FALCON
A multidisciplinary effort towards future lightweight infrastructure using FRP

Reza Haghani (Alann Andre, Abbas Khayyami, Erik Olsson)

Docent, Chalmers University of Technology

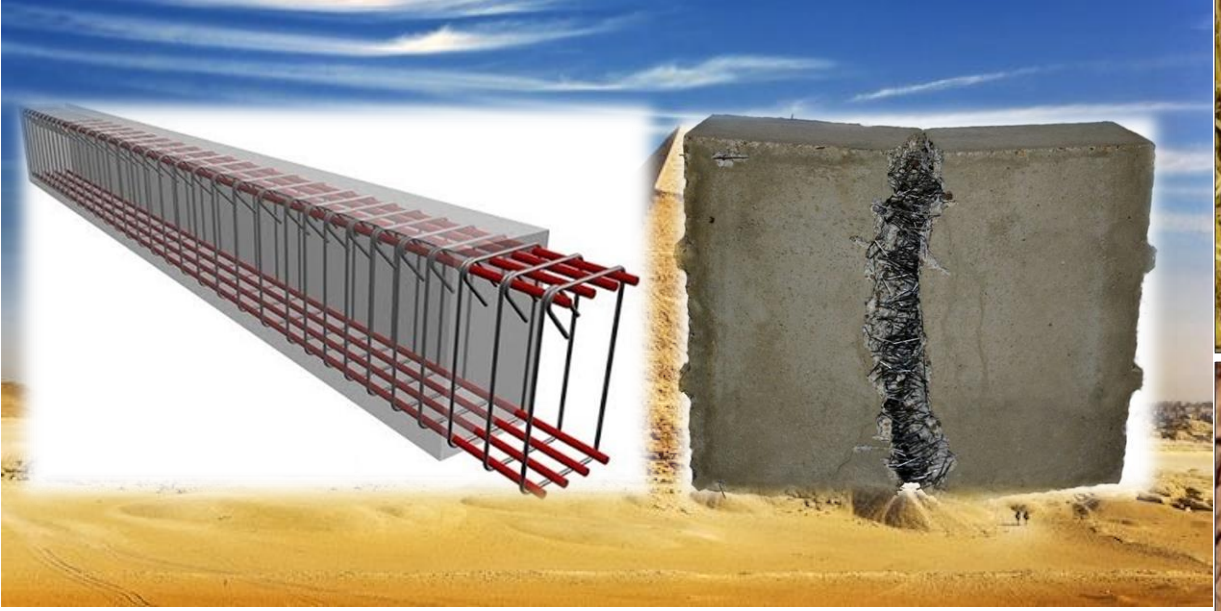
CONTENT

Composite materials in construction

FRP-bridges – examples

Onging in Sweden

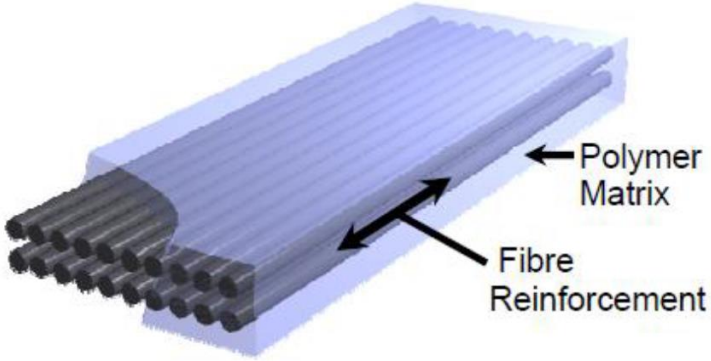
Concluding remarks

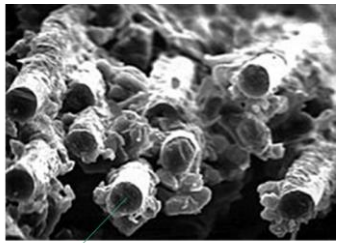


HISTORY OF COMPOSITE MATERIALS

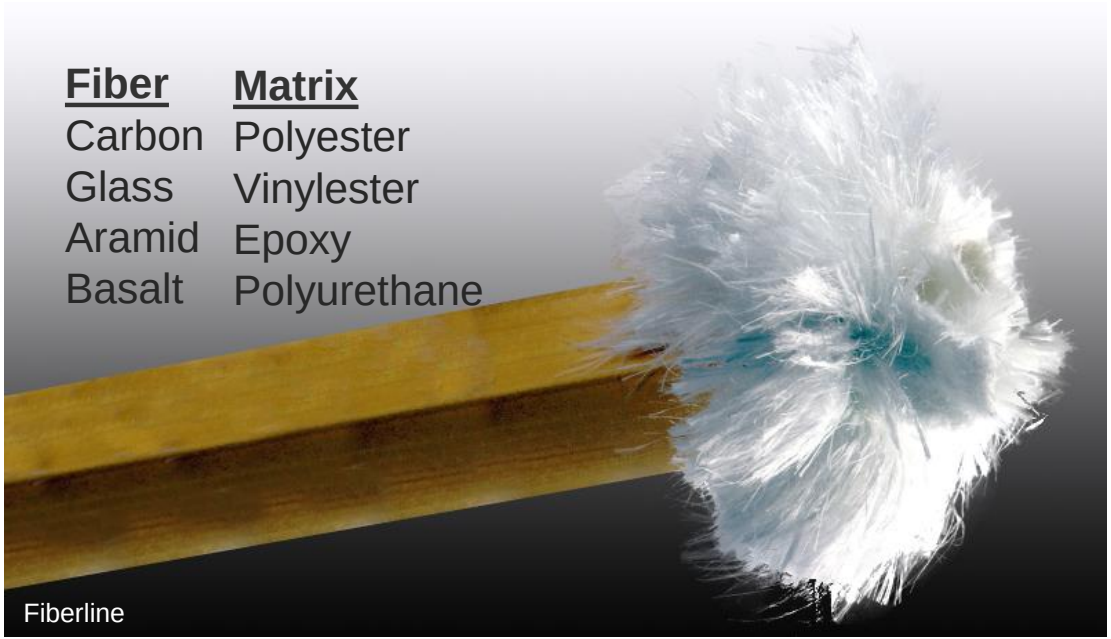
Khiva wall, 2500 years old (Uzbakistan)

FIBER REINFORCED POLYMER (FRP)





Fiber	Matrix
Carbon	Polyester
Glass	Vinylester
Aramid	Epoxy
Basalt	Polyurethane



MODERN FRP COMPOSITES

- LIGHT
  - DURABLE
    - STRONG
      - VERSATILE


1960s


1940s


1940s

FIELDS OF APPLICATIONS

FRP IN CONSTRUCTION

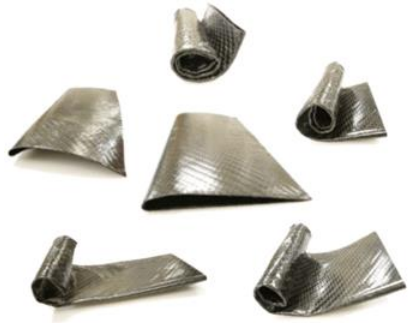
“ THE MONSANTO HOUSE OF FUTURE” 1957-1967

