CIR höstwebbinarium

Inverkan av nya/kommande krav på hållbarhet och cirkularitet

på konstruktörers och övriga projektörers arbete

Stainless Steel Corrugated Web Girders for Composite Road Bridges

2023-10-23

Fatima Hlal

Industrial PhD student, WSP

Chalmers University of Technology
Department of Architecture and Civil Engineering
Lightweight Structures Research Group

Table of contents

01
Background

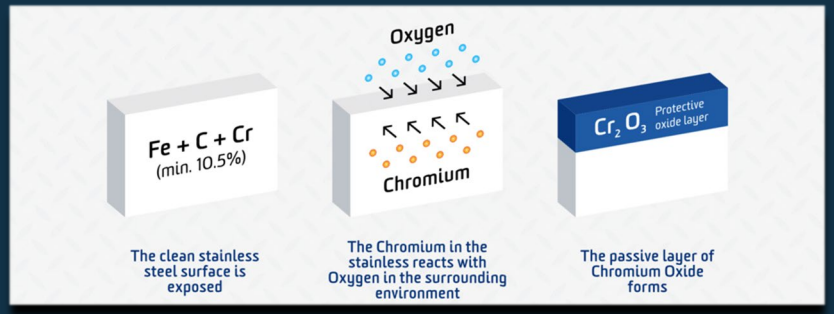
Stainless steel and corrugated web girders

Background

Stainless steel

Pros

Corrosion resistance



Reference: Does Stainless Steel Rust? - Unified Alloys (alliagesunifies.com)

Mechanical properties

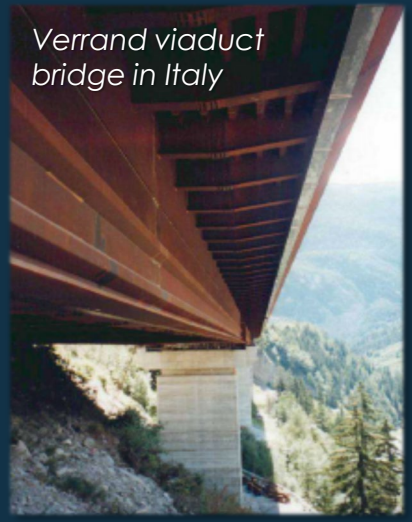
	Yield strength [MPa]	Tensile Strength [MPa]	Strength to weight ratio [kNm/kg]
Carbon steel (S355)	355	490	62.4
Duplex (EN 1.4462)	460	640	82.1
Duplex (EN 1.4162)	450	650	83.3

