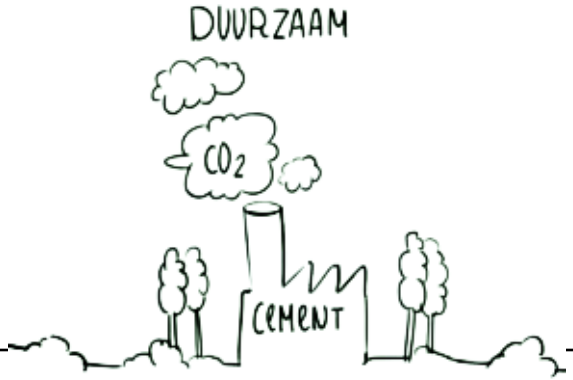
# Opportunities of new concrete types for buildings and infrastructure?!

Mladena Lukovic


- **New types of concrete**
- Demands of society
- Promising applications
- Conclusions

# Traditional concrete

Cement

Sand and gravel

Water

# Beside water, the most widely used material on Earth!

**WHY?**

- The cheapest and most readily available building material
- Ease of making any kind of shape
- Good durability

STORSEISUNDET BRIDGE, NORWAY

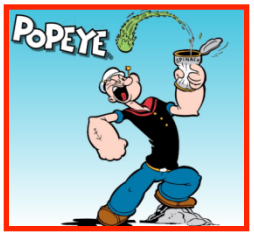
## “Recently” developed

## Ultra High Performance Concrete (UHPC)

http://www.ultrabrug.nl/ultrabrug-nieuws/


- Very dense
- Watertight
- Extra strong

**Normal strength**

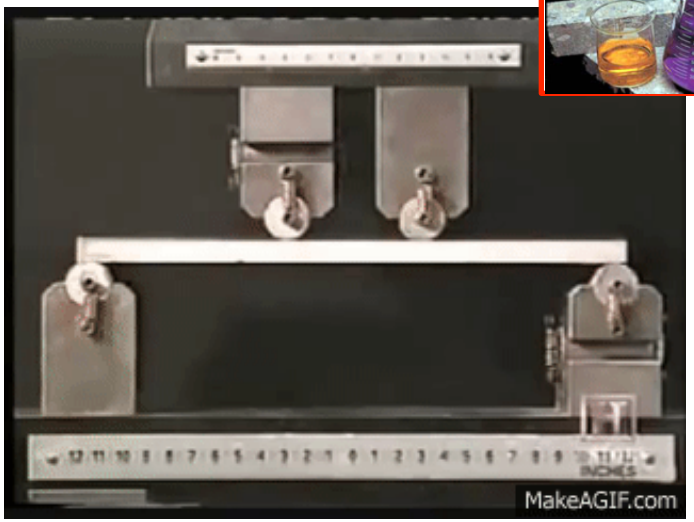




**Ultra high strength**

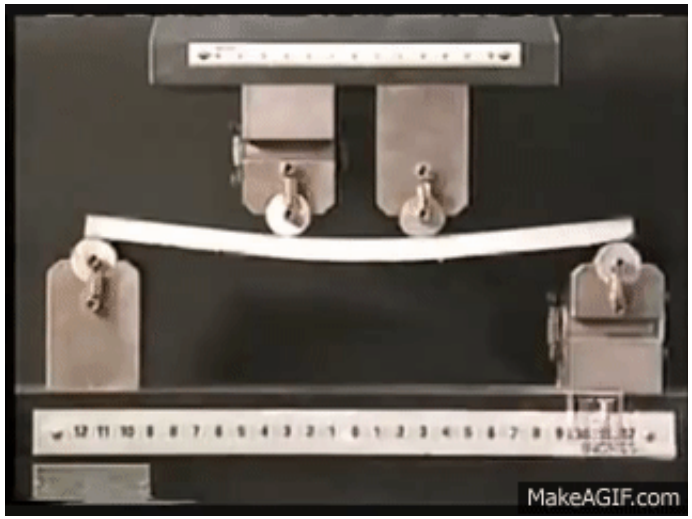
# Strain hardening cementitious composite (SHCC, “bendable concrete”)


- Very ductile
- Very small crack widths
- Damage resistant behaviour

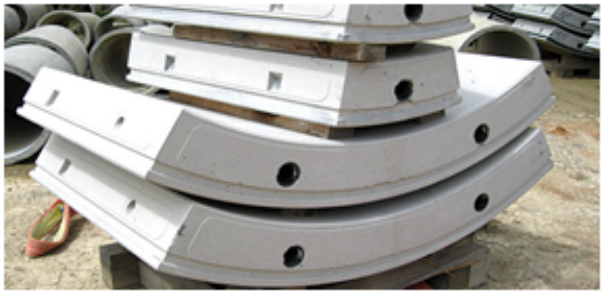
**Brittle**




**Ductile**

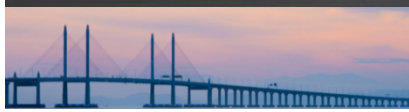


## Geopolymer concrete



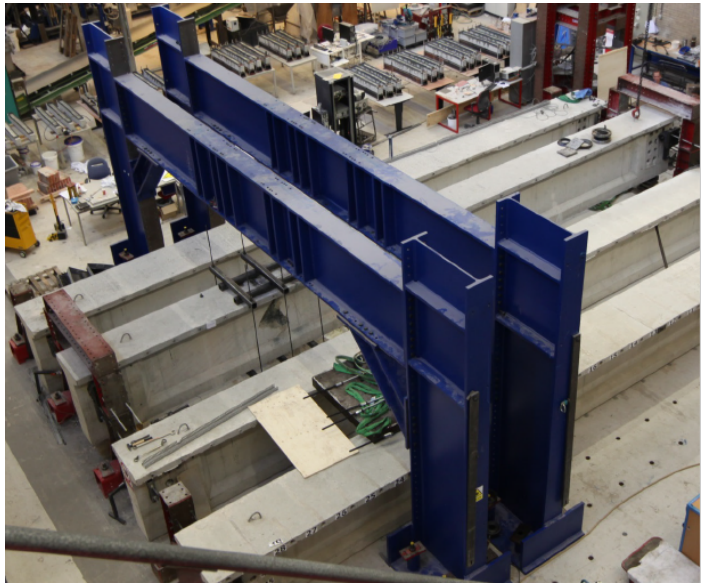
**“green concrete”?!**

- Reduce energy consumption
- Reduce $CO_2$ emission
- Use of industrial by-products

## TU Delft

- Faculty of Civil Engineering and Geosciences
  - Group of Concrete Structures
    - Existing concrete structures
    - Upscalling of innovative concretes
      - "SMART bridge" Albert Reitsema



