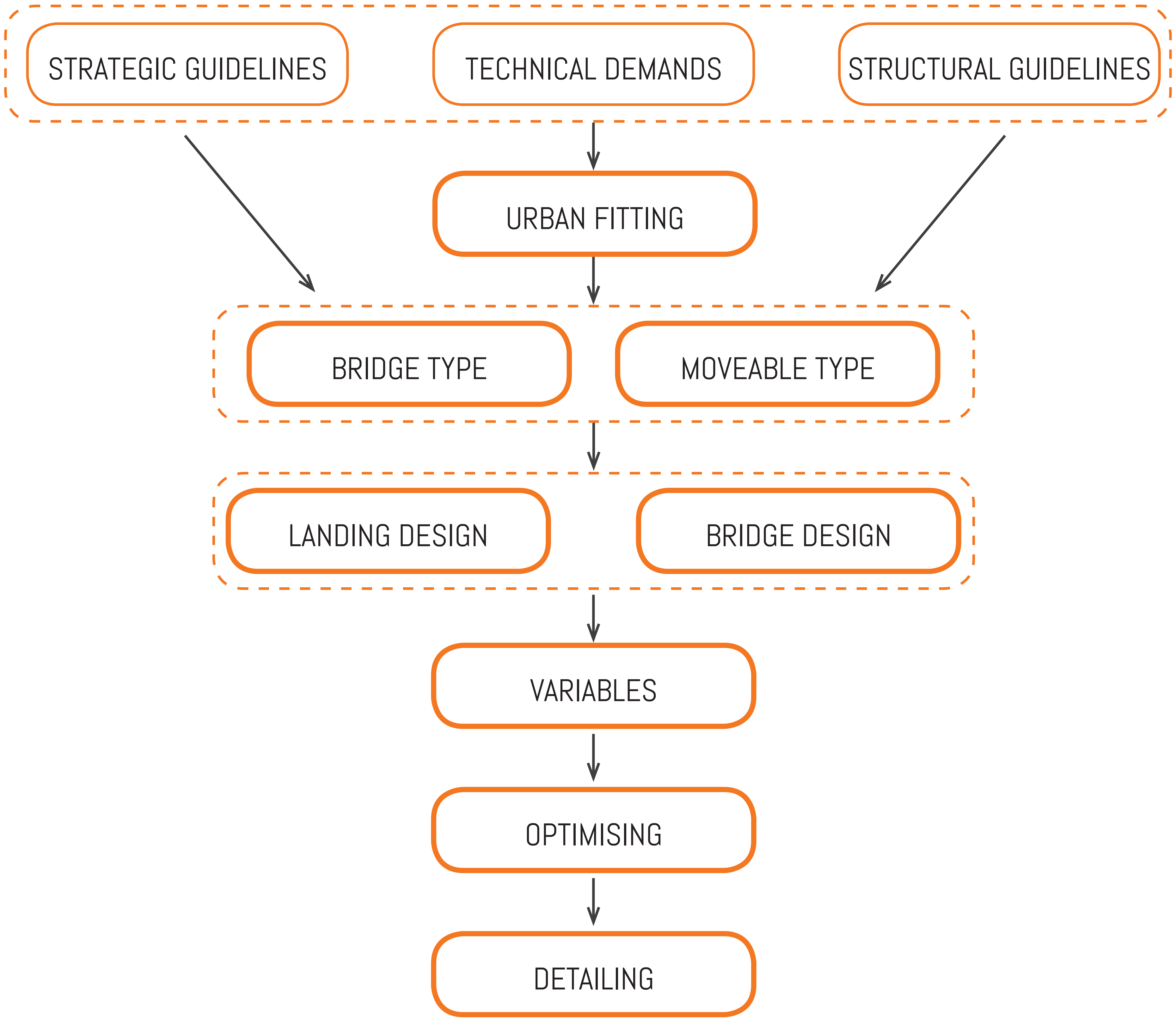
Methodology

Guidelines and Demands



Methodology

Design Study



Analysis Results

Analysis Results

Urban Plans

- Focus on sustainable means of transport
- Easily accessible
- Attractive public spaces with interesting quays
- Pedestrians have priority on quays

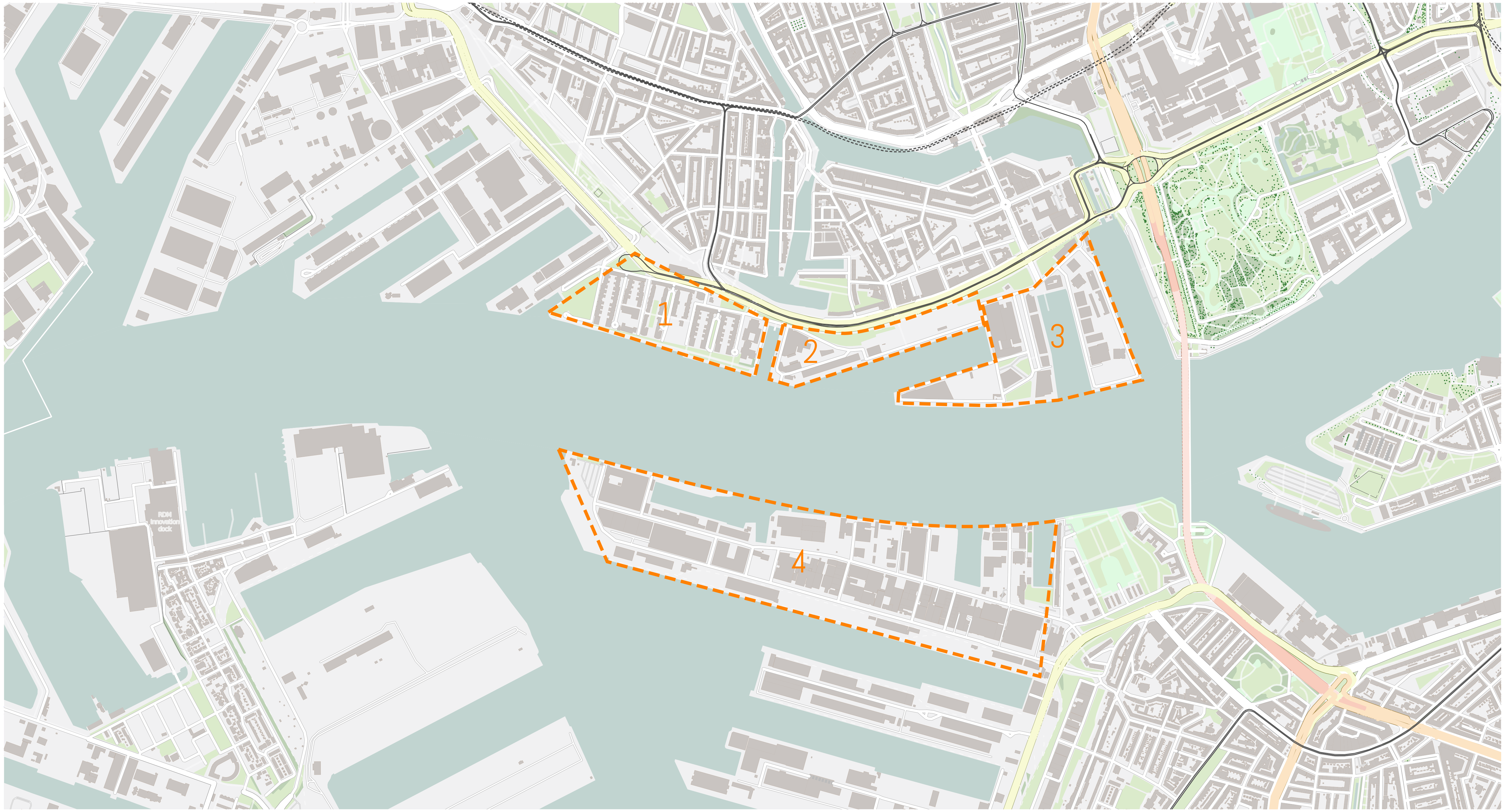
Analysis Results

Visual Impact

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

Analysis Results

Site specific

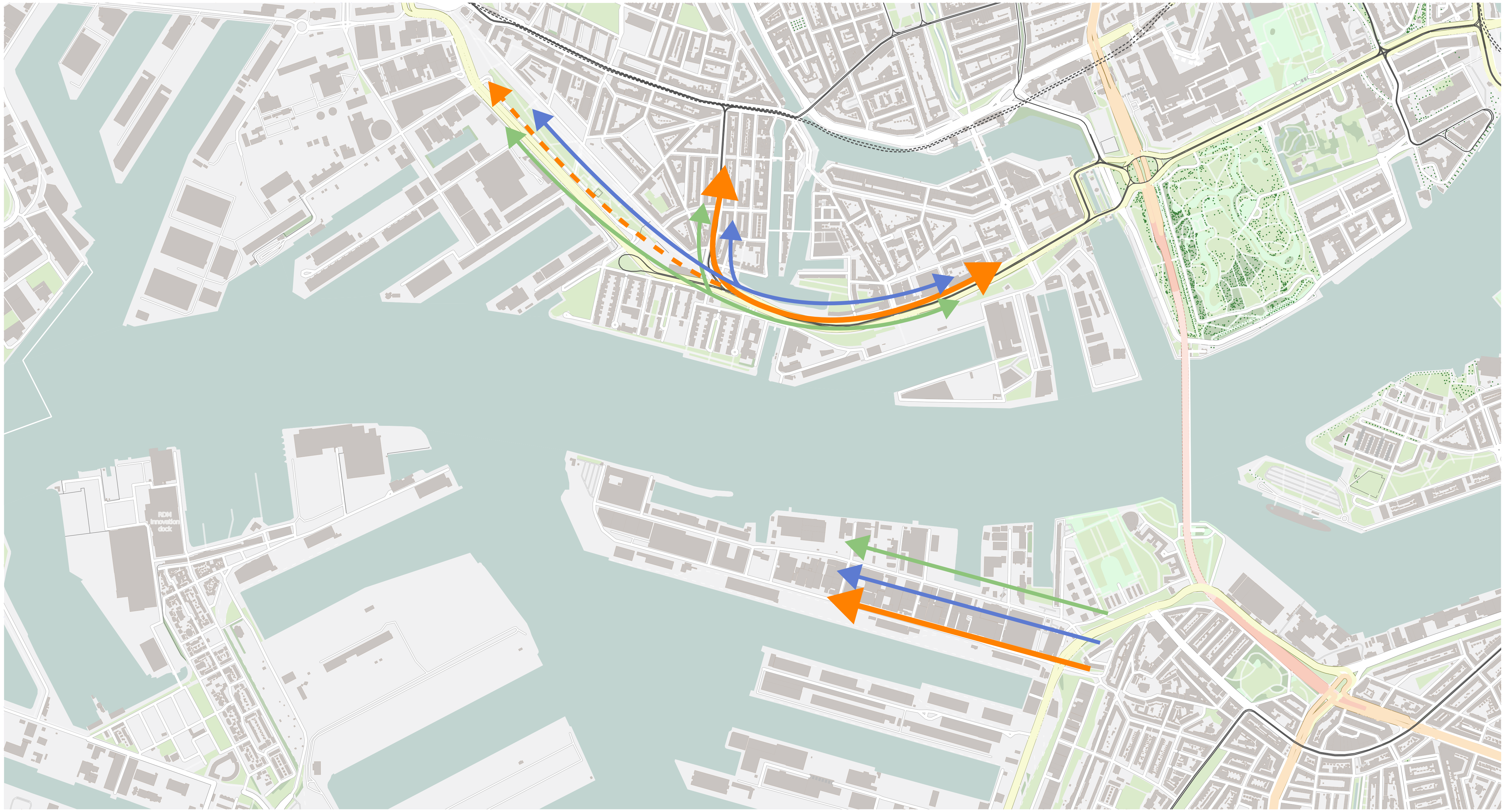


- River is ~390m to ~420m wide
- The Lloydkwartier (zone 3) is not suitable for a bridge landing
- The southern zone is free divisible

Analysis Results

Site specific

- Tram
- Pedestrians/Cyclists
- Car



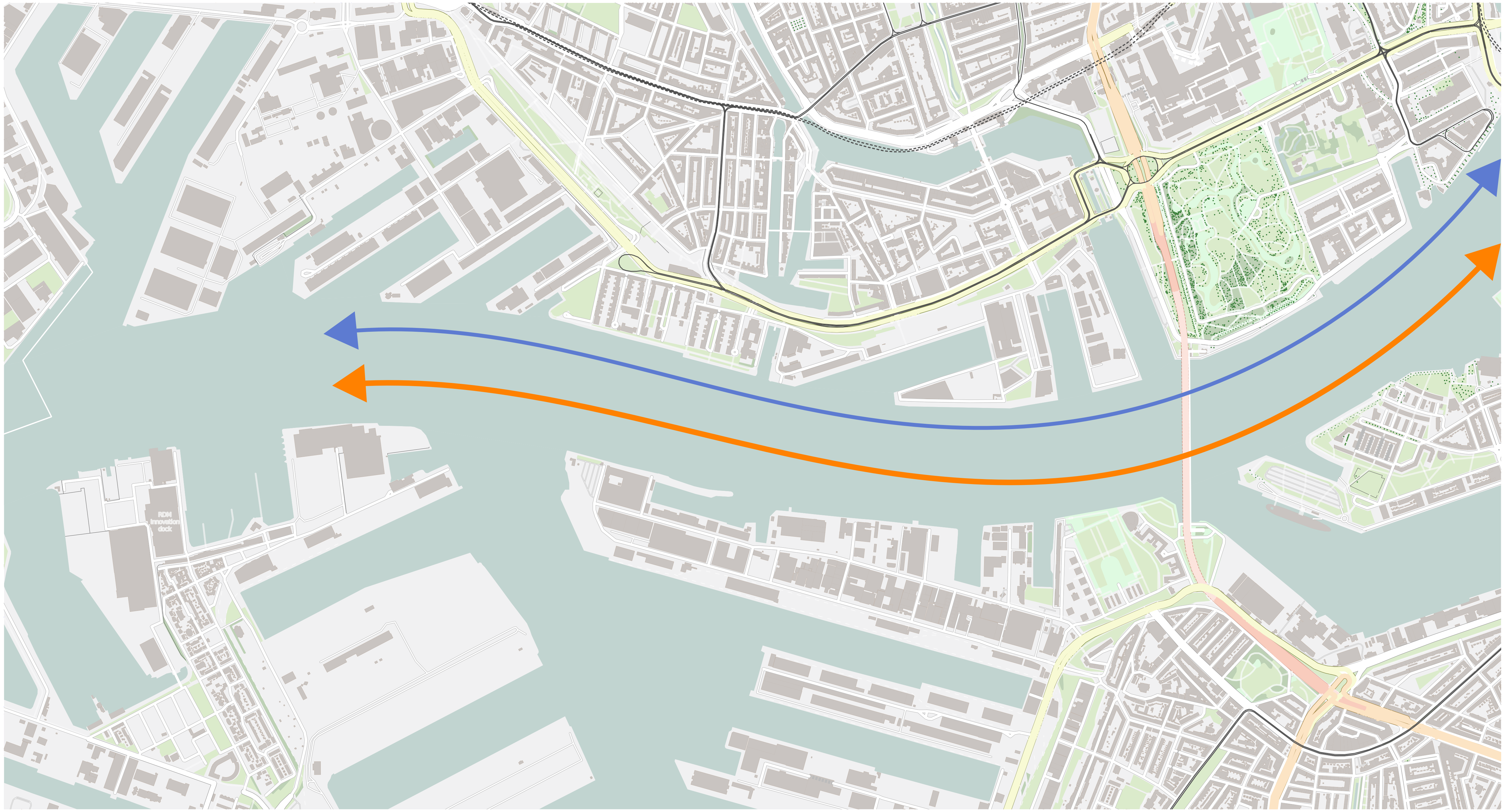
- The northern bank is entirely tangent to a main traffic route for public transport, cars, cyclists and pedestrians
- On the southern bank, all major traffic comes from the southeast

Analysis Results

Site specific

Over 12m height

Under 12 m height



- Ships under 12m height take northern route
- Ships over 12m height take southern route

Design Study

Design Brief

Context

Concept

Design Explanation

Design Study

Design Brief

Context

Concept

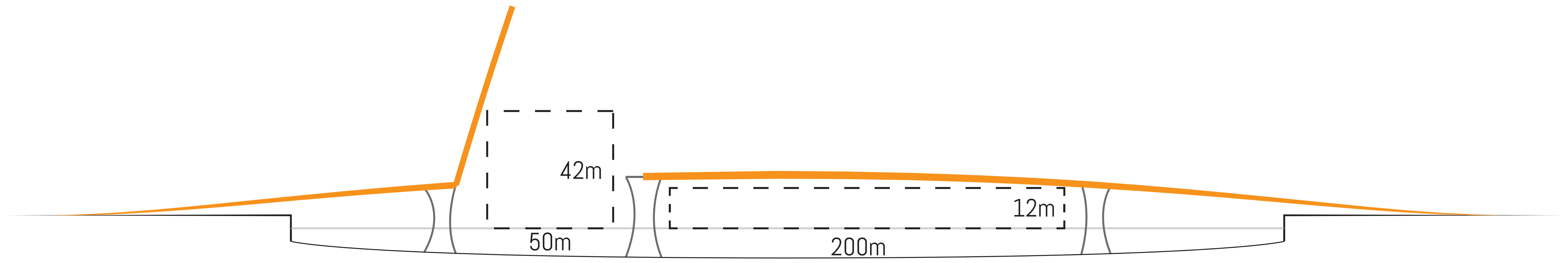
Design Explanation

Design Brief

- **Clearance**: Erasmusbrug and Hef Normative
- **Use/Traffic**: Sustainable means of transport
- **Aesthetics**: Low visual obstruction, Light-weight and elegant

Design Brief

Clearance



- The bridge crosses: 390m to 420m
- Static span clearance: 200m x 12m (Erasmusbrug normative)
- Movable part clearance: 50m x 42m (De Hef normative)

Design Brief

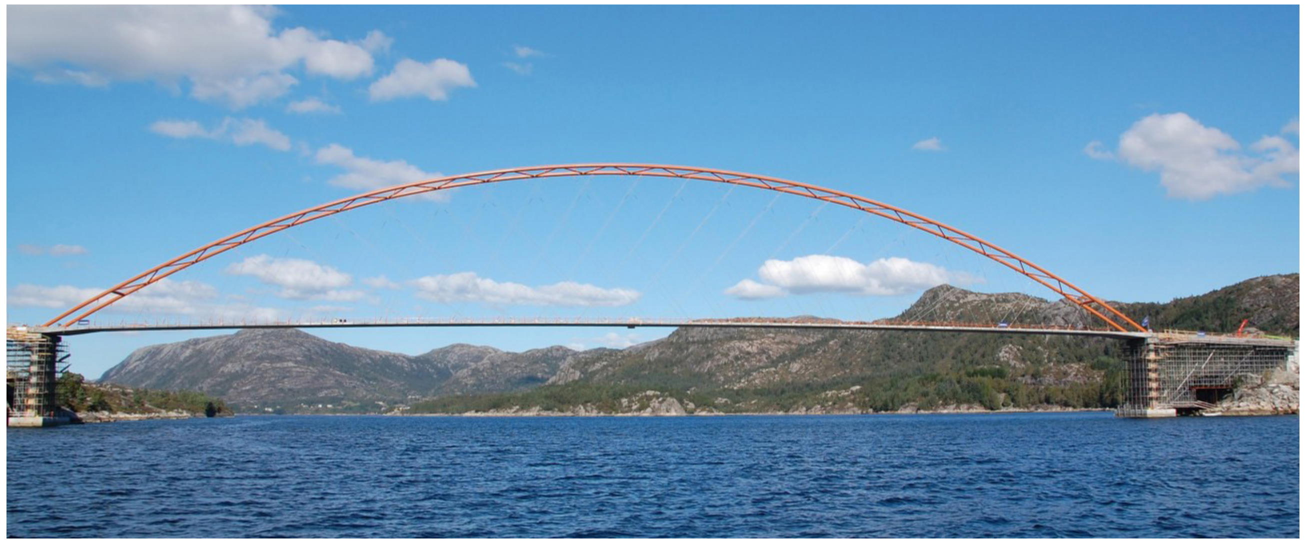
Use/Traffic

- Main Focus on sustainable means of transport:
    - Tram
    - Cyclists
    - Pedestrians
- Flexibility:
    - Possibility of cars in the future

Design Brief

Aesthetics

Low visual obstruction:



Elegant/Light-weight: Connection to city bridges

VS

Design Study

Design Brief

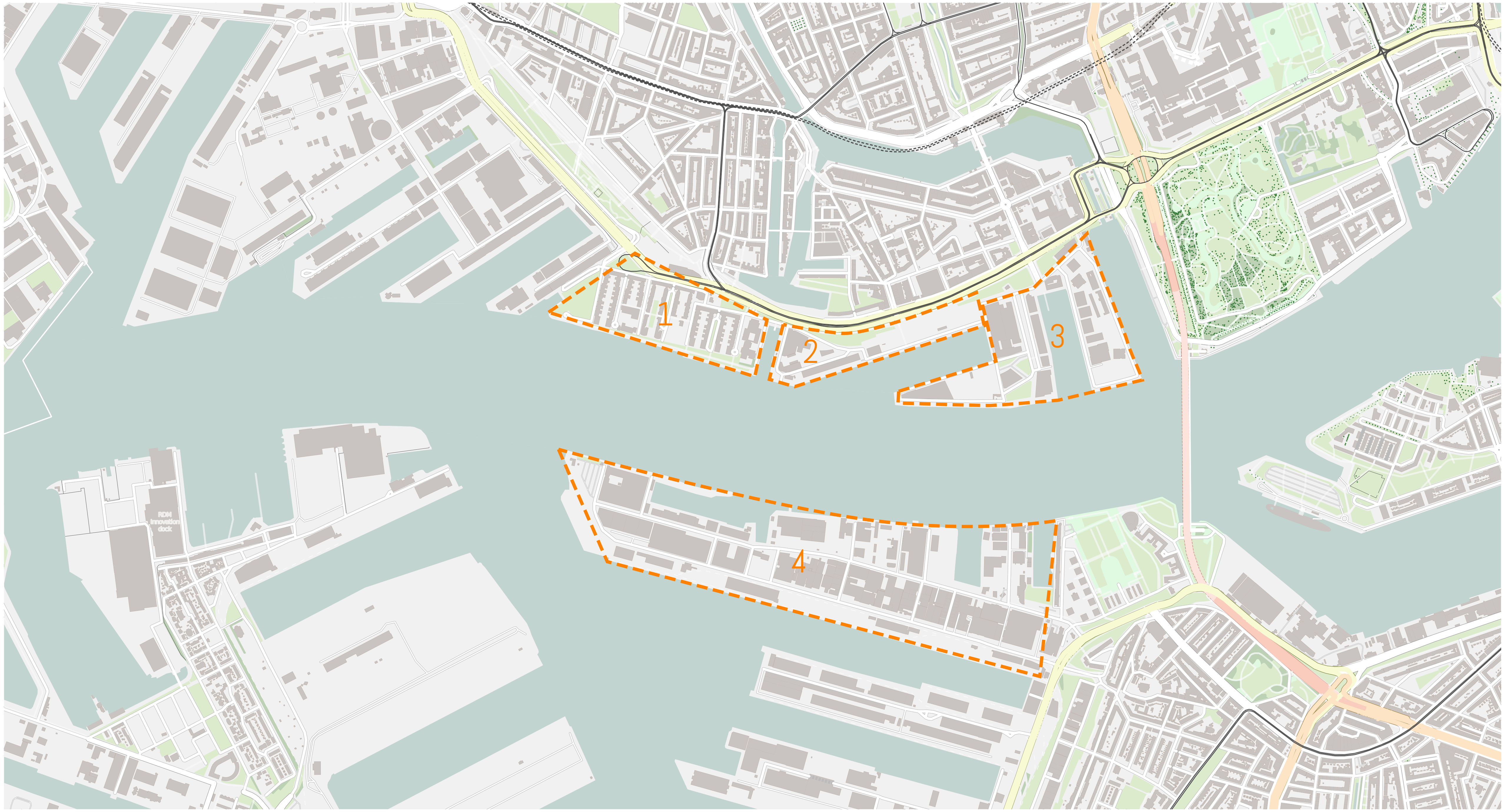
Context

Concept

Design Explanation

Context

Zones



Context

Options

Context

Option 1

Context

Option 2

Context

Choice

Context

Choice

Design Study

Design Brief

Context

Concept

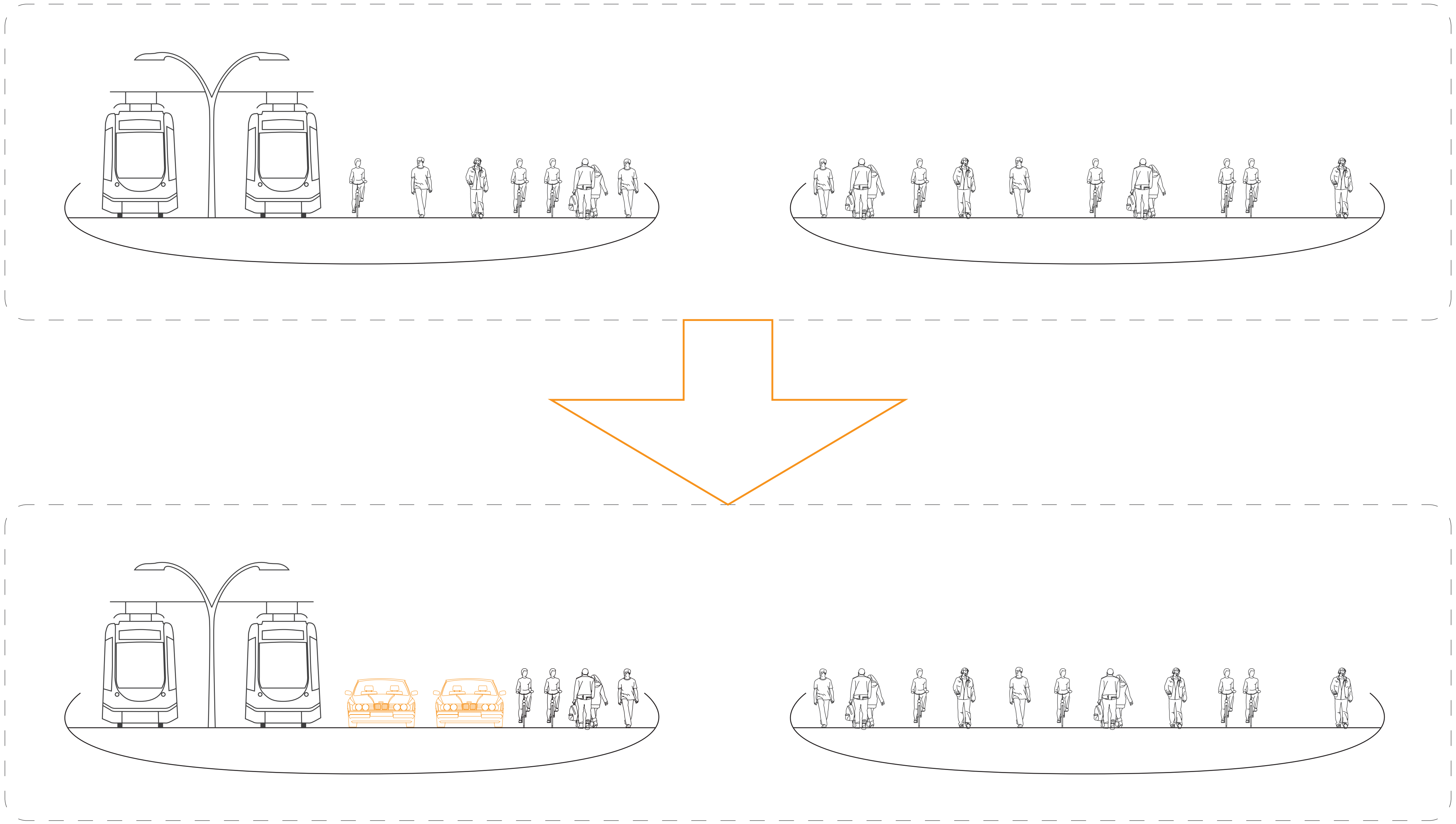
Design Explanation

Concept

- **Use:** Flexibility
- **Super Structure:** Light weight, elegant, transparent
- **Moveable part:** Uniform with the design
- **Optimisation**