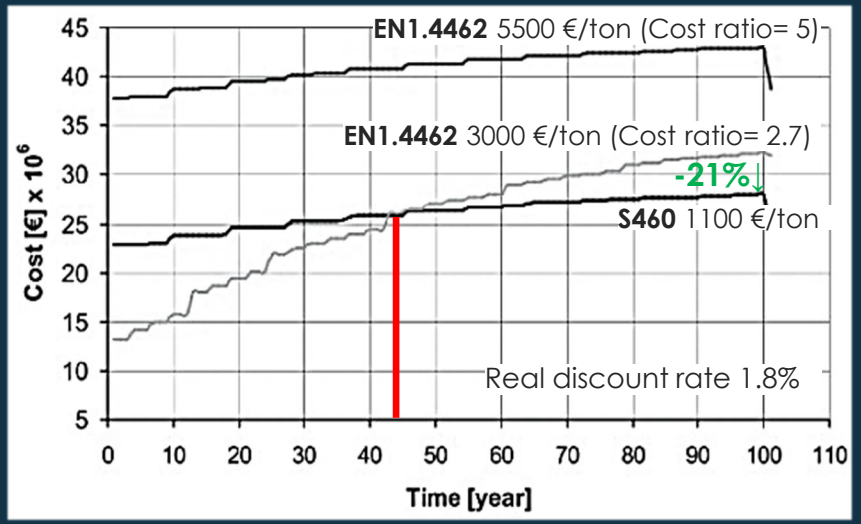
Cons

High material price

≈ 3 times carbon steel price

Background
Stainless steel for bridge construction



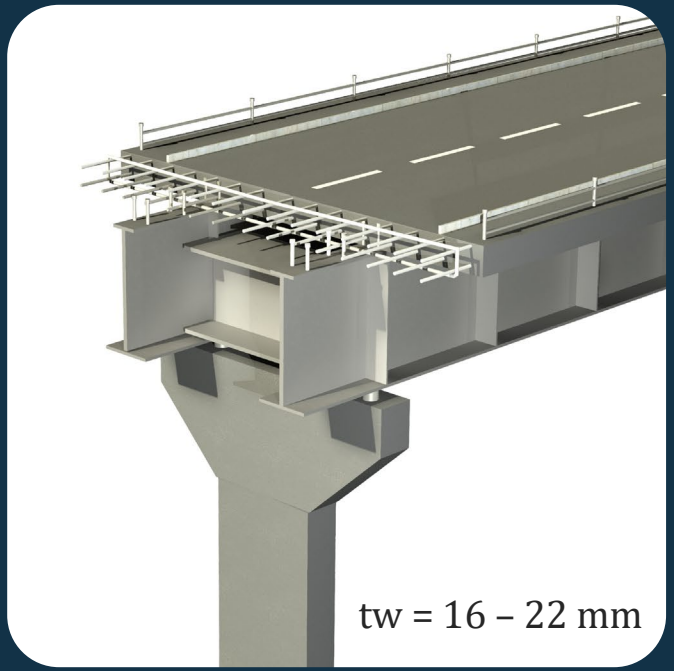


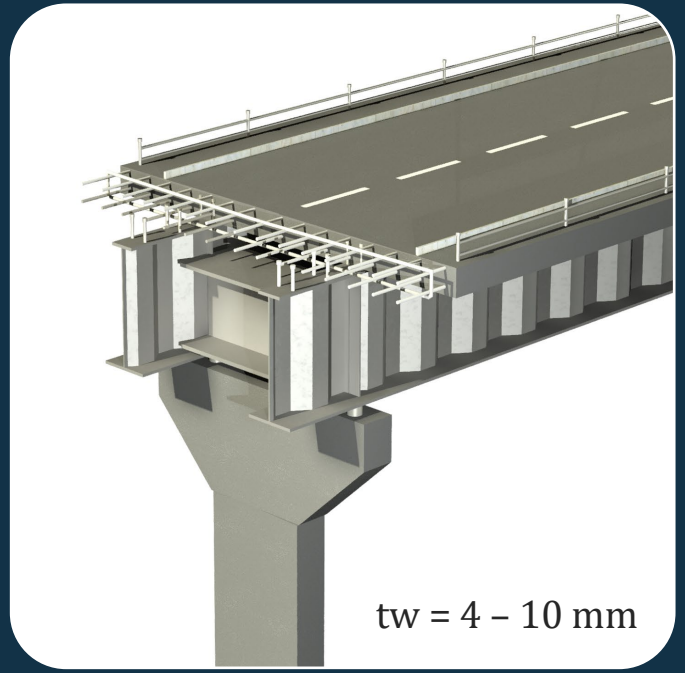
Good life cycle performance but high investment cost

Zilli, G., F. Fattorini, and E. Maiorana. (2008) Application of duplex stainless steel for welded bridge construction in aggressive environment; https://www.researchgate.net/publication/265668326. Paper presented at the International Conference Duplex 2007, Grado, Italy