- New types of concrete
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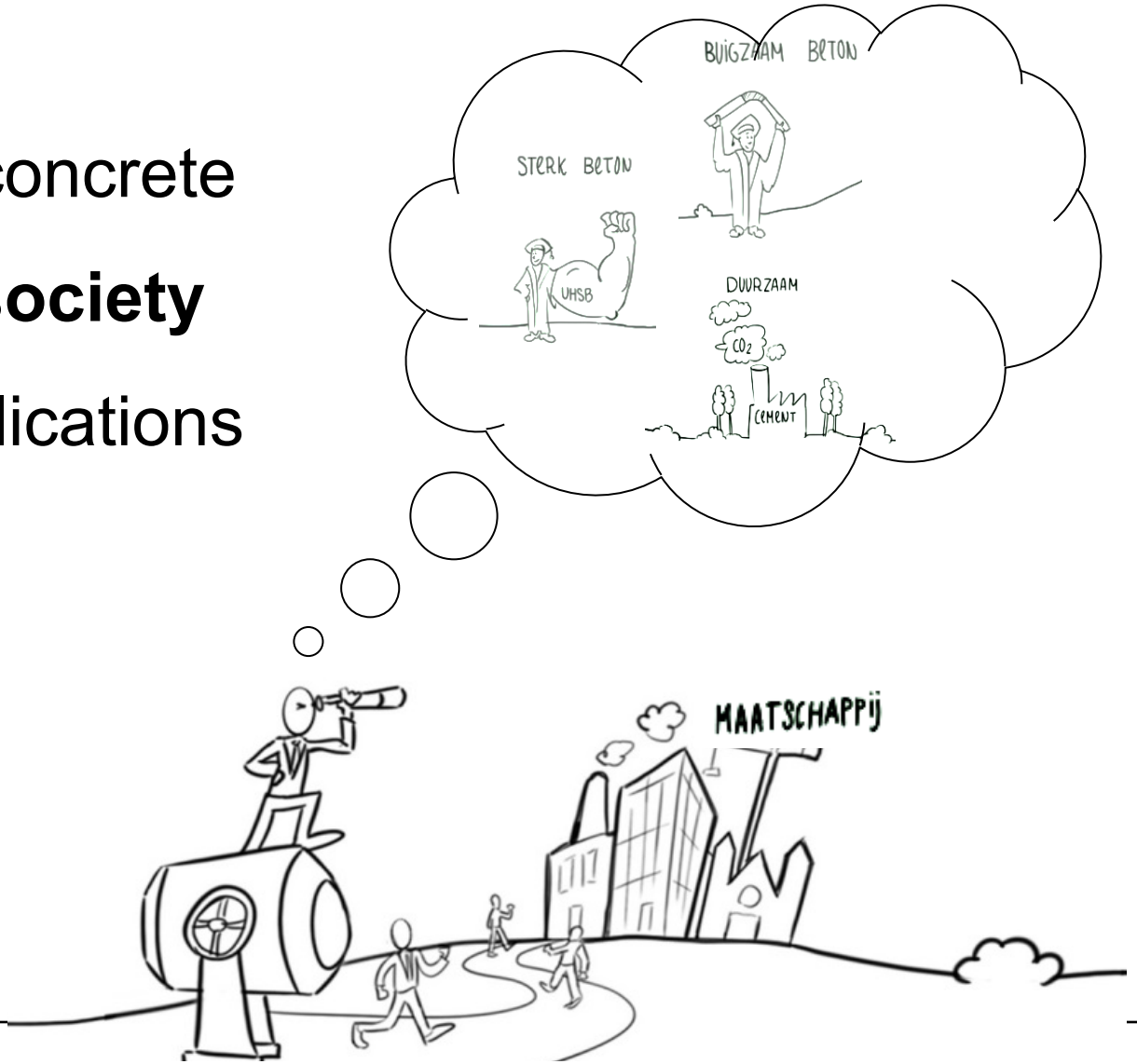


# Benefits?!

Economical? Esthetical? Sustainability? Less maintenance? Less hinder? High slenderness?

Lighter structure? Faster construction?

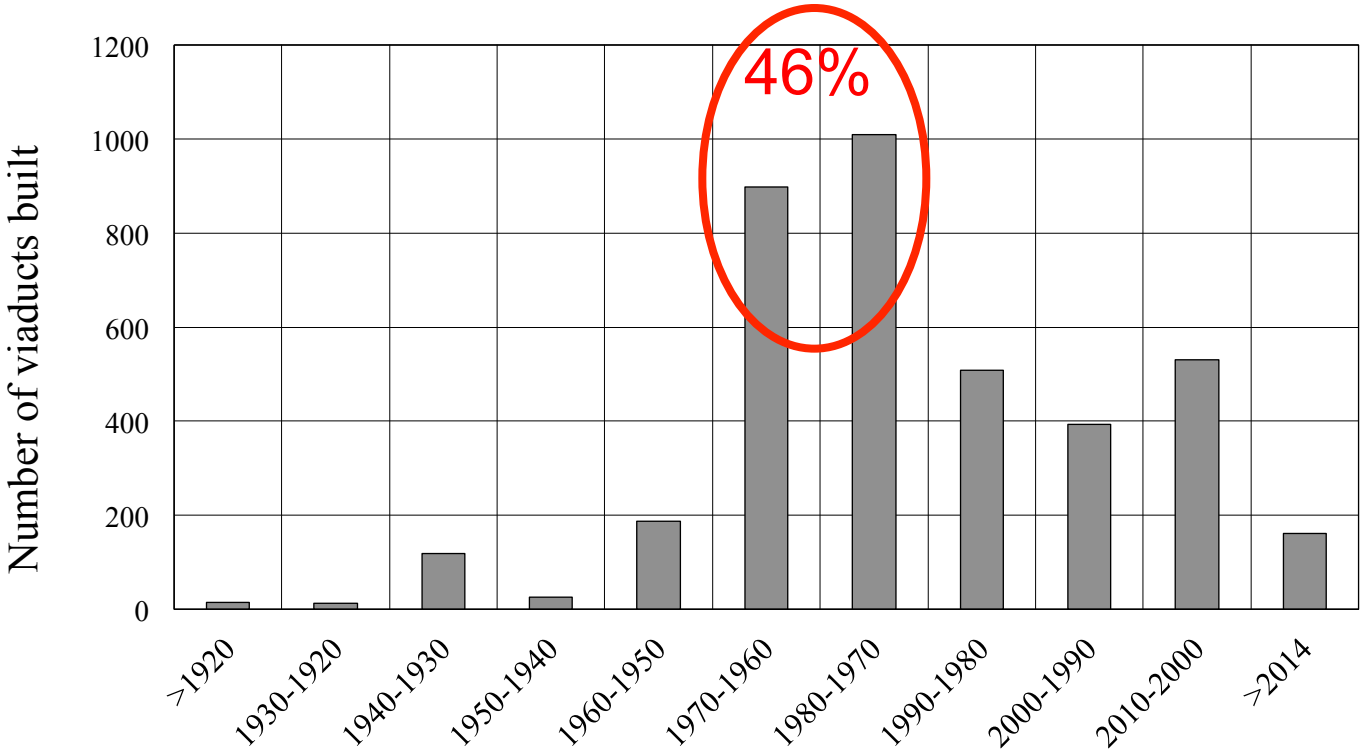

…how?

Develop guidelines, codes…


Challenges!

- Risk…
- Lacking experience…
- Difficulties in getting permissions

# Historical overview of viaducts in the Netherlands




**Soon we might face a huge replacement/repair task!**

# Demands

1960s

2020s

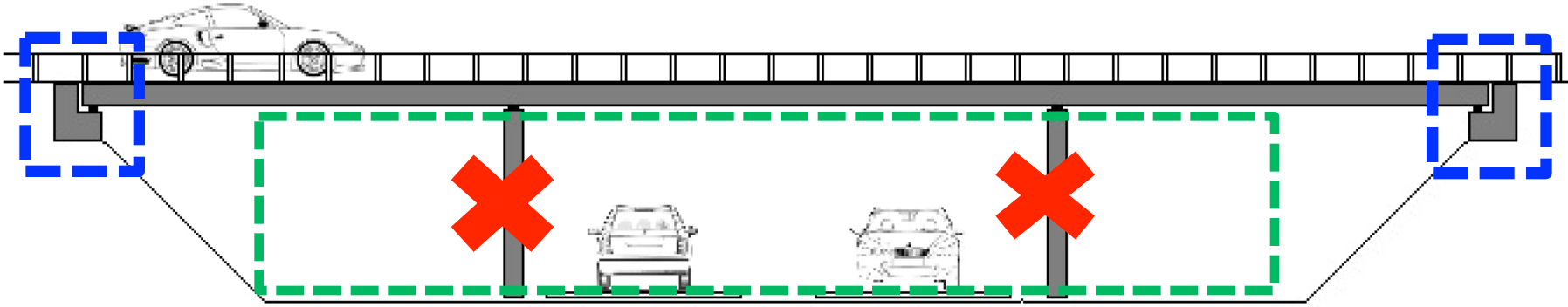
- Low construction time

- Freedom in space
- Keep existing traffic profile
- Minimize the additional ground work