Concept

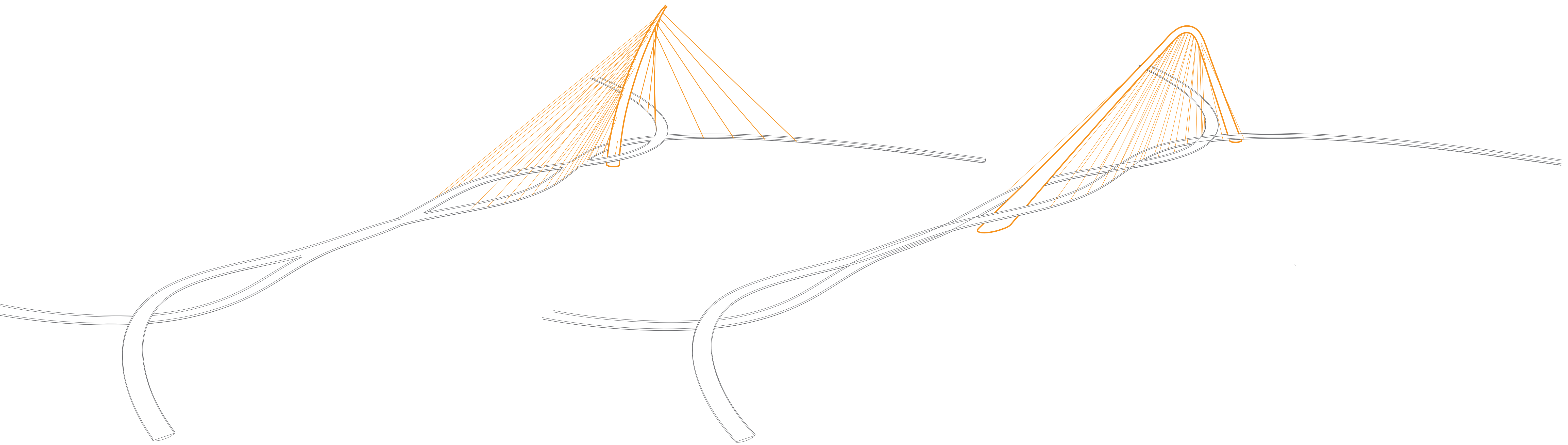
Flexibility



- Split deck to offer flexibility whilst maintaining comfort

Concept

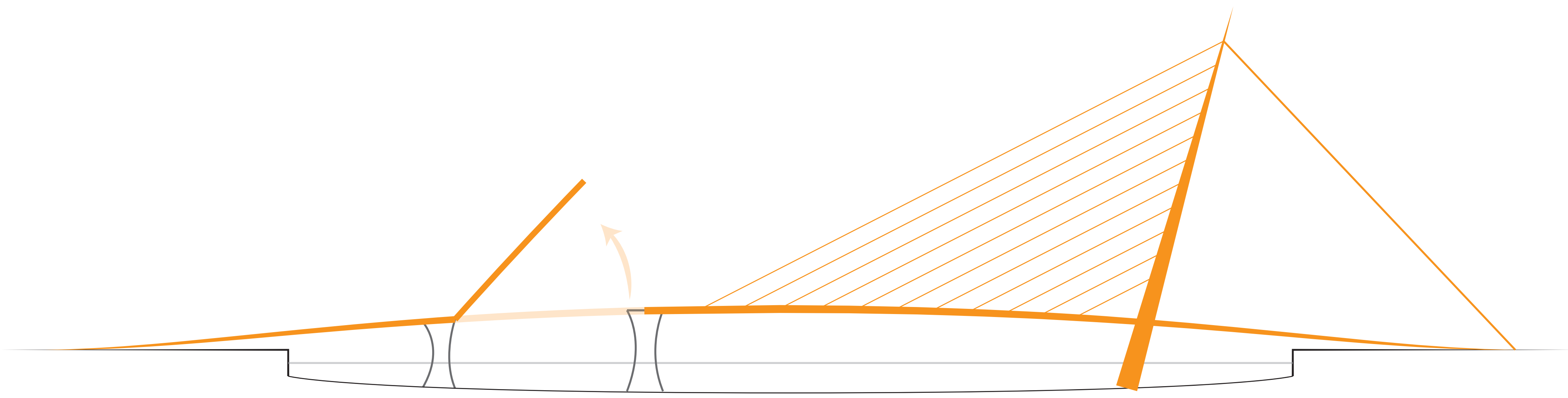
Superstructure

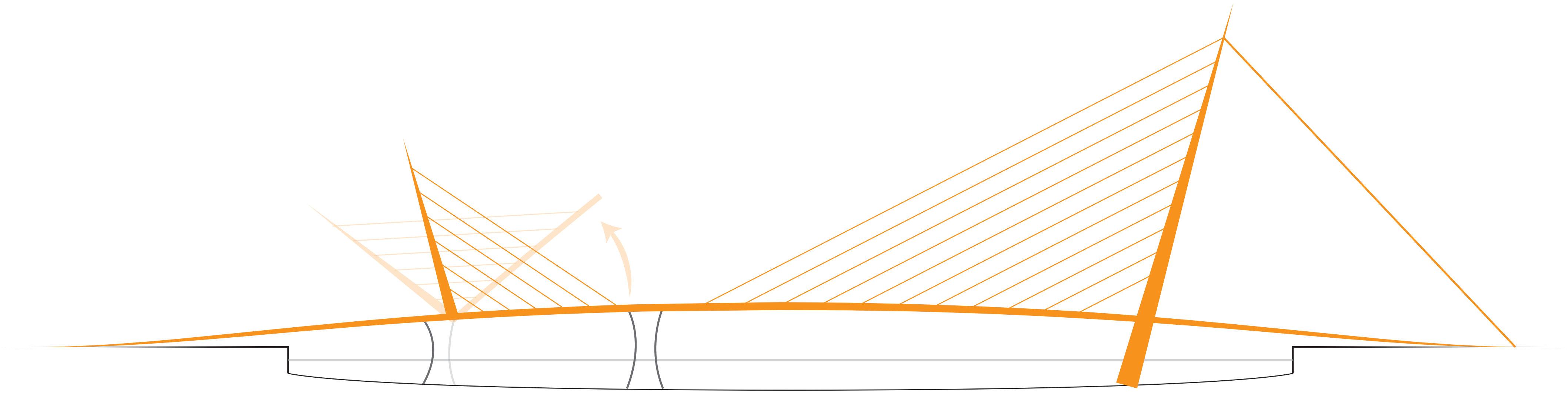


- Light-weight, elegant, transparent

Concept

Movable part

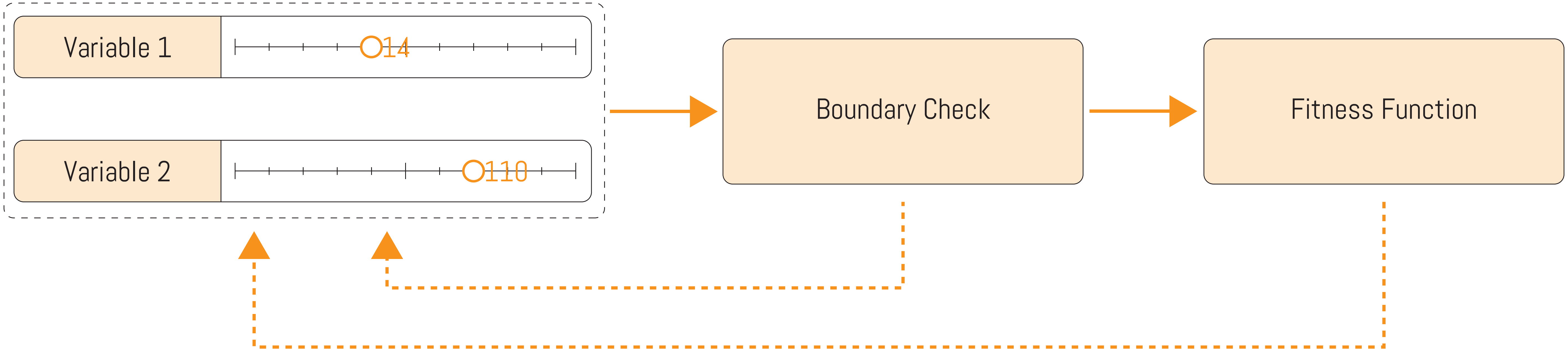




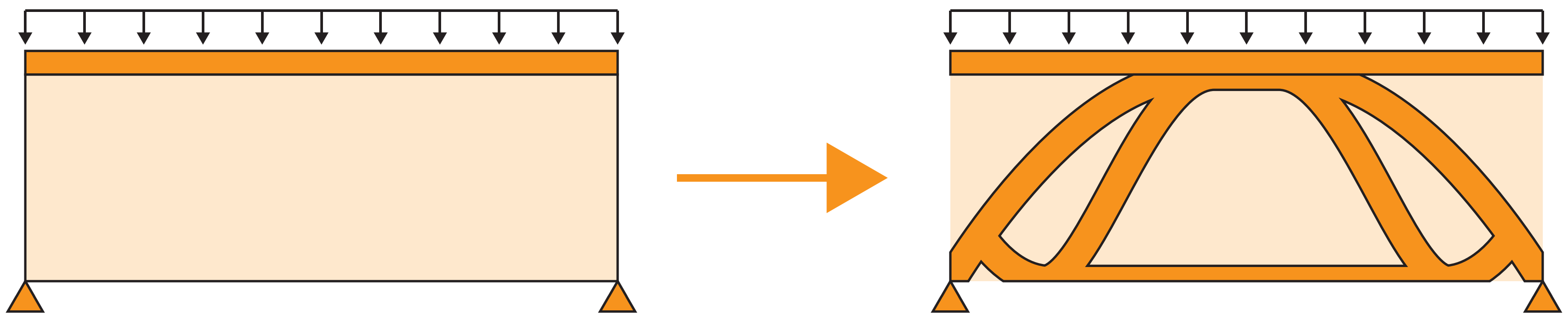
- Uniform design

Concept

Optimisation



- Shape



- Topology

Design Study

Design Brief

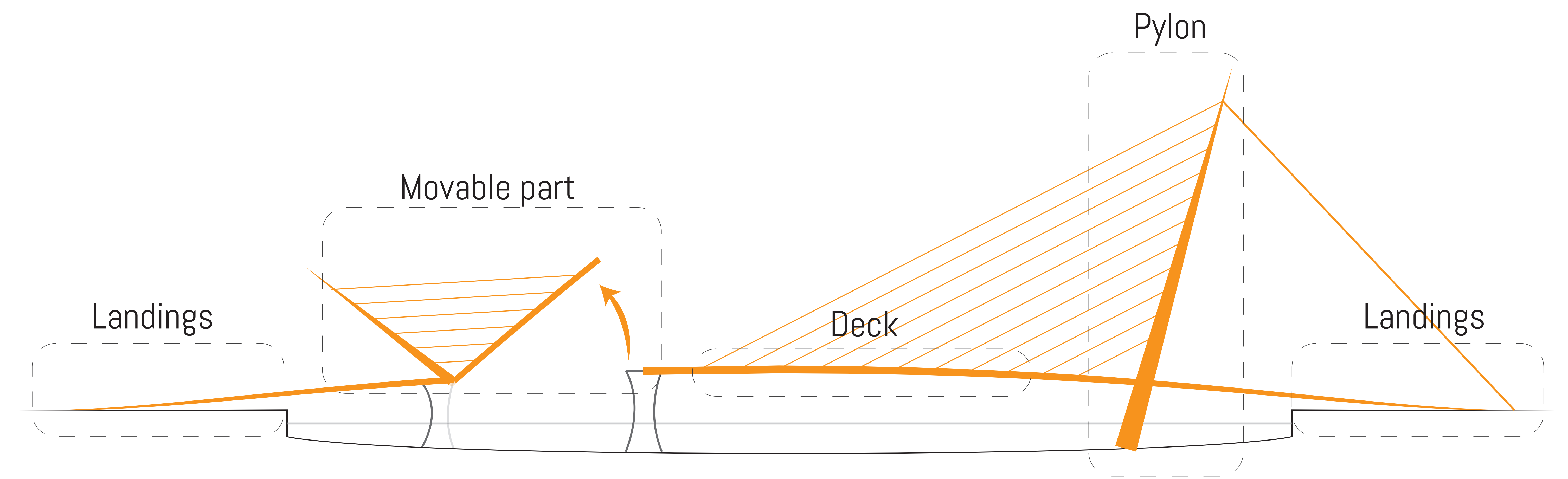
Context

Concept

Design Explanation

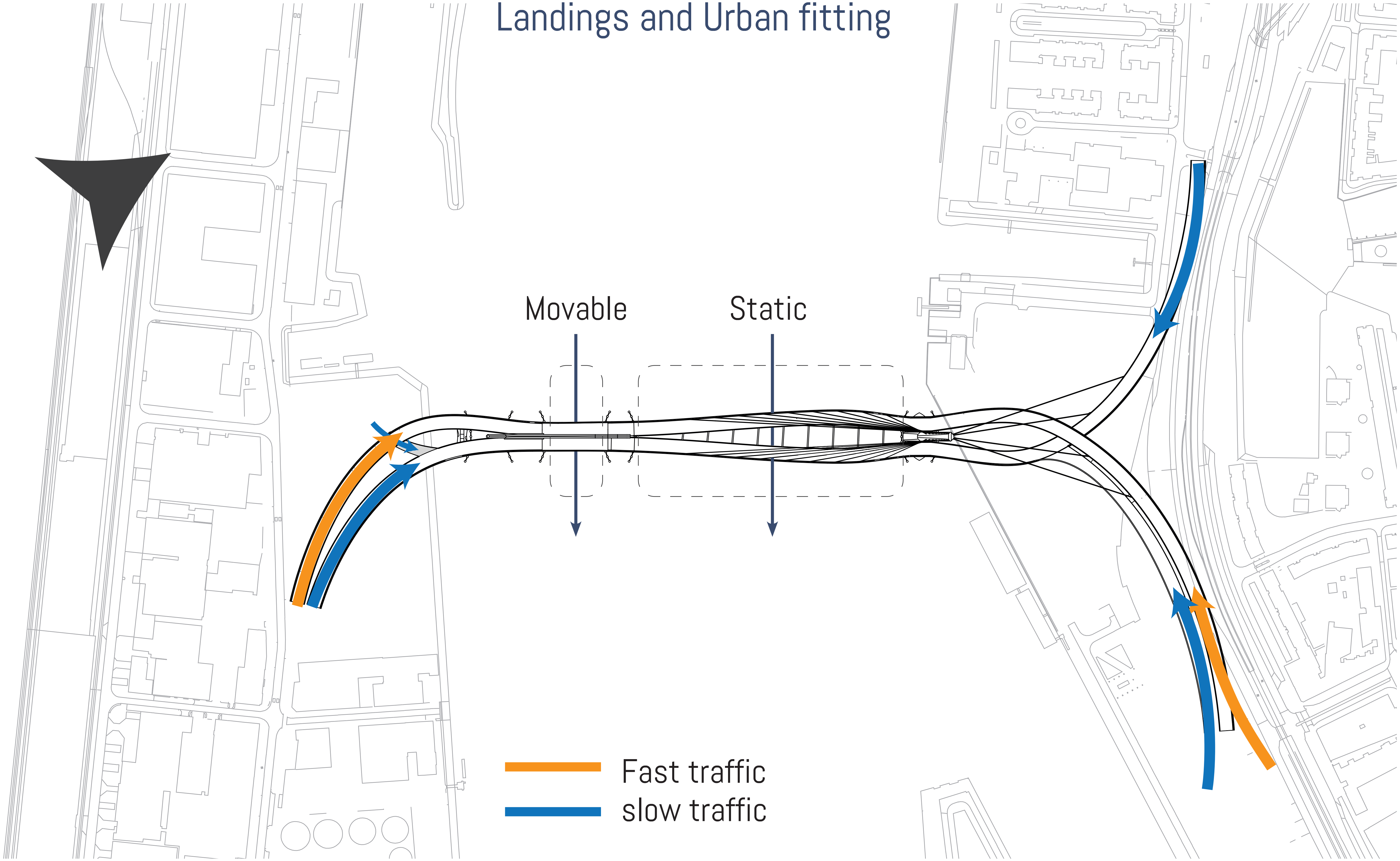
Design Explanation

Parts



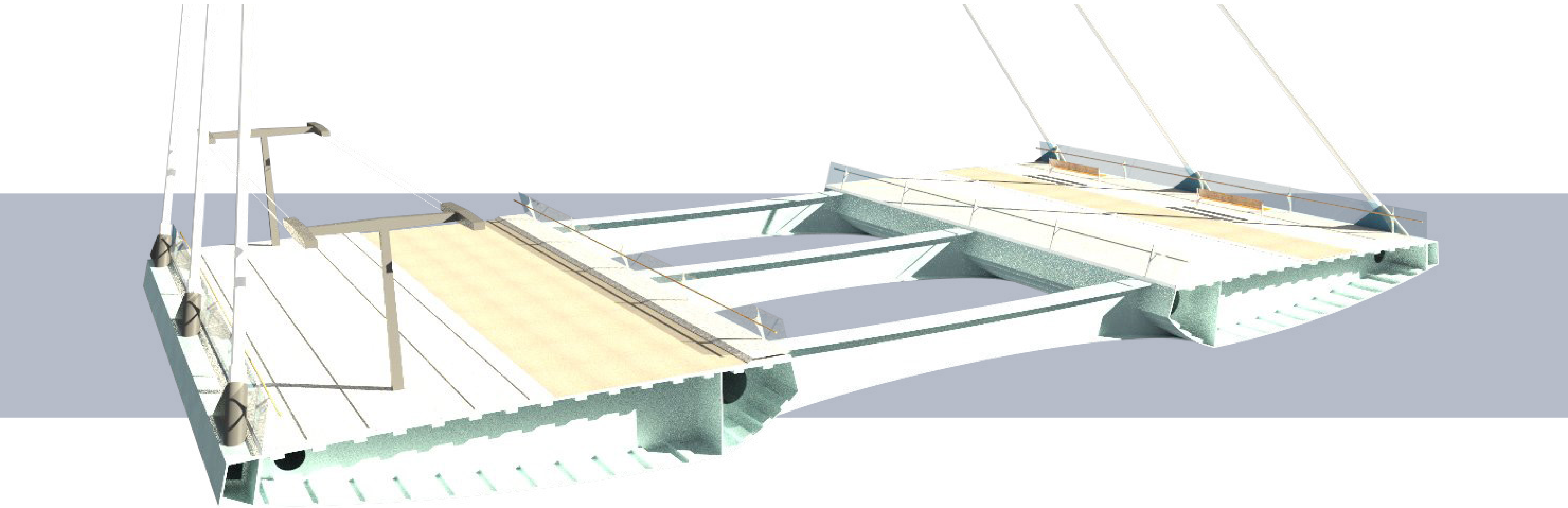
Design Explanation

Landings and Urban fitting



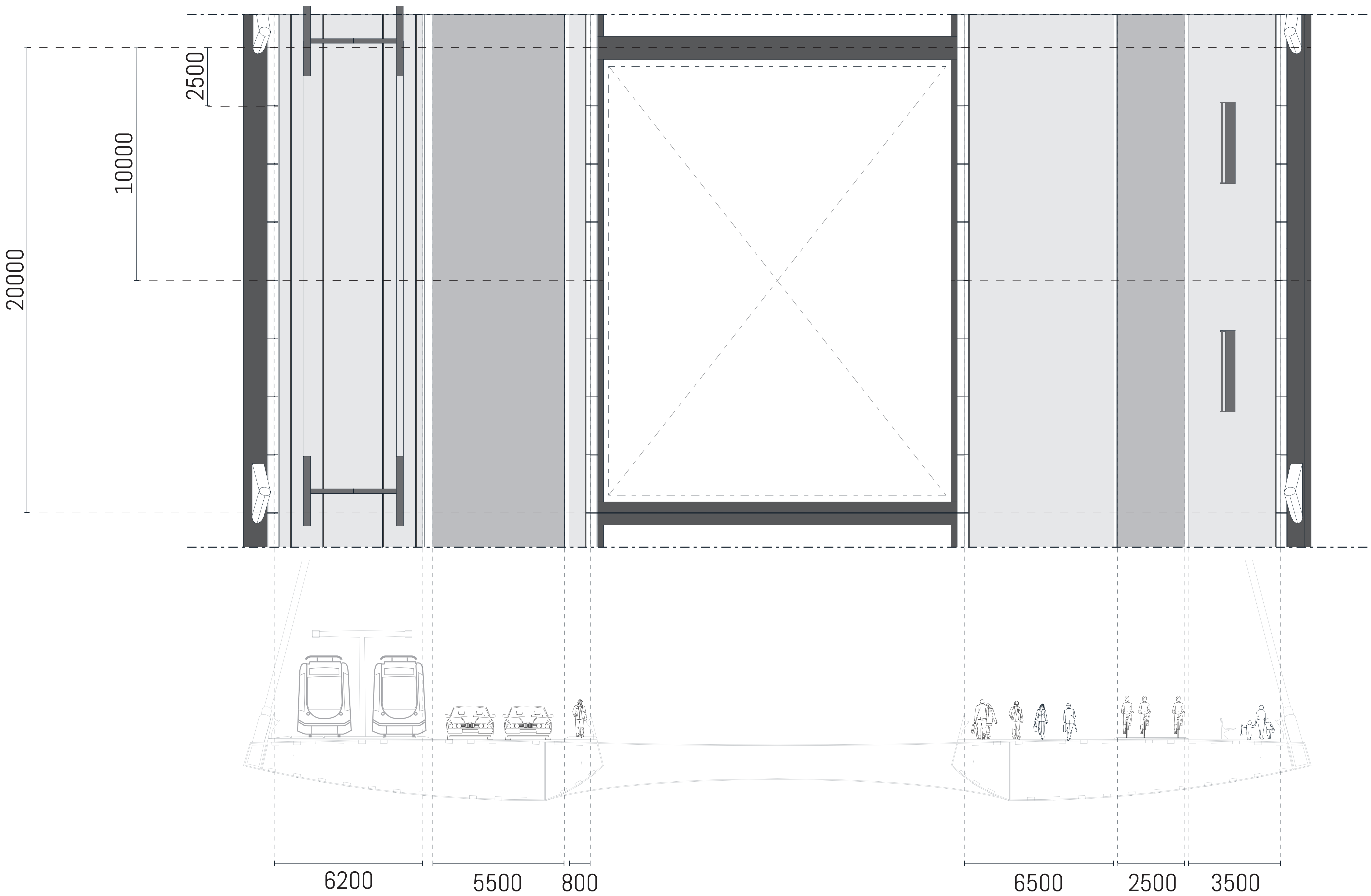
Design Explanation

Deck



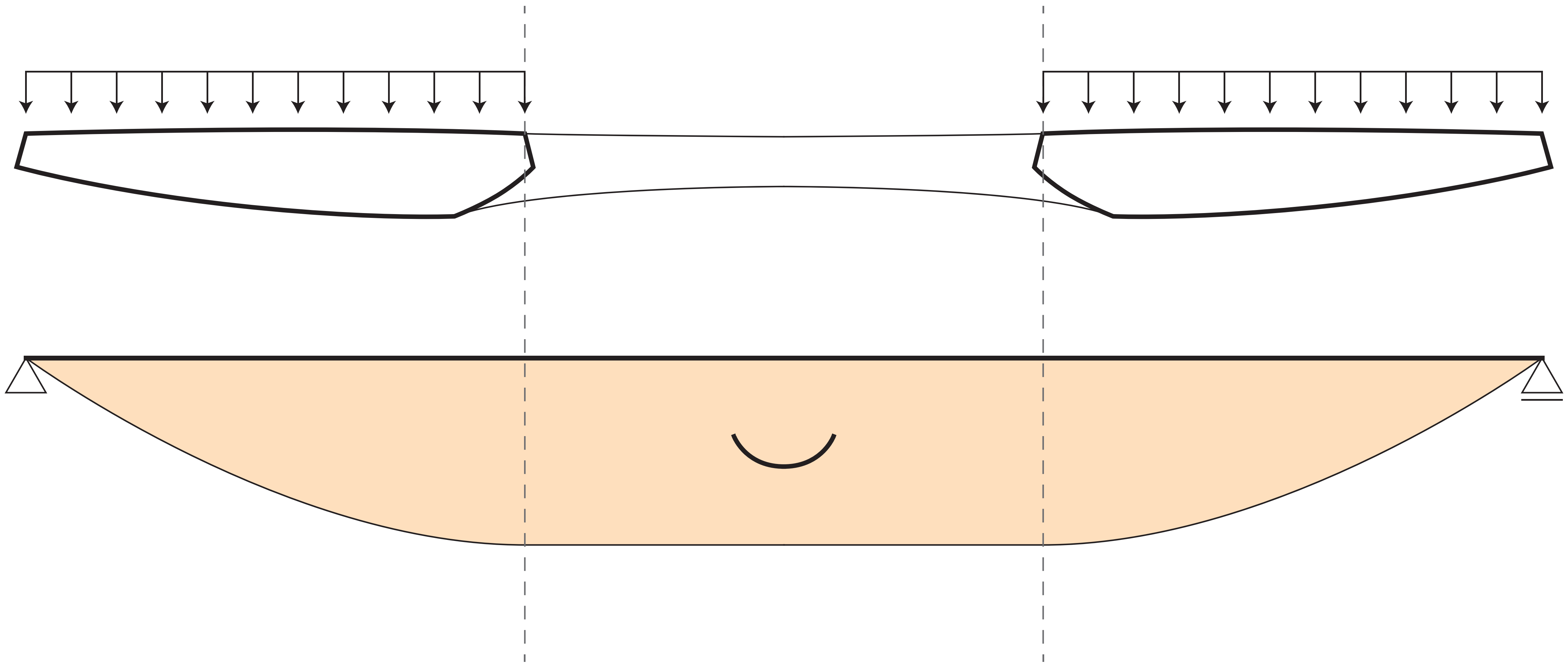
Design Explanation

Deck



Design Explanation

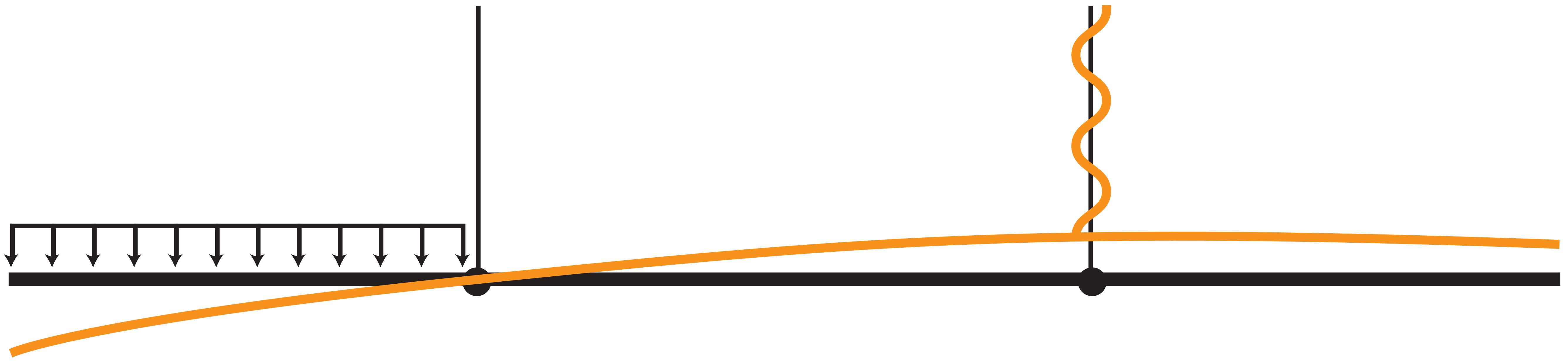
Deck



- Bending moments in deck

Design Explanation

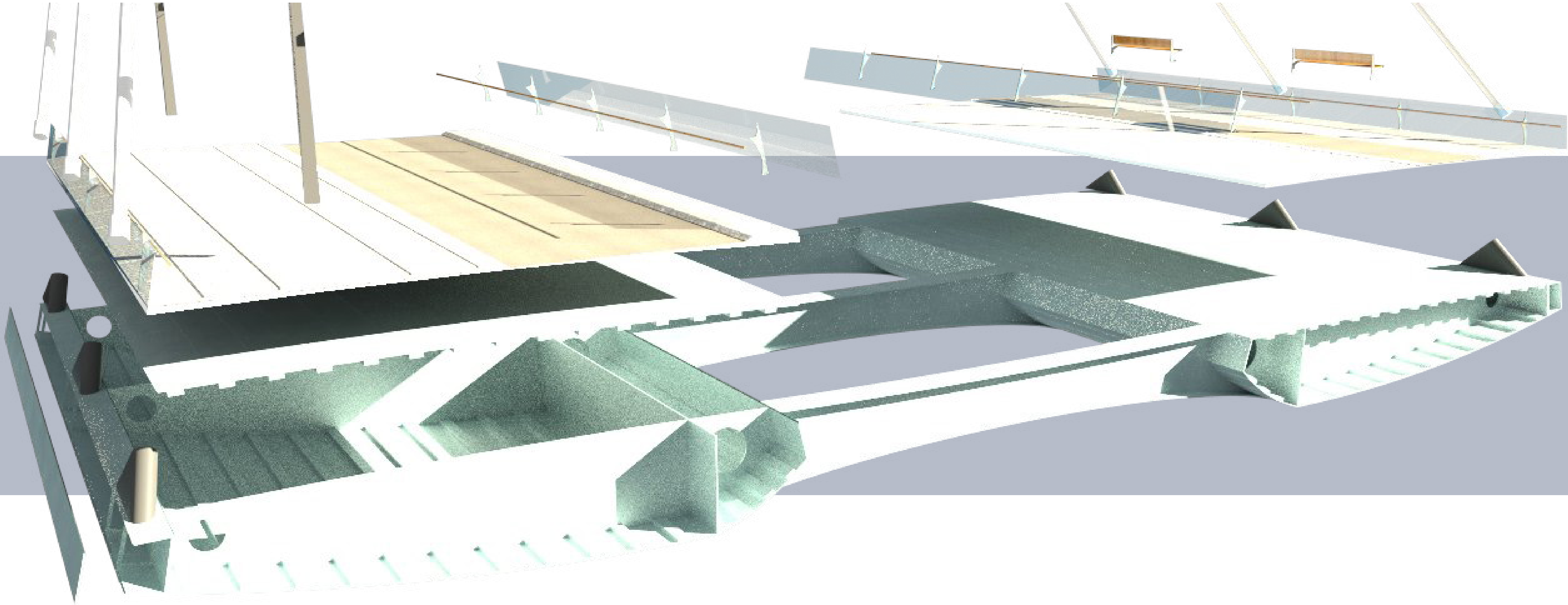
Deck



- Cable placement avoids tail-wagging effect

Design Explanation