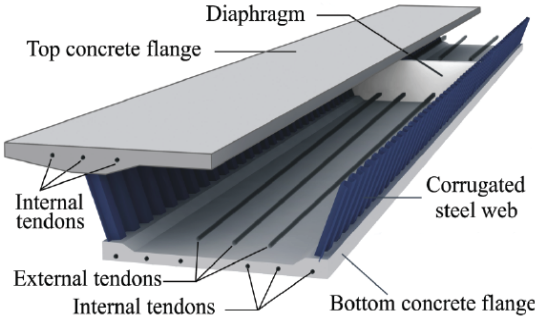
Background

Stainless steel corrugated web girders





Background
Corrugated web



Box-girder bridge, Pont en poutre-caisson, France

Girder bridge, Demonstration bridge in Bradford County, PA, USA

02
Aim of the study

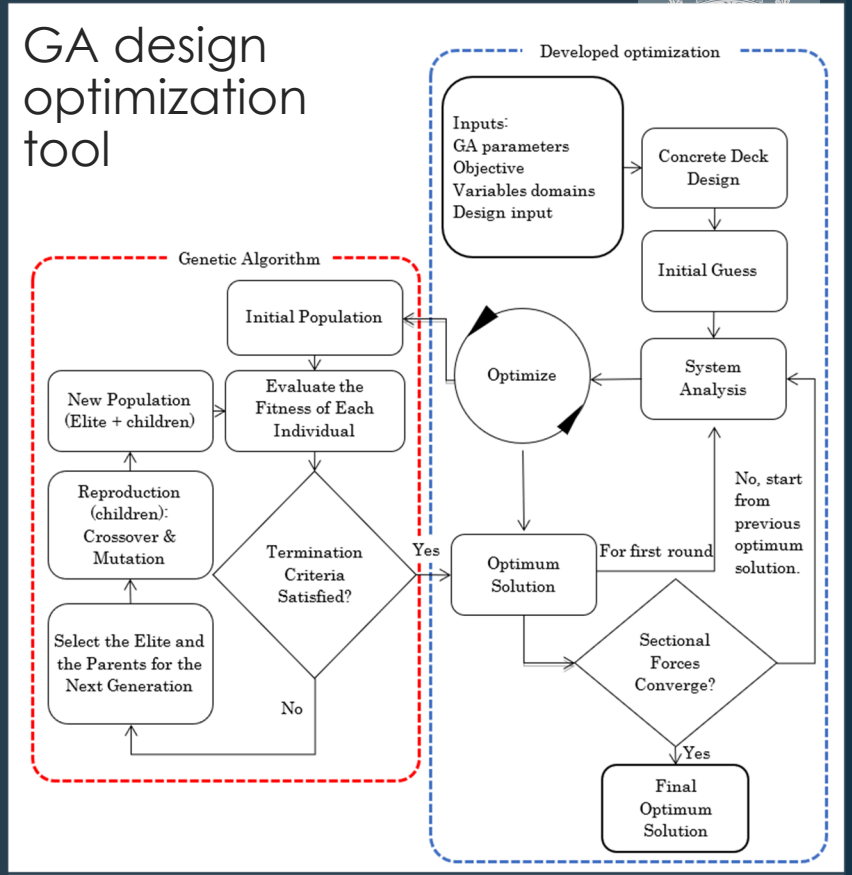
Aim of the study

- *Evaluate the new concept:*

  How will the new concept compare to the conventional one in terms of weight/investment cost/LCC/LCA?

03 Methodology

GA design optimization tool



Methodology
GA design optimization tool

Changing materials only is not enough

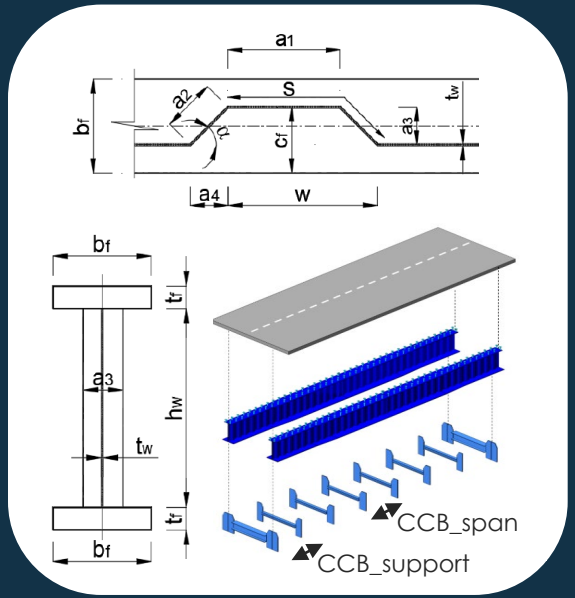
↓

Comparison of optimal design solutions

↓

GA design optimization tool

Optimization variables

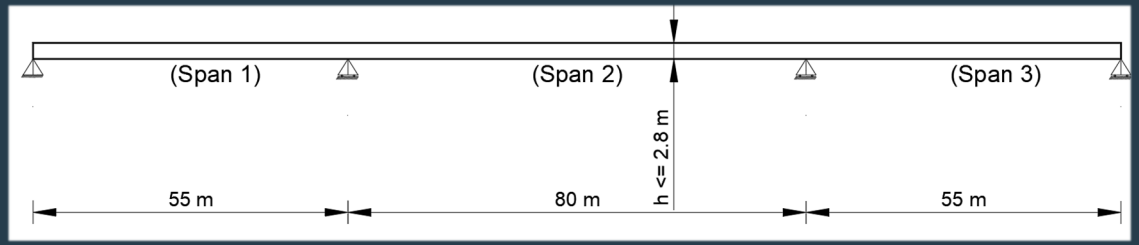


Optimization objectives

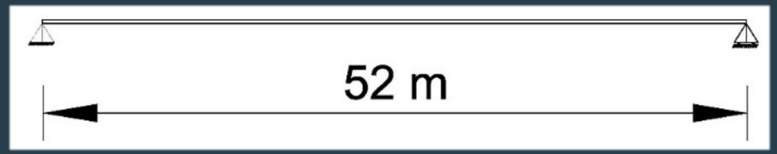
- Weight
- Investment cost
- LCC
- LCA

Methodology
GA design optimization tool

Case study:



Parametric study:



04
Case Study

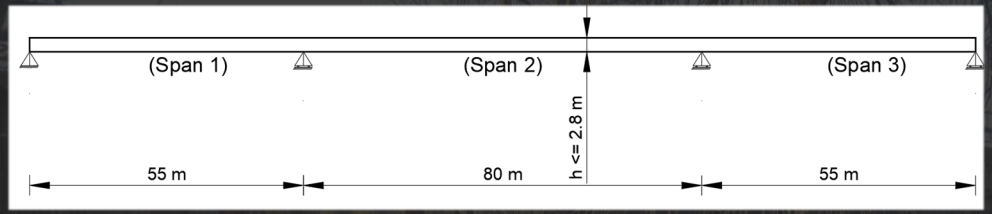
Kyrko bridge – Avesta, Sweden

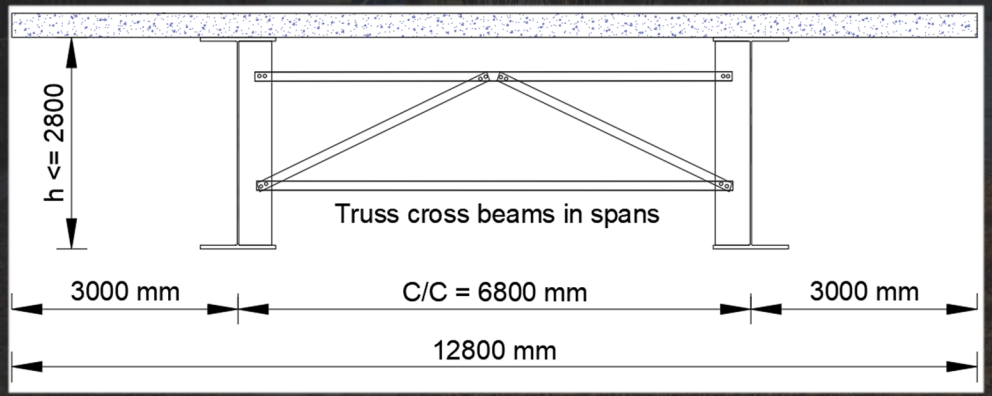
- Bridge length is 214 m
- The bridge needs to be replaced

Requirements:

- Replace the existing bridge
- ADT = 11 000 Vehicle/day
- $h_{max} = 2.8\ m$
- Design lifespan = 120 years

Investigated solution





1

Flat S355

2

Flat EN1.4162

3

Corrugated EN1.4162

Case study
Input data

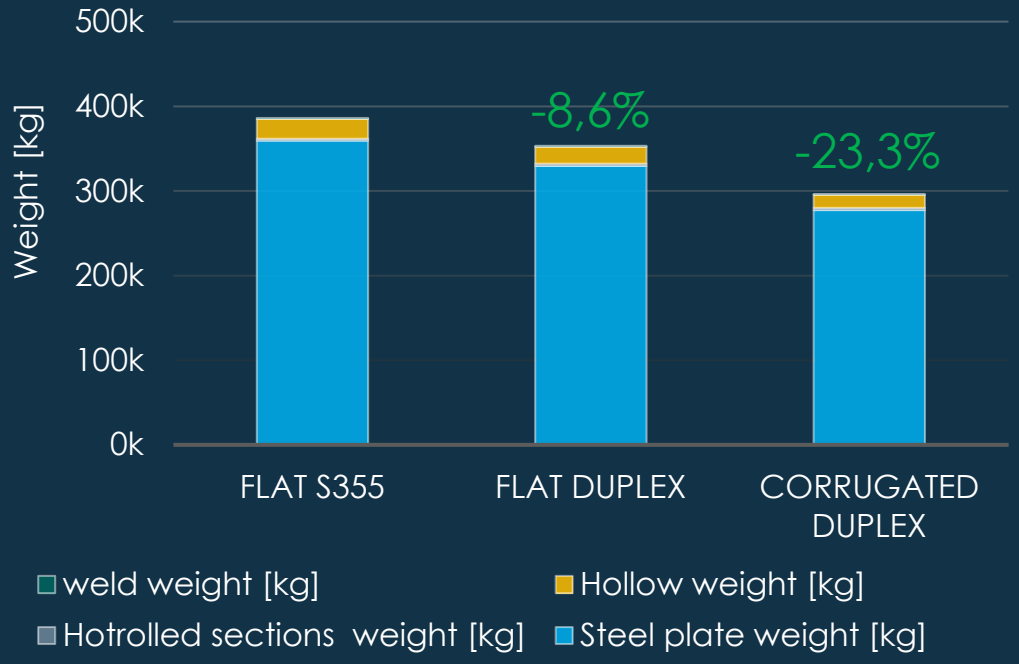
- Paint maintenance schedule:

Painting plan for the structural steelwork of a bridge in the environmental category C4 for 120 years (Trafikverket)

Activity	System age	Reference unit	Unit	Relative
Patch up	20 years	Initial painted surface	m^2	10%
Overcoating	40 years	Initial painted surface	m^2	20%
Remove & replace	60 years	Initial painted surface	m^2	100%
Patch up	80 years	Initial painted surface	m^2	10%
Overcoating	100 years	Initial painted surface	m^2	30%