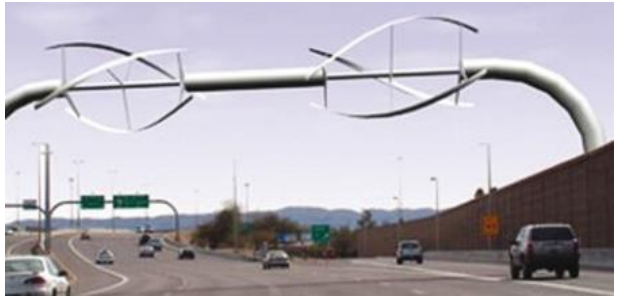
APPLICATIONS IN CONSTRUCTION

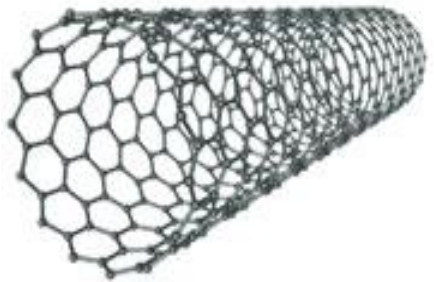




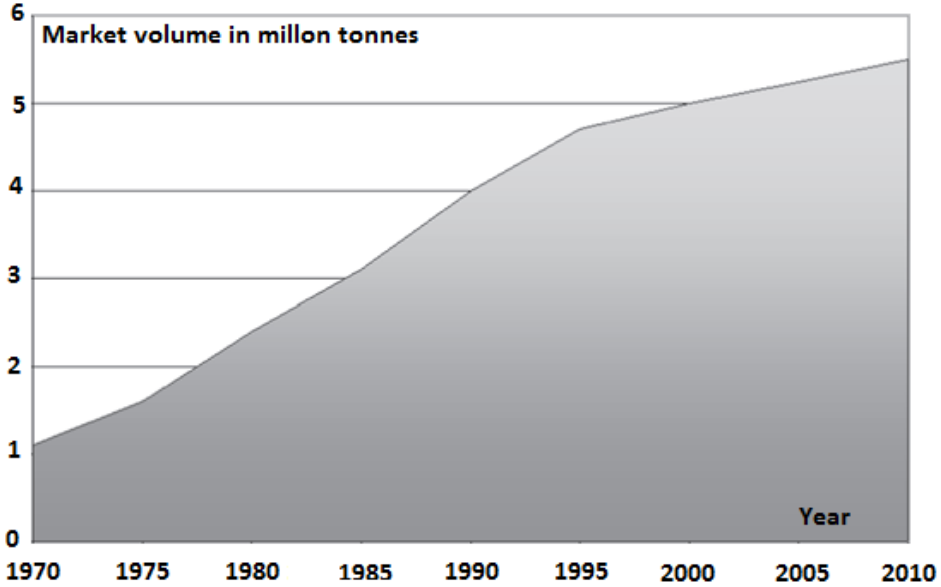

APPLICATIONS IN CONSTRUCTION

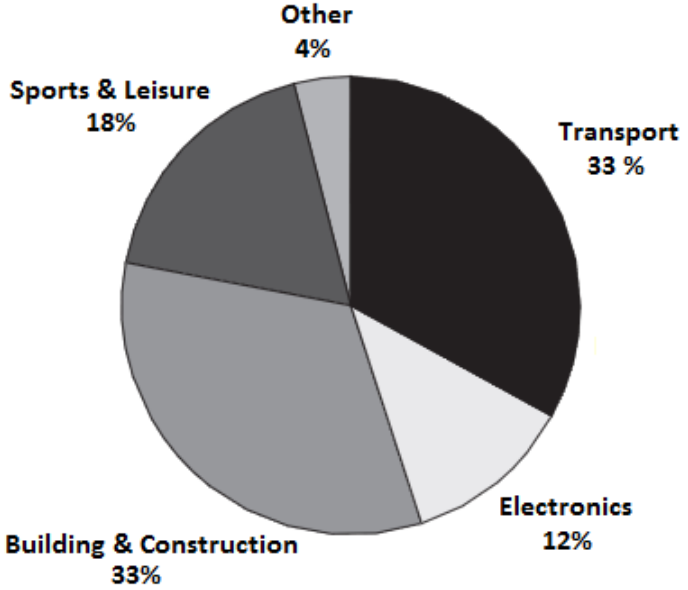






FRP MARKET

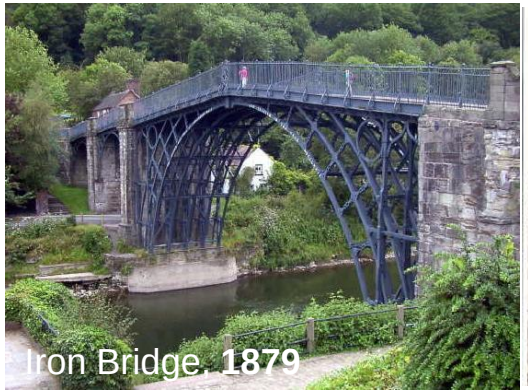

Market volume in millon tonnes
Year
0
1
2
3
4
5
6
1970
1975
1980
1985
1990
1995
2000
2005
2010

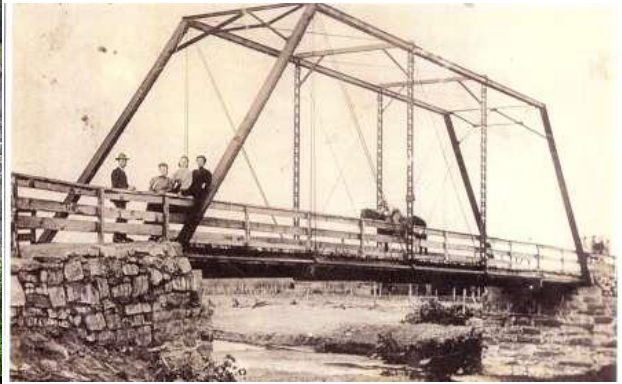

Other
4%
Sports & Leisure
18%
Transport
33 %
Electronics
12%
Building & Construction
33%

APPLICATION OF FRPS IN BRIDGE INFRASTRUCTURE

Vs.

Photo from Knippers et al.