Self-Propelled Modular Transporters

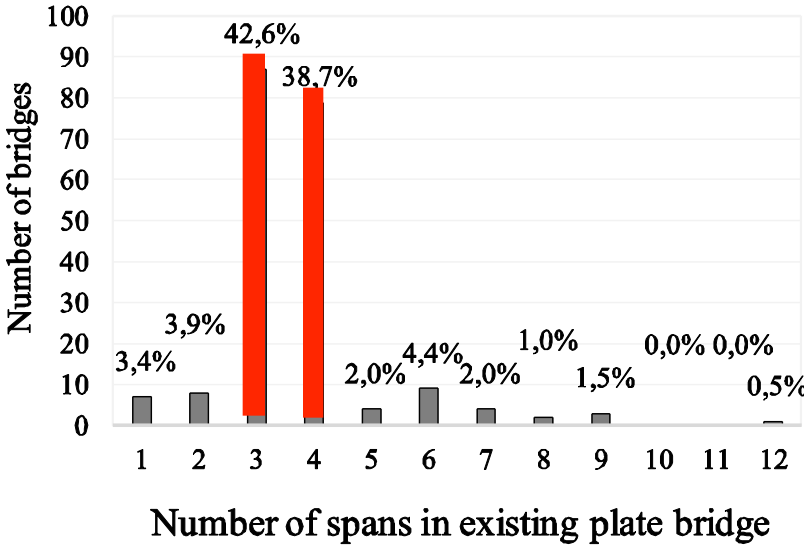
- Keep existing foundations

- Minimize the weight of construction

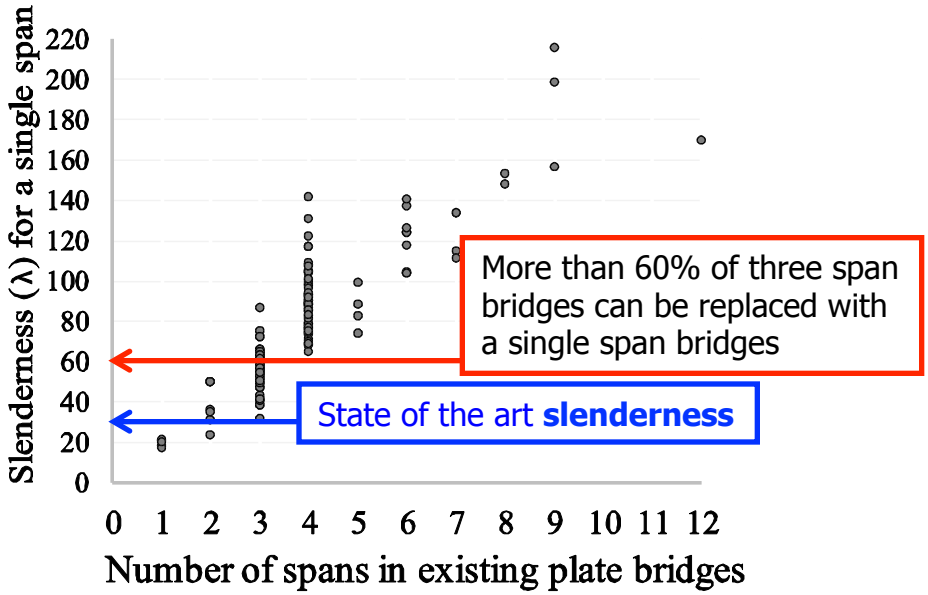


# Demands in the Netherlands

- Most of the existing bridges are 3 to 4 span bridges with a total span 20 - 60m.
- **Replace with a single span bridge with slenderness as high as 60?**




**Can UHPC be the solution?**



# A case study replacement task A29/N309 with UHPC

Three span plate bridge, total span 48 m

What is the achievable slenderness?

Three solutions proposed

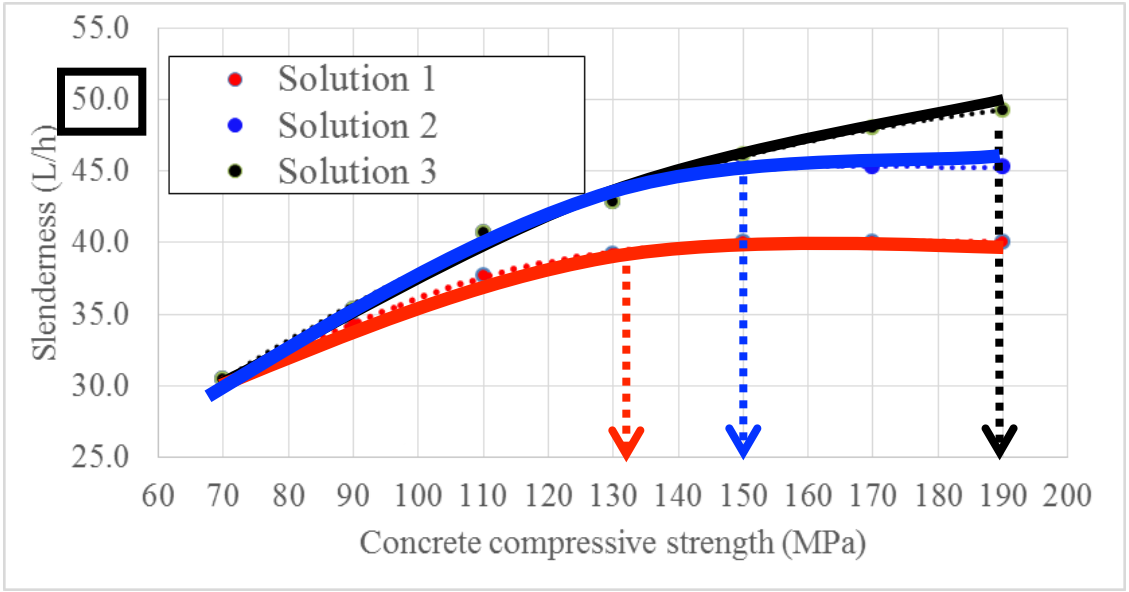

# A case study replacement task A29/N309 with UHPC

**Pretensioned prestressing (current production process of box girders)**

**Combination of pretensioned and post-tensioned prestressing**

**Combination of pretensioned and post-tensioned prestressing with reduced anchor distances**

**Only high strength is not enough!**




Maximum slenderness is 50!

Maximum slenderness is 45!

Maximum slenderness is 40!

# Application of UHPC in Dutch infrastructure
## Already a few UHPC footbridges

| Year | Name | Place | Company |
|---|---|---|---|
| 2011 | Gooise brug | De Meern, Utrecht | Romein beton |
| 2012 | Brug Hoekersingel | Rotterdam | FDN engineering |
| 2014 | Brugsysteem | Pijnacker | ipv Delft, Hi-Con, Pieters Bouwtechniek, Griekspoor |
| 2015 | Brug Zwaaikom | Eindhoven | FDN engineering |
| 2016 | Brugsysteem | Volmolen | Hi-Con |
| 2016 | Catharinabrug | Leiden | Hi-Con |