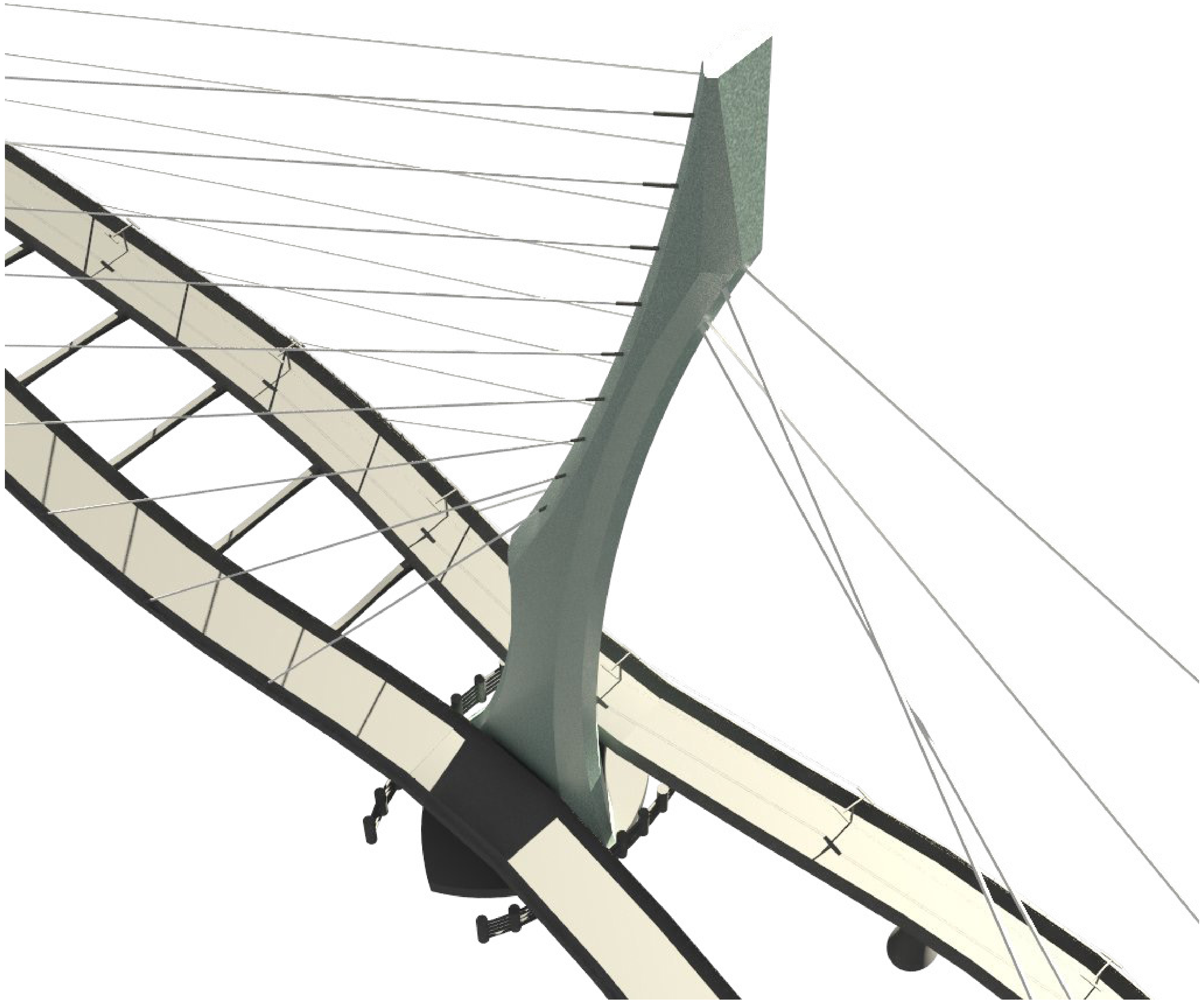
Deck



- Exploded view

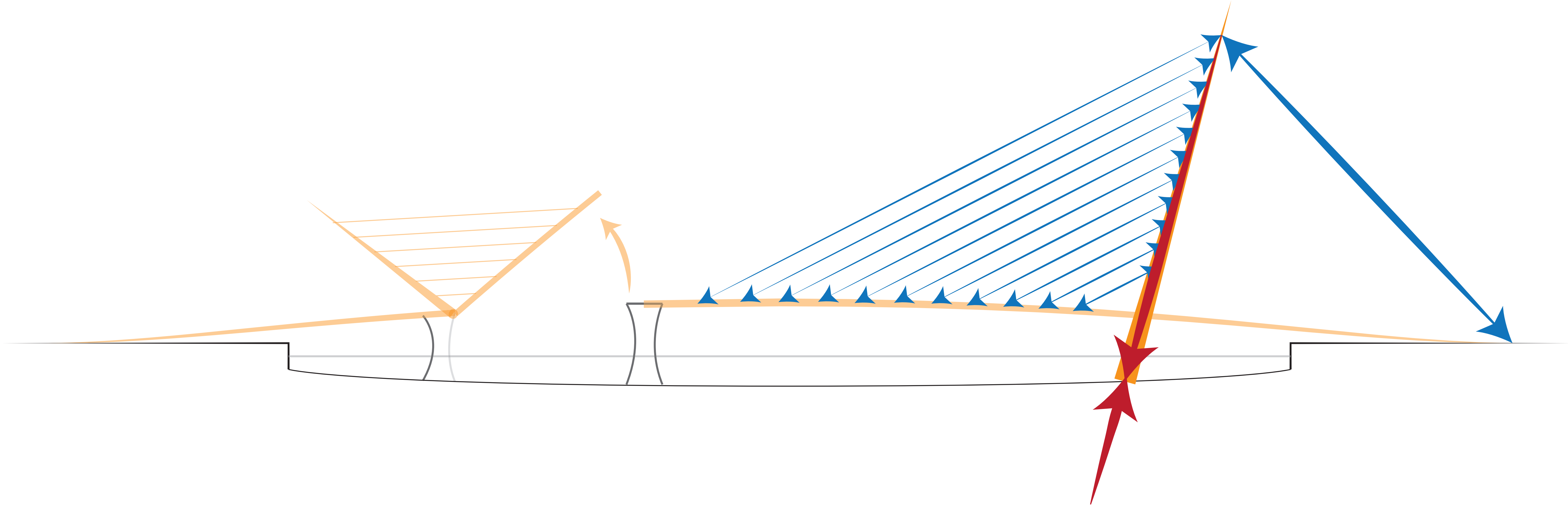
Design Explanation

Pylon



Design Explanation

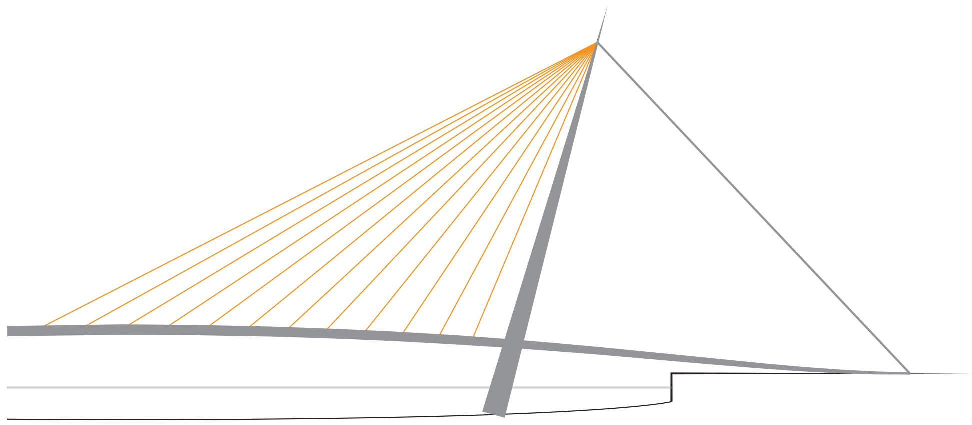
Pylon



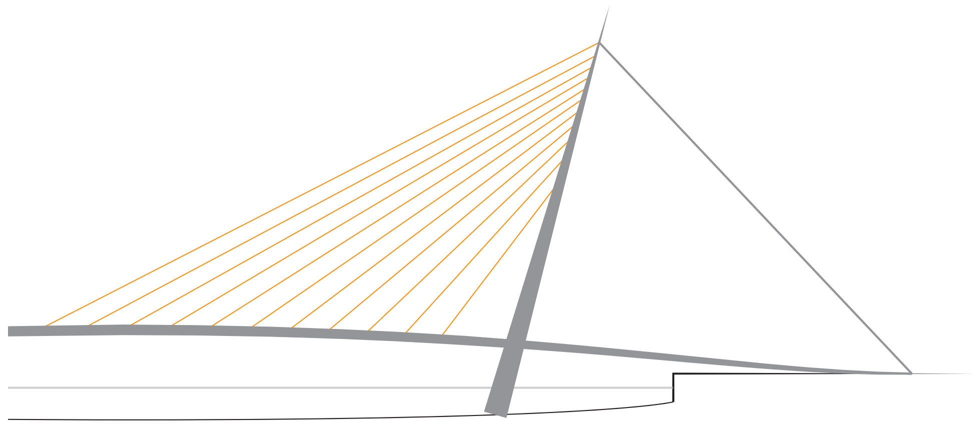
- Flow of forces

Design Explanation

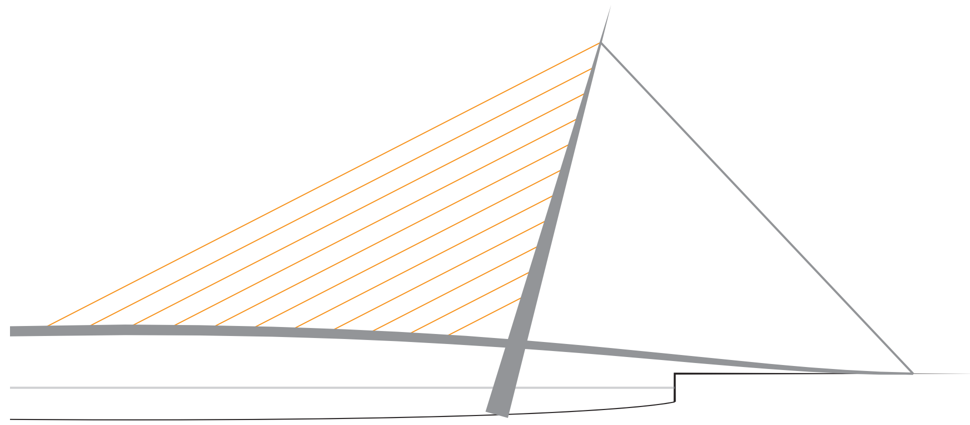
Pylon



Radial



Fan

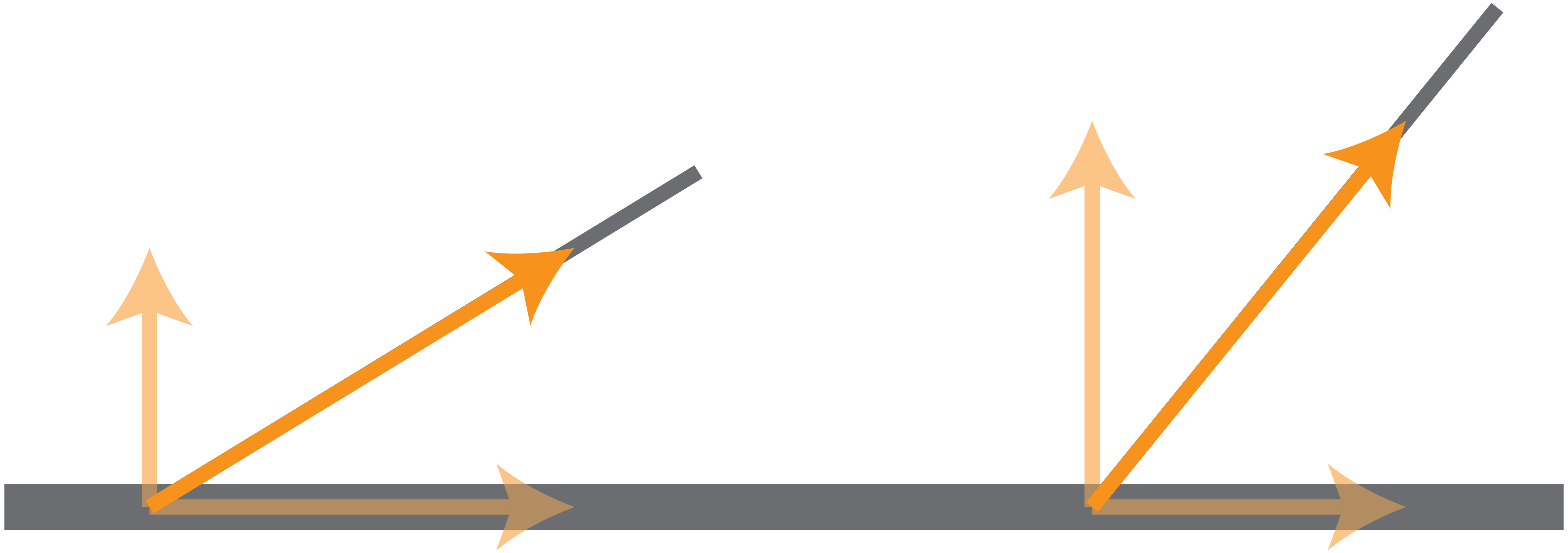


Parallel

- Cable layout

Design Explanation

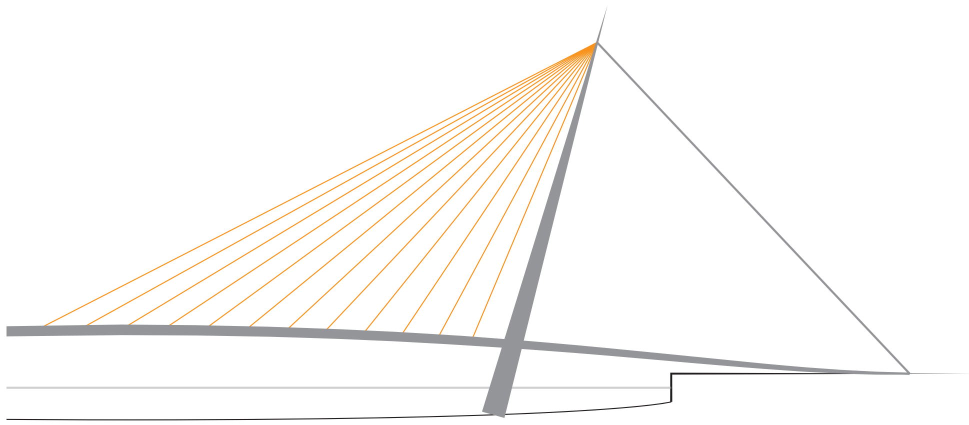
Pylon



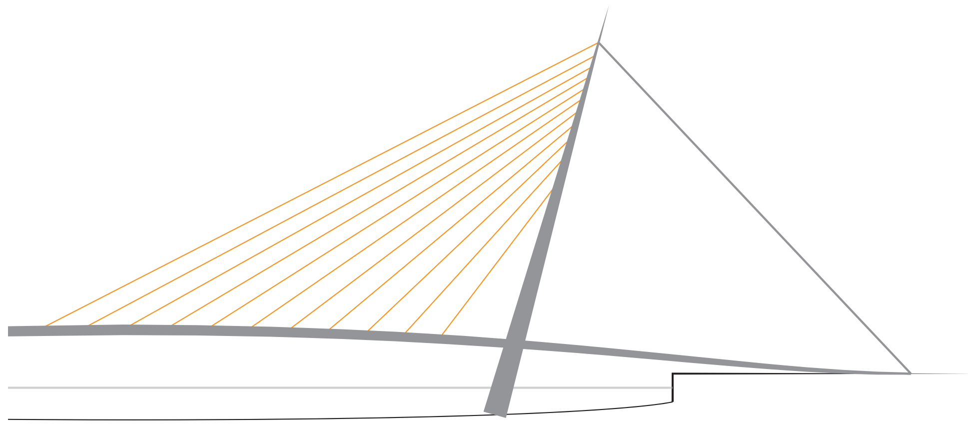
- Cable angle

Design Explanation

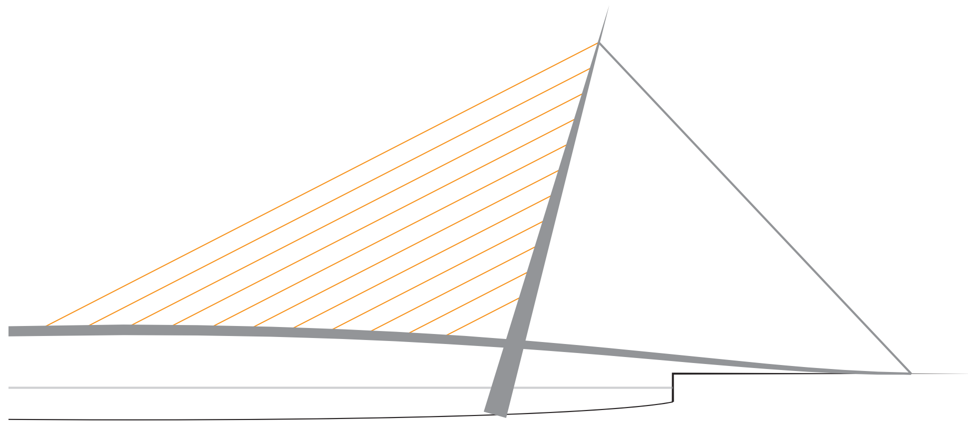
Pylon



Radial



Fan

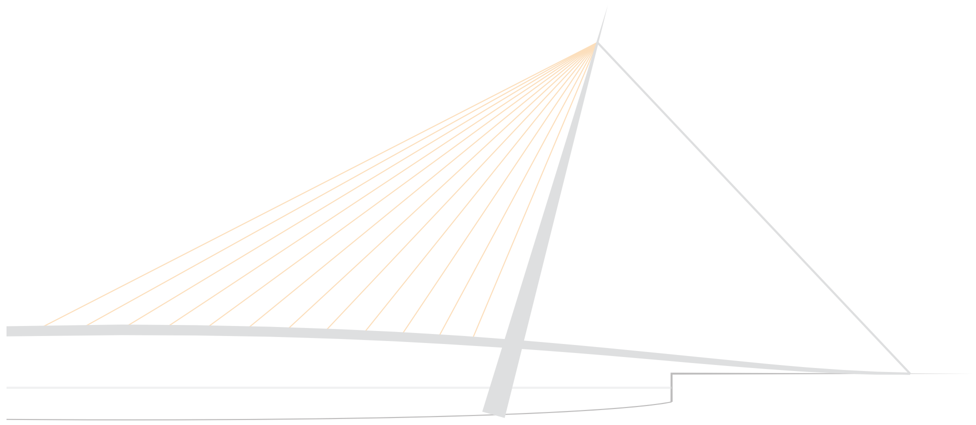


Parallel

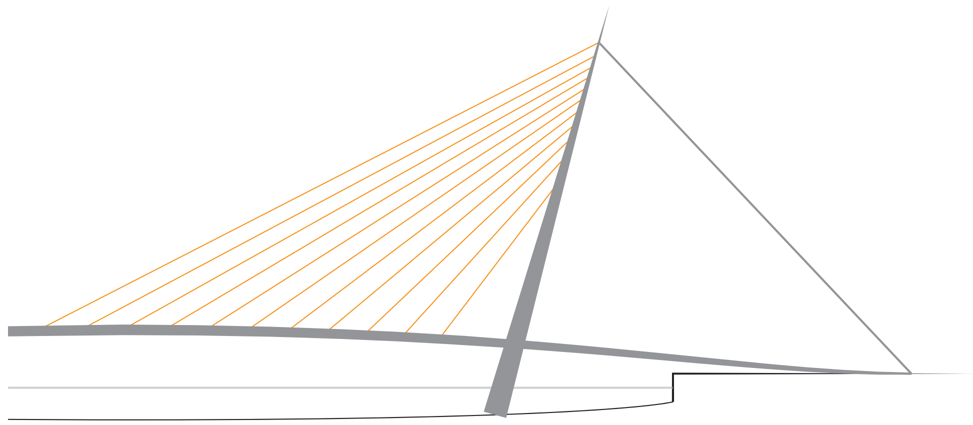
- Cable layout

Design Explanation

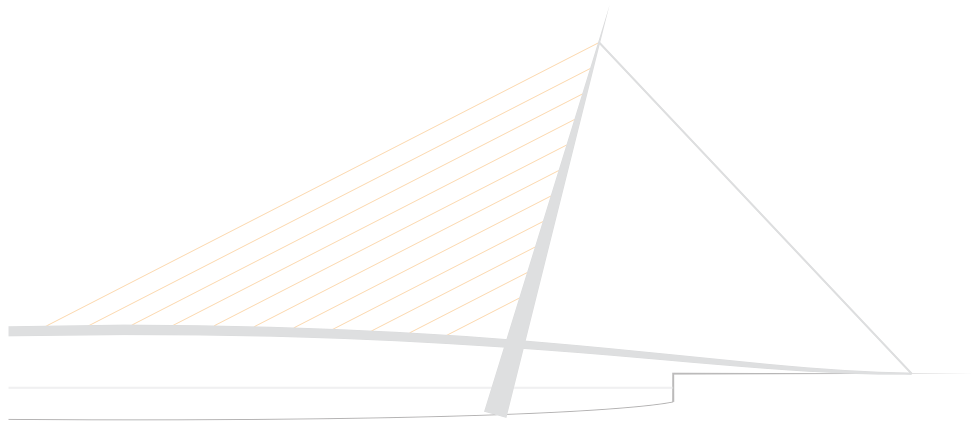
Pylon



Radial



Fan

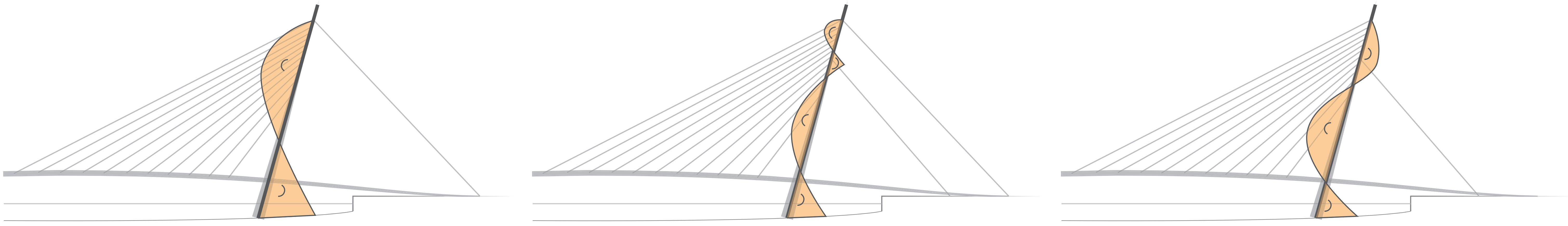


Parallel

- Cable layout

Design Explanation

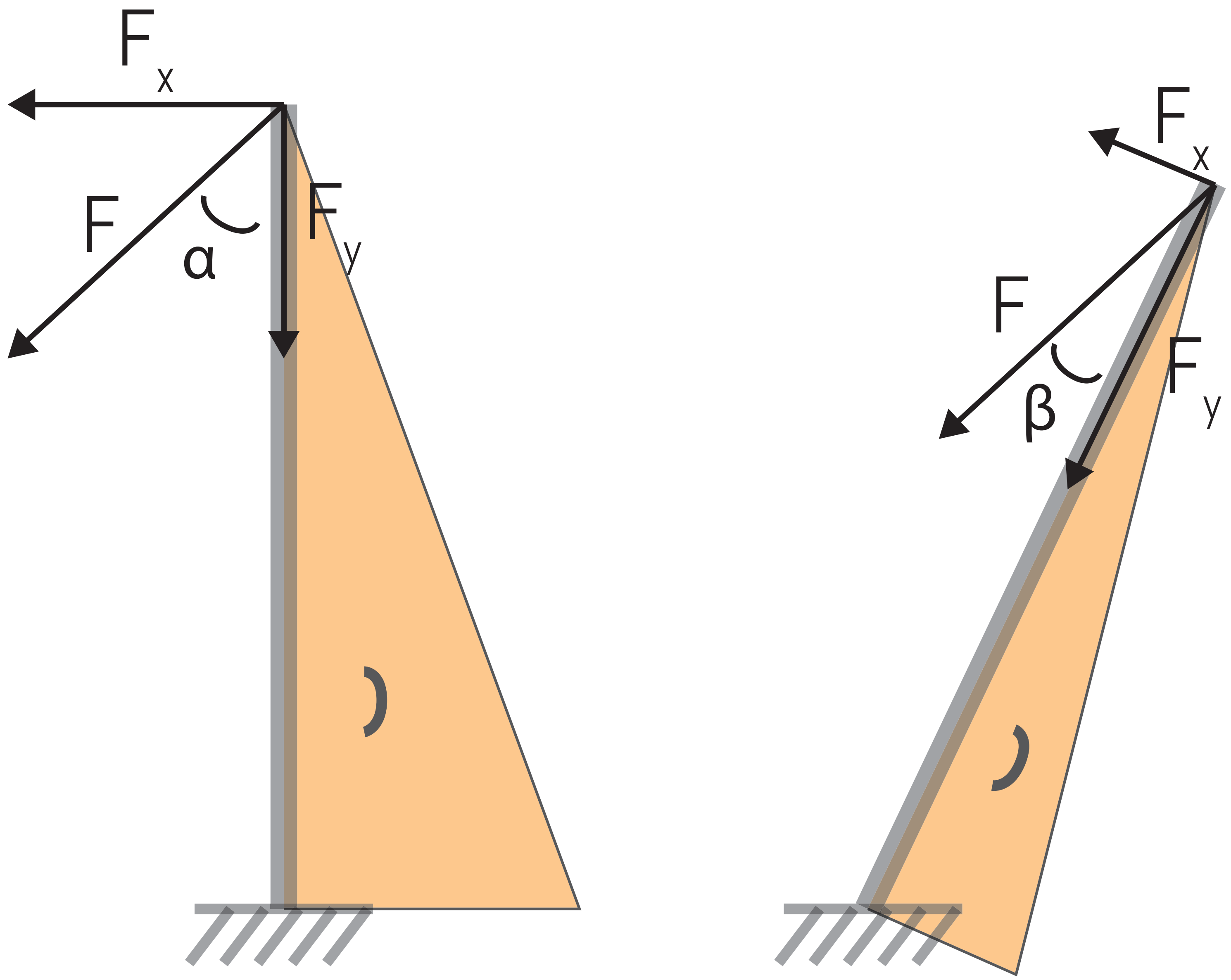
Pylon



- Backstay Cable layout

Design Explanation

Pylon



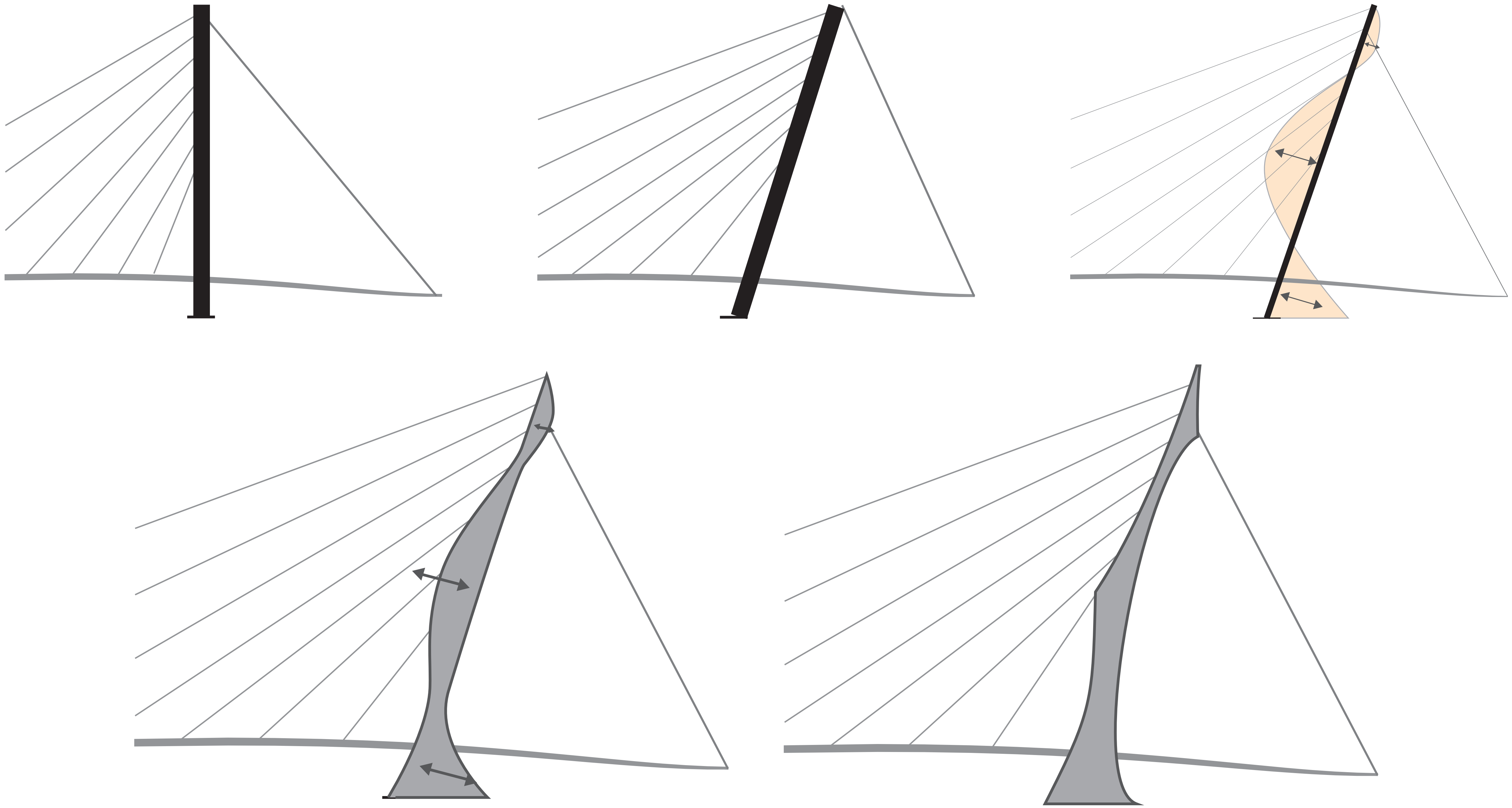
$$F_x = F * \tan \alpha \quad > \quad F_x = F * \tan \beta$$