Iron Bridge, **1879**



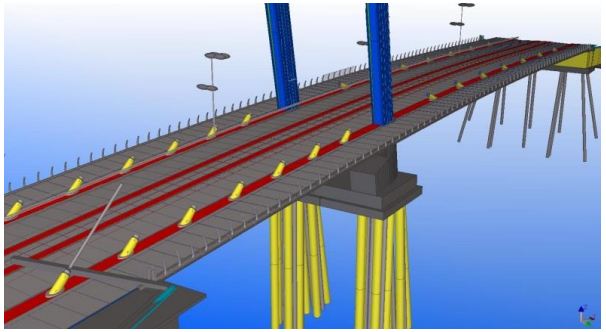

Årstabron


Firth of Fourth

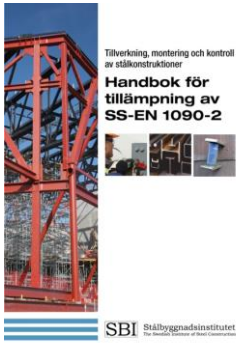

Sutong Bridge, **2003**


*The Infinity Bridge, **2009***

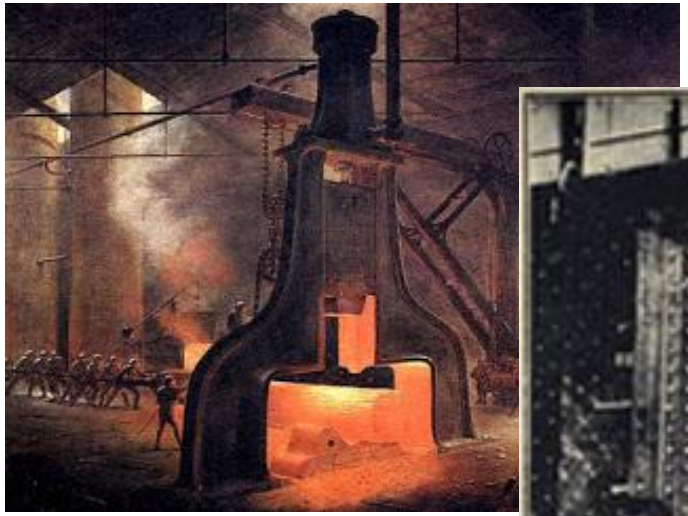
Increased knowledge and better calculation



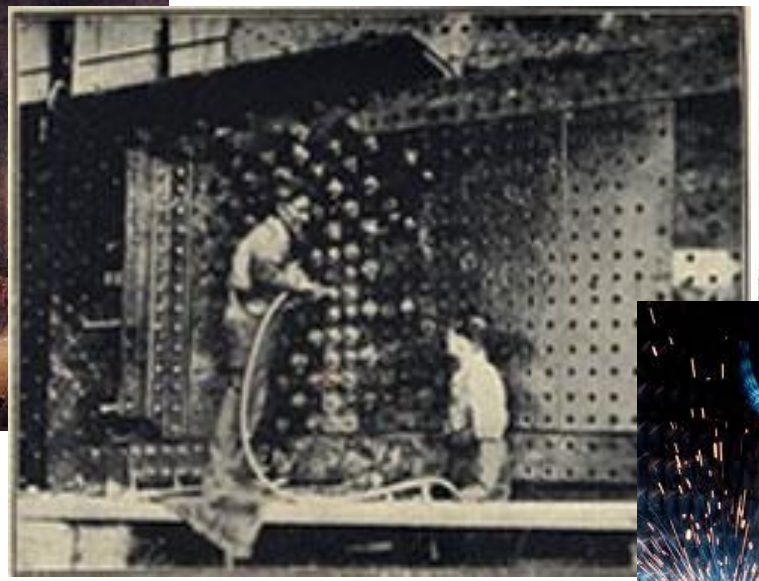
Development of standards



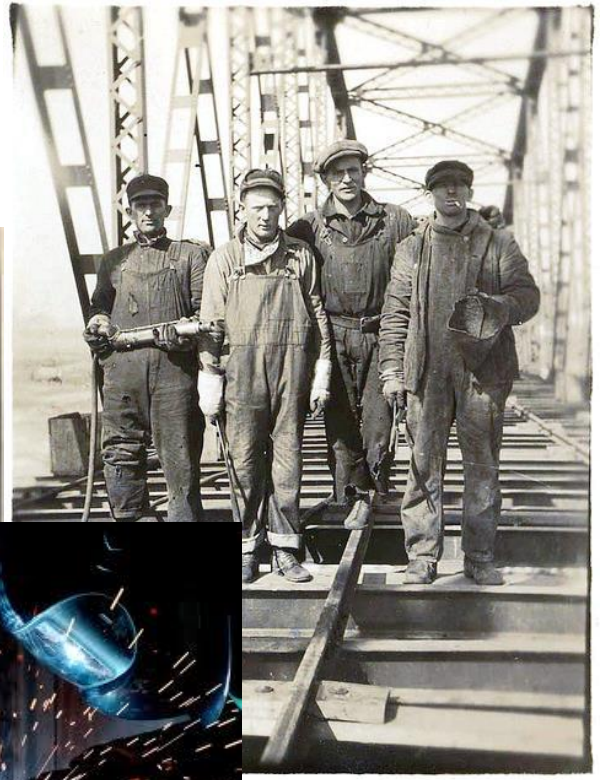
Connection methods



Smithery



Riveting



Welding

NEW MEASURES

Life cycle aspects

Energy efficiency

Sociala values

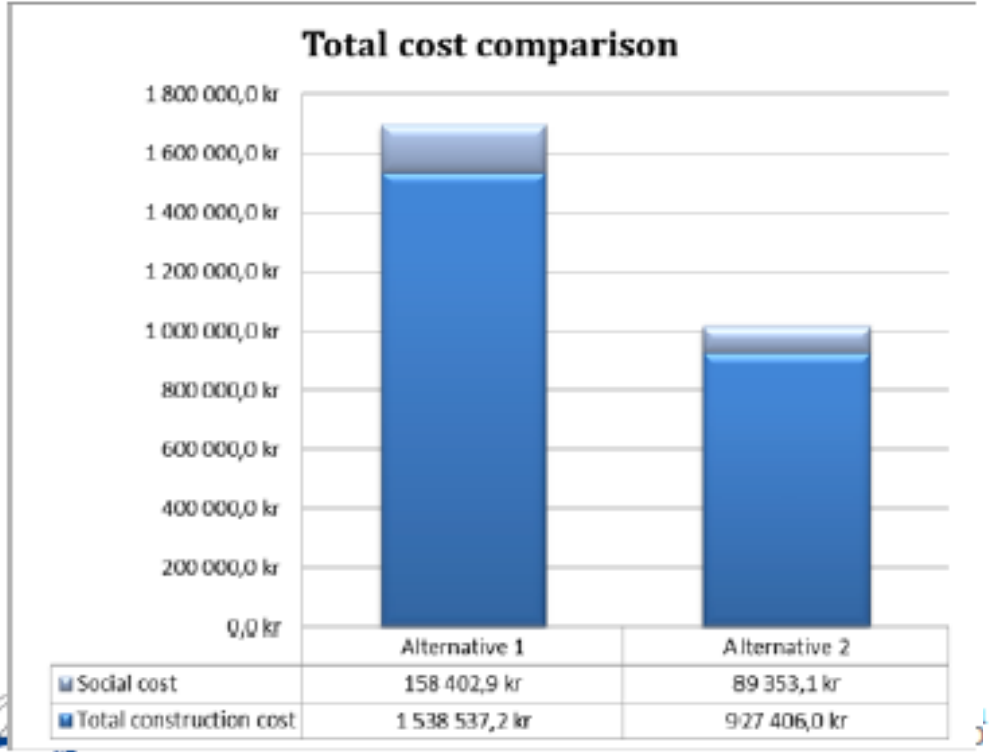
We cannot solve our problems with the same thinking we used when we created them

Albert Einstein

WHY FRPS ARE ATTRACTIVE IN INFRASTRUCTURE?