Gooise brug, 2011


Brug Hoekersingel, 2012


Zwaaikom, 2015


Catharinebrug, 2016

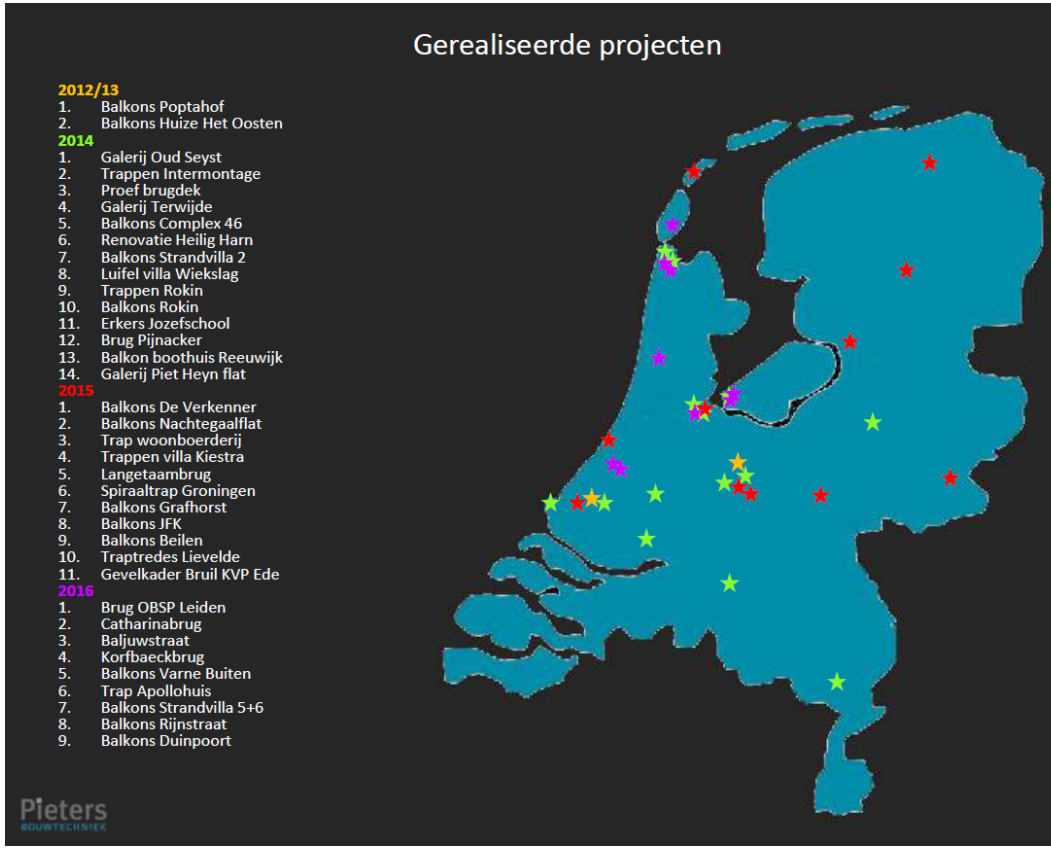

Pijnacker, 2014


Volmolen, 2016

# Balconies

**300 mm** → **60-70 mm**

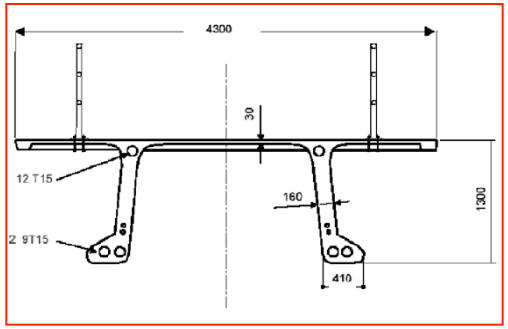
Poptahof, 2012/13



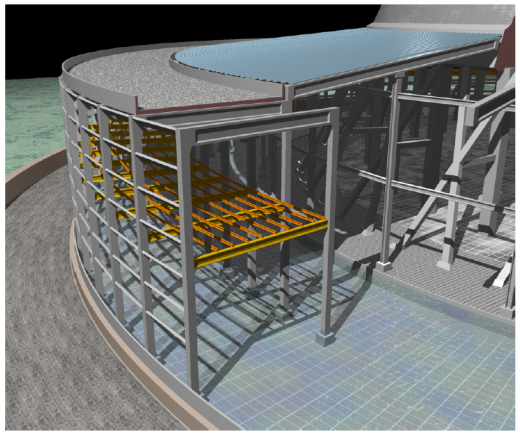

Rogier Nalta

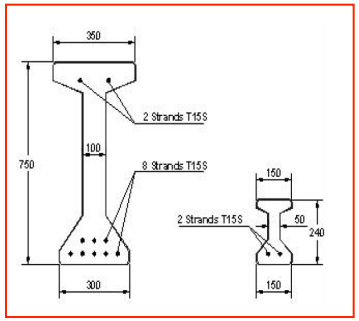
# Applications worldwide…

UHPC Roof elements: Shawnessy station at Calgary, Canada




Longest UHPC bridge: Seonyu footbridge in Seoul

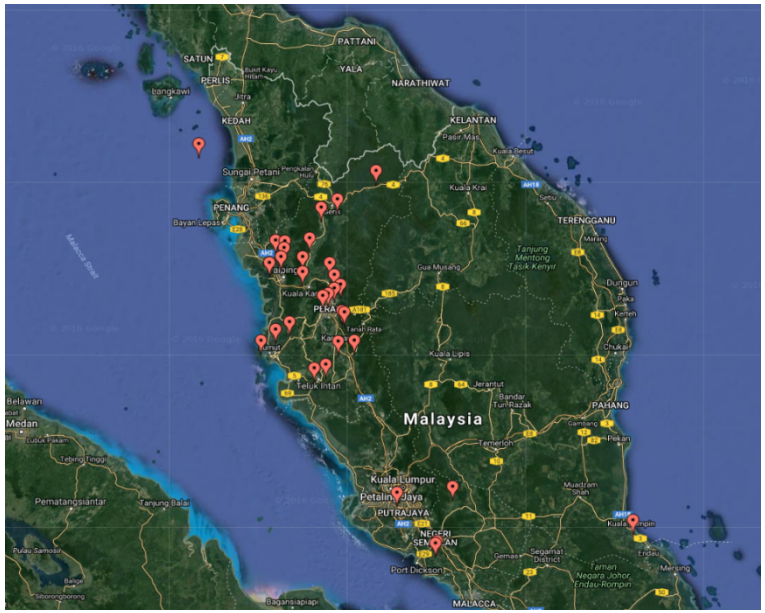




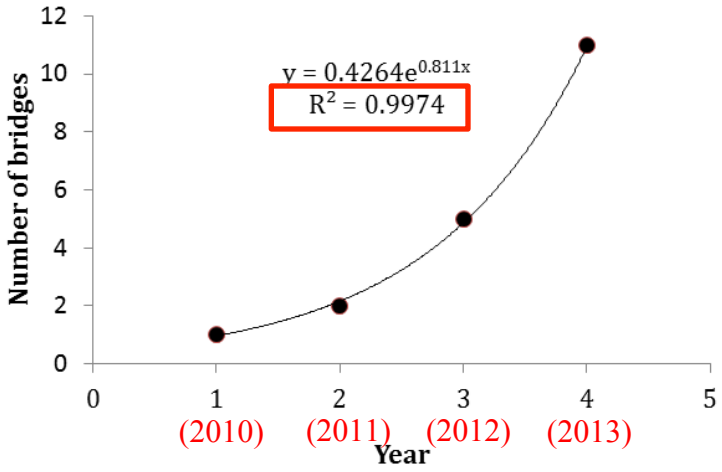

UHPC prestressed beams: Cattenom and Civaux nuclear power plants, France

aesthetics, lightness, high durability and fast construction…

# In Malaysia more than 100 UHPC road bridges!





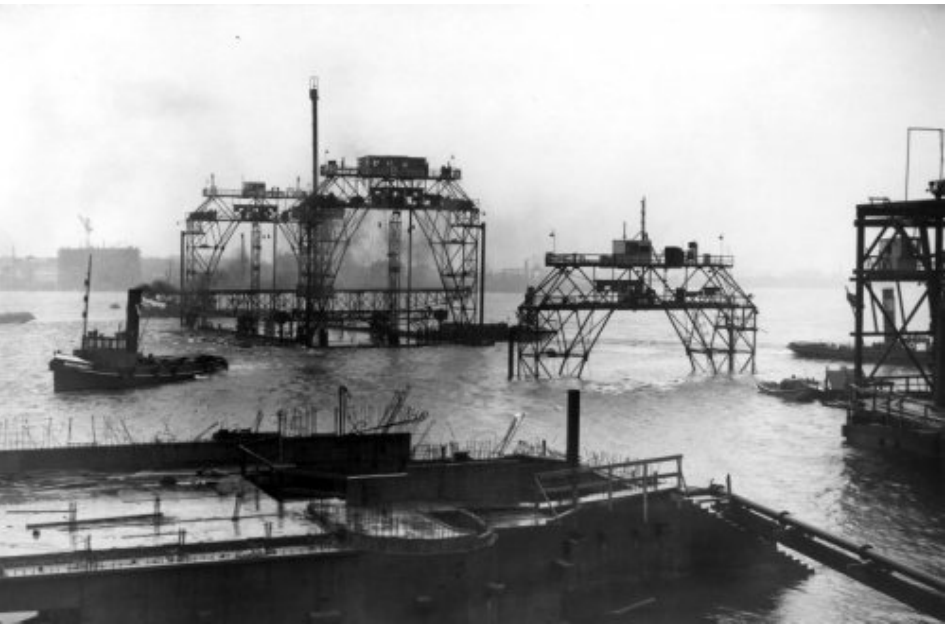



**By 2020 around 5800 road bridges in Malaysia only?**

This is almost 50% of existing bridges there now

# Some structures cannot be replaced… **Maastunnel**

- Daily 60000 cars, 5000 cyclists, 1000 pedestrians
- Not only important connection
- Europe's first immersed tunnel
- **Historical treasure to be preserved!**