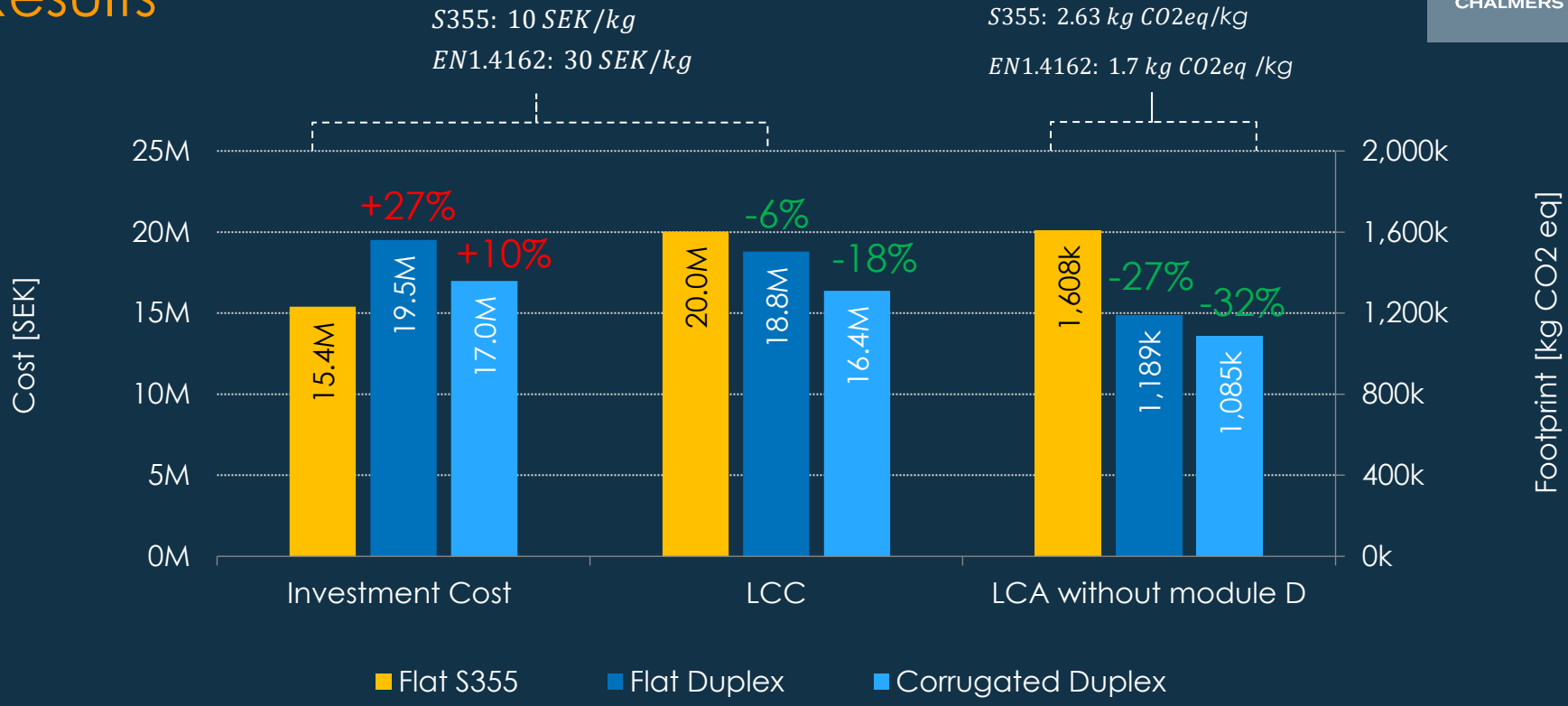
- Time required for each activity → Patch up: 2 days, Overcoating: 5 days, Repainting: 5 days
- Inflation and discount rates → i = 1.5%, d=3.5%
- Environmental impact → two manufacturers in Sweden

Case study
Results



- *Optimization objective: weight*
- *Saving mainly from the web*
- *tw: from 4 to 10 mm, as opposed to the 14 to 25 mm*