$$M_a = F_x * L \quad > \quad M_b = F_x * L$$

- Tilted pylon reduces bending moment

Design Explanation

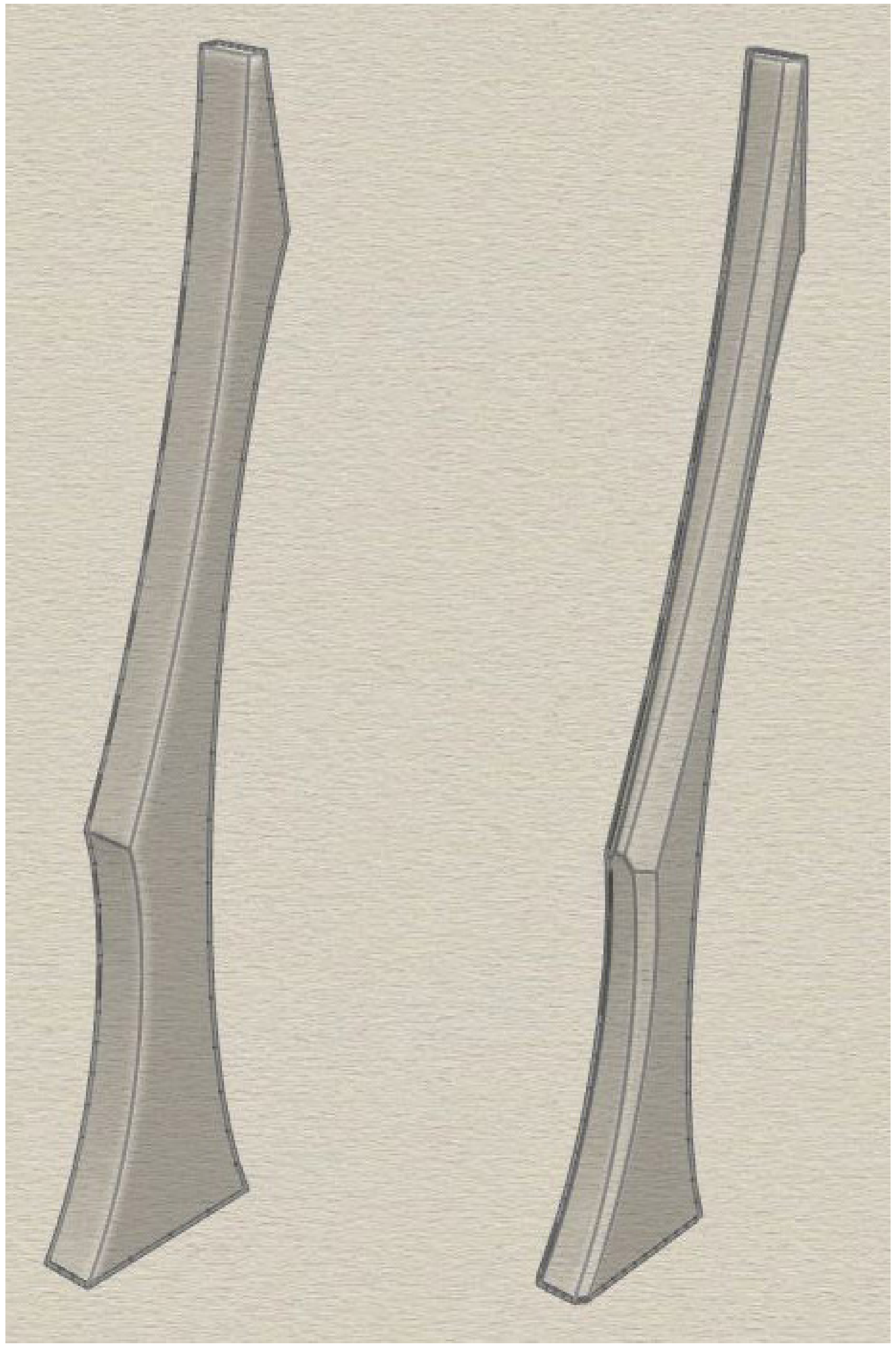
Pylon



- Thinking process

Design Explanation

Pylon



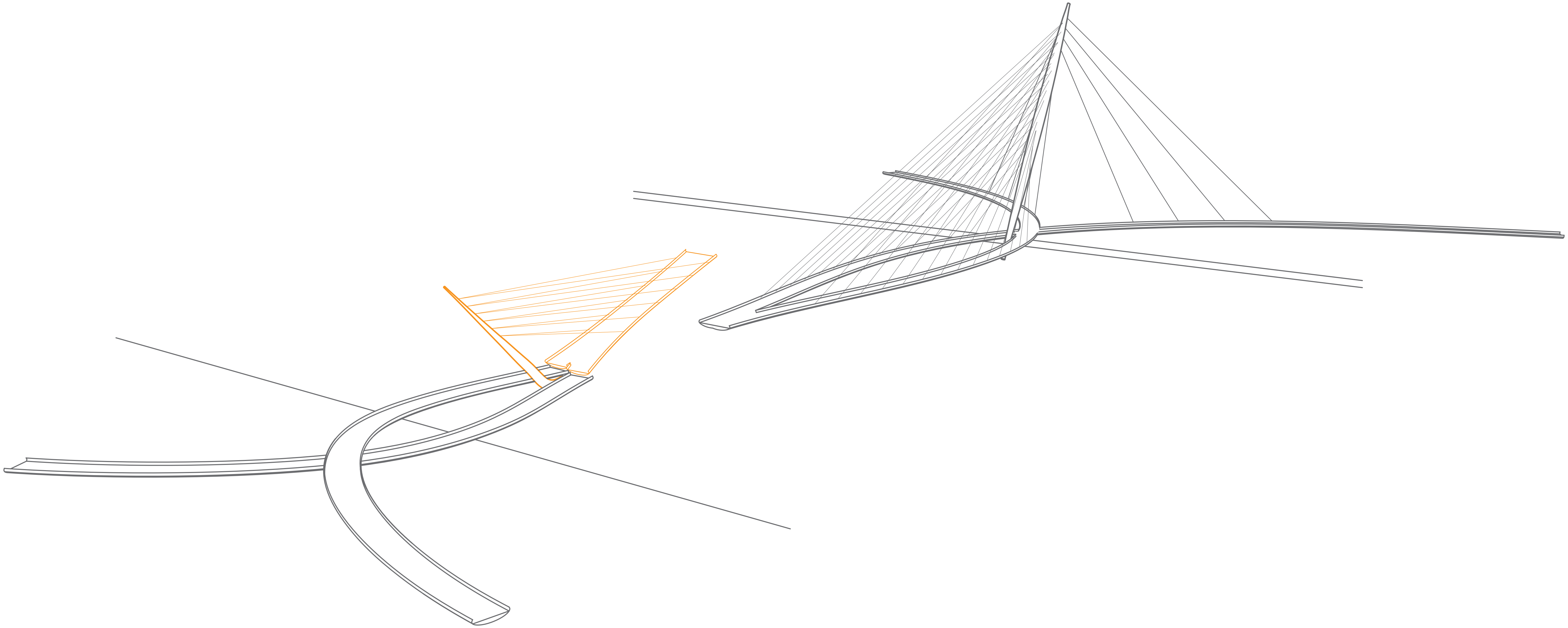
- Chamfering the pylon

Design Explanation

Pylon

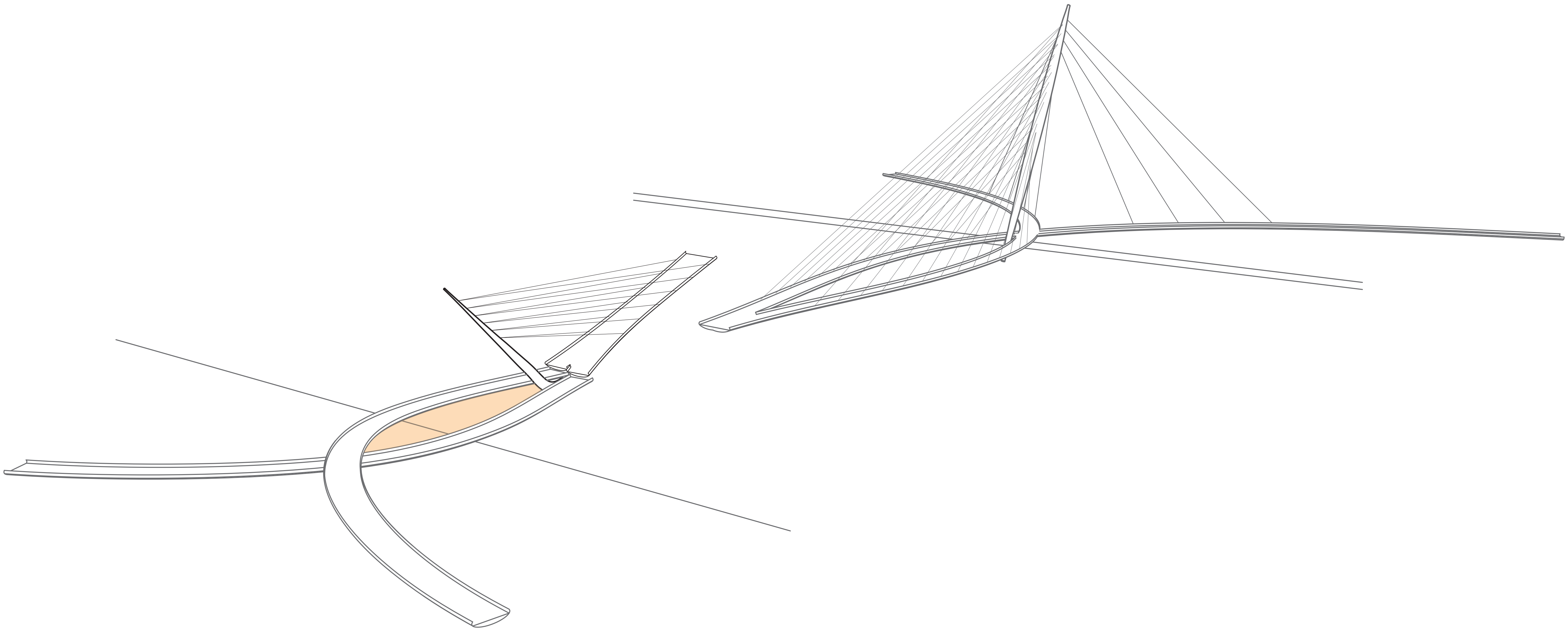
Design Explanation

Movable part



Design Explanation

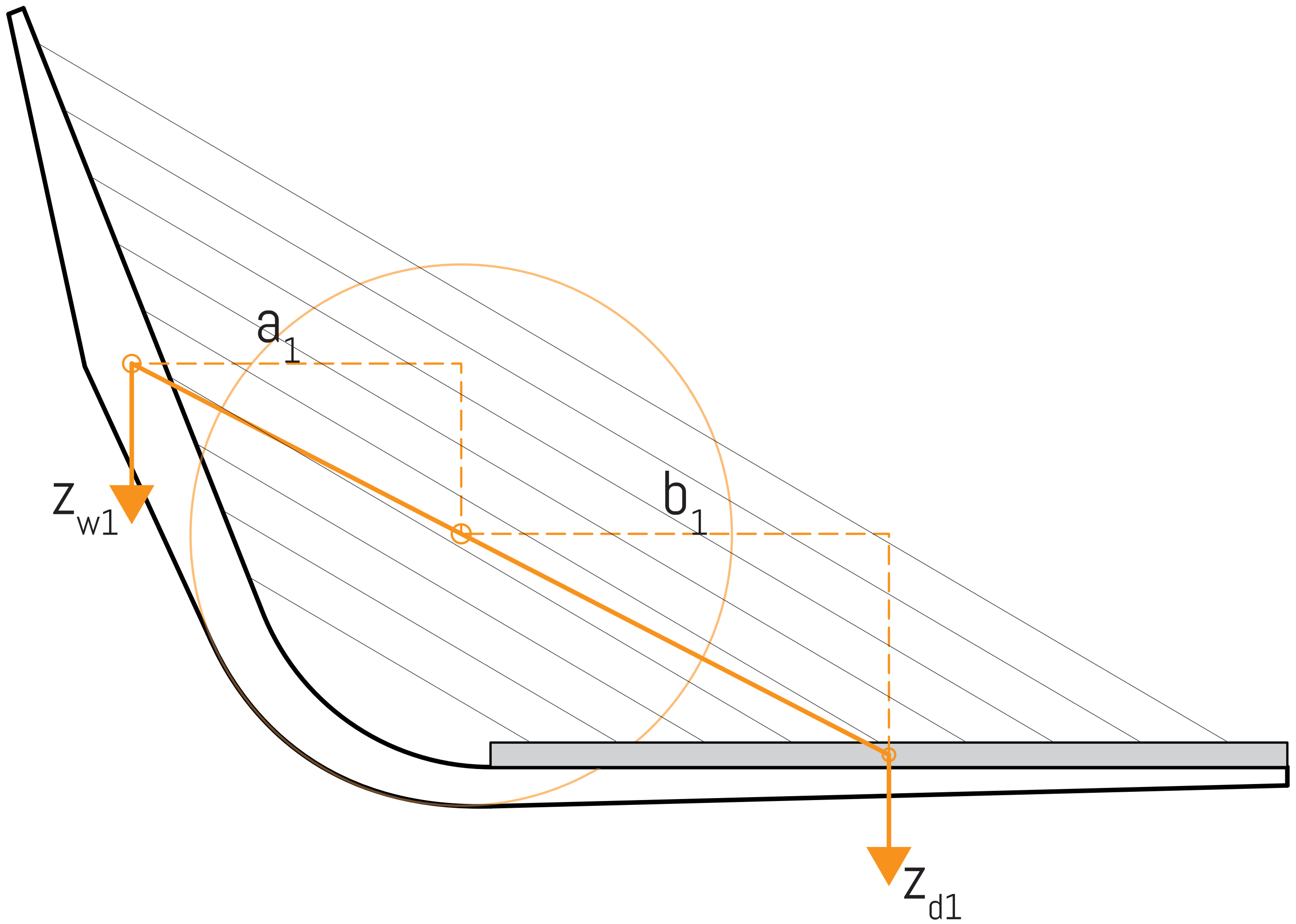
Movable part

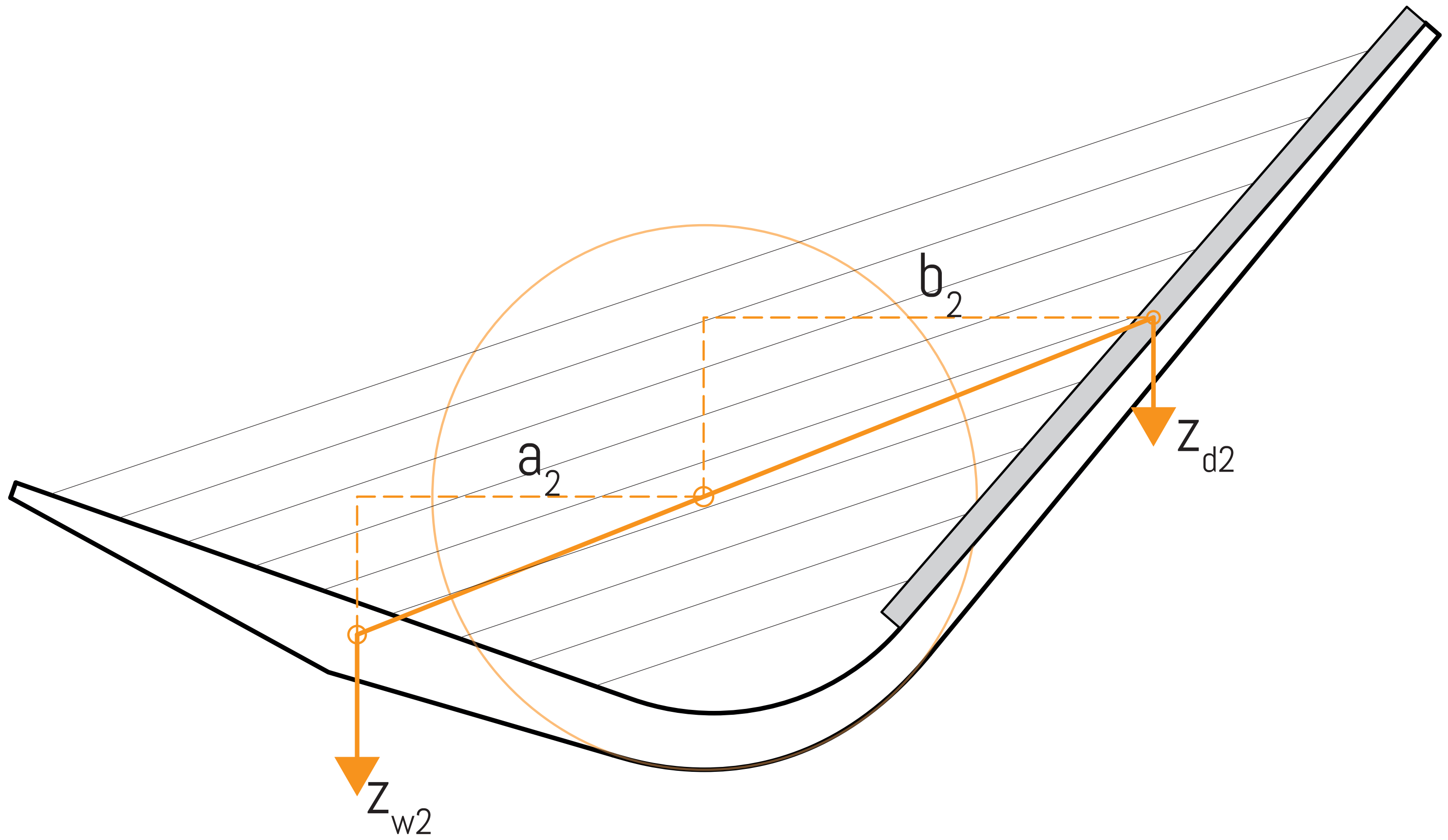


- Counterweight drops between decks

Design Explanation

Movable part



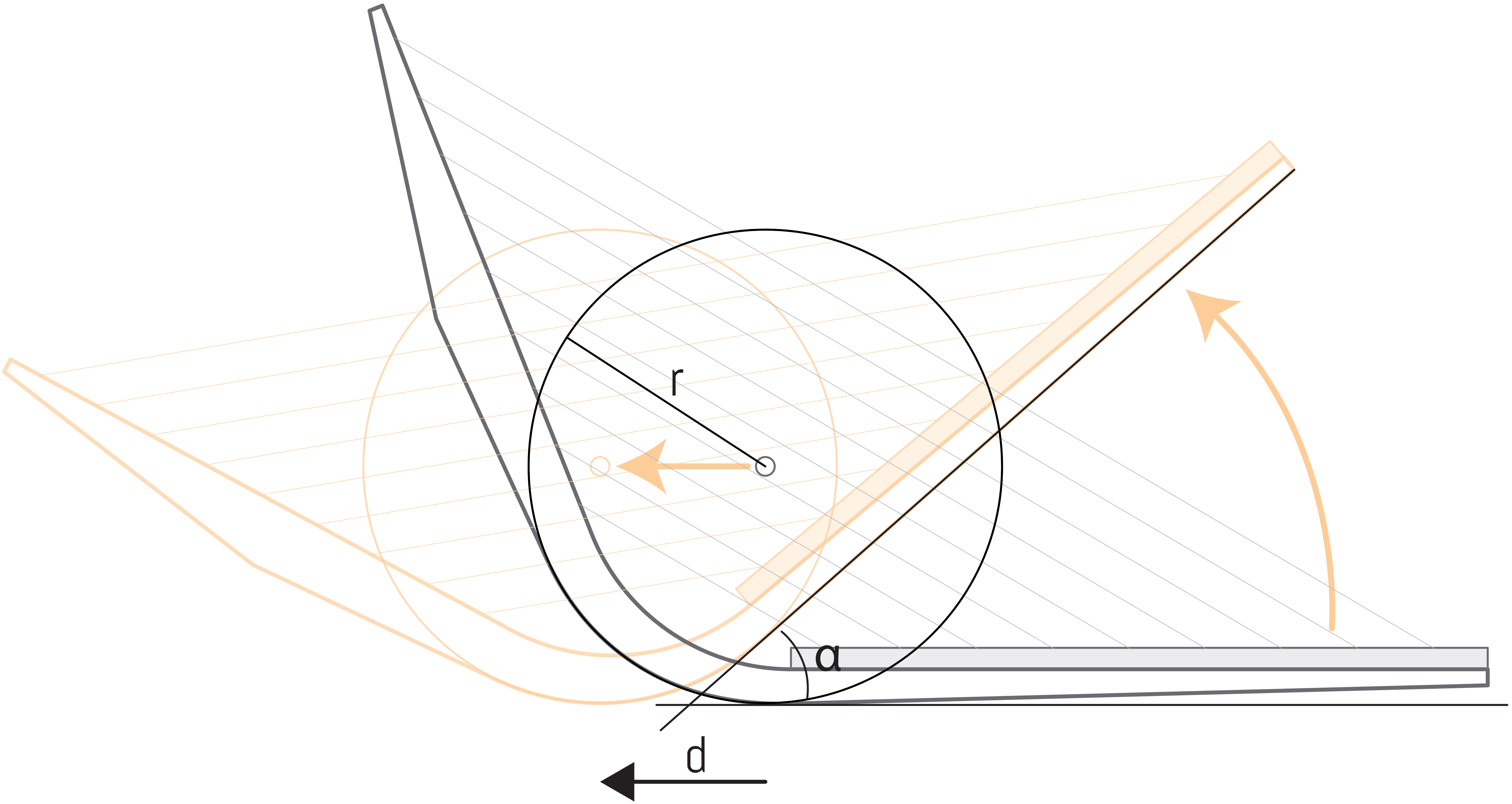


Equilibrium: $z_{w1} * a_1 = z_{d1} * b_1$ $z_{w2} * a_2 = z_{d2} * b_2$

C.o.g. on one line with virtual pivot point, so that: $$\frac{z_{w1} * a_1}{z_{w2} * a_2} = \frac{z_{d1} * b_1}{z_{d2} * b_2}$$