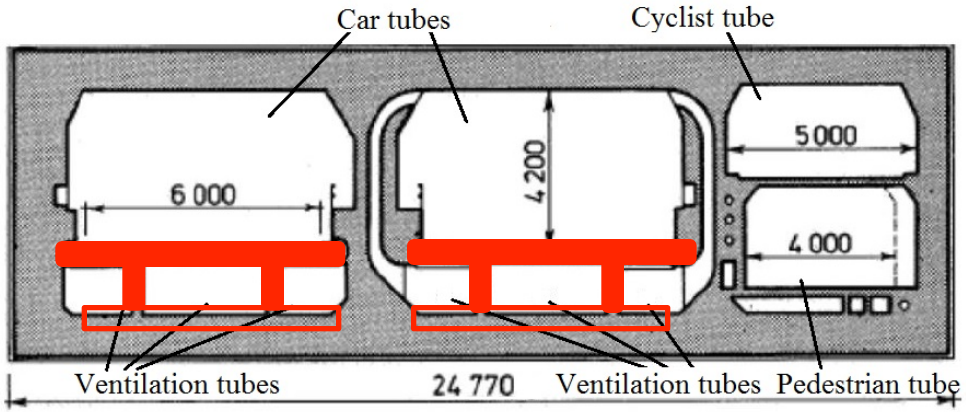
Constructed 1937 - 1942

© Aart Klein / nfa, coll. Nederlands fotomuseum

Opened in 1942

# What if damage continues?

How clean is clean enough?




Damage in ventilation tubes, 2015

Performance of earlier repairs

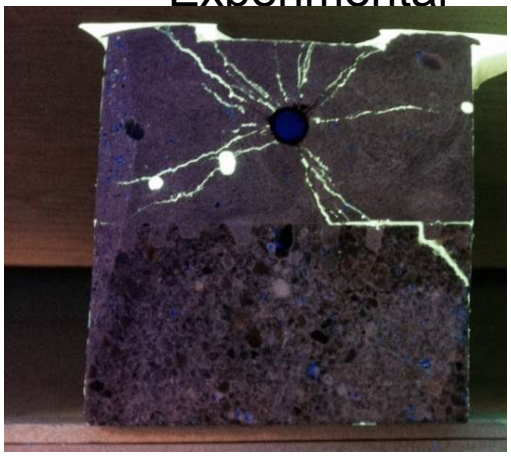
- Reduced crack widths and reduced corrosion rate

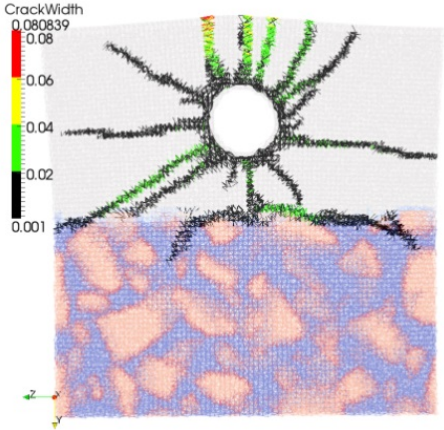
Grubb et al. (2007), Jen and Ostertag (2016)

Experimental

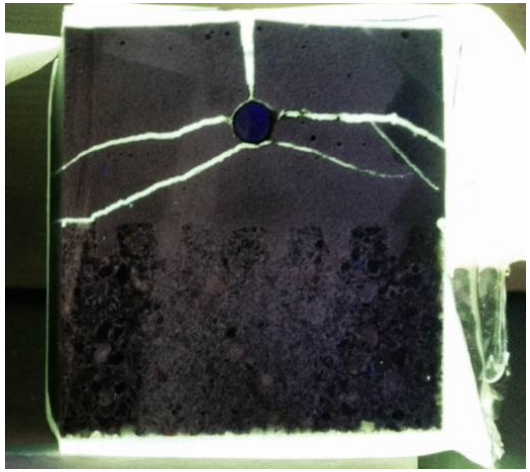
Numerical

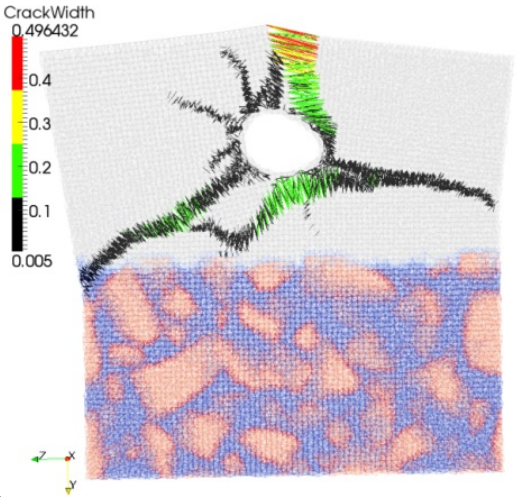
SHCC



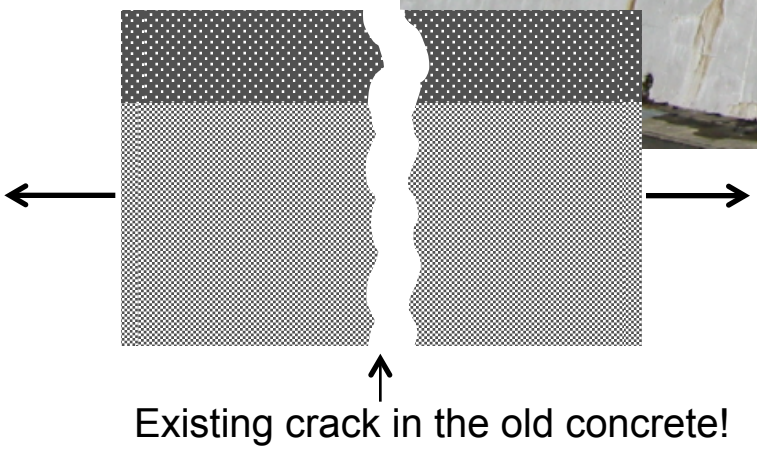



Commercial mortar

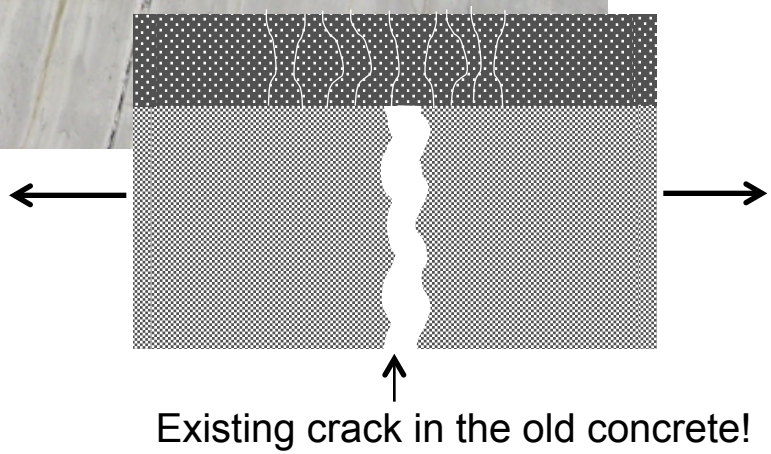




# In Japan used for repairing ASR induced damage

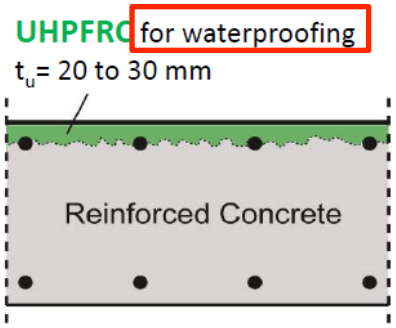


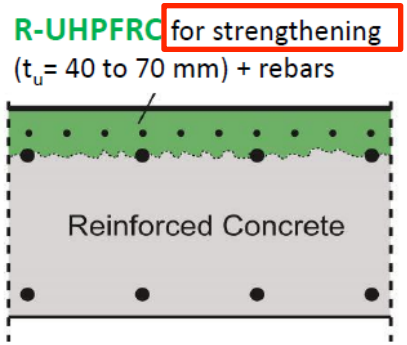
Existing crack in the old concrete!