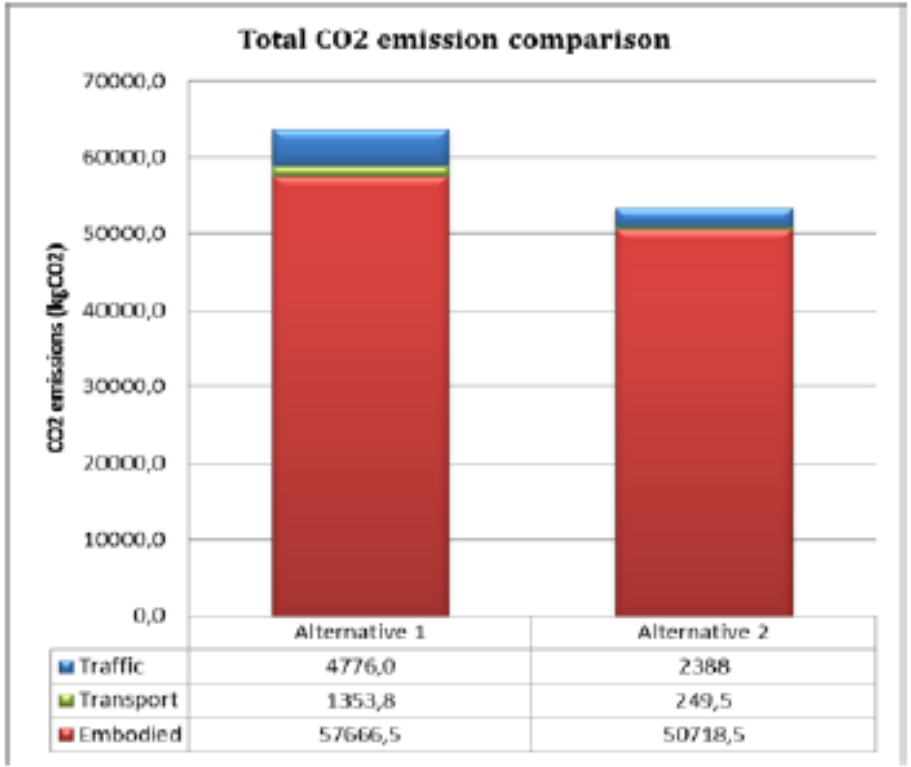
- Lightweight (easy to handle)
- Strong
- Industrialized manufacturing (i.e. quality control)
- Prefabrication
- Durability (i.e. non-corroding) → low maintenance
- Lower embodied energy and environmental impact (material and transportation)
- Workers' safety (lightweight)
- More expensive
- Complex design

Life Cycle Cost analysis

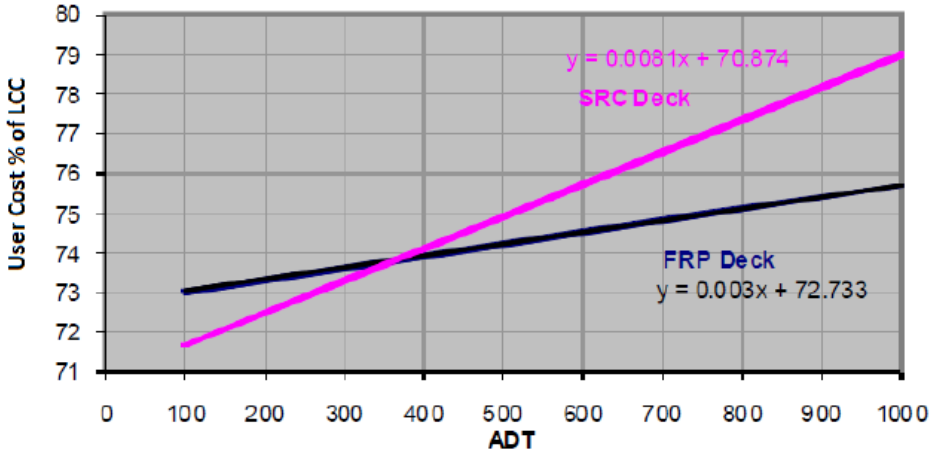


	Alternative 1	Alternative 2
Social cost	158 402,9 kr	89 353,1 kr
Total construction cost	1 538 537,2 kr	927 406,0 kr

Life Cycle Assessment



	Alternative 1	Alternative 2
Traffic	4776,0	2388
Transport	1353,8	249,5
Embodied	57666,5	50718,5



USER COSTS

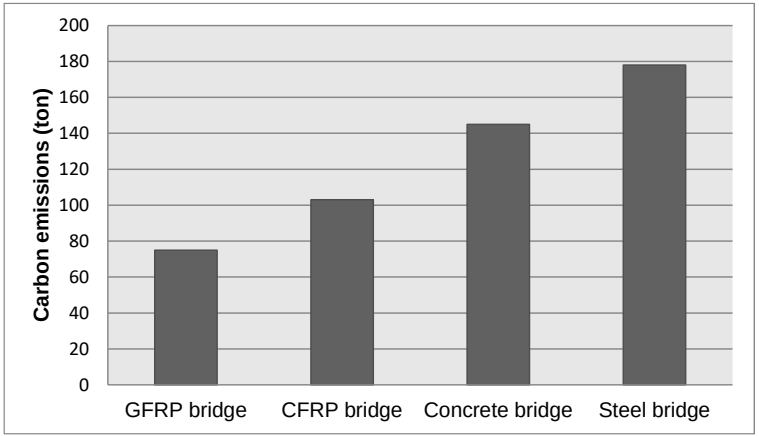
Can greatly influence the project's economy