Design Explanation

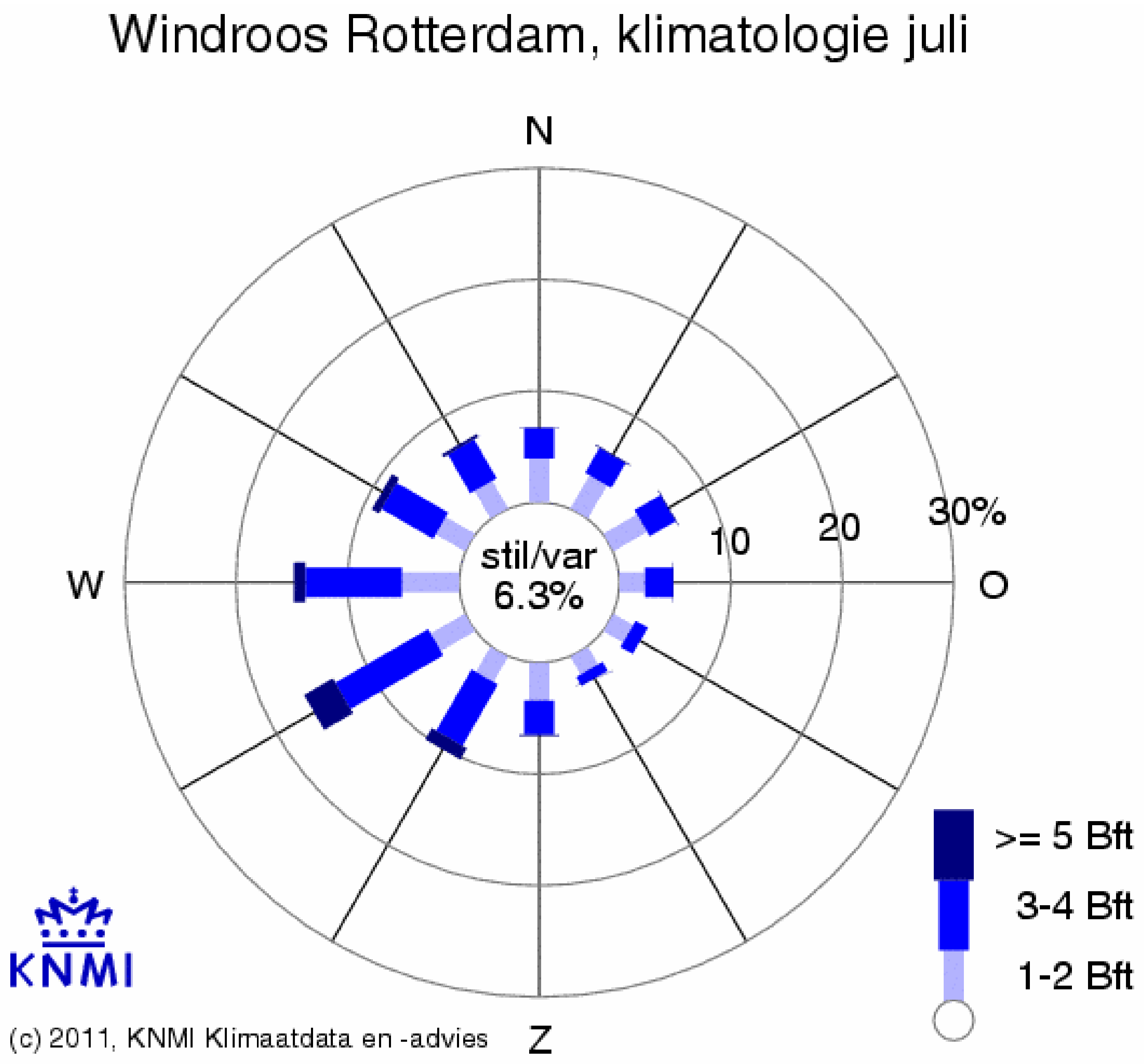
Movable part

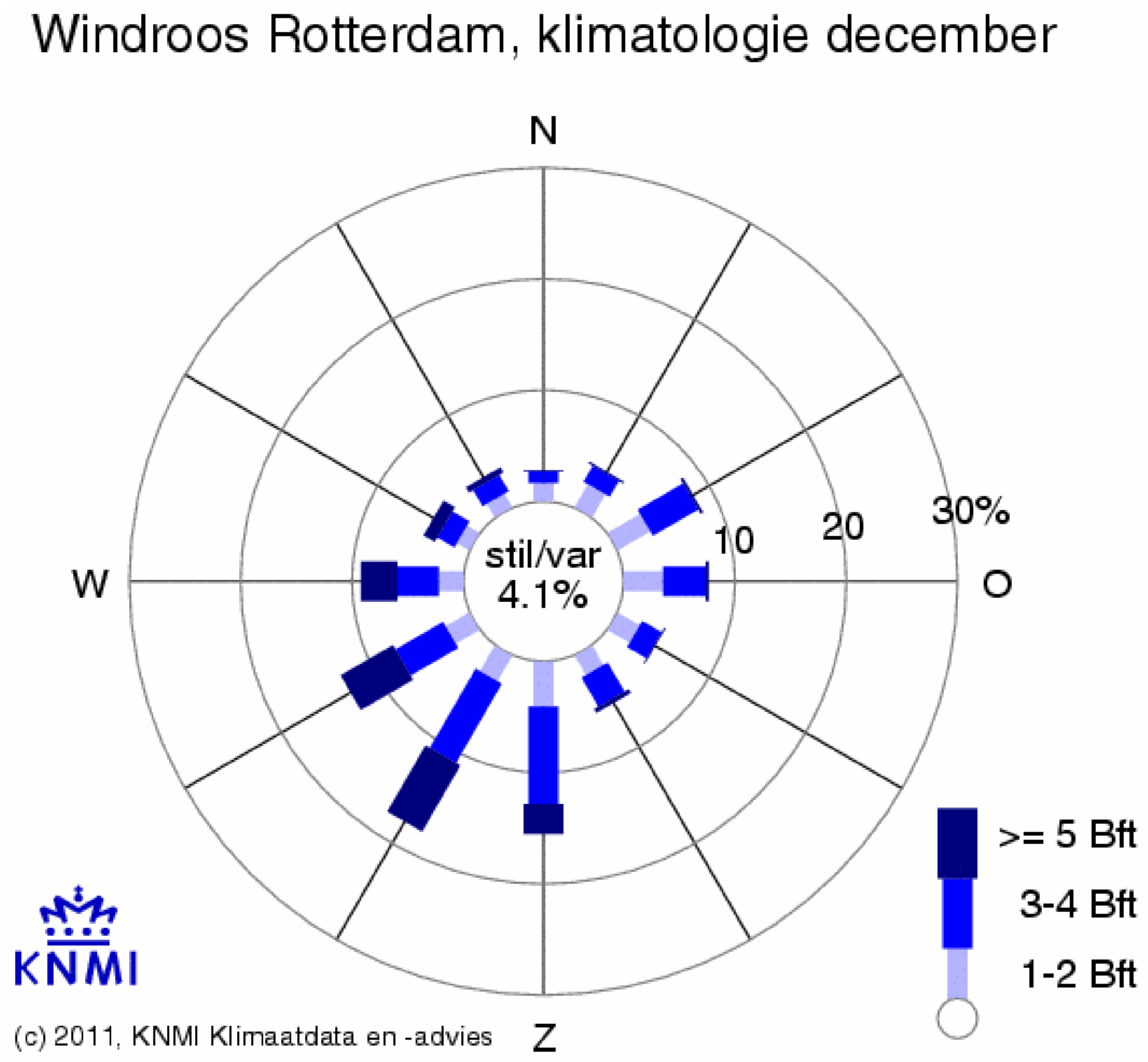


d = (α /360) * 2 πr

Design Explanation

Movable part

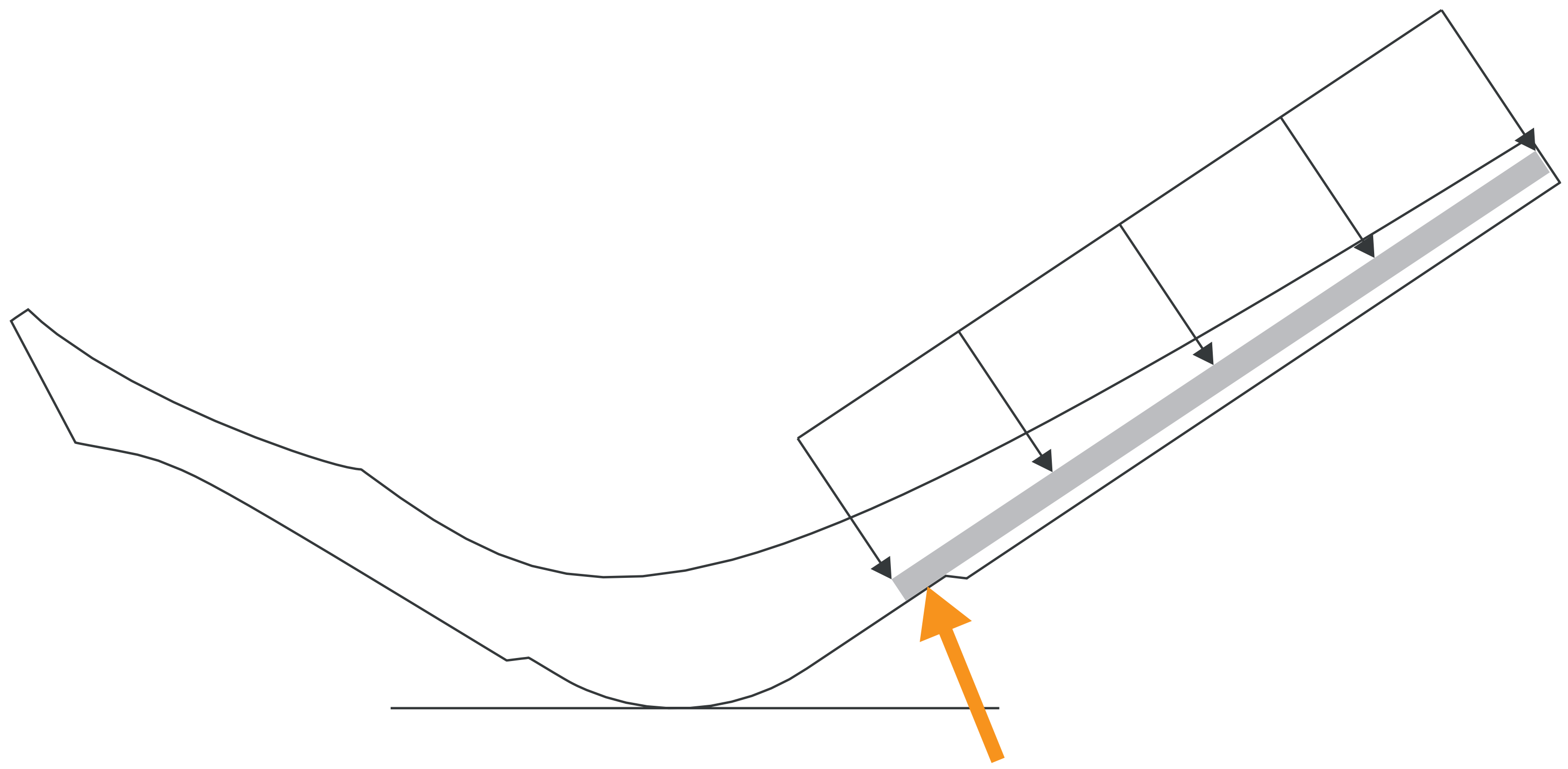


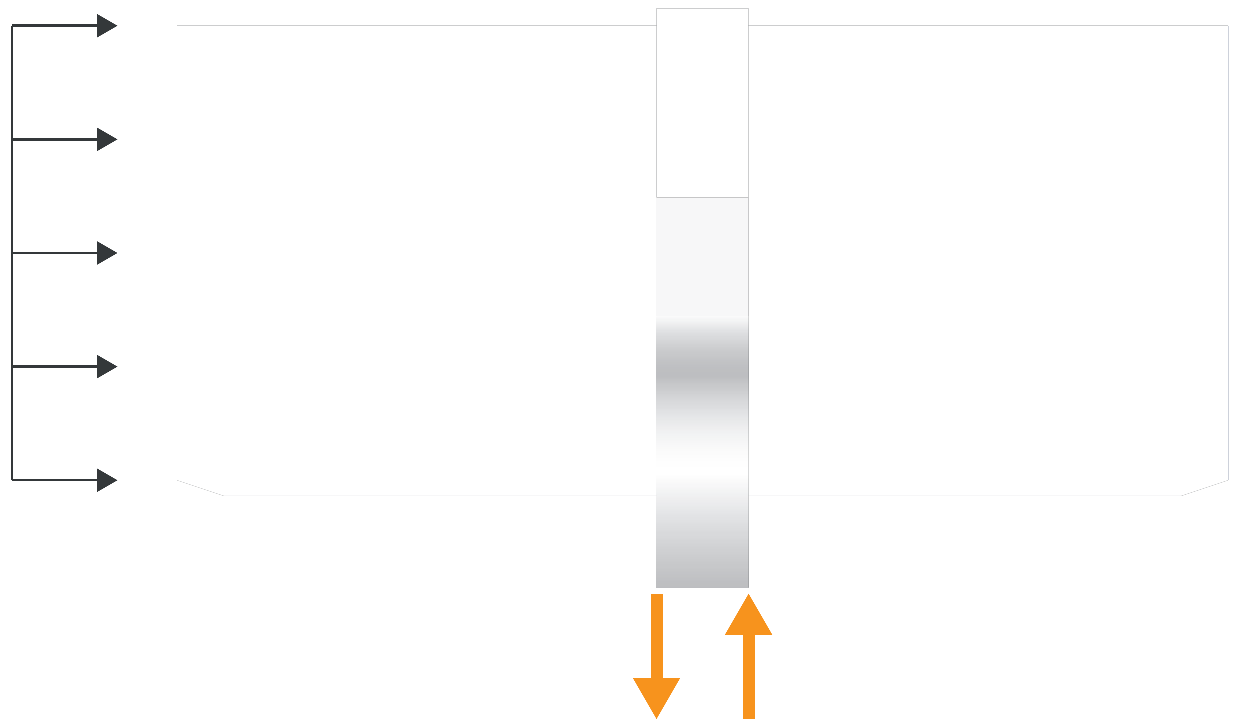


- Main wind direction

Design Explanation

Movable part

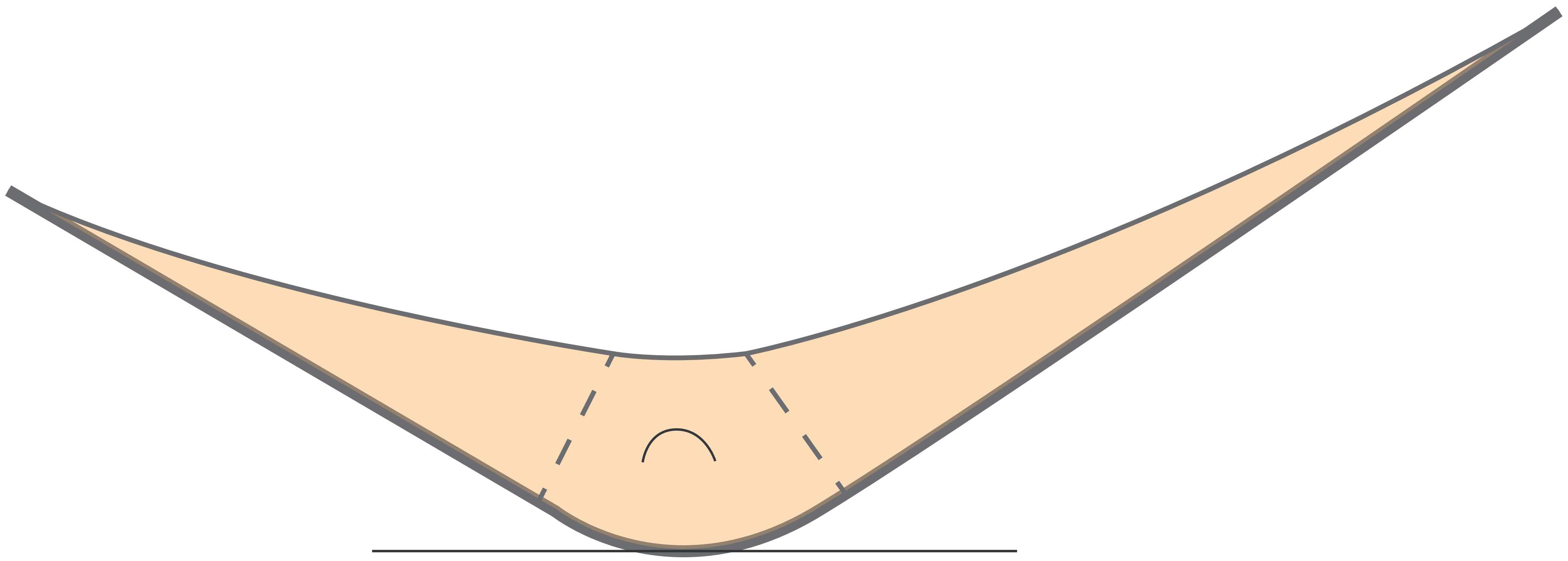


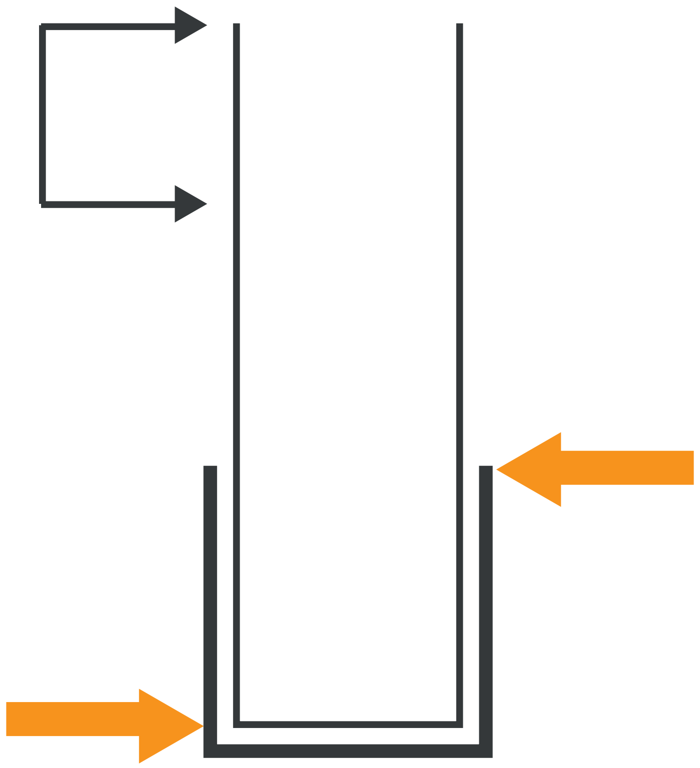


- Wind force on roll bascule

Design Explanation

Movable part

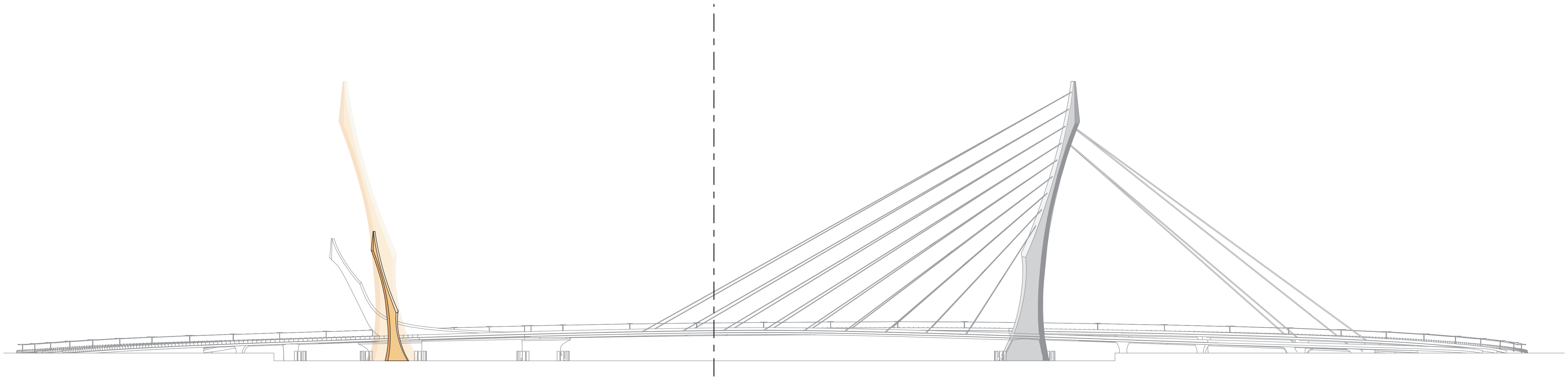


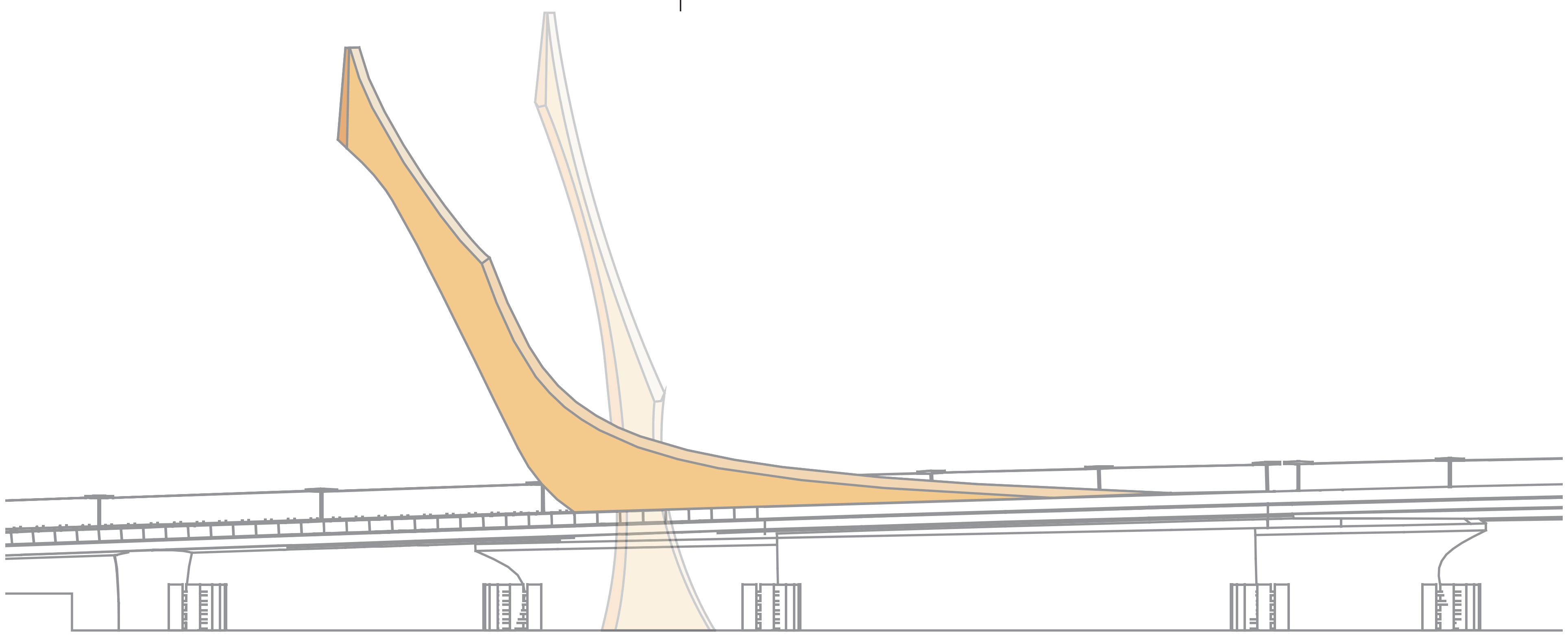


- Bending moments in roll bascule

Design Explanation

Movable part

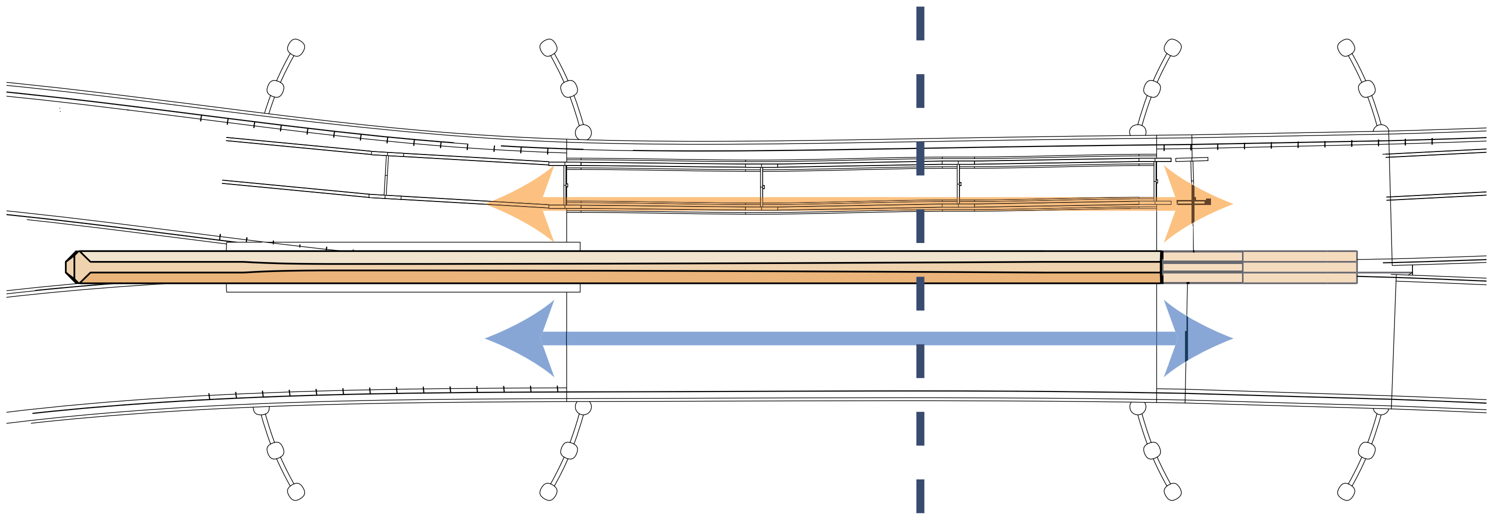


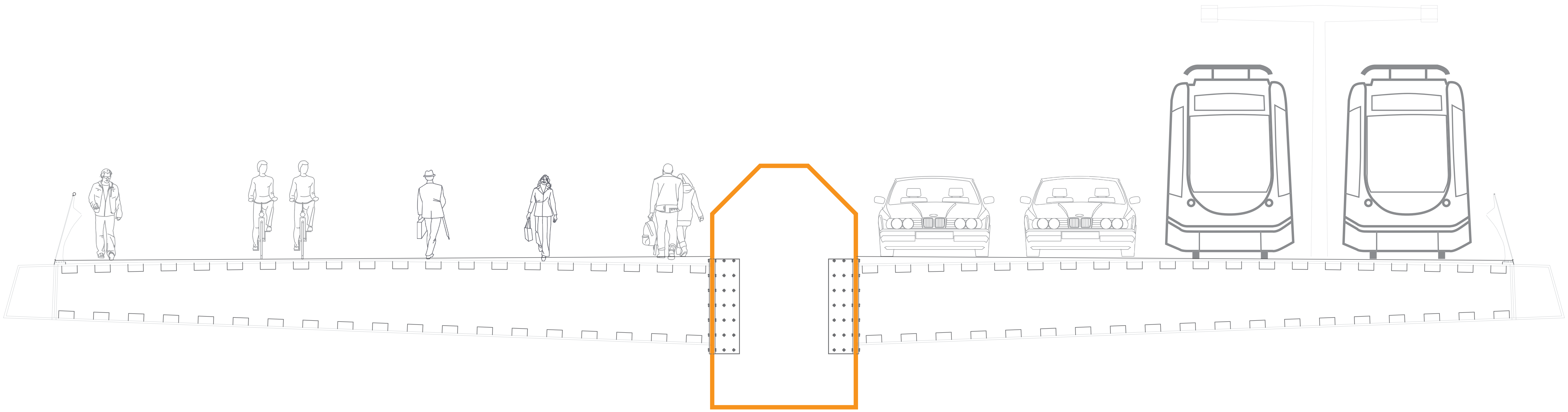


- Thinking process

Design Explanation

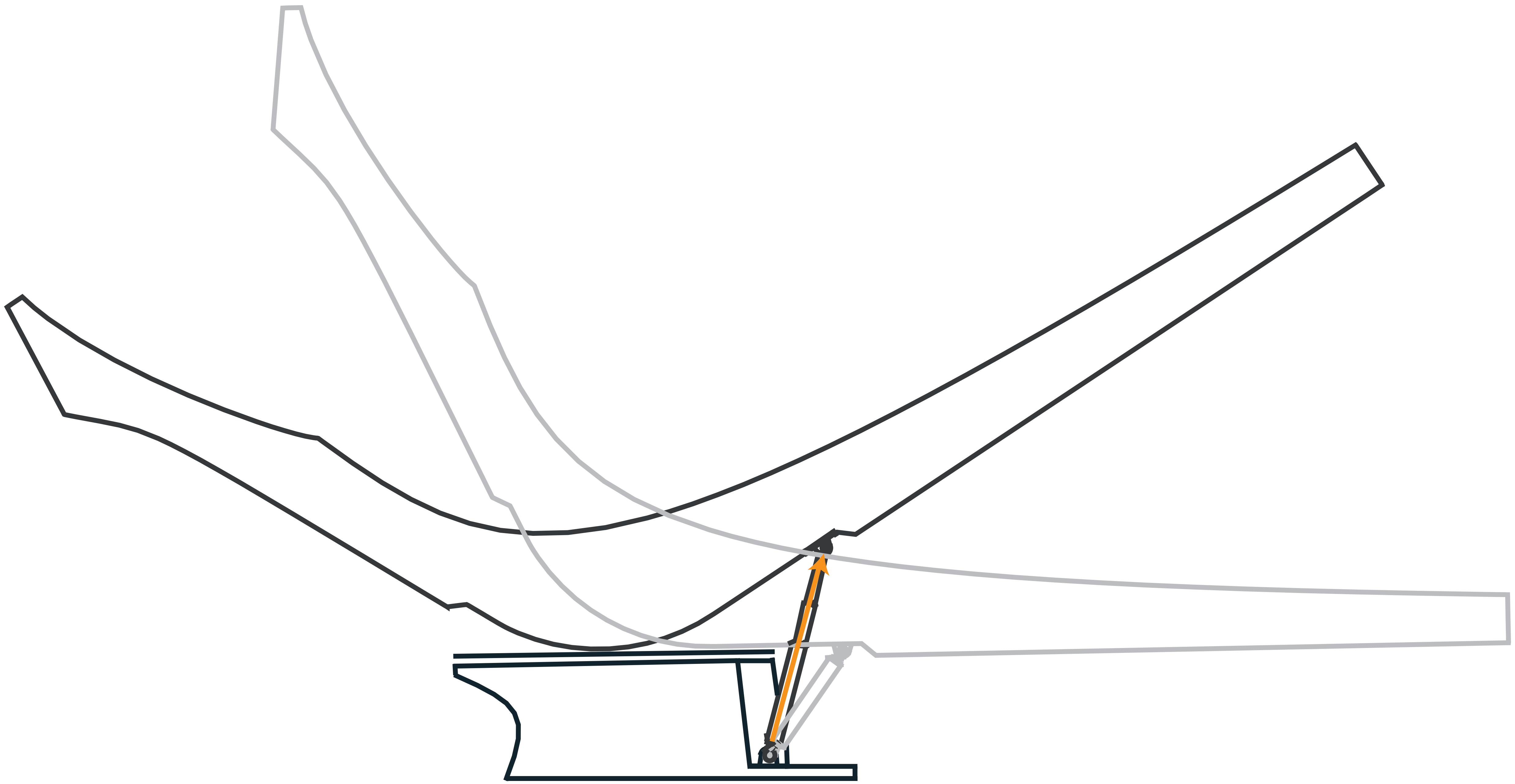
Movable part





Design Explanation

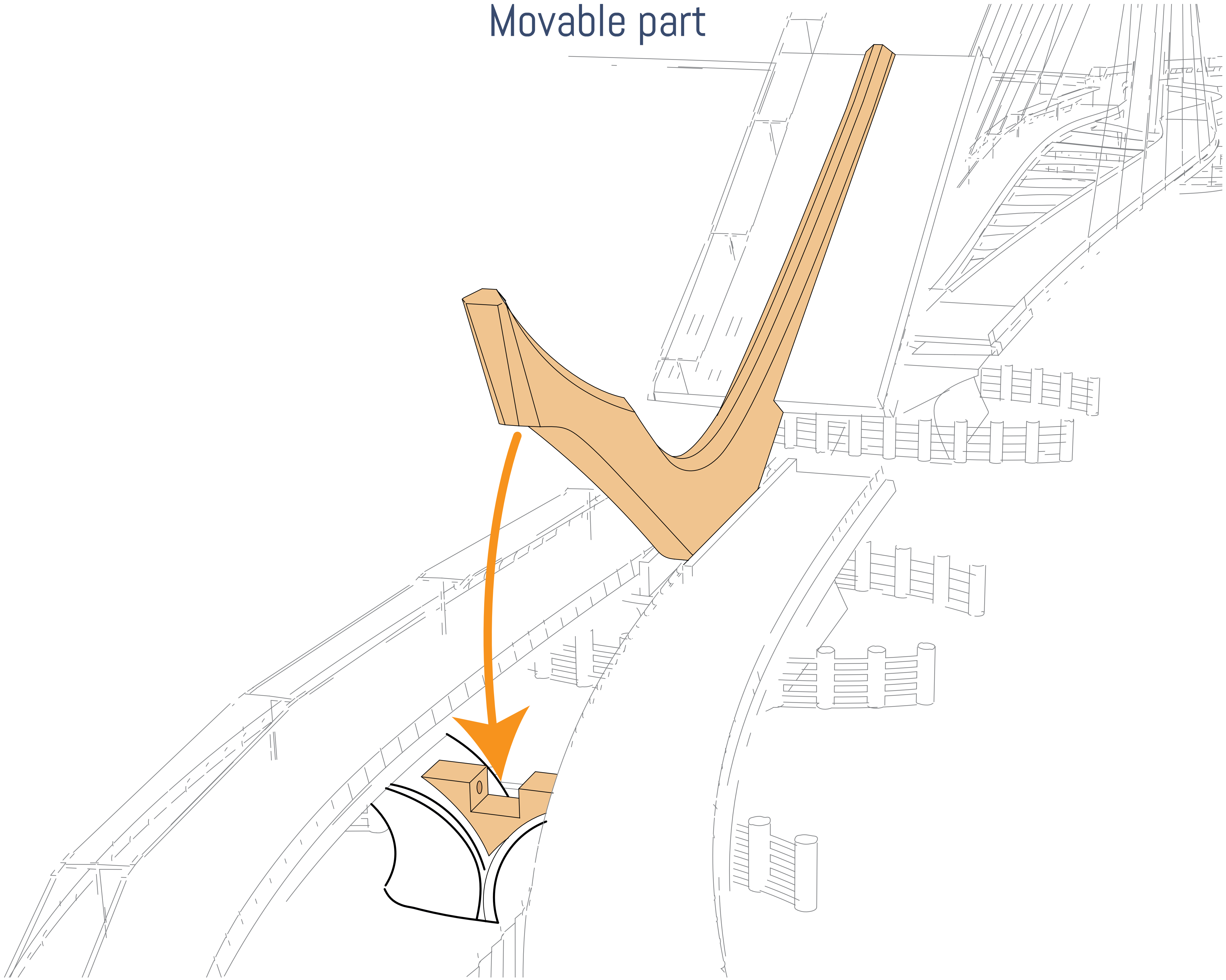
Movable part



- Opening mechanism

Design Explanation

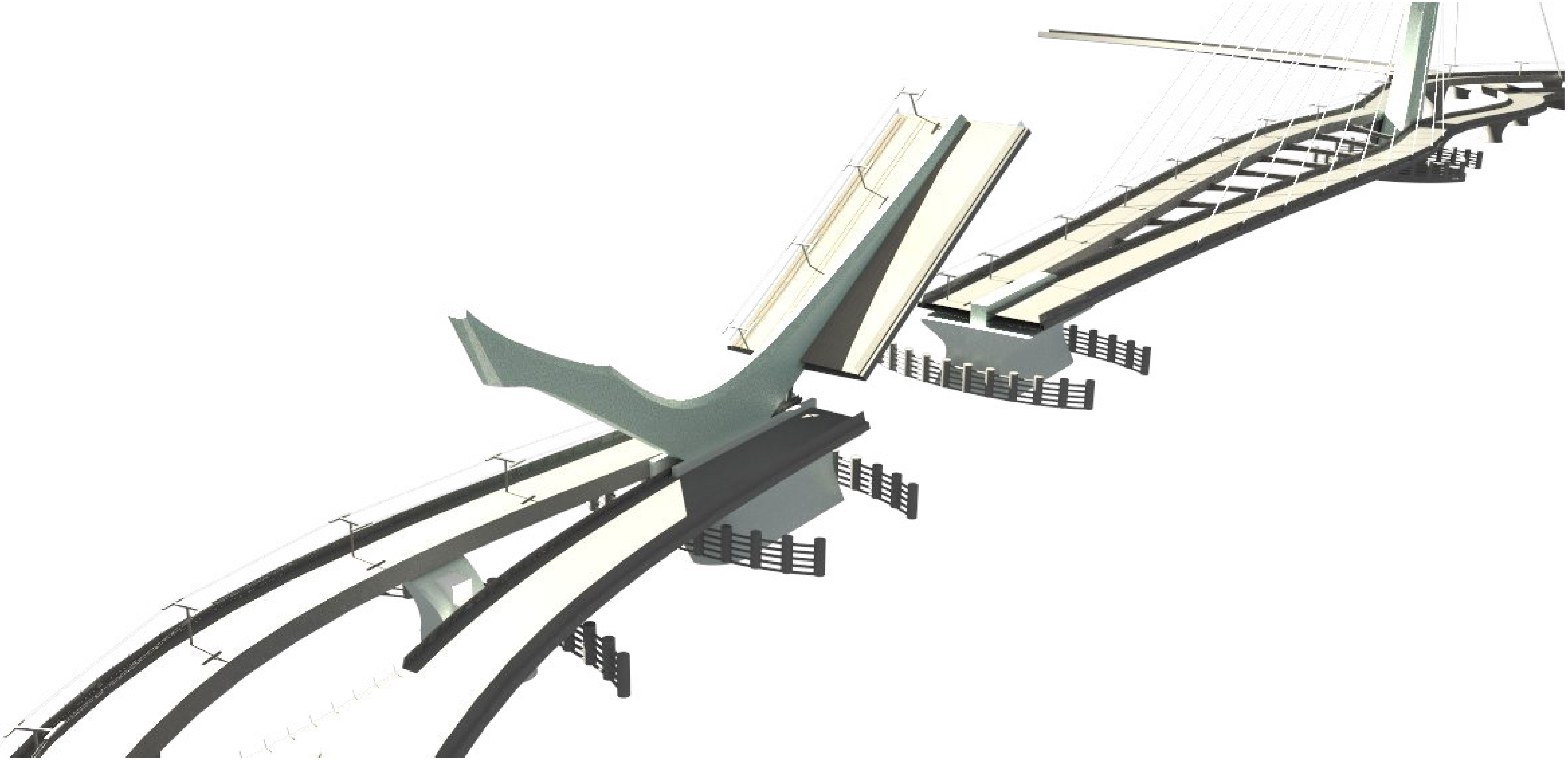
Movable part



- Locking mechanism

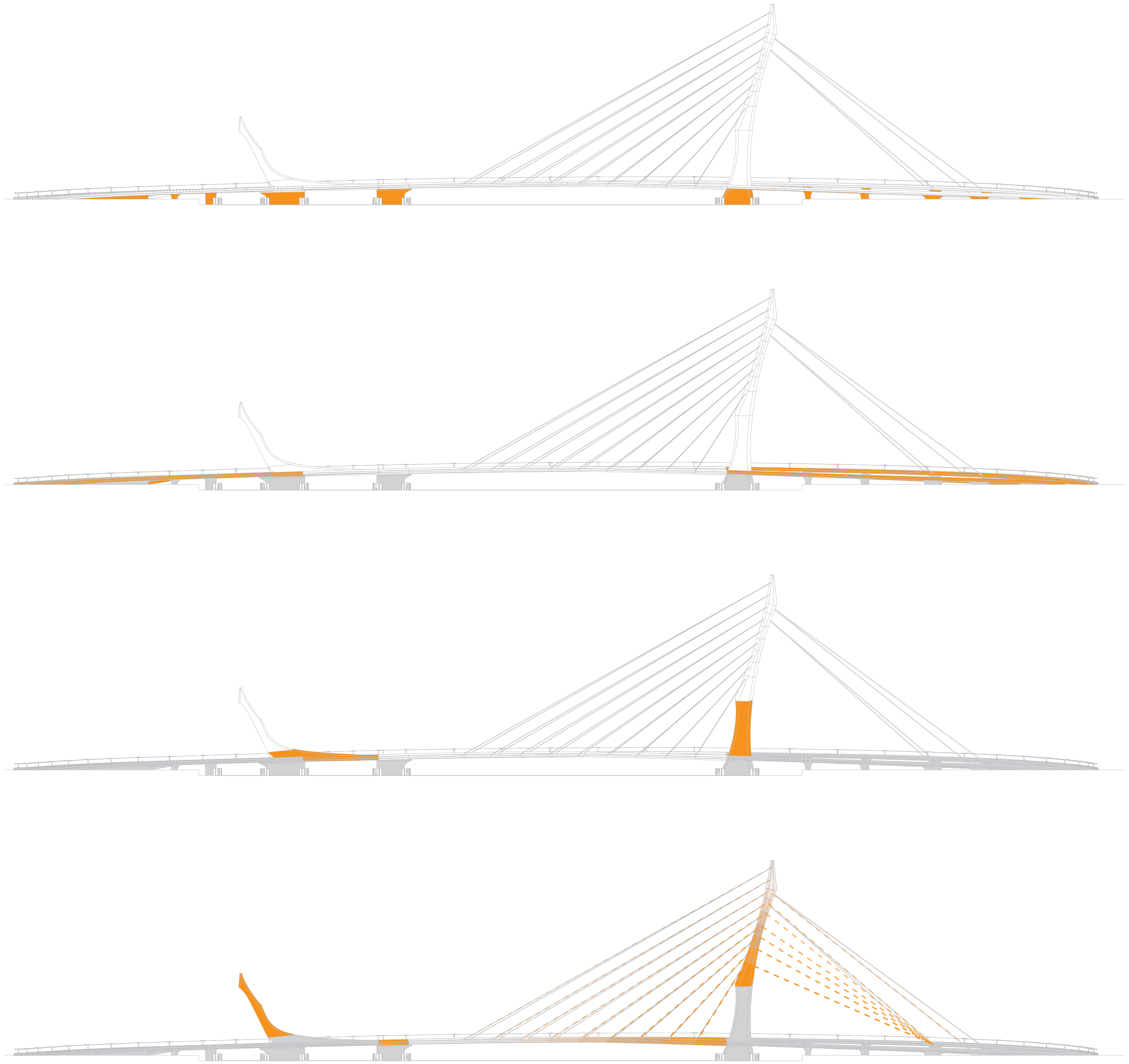
Design Explanation

Movable part



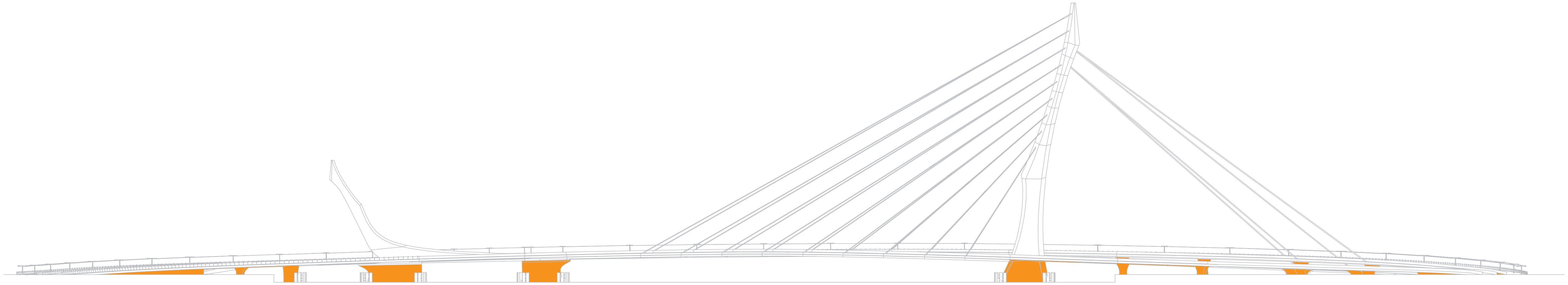
Design Explanation

Building sequence



Design Explanation