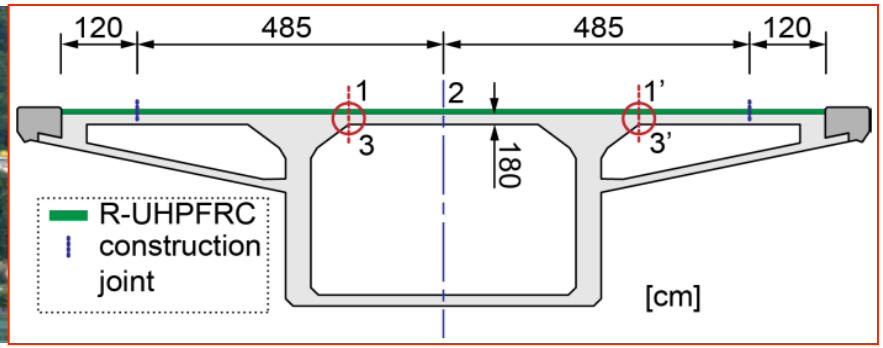


Existing crack in the old concrete!

- In Switzerland repair and strengthening with UHPC applied since 2004
- Since then more than 50 retrofitting projects is realized



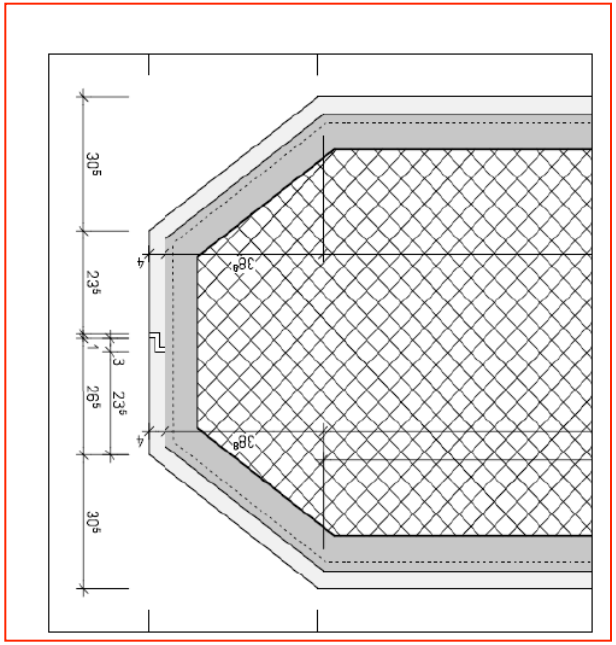




Chillon viaducts along Lake Geneva, Switzerland

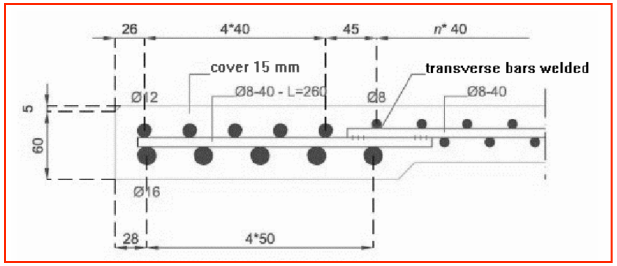
# Retrofitting with prefabricated UHPC shell elements

**minimized “out-of-use” periods**

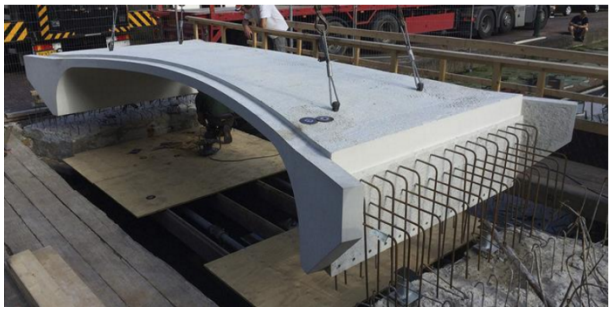



Rehabilitated bridge pier, Switzerland

# Retrofitting with prefabricated UHPC in the Netherlands




Replacement of the old wooden bridge decks with UHPC panels in Kaag Bridges



Renovation of Langetaambrug in Maasland

aesthetics, lightness, high durability, maintenance costs and sustainability…

**Sustainability** is becoming an increasingly important issue!

Investigate the structural capacity and durability of "green concrete"