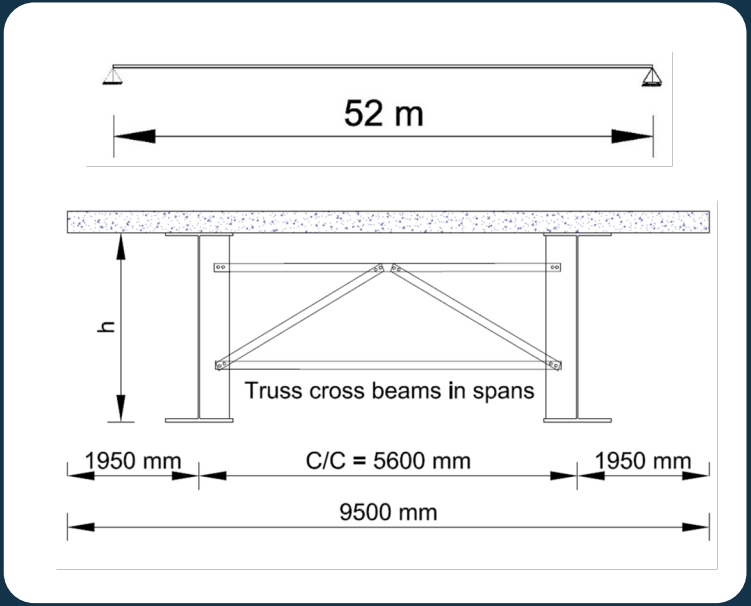
Case study
Results



05
Parametric study

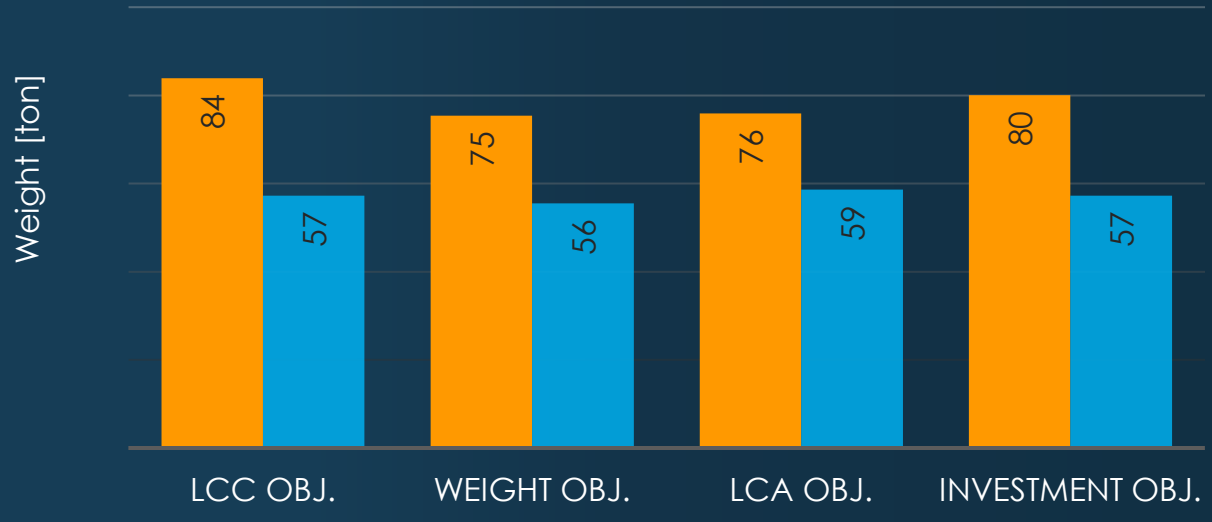
Parametric study
Studied parameters

- Optimization objective
- Paint maintenance schedule
- Inflation and discount rates
- ADT&N_{obs}
- Height limitations
- Span length



Parametric study

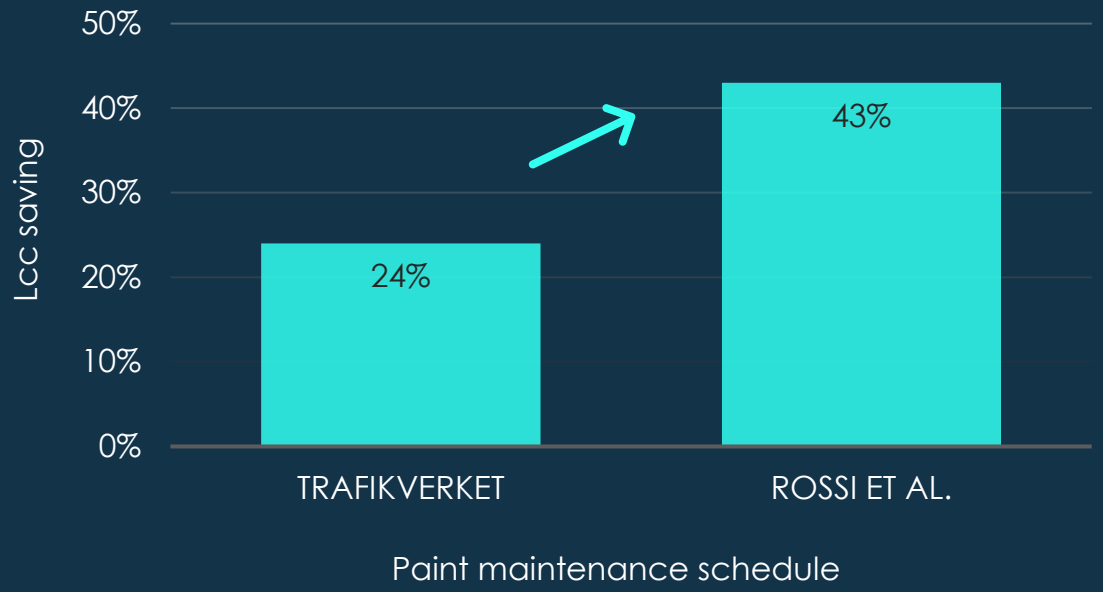
Results: Parameter 1 – Optimization Objective