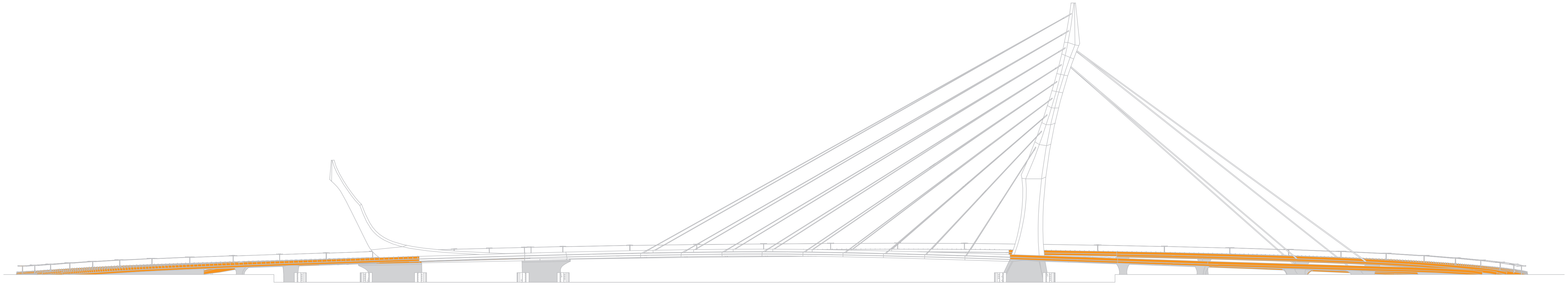
Building sequence



- Pillars

Design Explanation

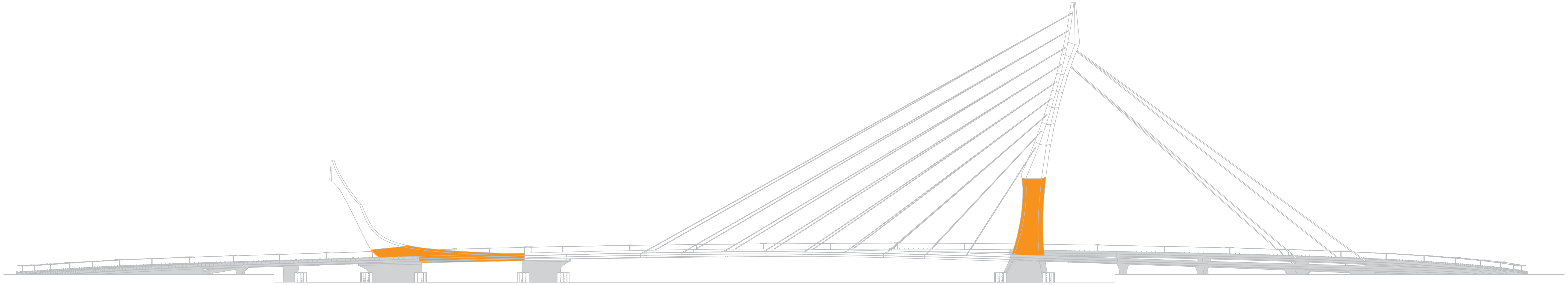
Building sequence



- Landings

Design Explanation

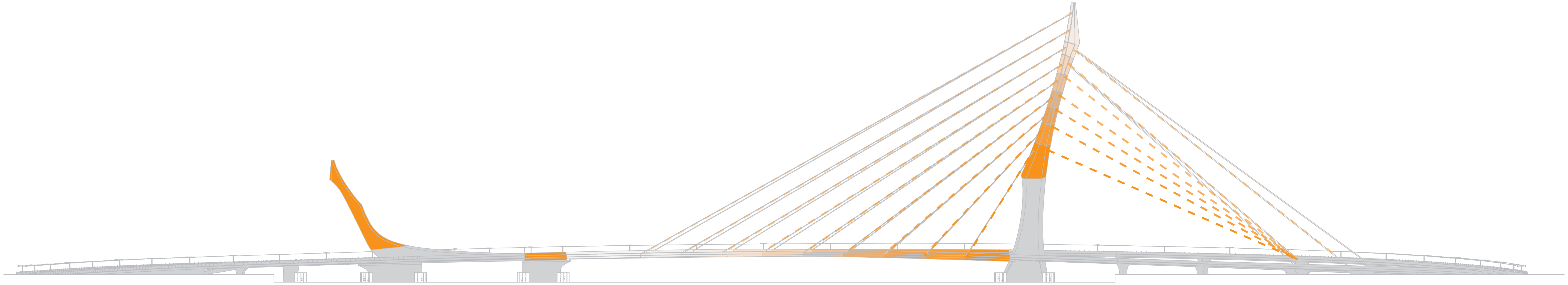
Building sequence



- Movable deck and first part of pylon

Design Explanation

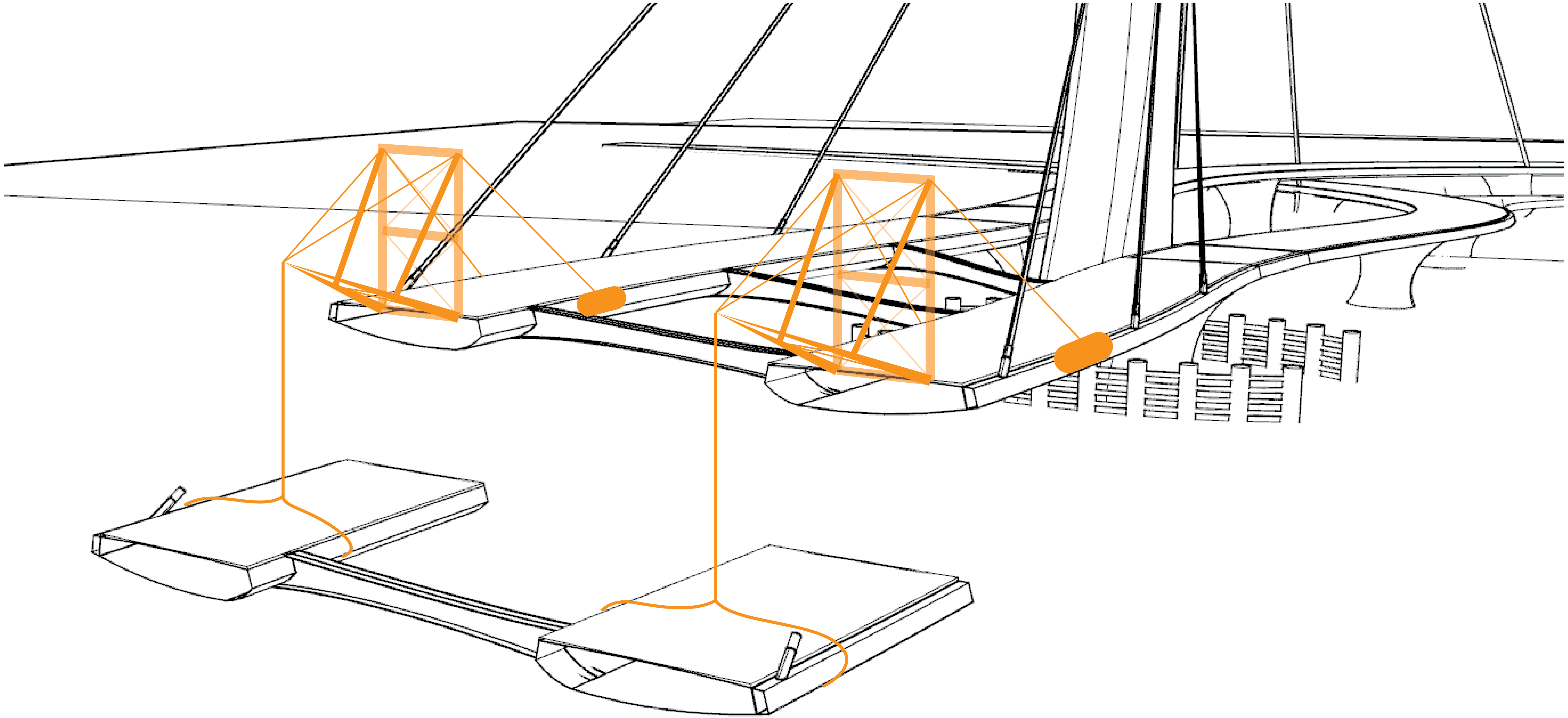
Building sequence



- Rest of movable part and main span one-by-one

Design Explanation

Building sequence

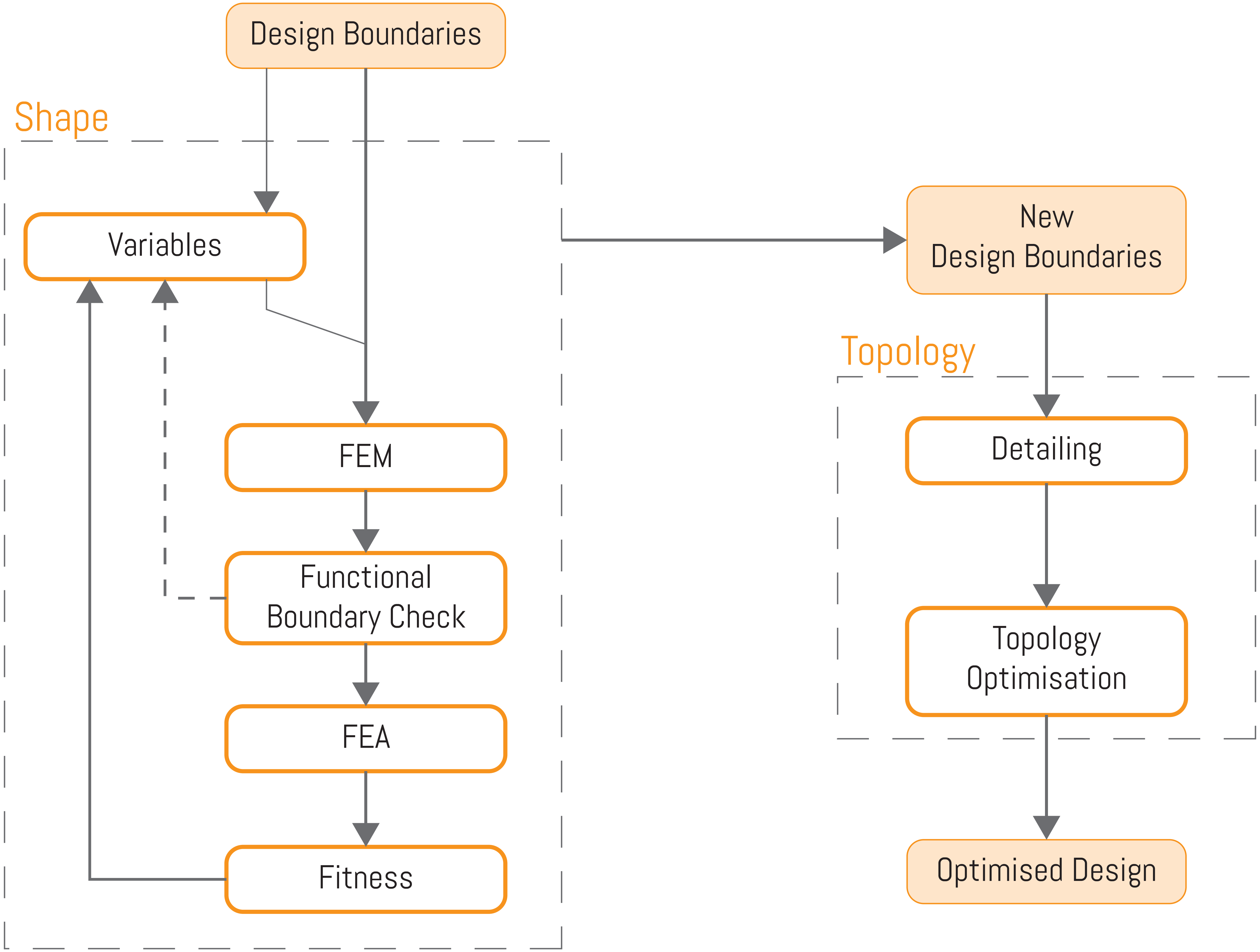


- Main span construction system

Simulation and Optimisation

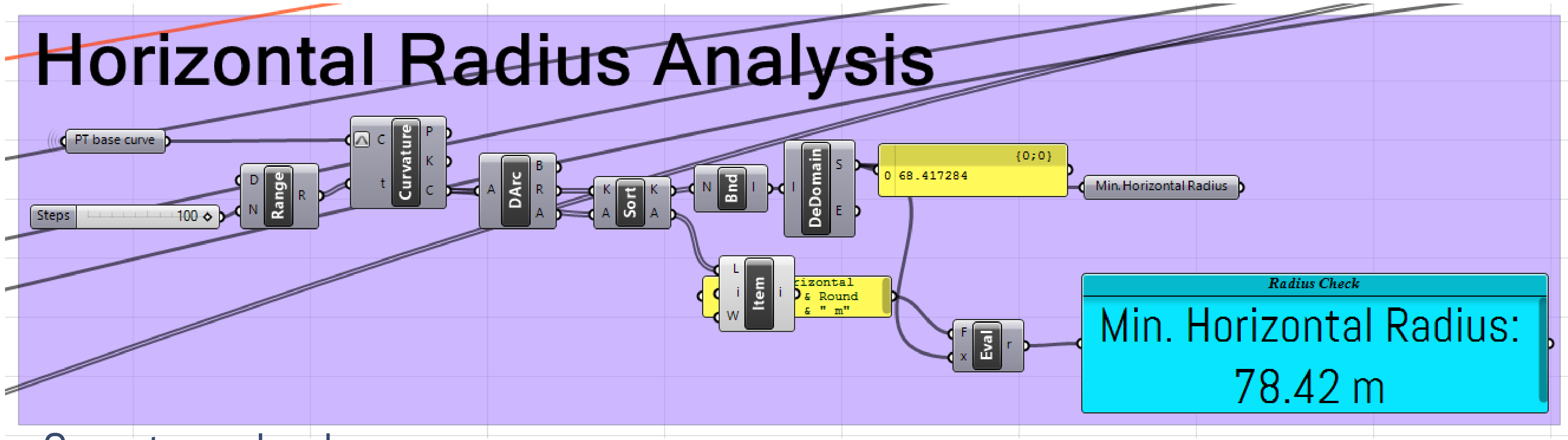
Simulation and Optimisation

Process

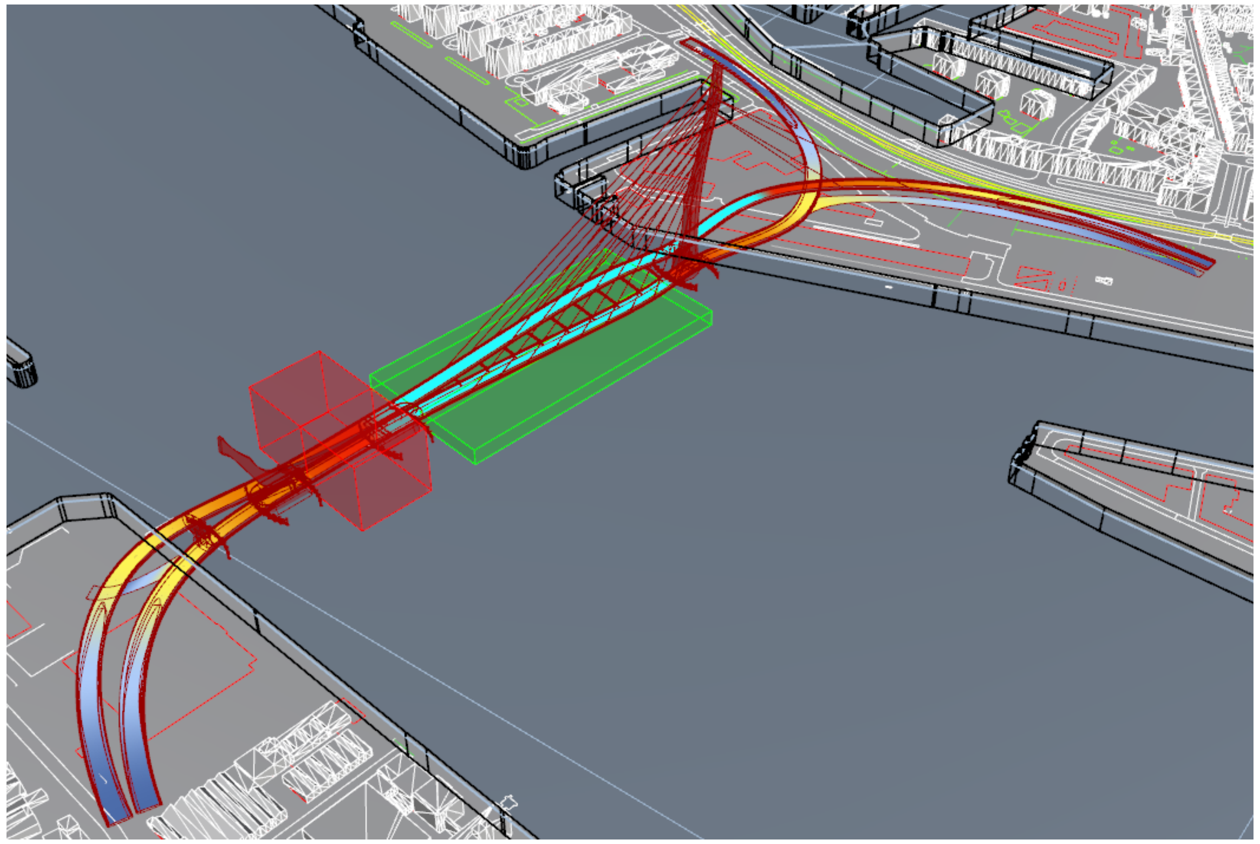


Simulation and Optimisation

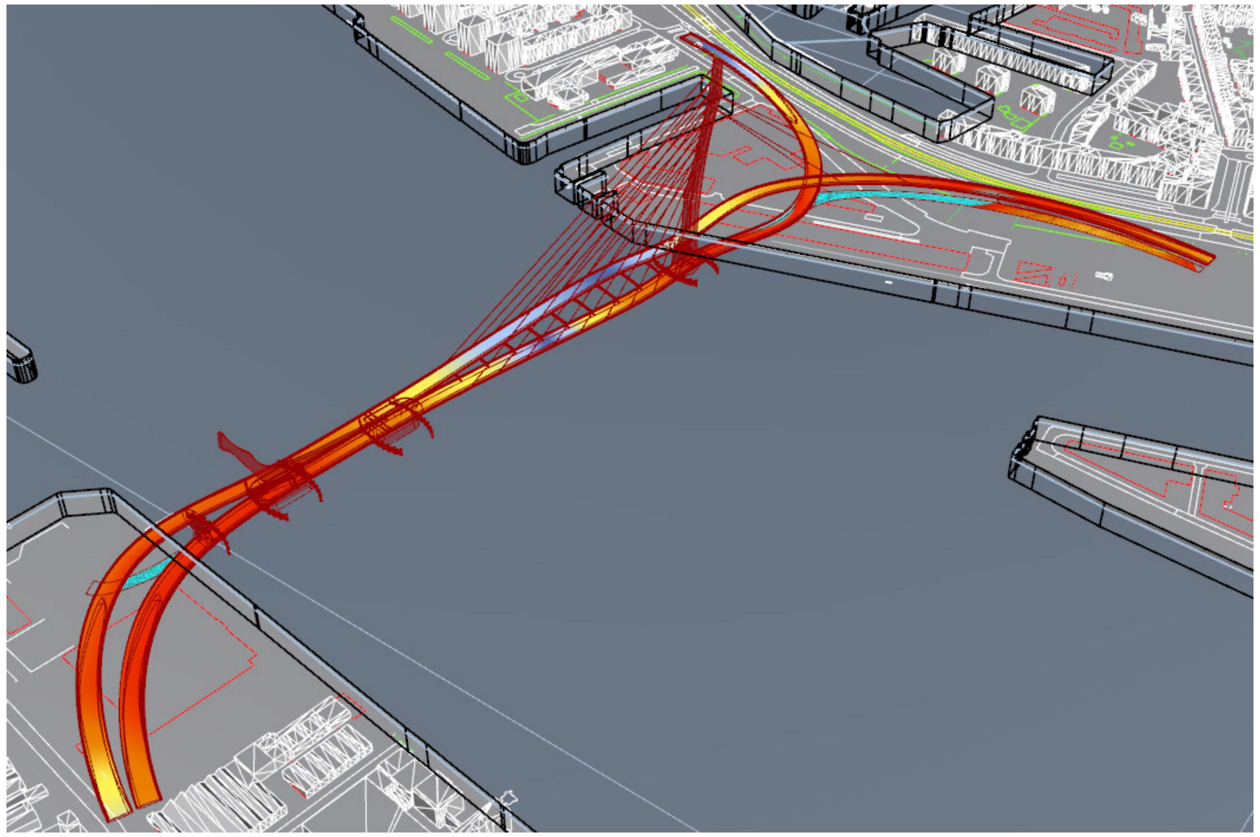
Boundary checks



- Curvature check



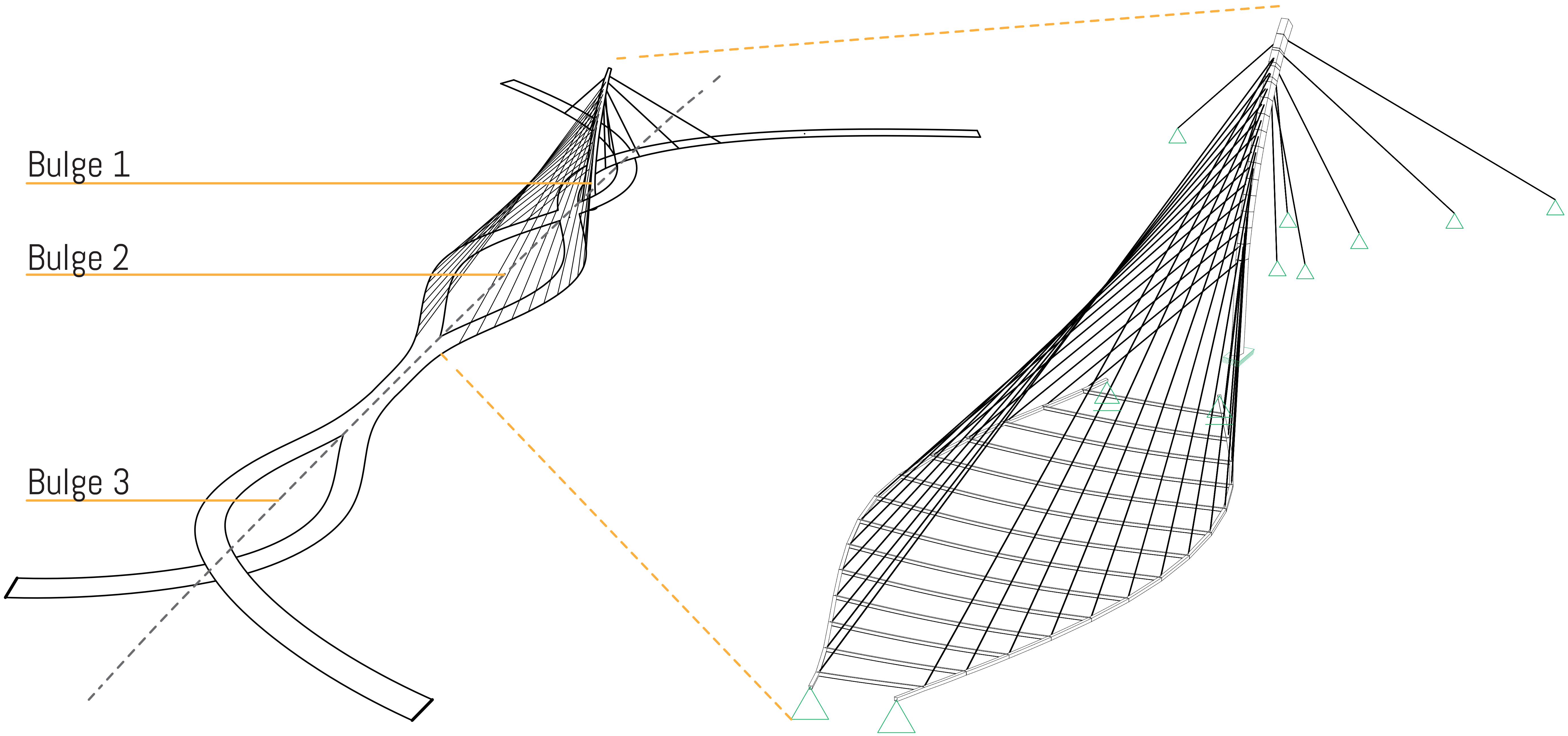
- Clearance check



- Slope check

Simulation and Optimisation

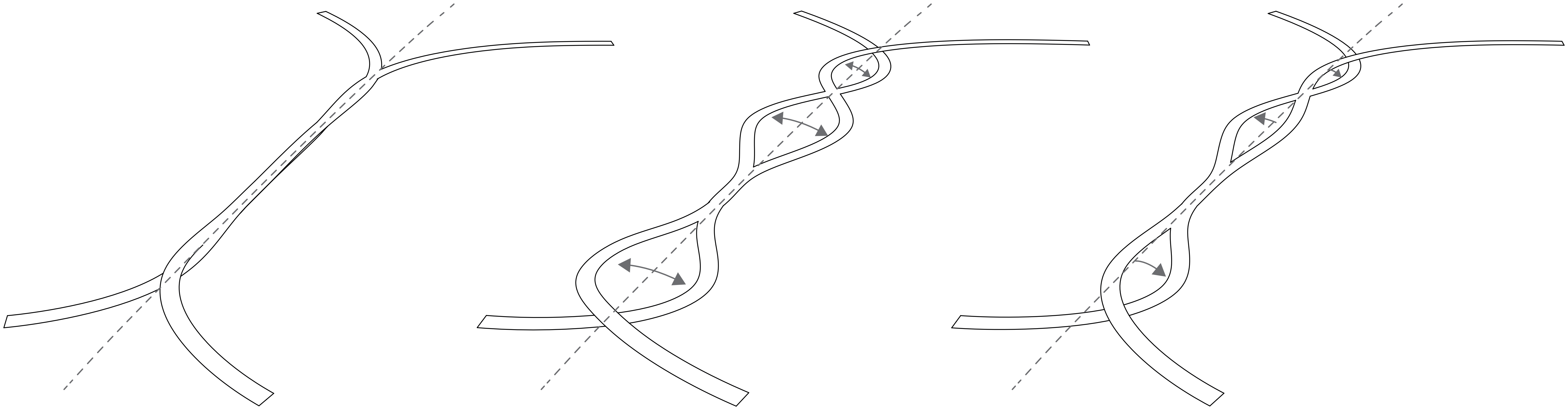
Deck



- Variables and Finite Element Model

Simulation and Optimisation

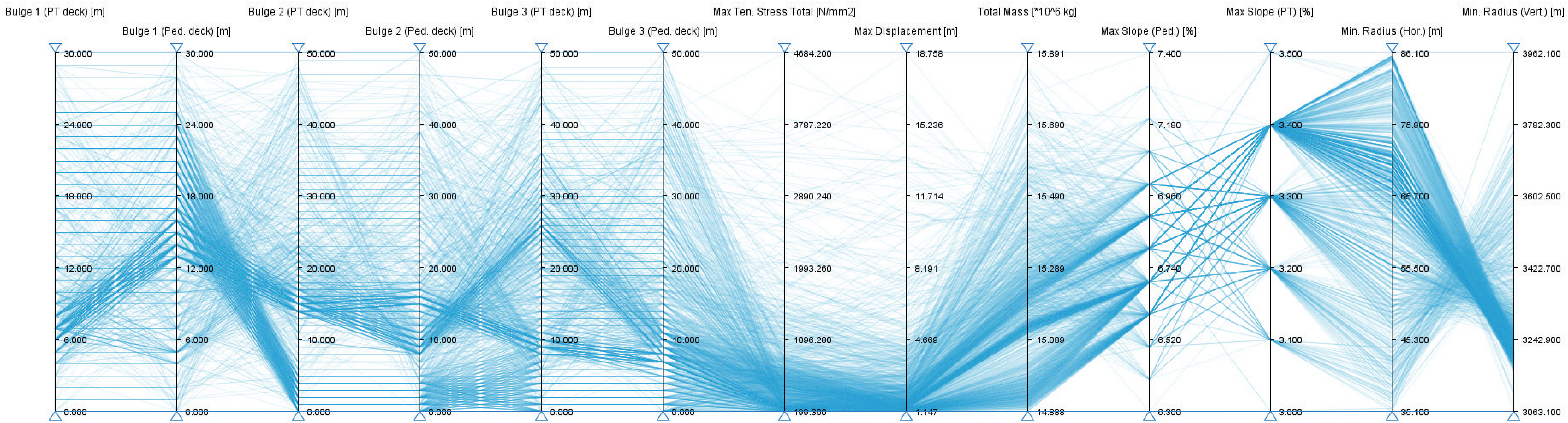
Deck



- Variable adjustments

Simulation and Optimisation

Deck



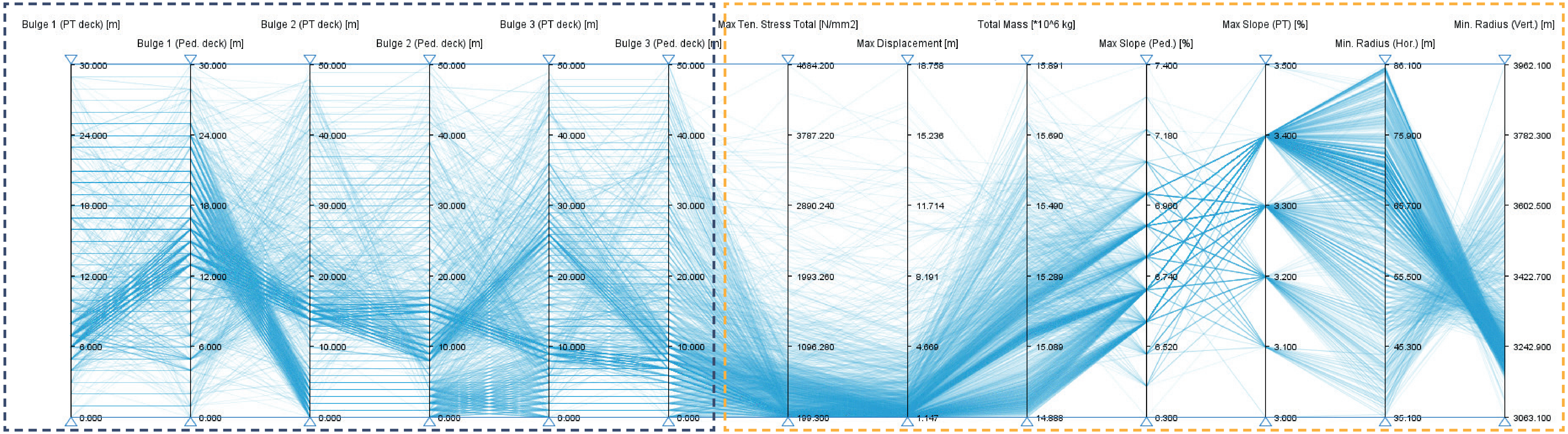