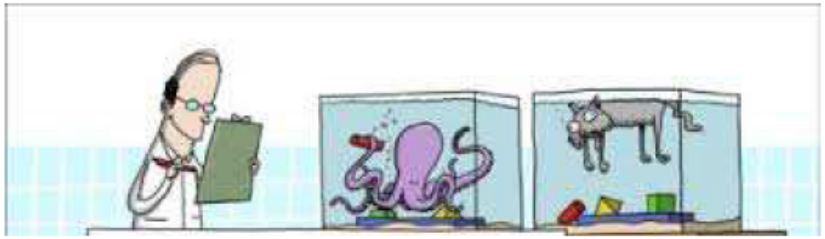
Geopolymer canoe

Geopolymer bench

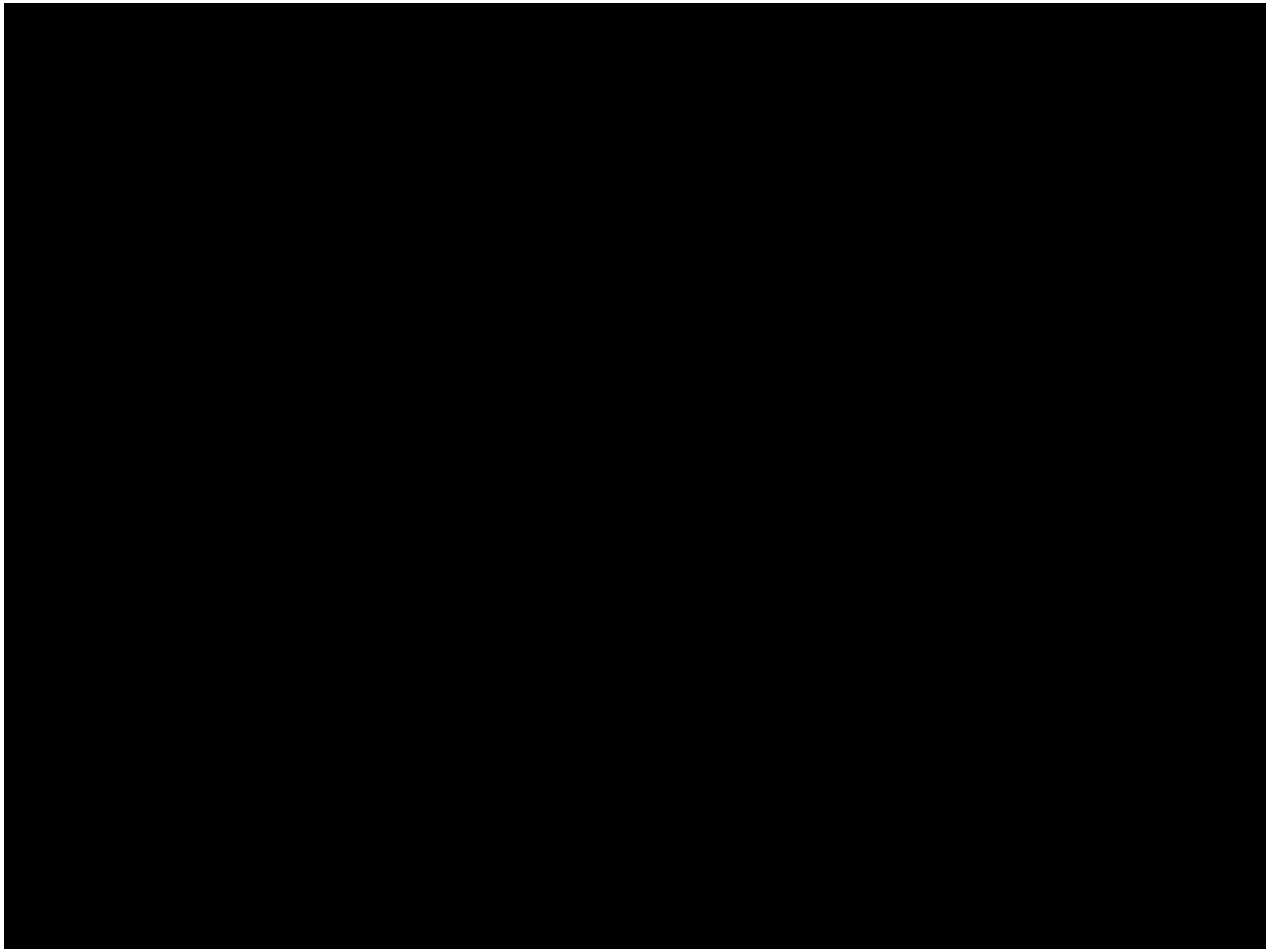
Gemeente Rotterdam

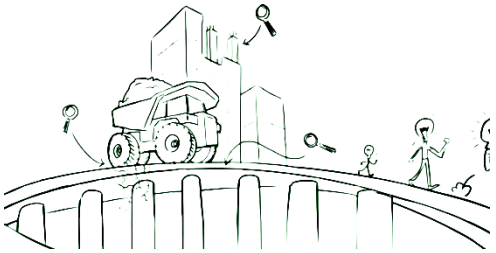
**Stay critical!**

- "Professor Jones proves that the octopus is more intelligent than the cat, when tested under identical conditions"



# Sustainability - all about the future!





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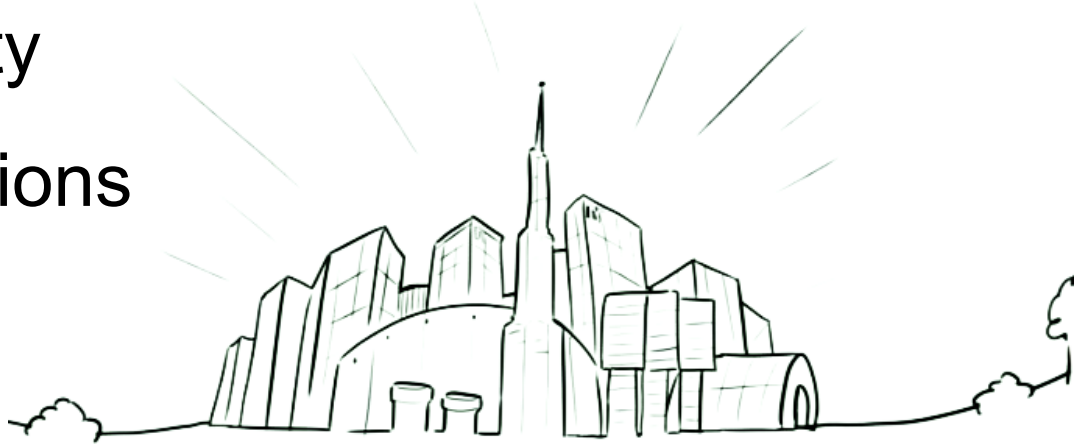
- **Conclusions**



# Conclusions

**Huge replacement/repair task is waiting for us!**

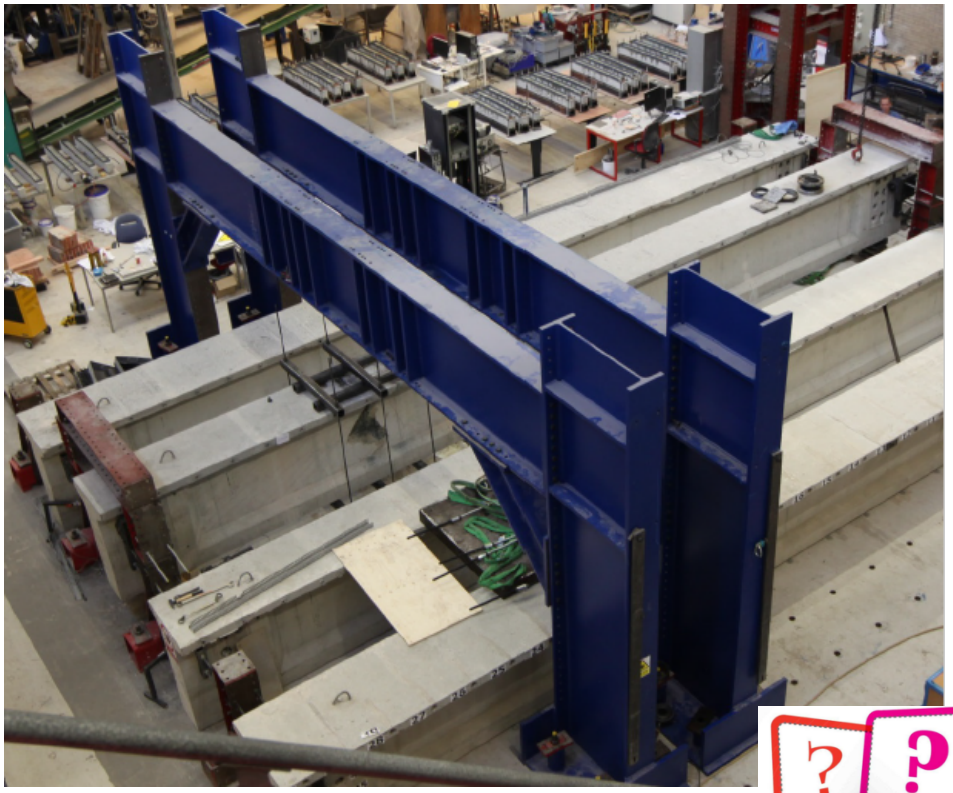
Due to the current demands of society we will probably not do it in the traditional way.

New materials might be solution

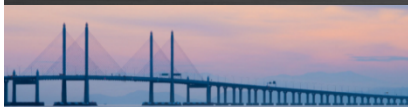
We have neither codes nor experience with these materials!

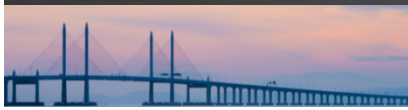
If we want to be ready, **research has to start now**!