The optimization behaves differently

Parametric study

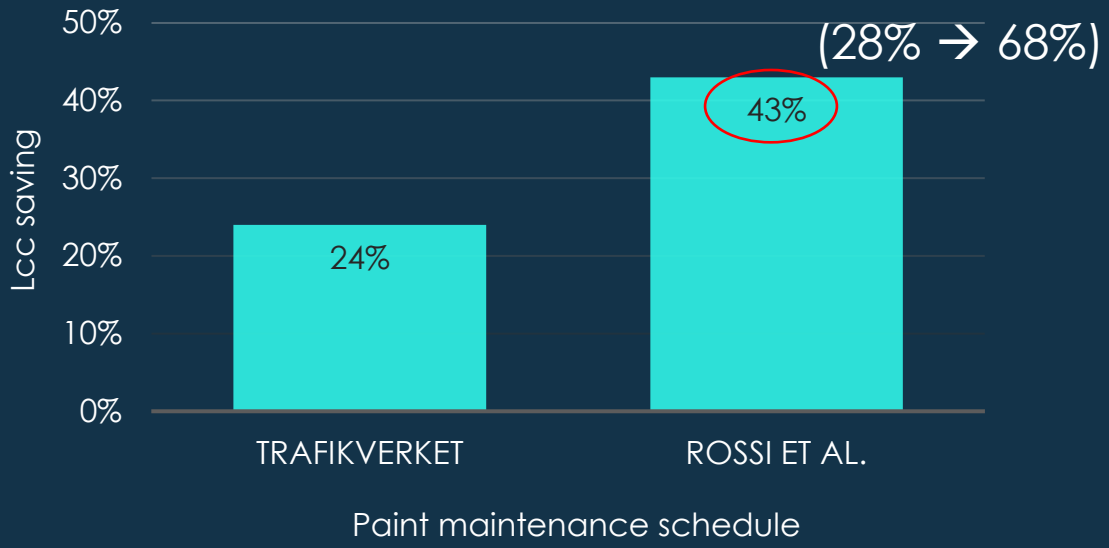
Results: Parameter 2 – Paint maintenance schedule



The saving becomes more significant with a more extensive paint maintenance schedule.