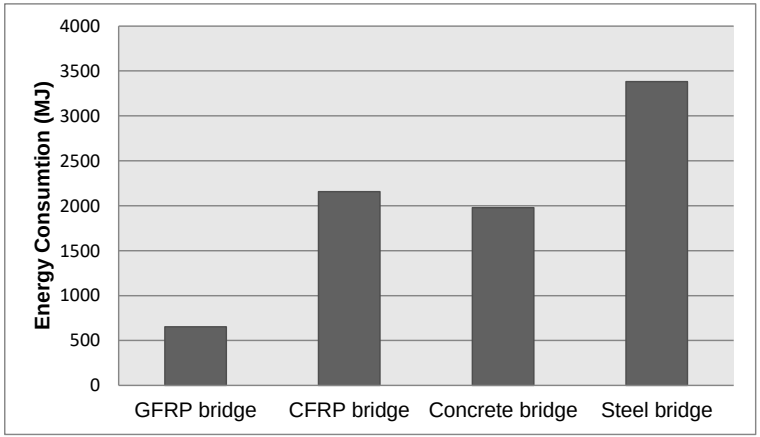
LCA – ROAD BRIDGE IN DENMARK

For a 12 m long road bridge

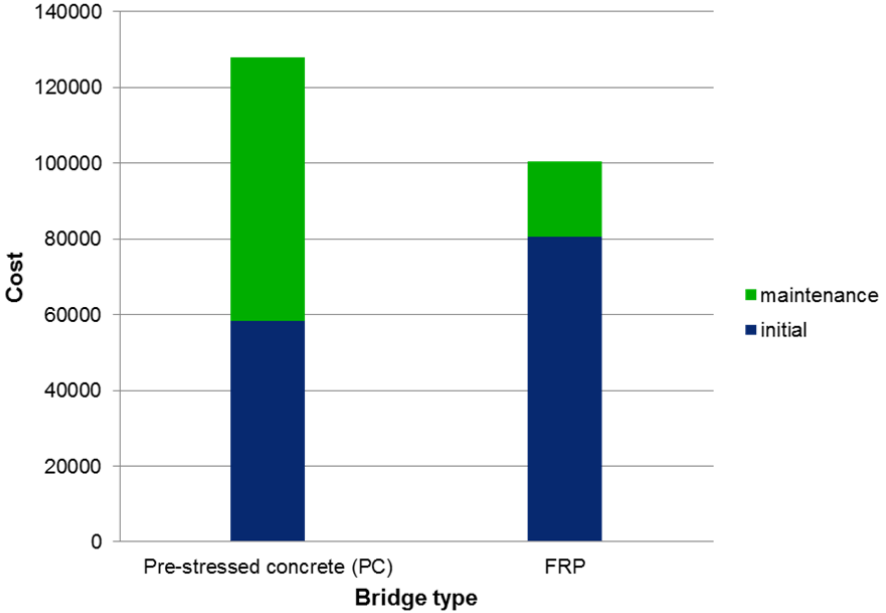
Four different bridge concepts

Service life: 100 years



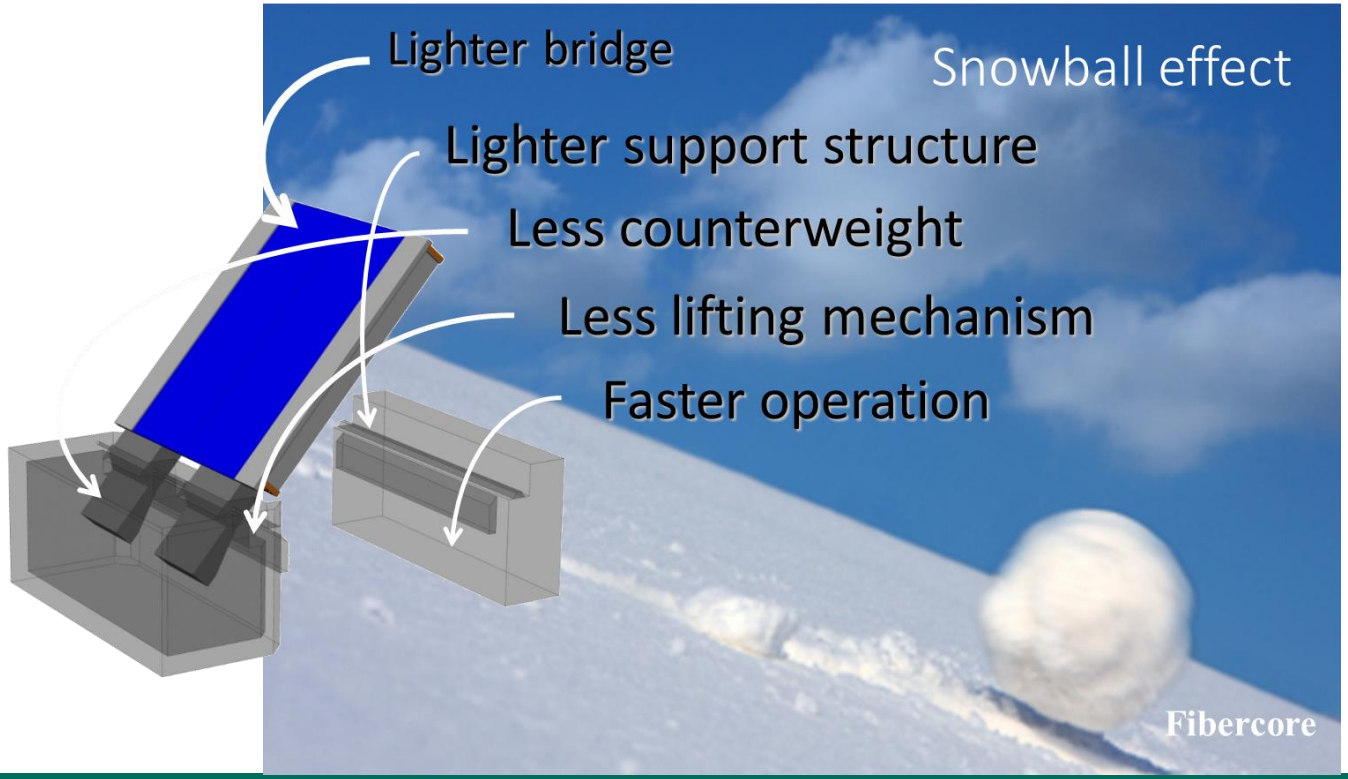


MAINTENANCE COSTS



Footbridge- Okinawa, Japan

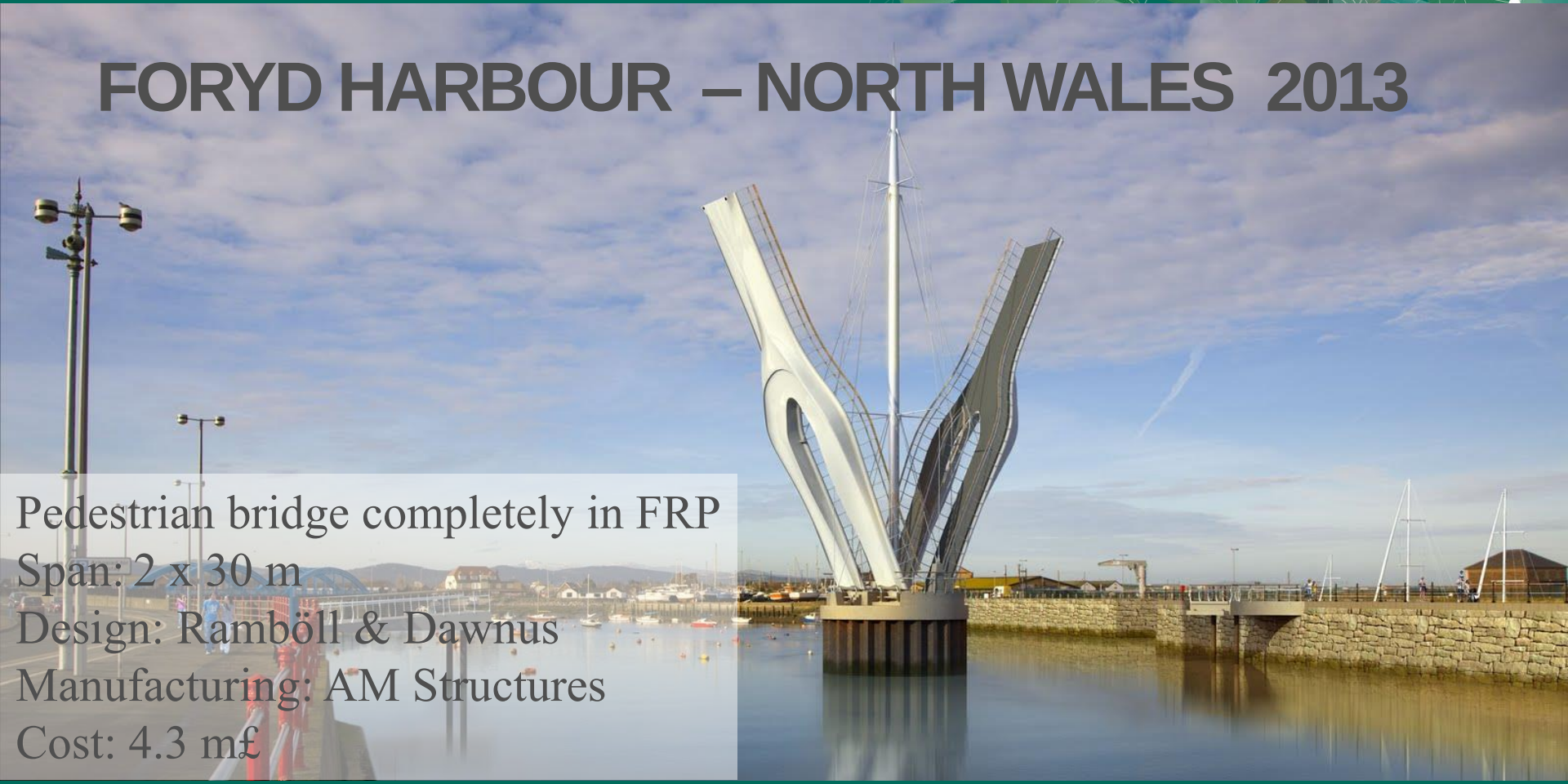
MOVABLE BRIDGES



VESTERELVENS BRO – FREDRIKSSTAD 2003

Span: 2 x 28 m
Bascule eeight: 20 t (FRP 9 t)
Design: Griff kommunikasjon AS
Maufacturing: Marine Composites AS, Arendal

FORYD HARBOUR – NORTH WALES 2013



Pedestrian bridge completely in FRP
Span: 2 x 30 m
Design: Ramböll & Dawnus