# THANK YOU FOR YOUR ATTENTION!

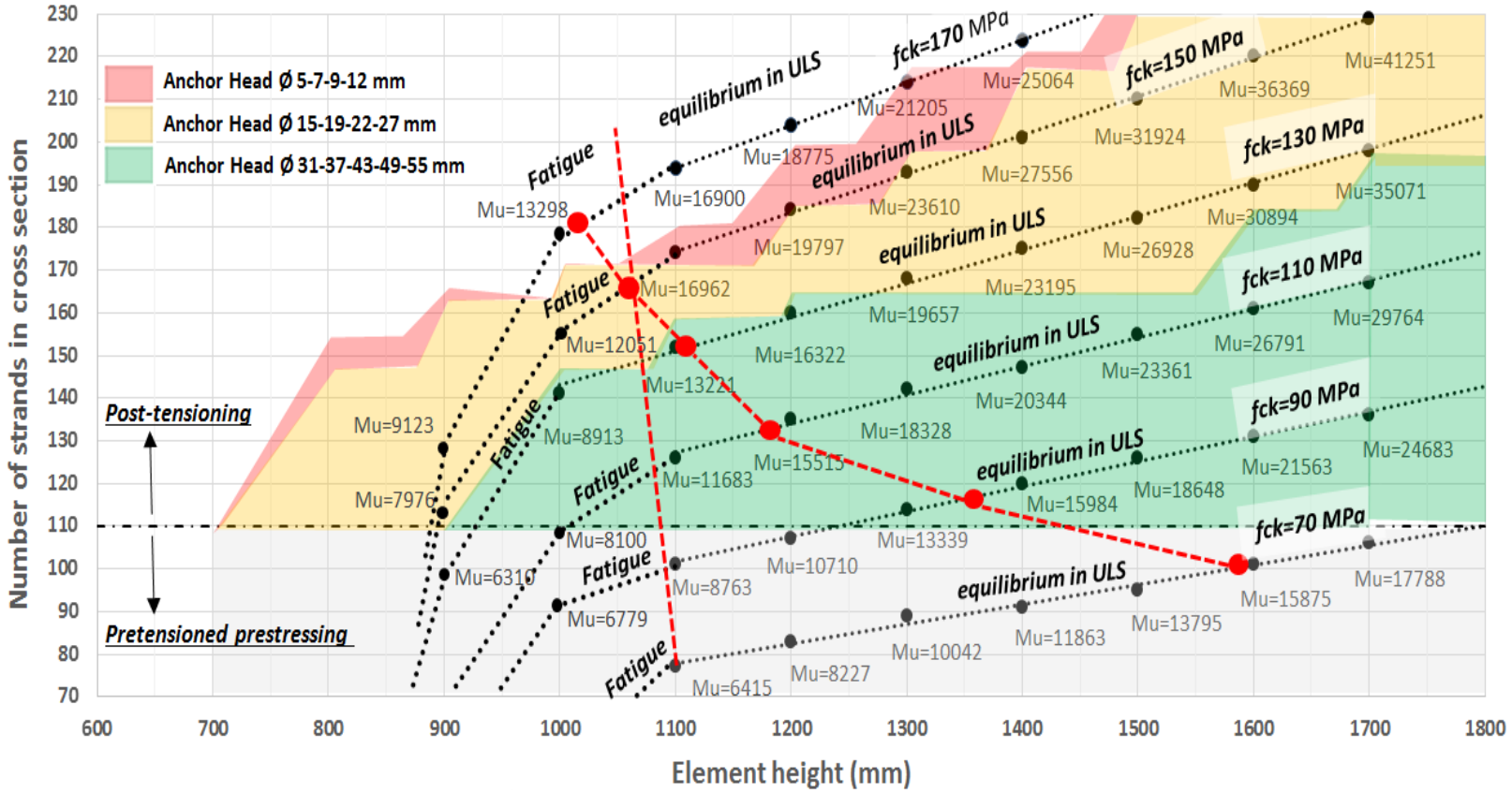



## Questions?

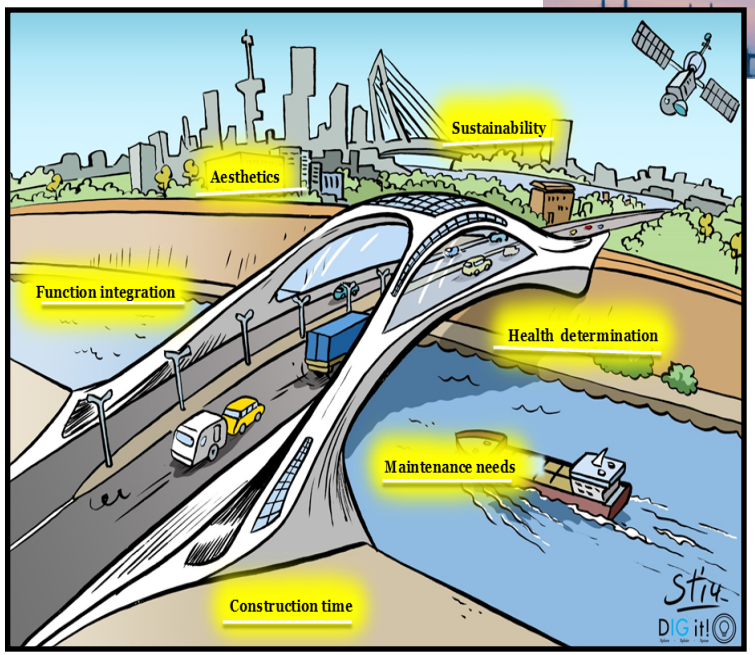


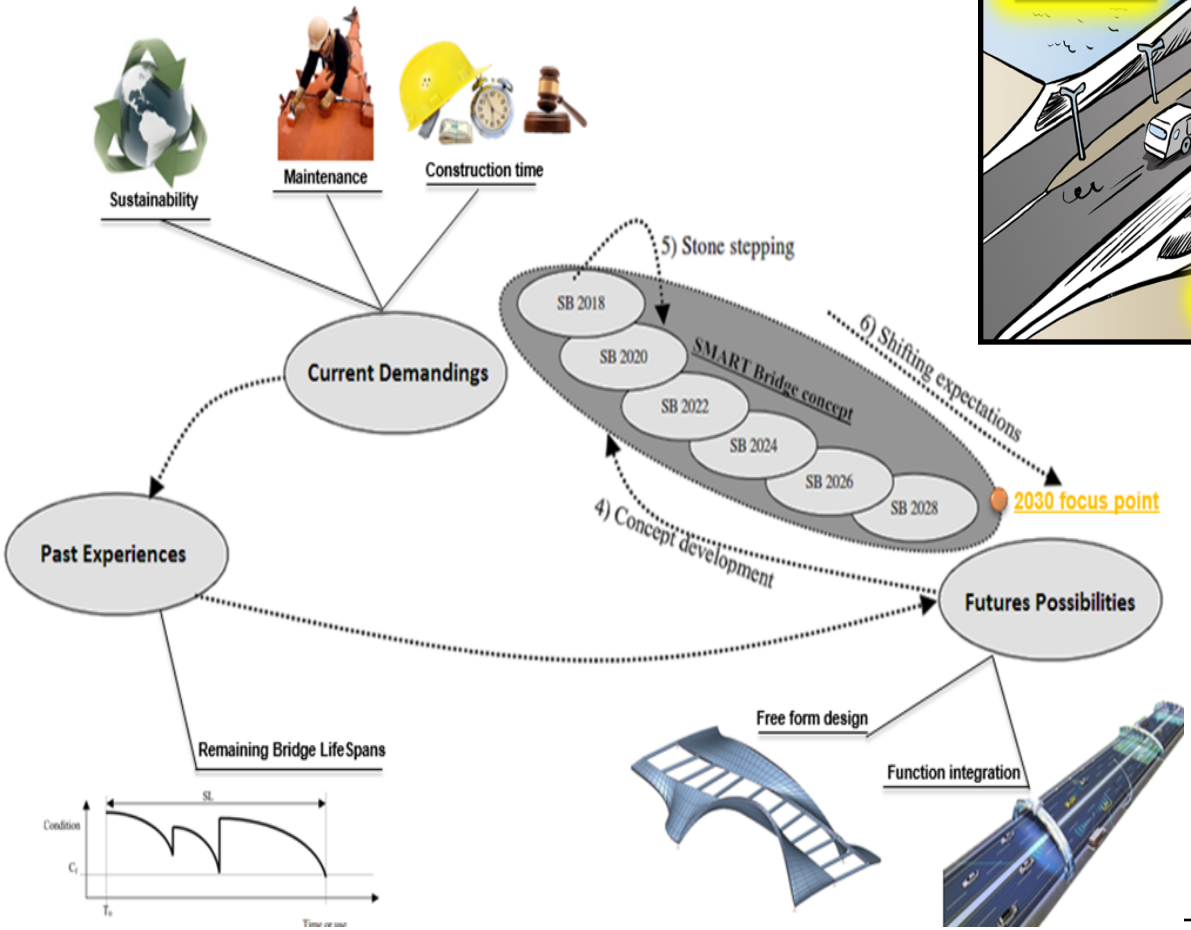


# Combined pretensioned prestressing and post-tensioning in a prefabricated box girder



# Towards elaborated bridge concepts and towards our future SMART BRIDGEs!



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