Parametric study

Results: Parameter 3 – Discount and inflation rates

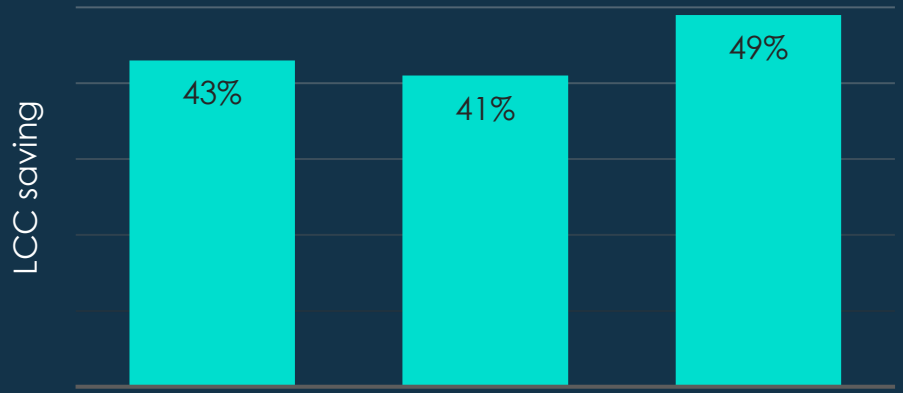


d= 2% → 5%
i= 0% → 3%

Irrespective of the assumed values, the new concept is still competitive

Parametric study

Results: Parameter 4 – ADT&N_{obs}

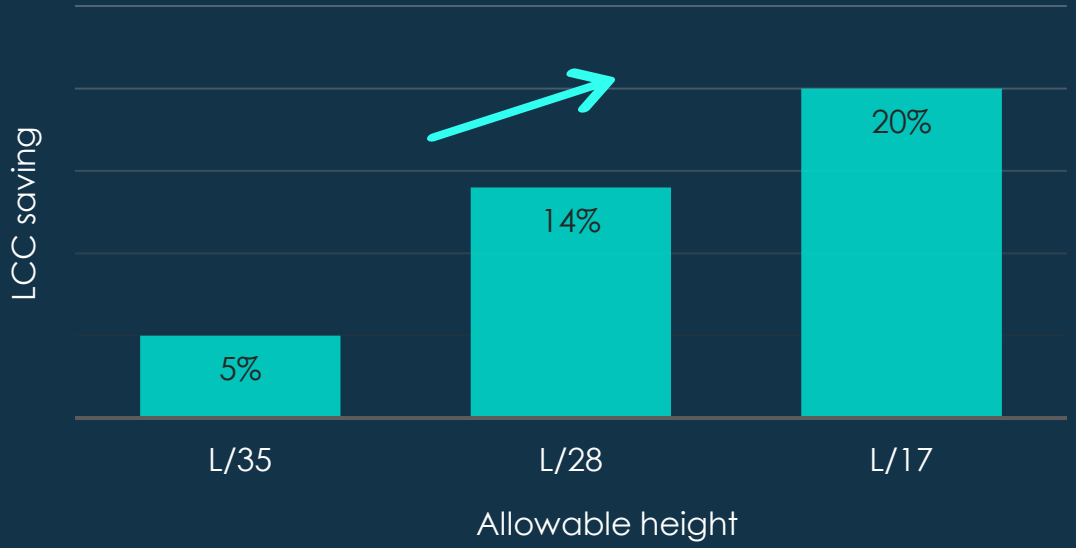


ADT*Nobs	200*50,000	11,000*500,000	50,000*500,000
Governing limit state →	ULS	FLS	FLS
User cost [KSEK] →	4.7	259	1 172

Irrespective of the what limit State governs the design and irrespective of ADT&Nobs a considirable saving by the new concept can be achieved.

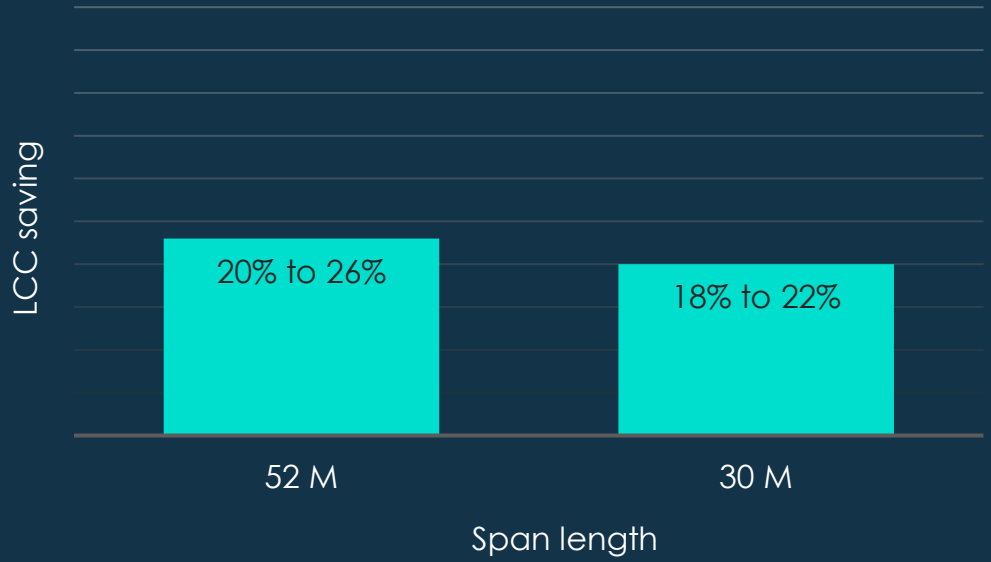
Parametric study

Results: Parameter 5 – Height limitations



Saving increases for deeper girders

Parametric study
Results: Parameter 6 – Span length



The results are consistent for short and long spans

06
Conclusions

Conclusions

- Saving in weight, LCC, and LCA

Conclusions

- Saving in weight, LCC, and LCA
- Slightly higher investment cost

Conclusions

- Saving in weight, LCC, and LCA
- Slightly higher investment cost
- Deeper girders

Conclusions

- Saving in weight, LCC, and LCA
- Slightly higher investment cost
- Deeper girders
- More intense maintenance activities, higher ADT

Conclusions

- Saving in weight, LCC, and LCA
- Slightly higher investment cost
- Deeper girders
- More intense maintenance activities, higher ADT
- The saving from using the new concept is coming from:
  - Material: web, flanges
  - Production costs: painting, grinding , cutting, welding
  - Maintenance: painting, traffic disturbance cost

Sustainable Maintenance-free Bridges

BBT Project No. TRV 537 2020/117504

Thank you!

Fatima Hlal
Industrial PhD Student

Chalmers University of Technology
Department of Architecture and Civil Engineering
Lightweight Structures Research Group

CHALMERS
UNIVERSITY OF TECHNOLOGY