- Analysis results

Simulation and Optimisation

Deck

Variables

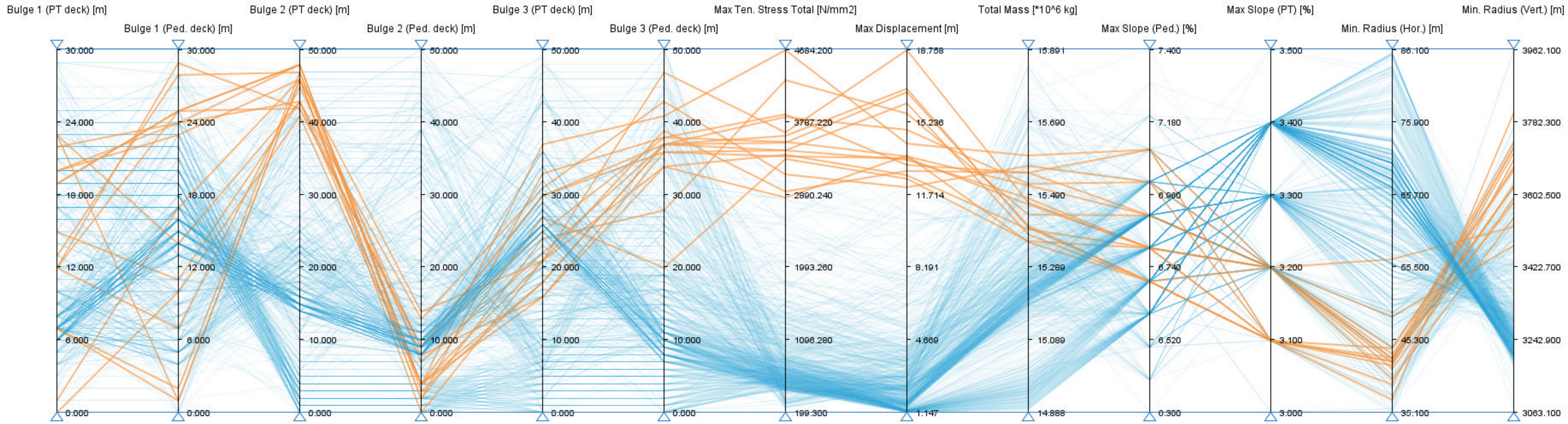
Fitness and boundary



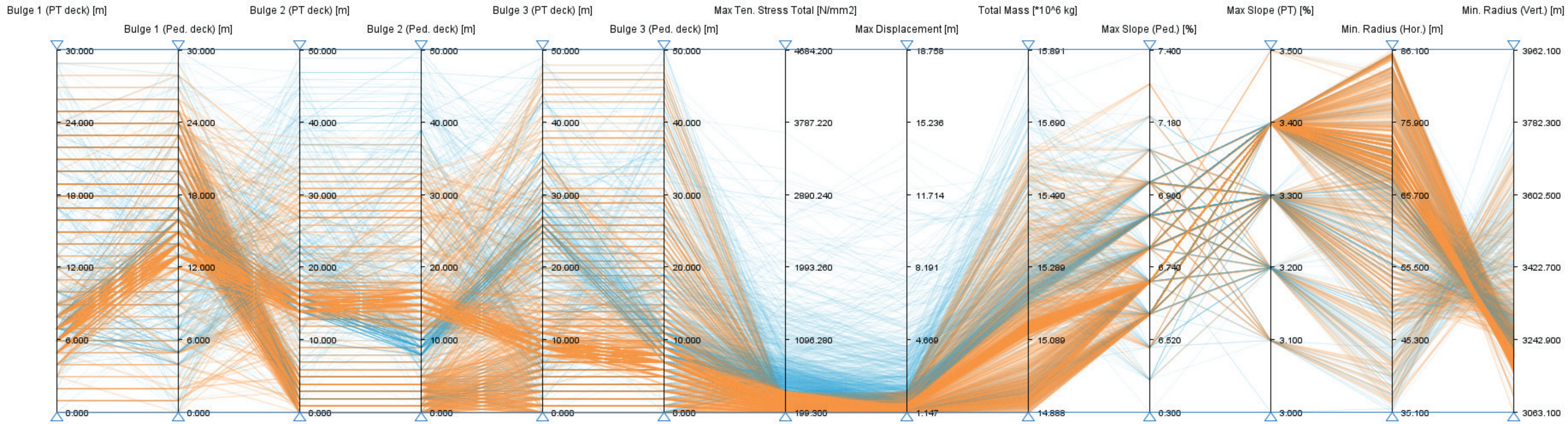
- Analysis results

Simulation and Optimisation

Deck



Collection of high displacement and tensile stress

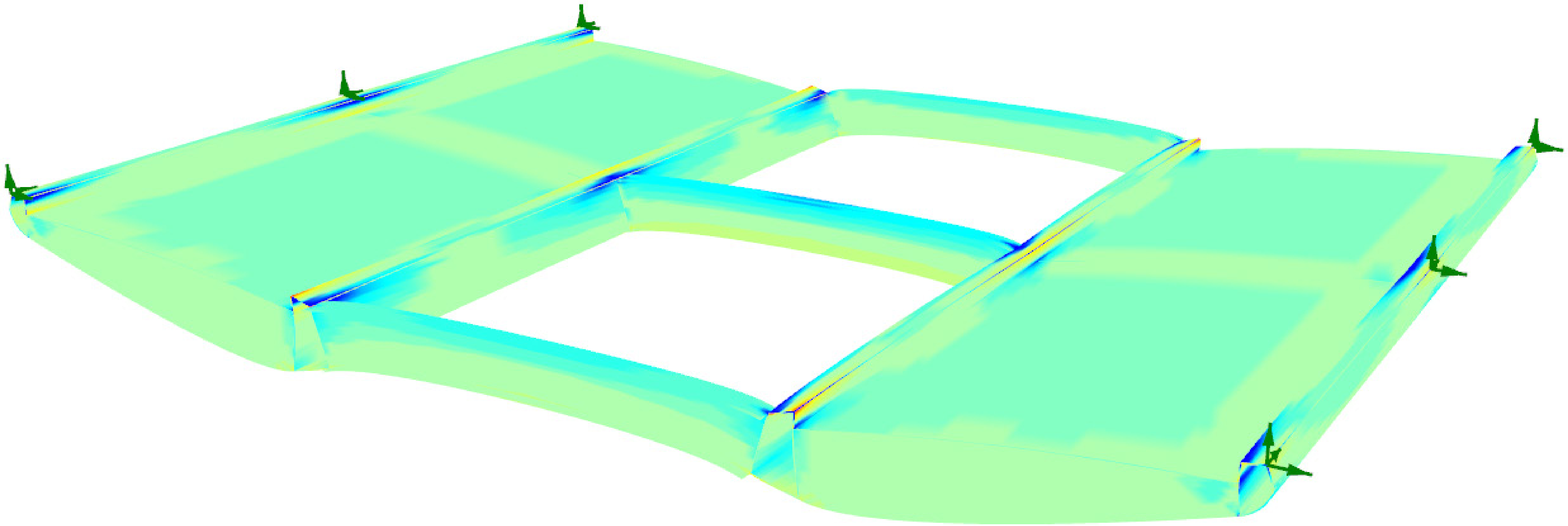


Collection of low displacement and tensile stress

- Desired behaviour vs. undesirable behaviour

Simulation and Optimisation

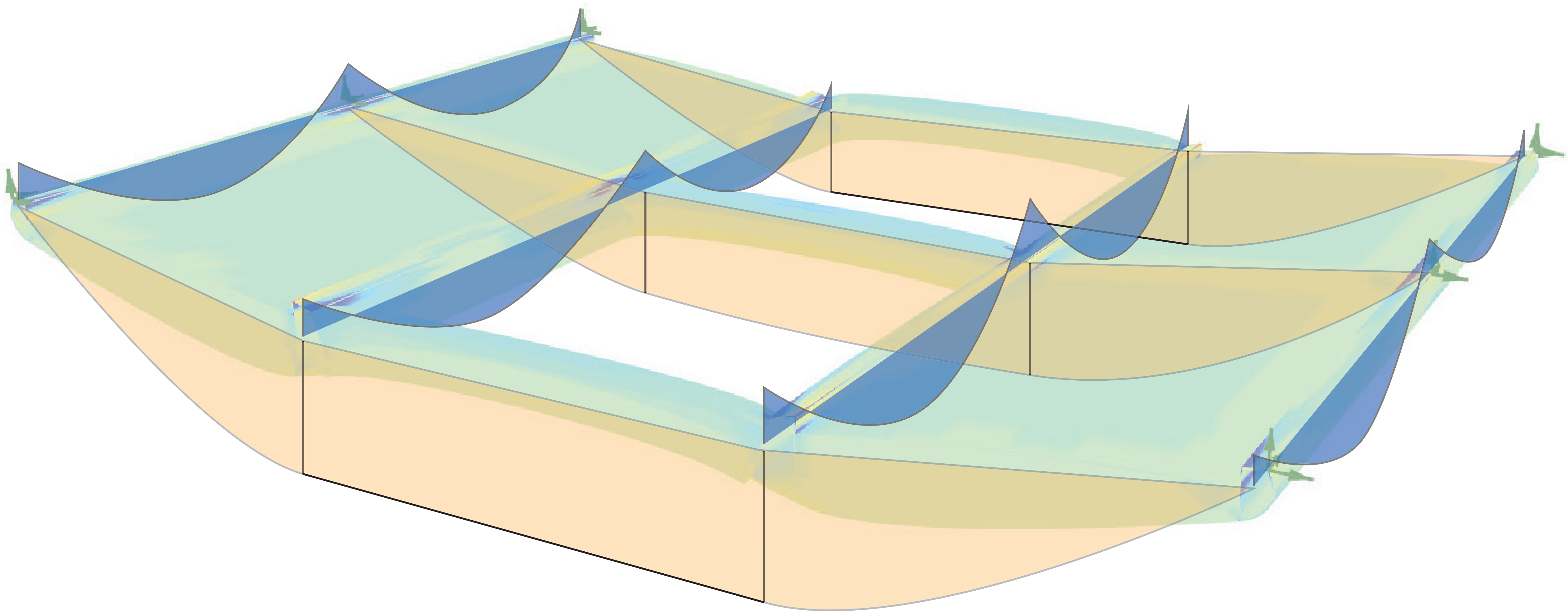
Deck



- Peak stresses in deck partition

Simulation and Optimisation

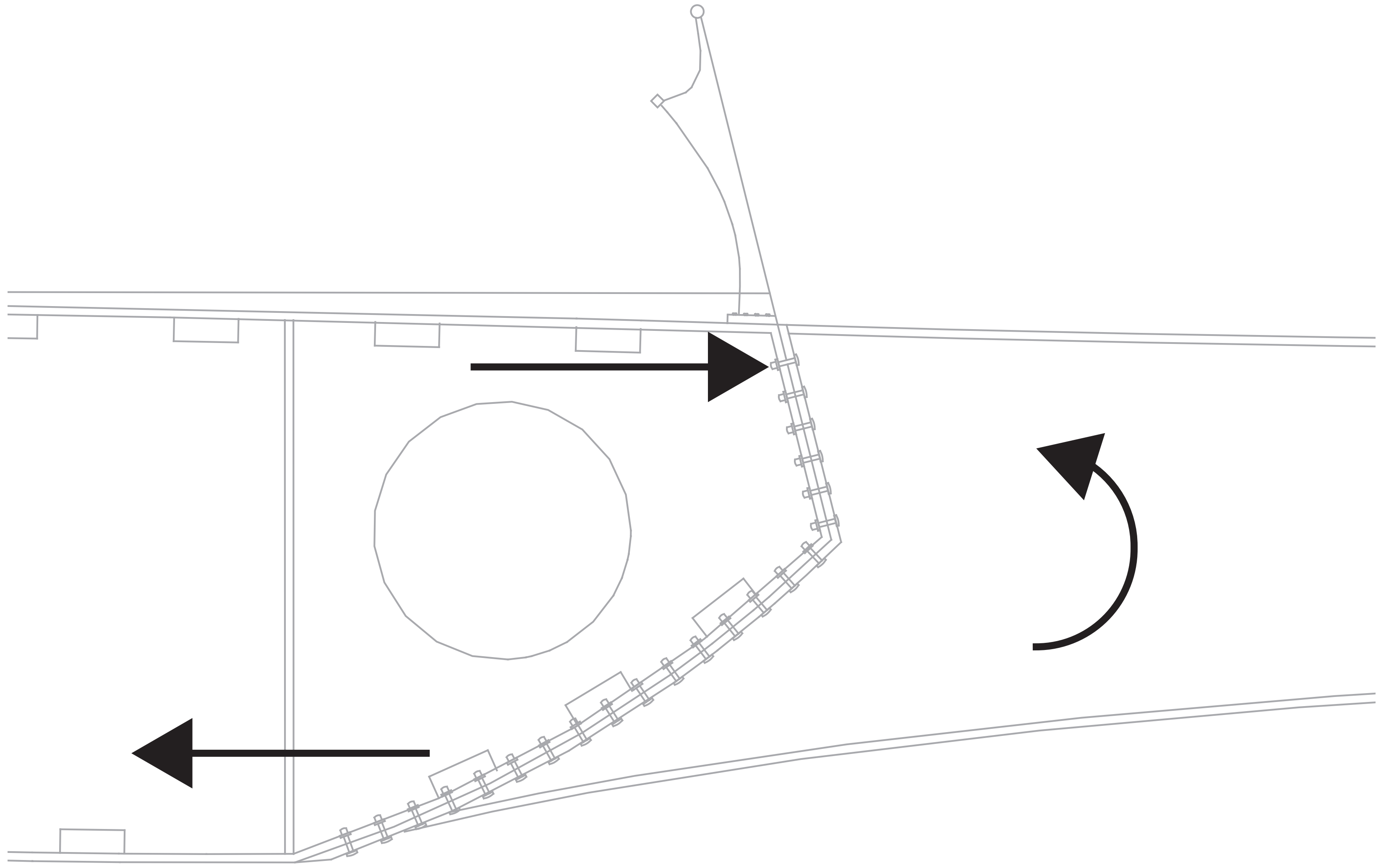
Deck



- Bending moments in deck partition

Simulation and Optimisation

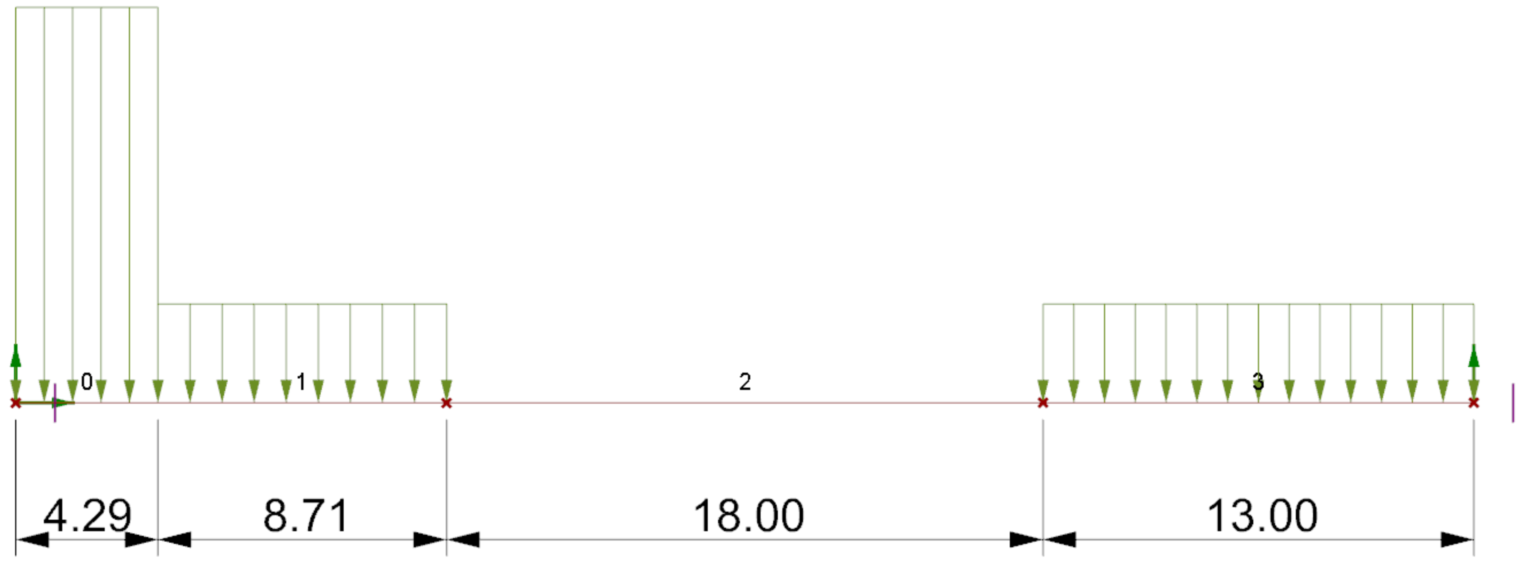
Deck



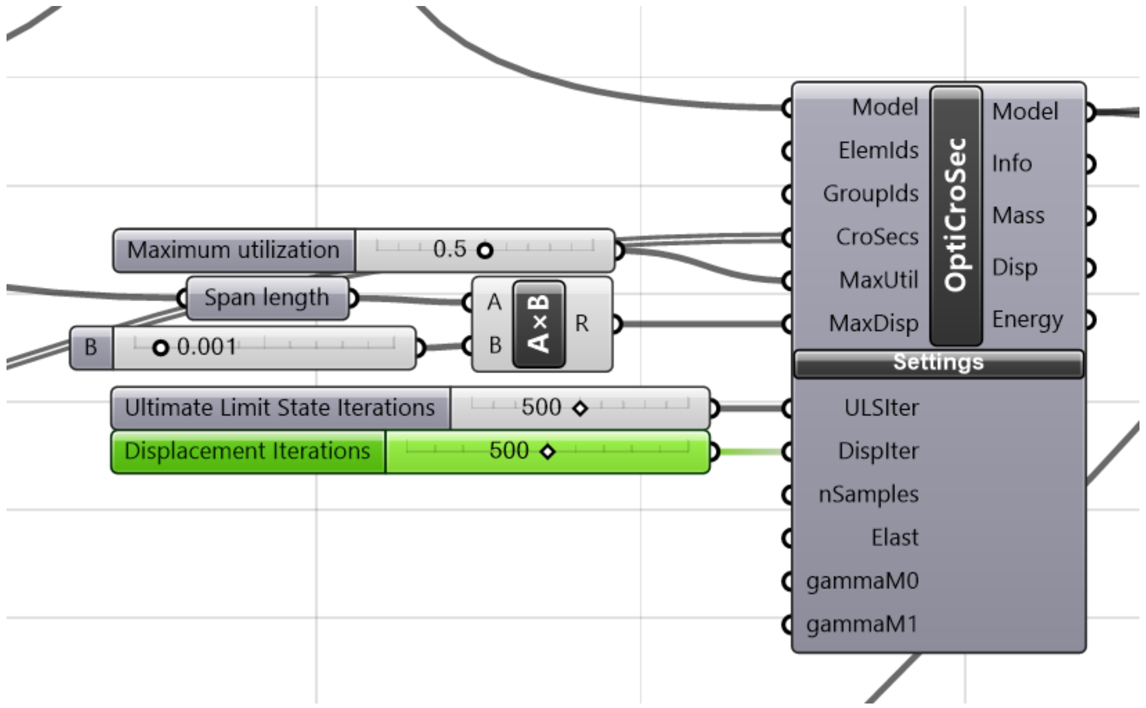
- Bending moment in connection deck-cross beam

Simulation and Optimisation

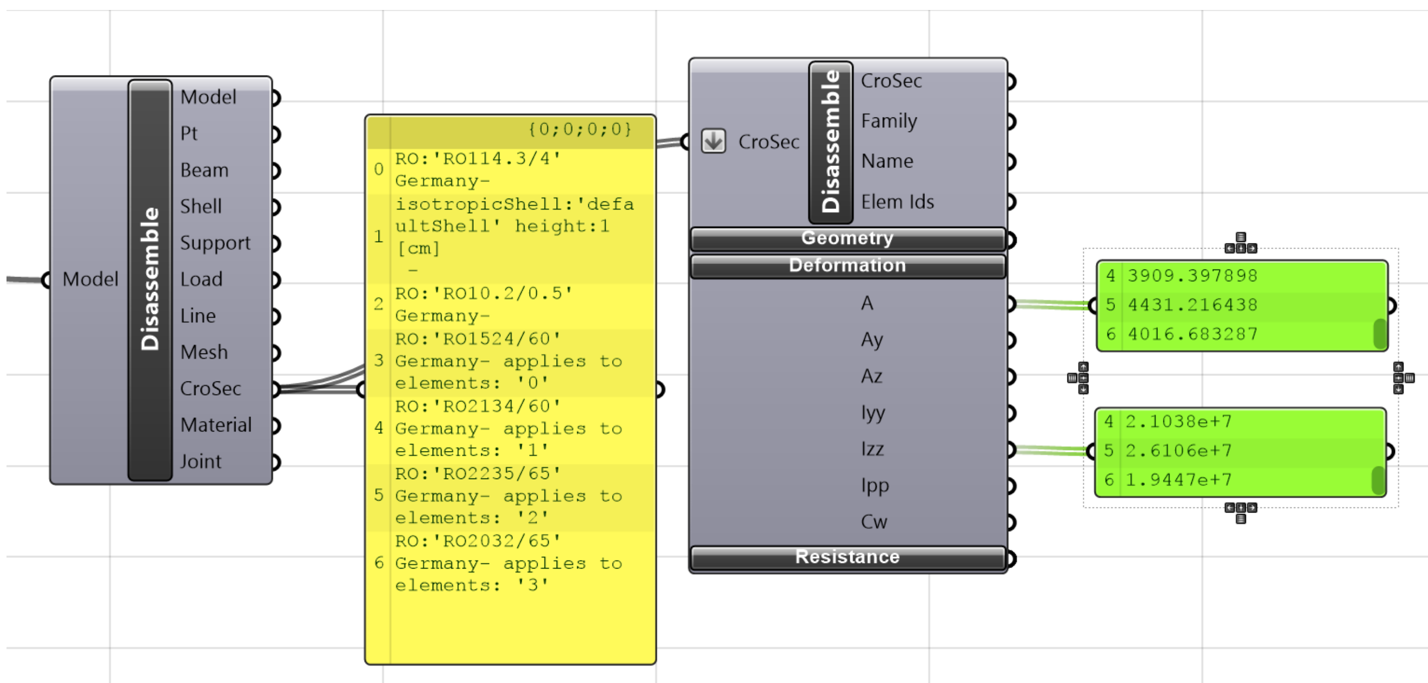
Deck



Static scheme



Input optimiser

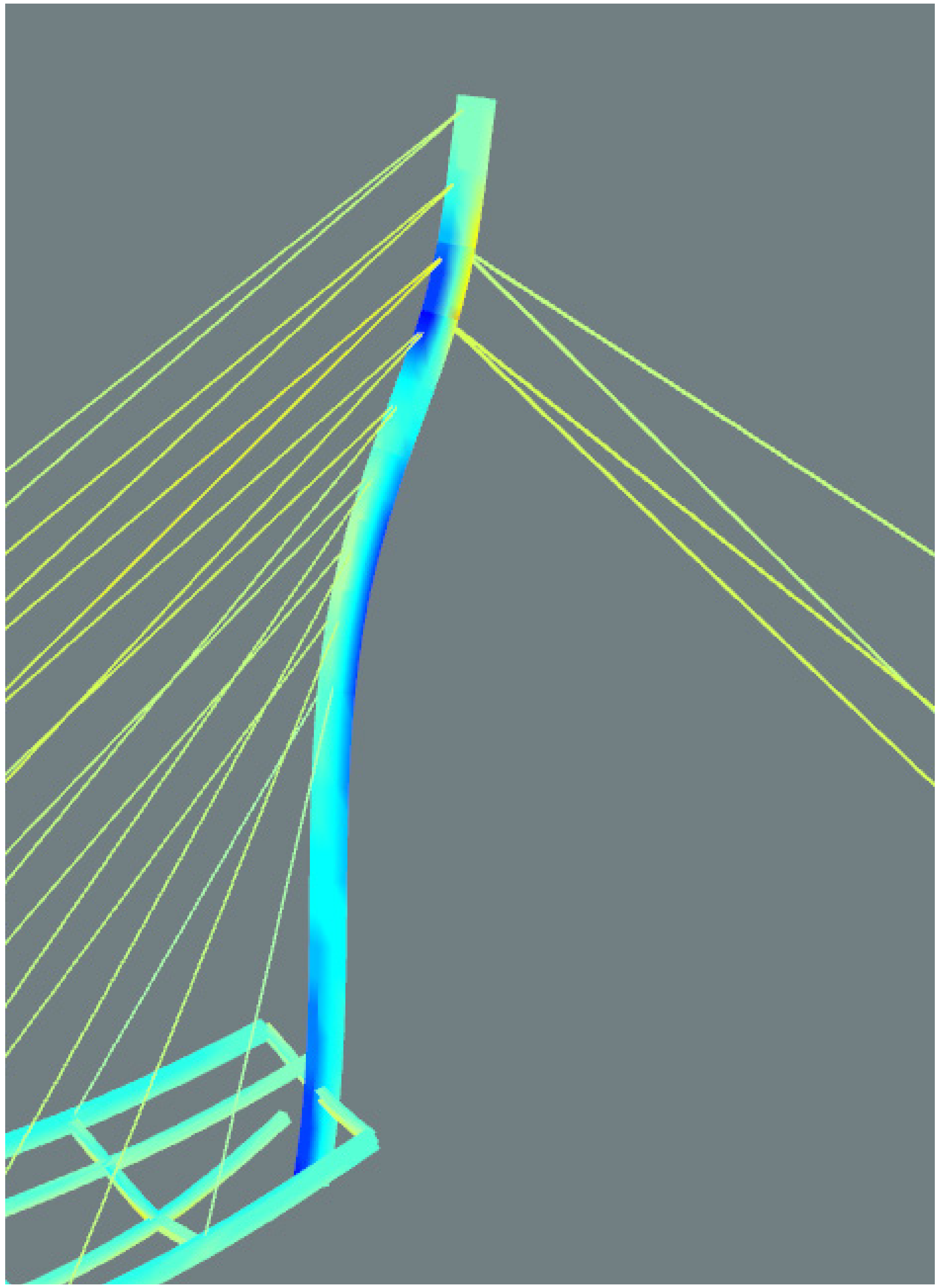


Output optimiser

- Cross beam optimisation

Simulation and Optimisation

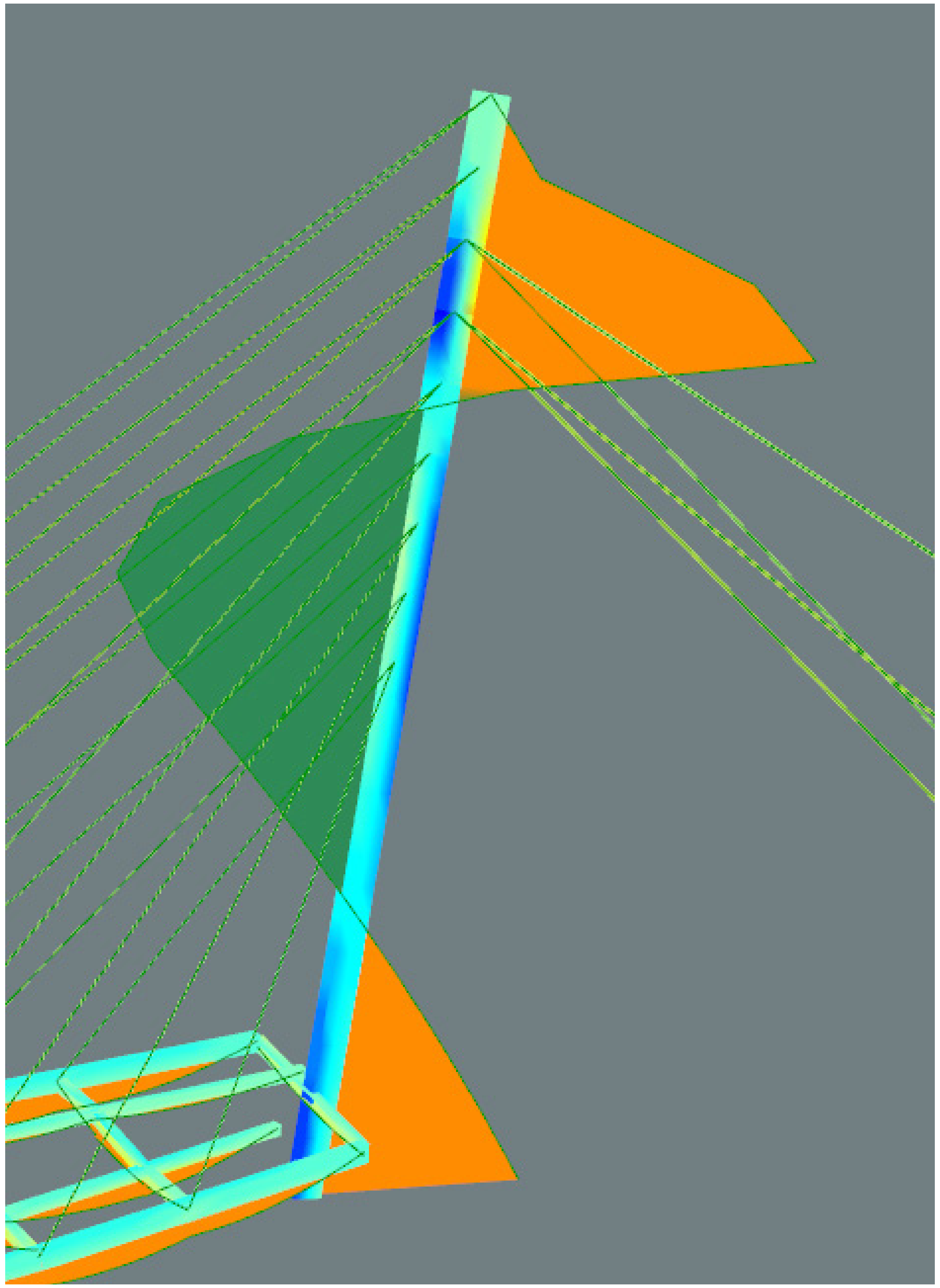
Pylon



- Deformed pylon with utilisation (Blue=Compression, Red= Tension)