Manufacturing: AM Structures
Cost: 4.3 m£

TRAFFIC BRIDGE OOSTERWOLDE, NL

Dimensions: 12,5 x 12,5m
Traffic class: 600 kN
year: 2010

BROADWAY BRIDGE, USA – EXISTING BRIDGE

30,000 veh/day
FRP deck – ZellComp
Bascule length: 42,6 m
width: 14 m

GRASSHOPPER BRIDGE 2011 - DENMARK

FRP däck – Fiberline, DK
Span: 25 m
Width: 5 m
Weight: GFRP-deck 13 t

FRIEDBERG BRIDGE (HYBRID) – FRANKFURT 2008

FRP deck – Fiberline, DK
Span: 27 m
Width: 5 m
Weight: 60 t
Design: Knippers Helbig AE

ASTURIAS BRIDGE, SPAIN 2004

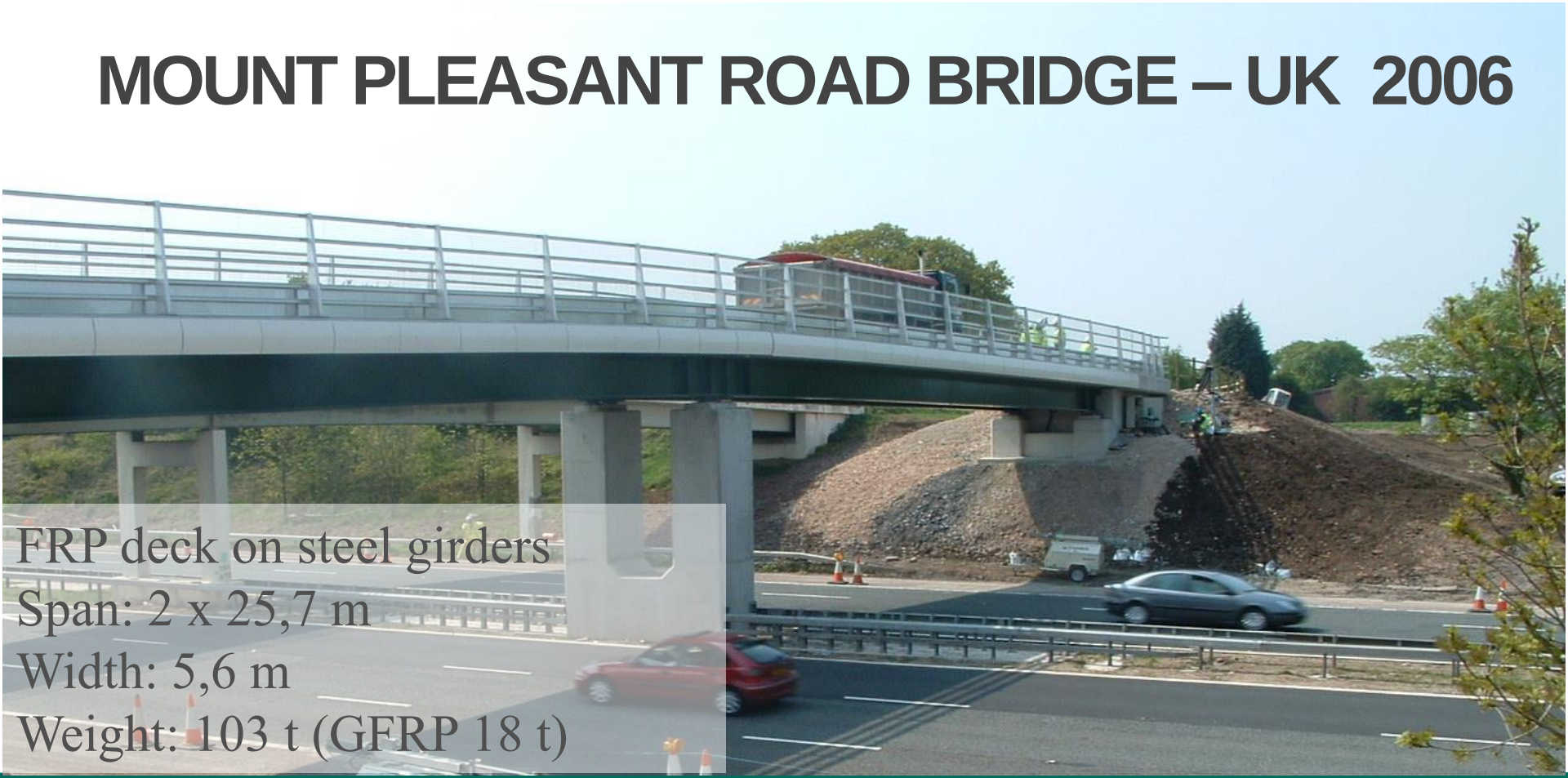
Span: 10 + 13 + 13 + 10 m
Width: 5.6 m
Weight: 4.6 t / girder
Design & Production: ACCIONA

ASTURIAS BRIDGE, SPAIN 2004

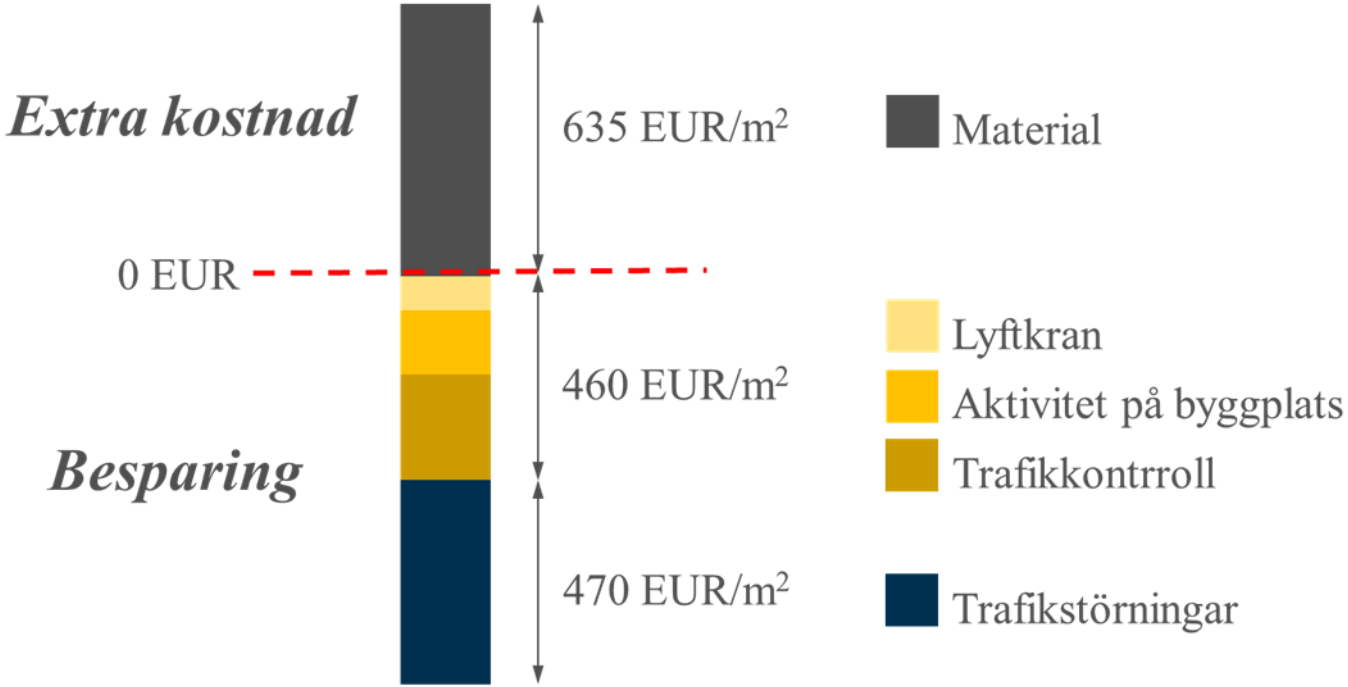
3 U-shaped carbon fiber girders with stay-in-place GFRP formwork

The bridge was mounted in 3 hours

MOUNT PLEASANT ROAD BRIDGE – UK 2006



FRP deck on steel girders
Span: 2 x 25,7 m
Width: 5,6 m
Weight: 103 t (GFRP 18 t)

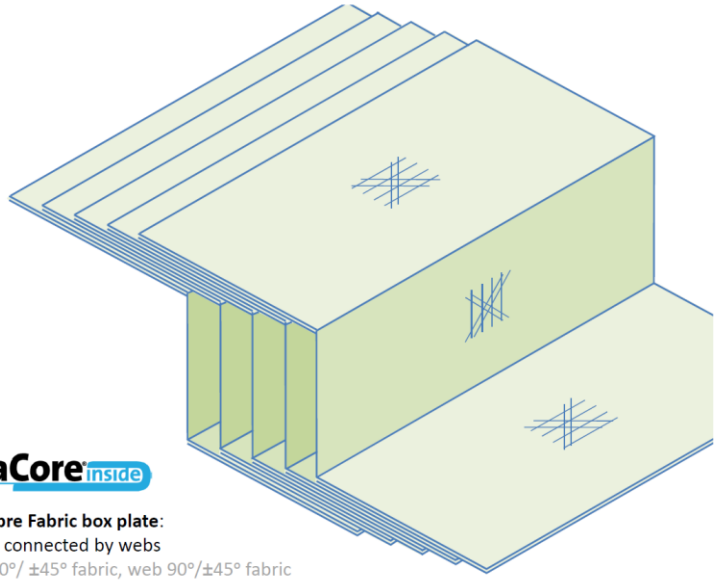

Extra kostnad
635 EUR/m2
Material
0 EUR
Lyftkran
460 EUR/m2
Aktivitet på byggplats
Trafikkontrroll
Besparing
470 EUR/m2
Trafikstörningar
Pris: 1600 EUR/m2

APPLICATIONS IN SWEDEN

- Started at Chalmers in 2010 in collaboration with Swedish Transport Administration
- Continued by EU PANTURA (2011-2014) project
- Followed by FALCON (Future Advanced Lightweight CONstruction) project funded by Vinnvoa LIGHTer program (2016-2019)

REFURBISHMENT OF A BASCULE BRIDGE IN MALMÖ BY CHANGING THE EXISTING DECK TO FRP (2016)

- The deck was in very bad shape
- The bridge has 9 longitudinal steel girders
- The width of the deck is 8.9m (divided into two lanes). Each lane has dimensions of 4.44x32.86 m

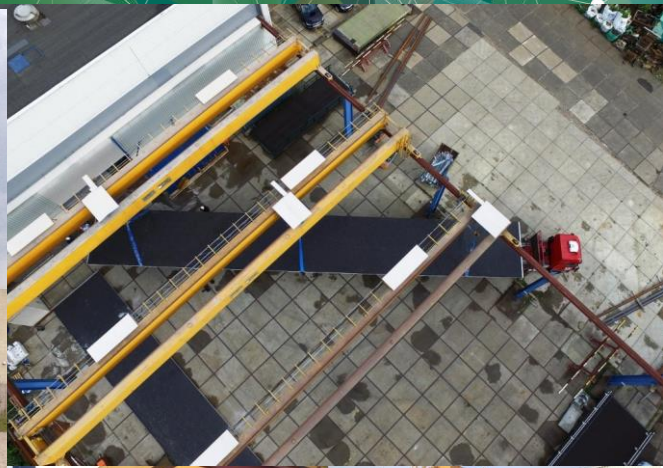


InfraCore inside

Glass Fibre Fabric box plate:
Flanges, connected by webs
Flanges 0°/ ±45° fabric, web 90°/±45° fabric