Simulation and Optimisation

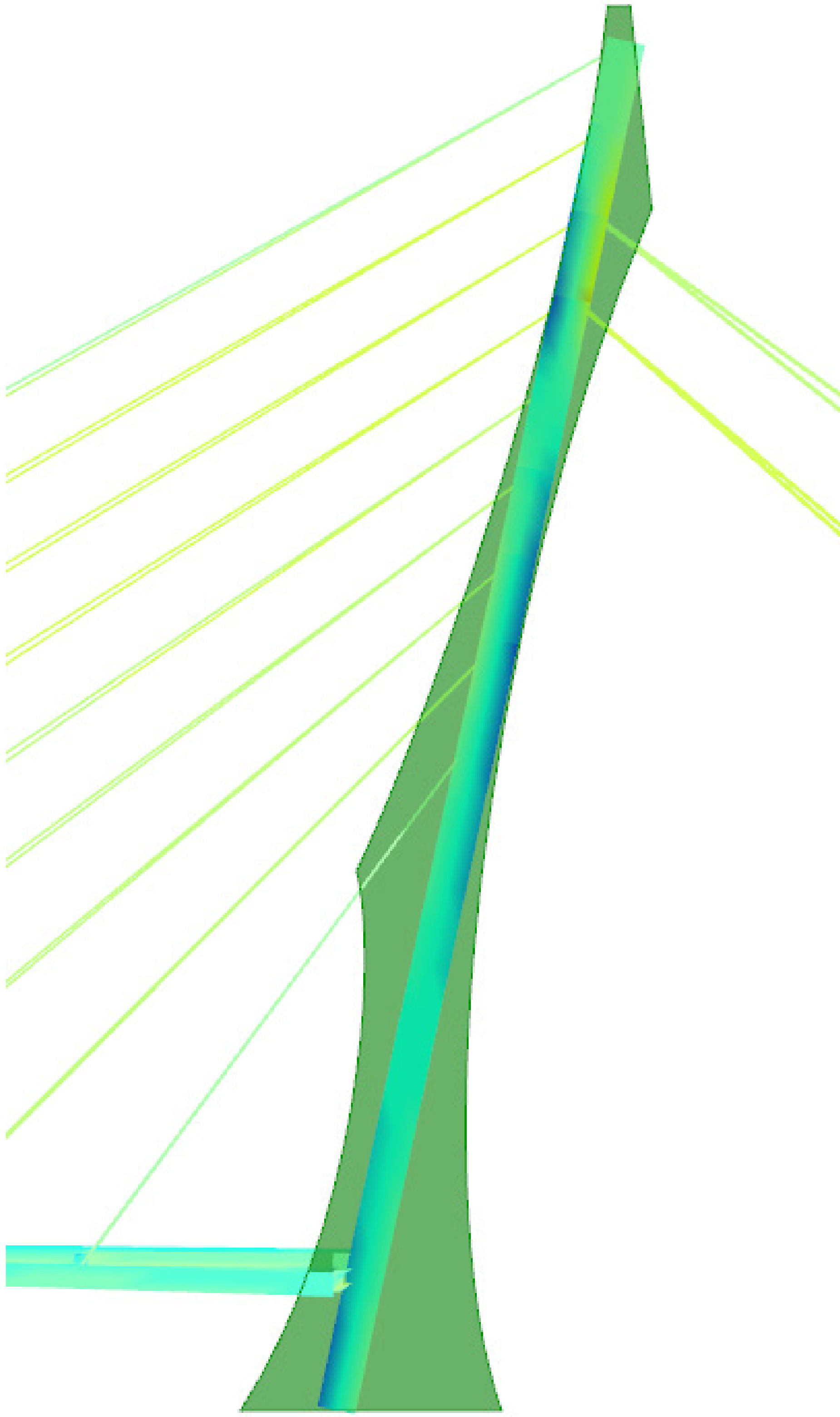
Pylon

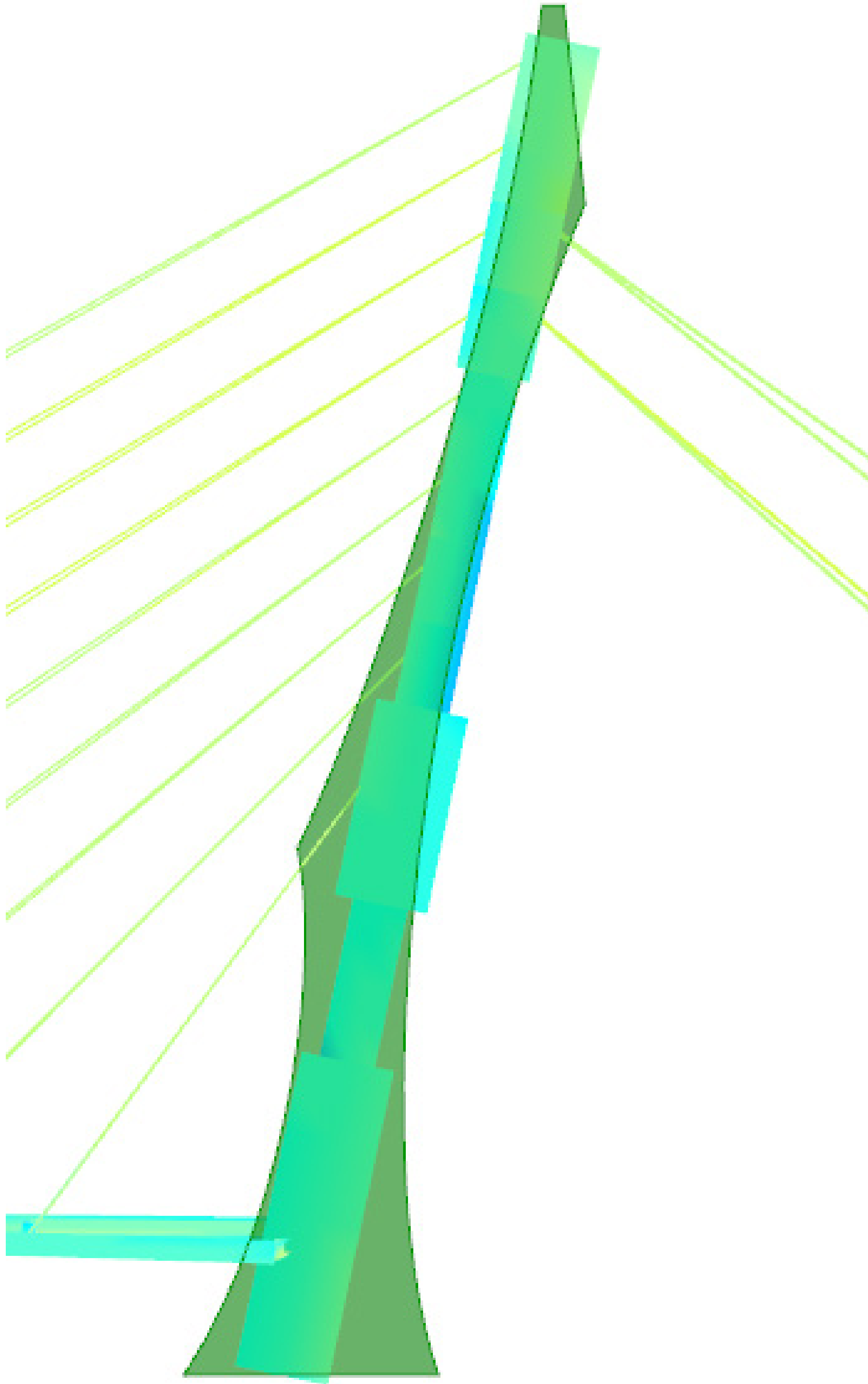


- Bending moment in pylon

Simulation and Optimisation

Pylon

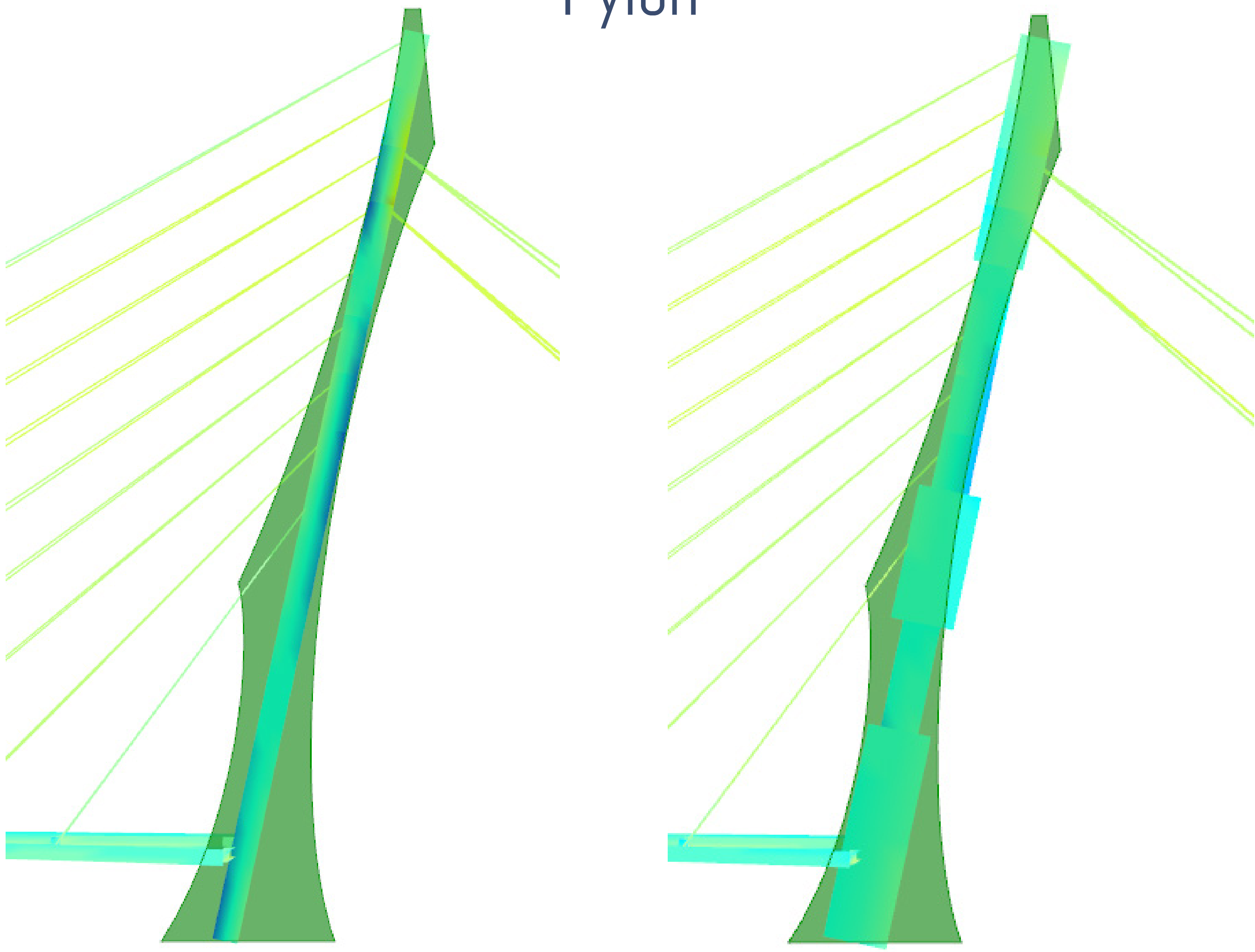


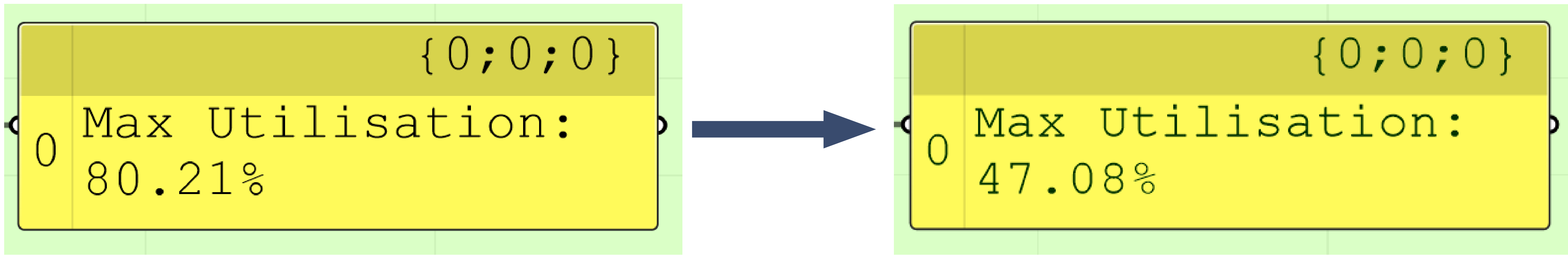


- Adjustment of section

Simulation and Optimisation

Pylon

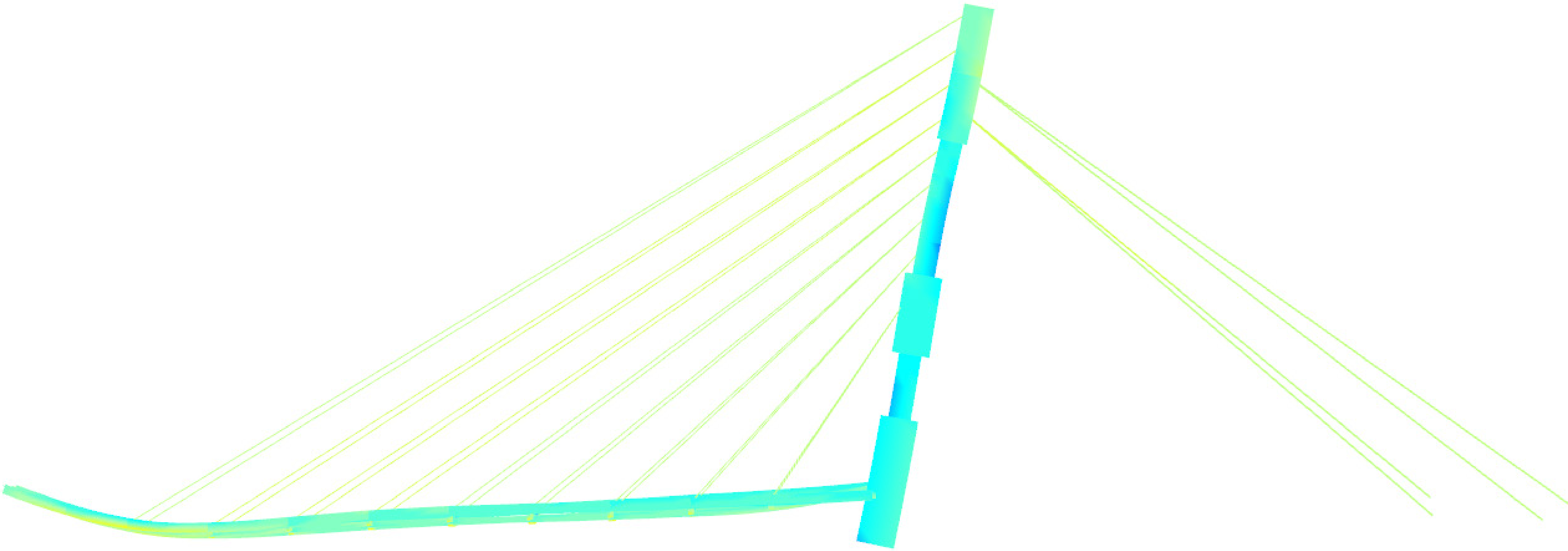




- Adjustment of section

Simulation and Optimisation

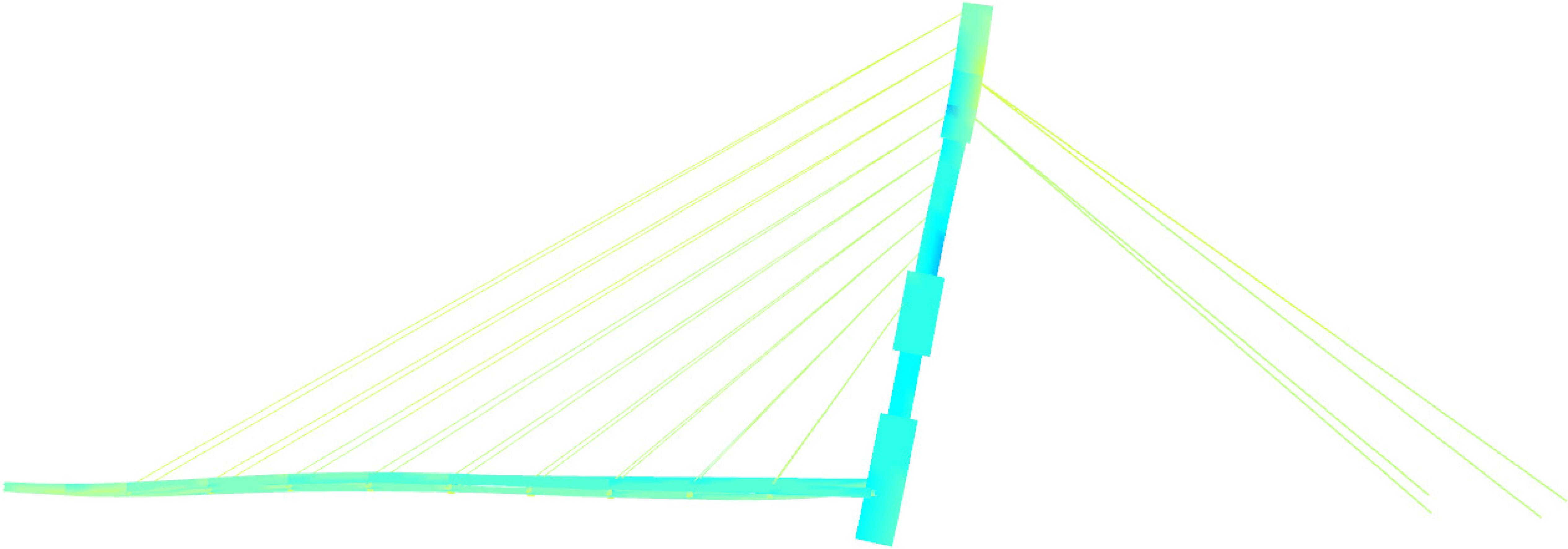
Cables



- Dead load deformation

Simulation and Optimisation

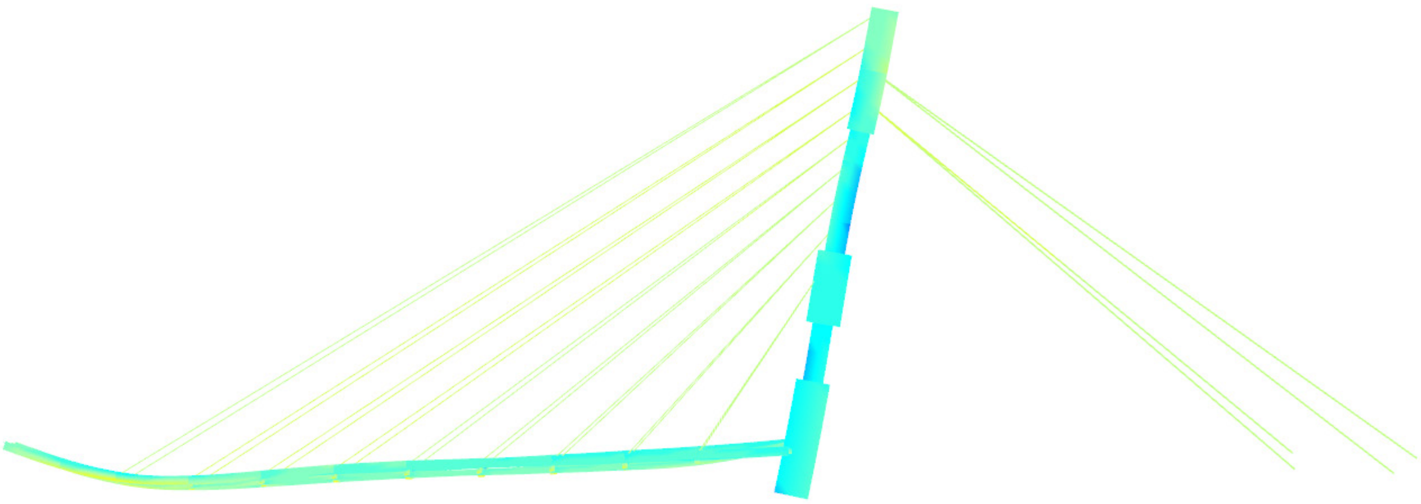
Cables

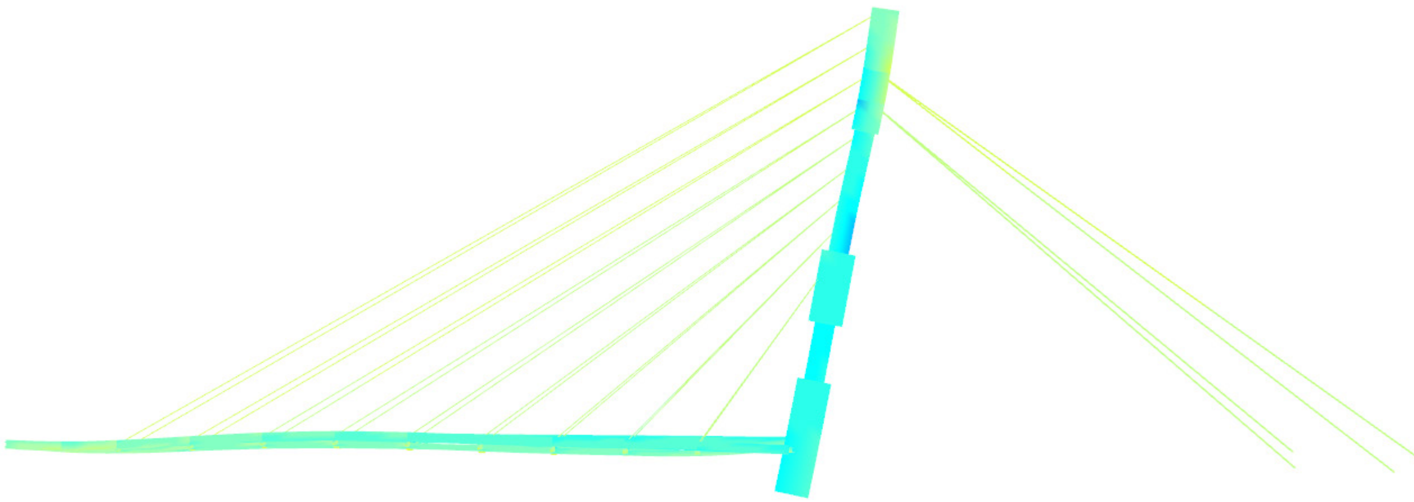


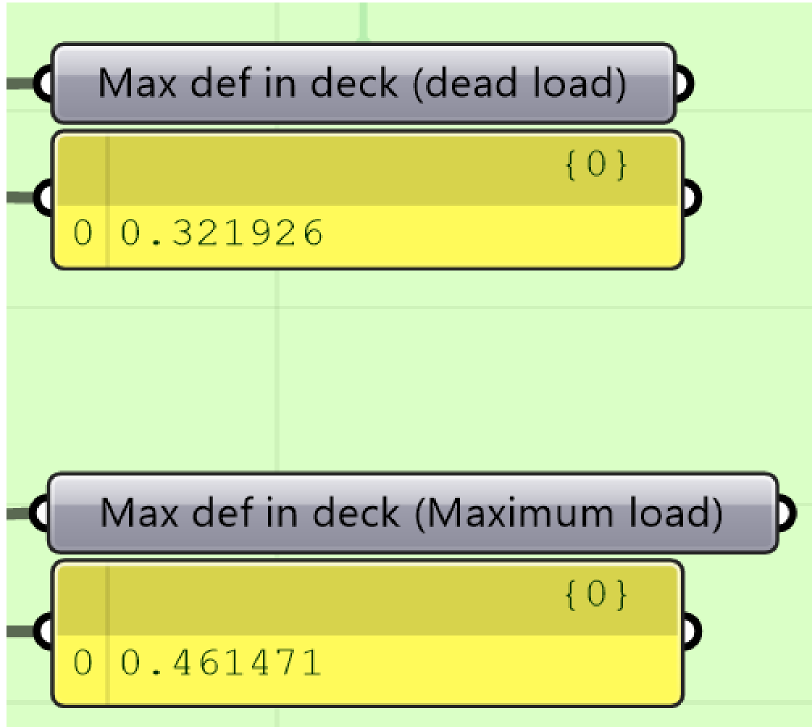
- Dead load deformation after tensioning cables

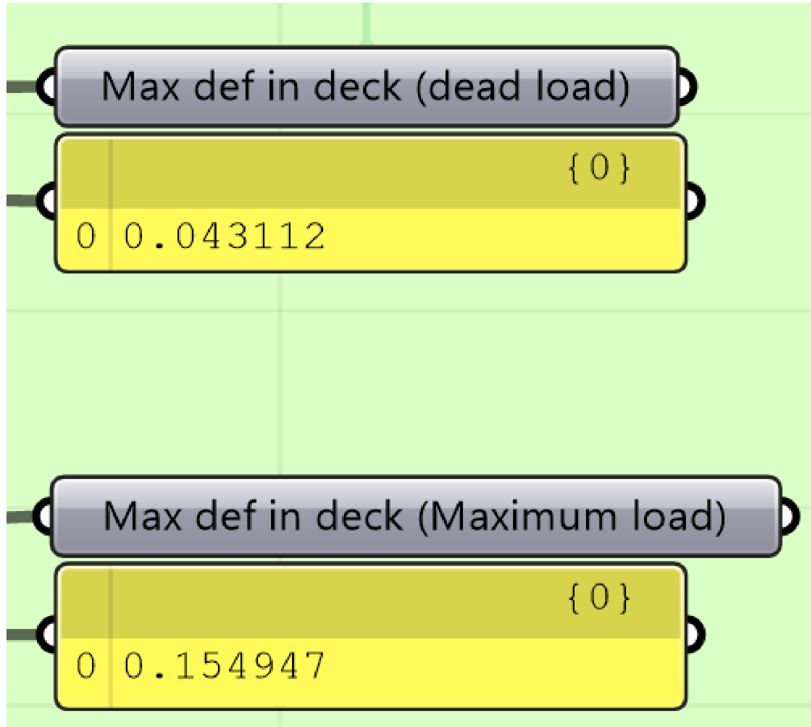
Simulation and Optimisation

Cables





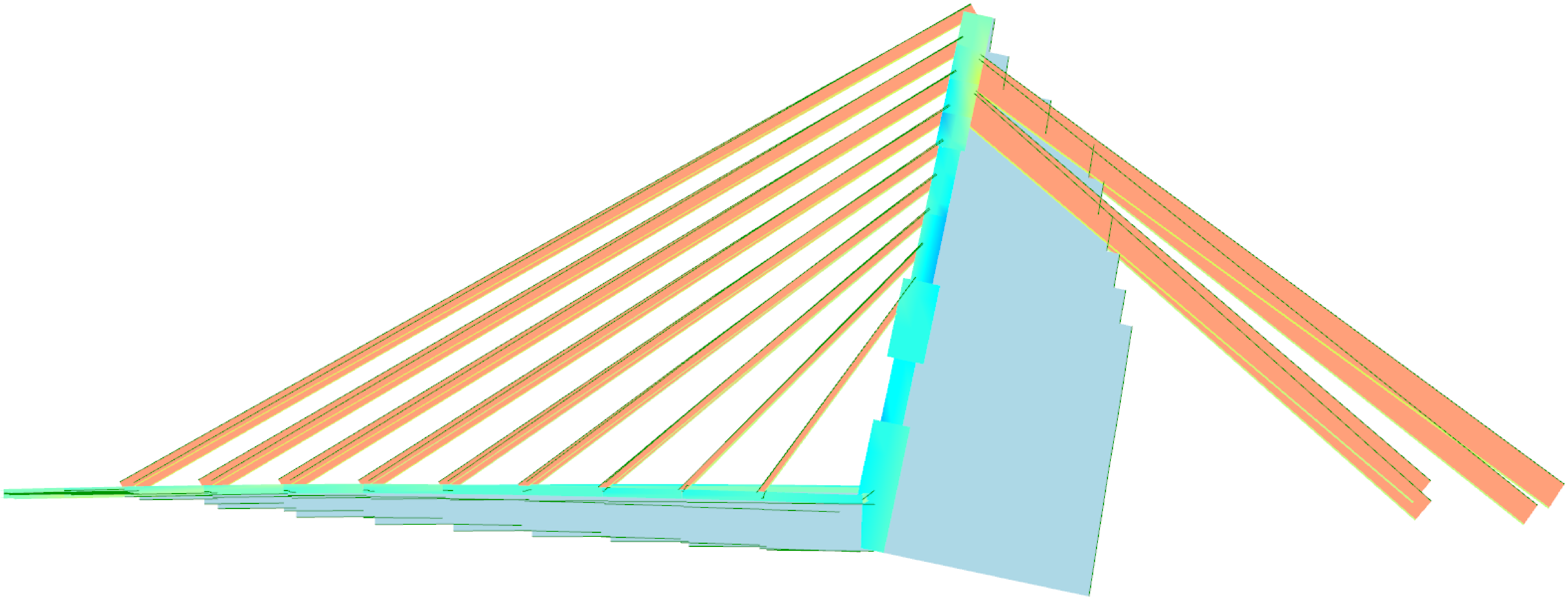




- Deformation before and after tensioning cables

Simulation and Optimisation

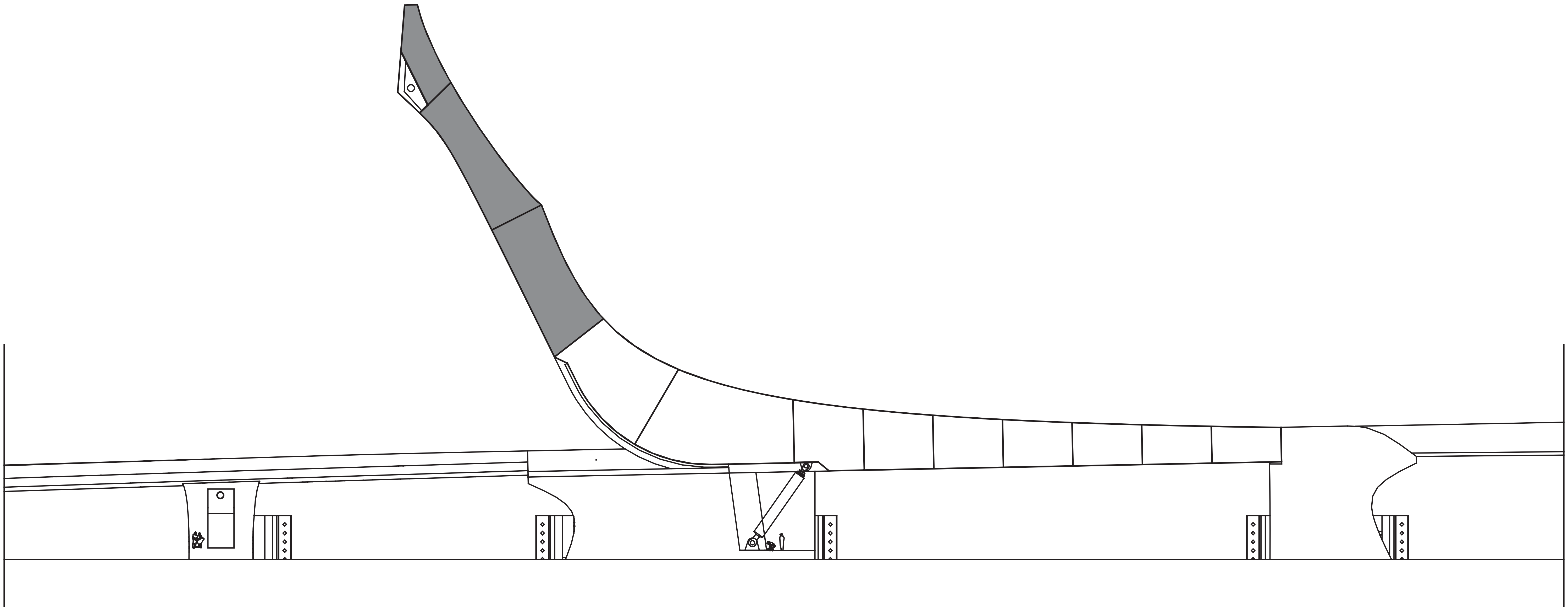
Cables



- Normal forces in system (Blue=Compression, Red=Tension)

Simulation and Optimisation

Movable part



- Counterweight calculation

Final remarks

Final remarks

Conclusion

Rotterdam

- A new connection can improve the development of the area
- The location is very suitable for complementing the mobility plan
- The social cohesion within the city would benefit greatly from a new connection

Parametric design

- Implementing a parametric model in the design process improves comprehension of consequences
- Design changes can easily be made
- Future problems can be avoided

Final remarks

Recommendations

- Material research
- Topology optimisation
- Large span movable bridges

Questions?