5


LENSVELD
DAF
NOOTEBOOM
WWW.NOOTEBOOM.COM




LENSVELD

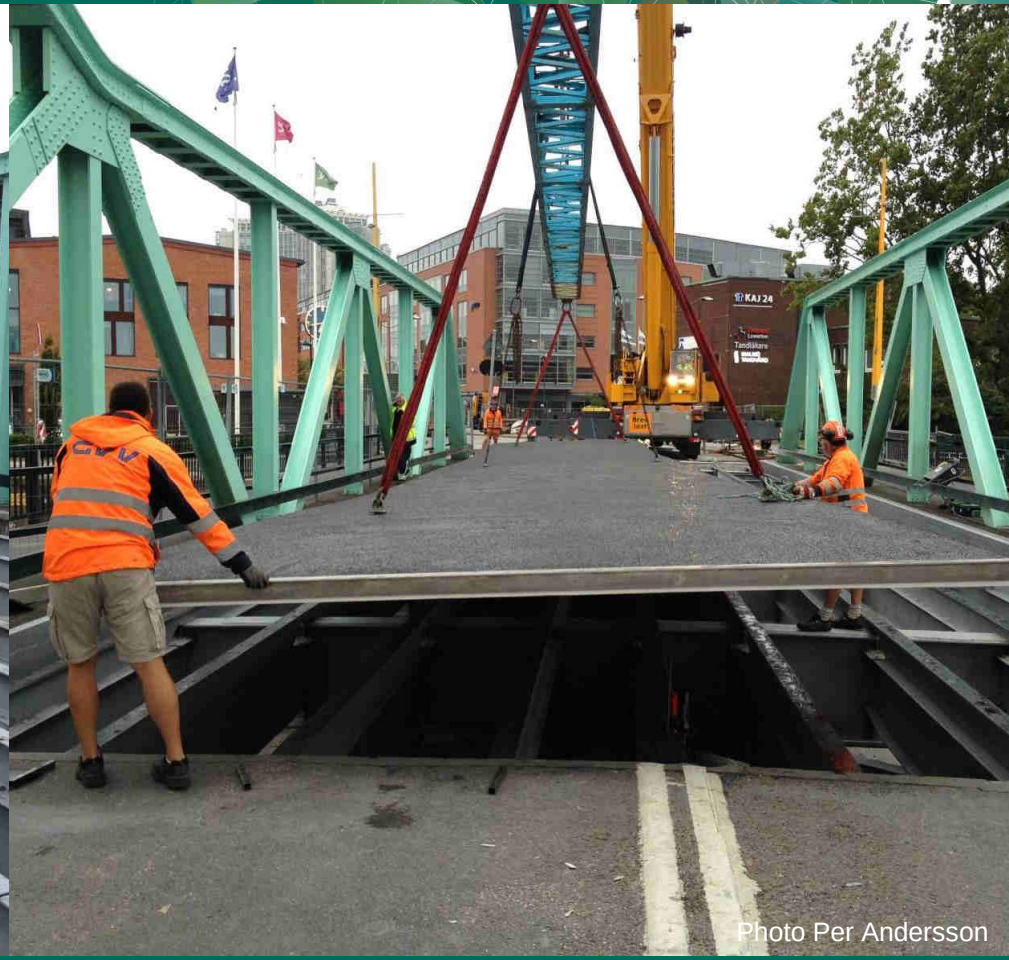


Photo Per Andersson

Photo Per Andersson

Total cost of 4.5 MSEK, equivalent to ca. 15000 SEK/m2

Photo Per Andersson

THE FIRST WHOLE FRP BRIDGE IN SWEDEN (2019)- NEPTUNI BRIDGE

Photo Abbas Khayyami

The bridge weight was ca. 9 tons compared to a 70 ton concrete counterpart

Photo Abbas Khayyami

REFURBISHMENT OF UNIVERSITY BRIDGE IN MALMÖ (2017)

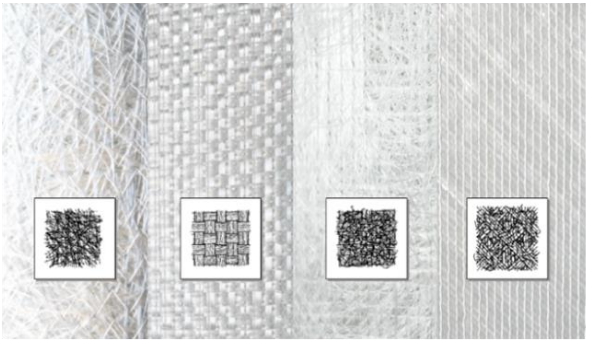
Photo Abbas Khayyami

Photo Abbas Khayyami

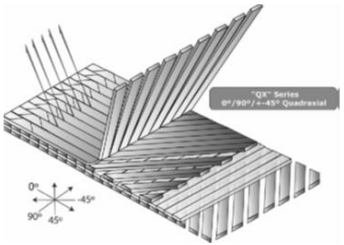
Photo Abbas Khayyami

CONCLUSION REMARKS (CHALLENGES)

Huge choice of material & endless possibilities for material combinations



+ bespoke mechncial properties ..
+ optimal material utiliztion & construction
+ possibilitie for creativ solutions



- Complex material (calcuations)
- Harder to standardize (comp. To steel and concrete)
- Hard to compare solutions / design

Many choose to buy ”Products” →

material and production secrets

CONCLUSION REMARKS (CHALLENGES)

Market and Organization

- FRP industry is not familiar with bridge market
- Clients & structural engineers not familiar with the material
- Yet, limited experince with managing innovation
- Limited market volume
- Few actors on the market, with limited experience

Clients interest and engagement is essential

CONCLUSION REMARKS (CHALLENGES)

Competence development

- Education & training
- Knowledge dissemination & experience feedback

Courses for students and designers

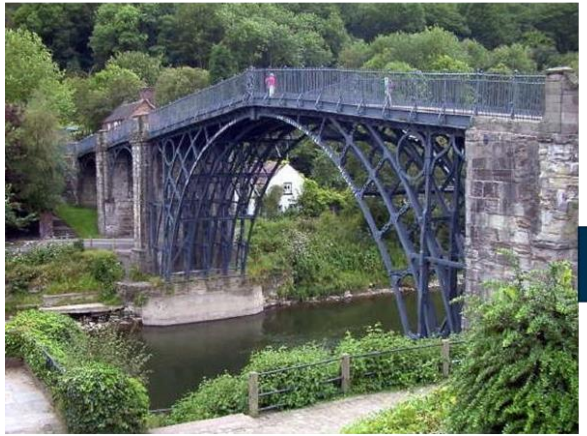
Seminar and workshops

Information materials

CONCLUSION REMARKS (CHALLENGES)

Research

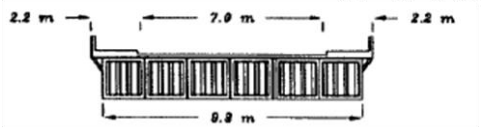
- Design rules & simplified calculation models
- Long term behavior, degradation over time .. A bridge lasts 80 years!
- Repair- and strengthening methods
- Quality assurance, inspection methods, NDT
- Measurements and monitoring
- Hybrid solutions .. Many advantages and many challenges
- Connections



34 år

Iron Bridge, **1779**

Sveriges första järnbro över Götakanal, **1813**



MIYUN BRIDGE, CHINA
1982

37 år

Sveriges första FRP bro, **2019**

Bridge crossing Thames - Concept: Optima projects, UK

CHALMERS

UNIVERSITY OF TECHNOLOGY