Webinar: The maritime potential of aluminium

Hydro

Jon Aaby Møretrø, January 27th 2023

Introduction

The goal of the MARINAL project is to strengthen and extend the use of aluminium alloys in marine applications.

This presentation aims to highlight what makes Al suitable in the marine environment, and show some potential growth areas.

Parts of this presentation draw on the work done by the SFI Blues group on use of aluminium as structural components of offshore structures (Delhaye, 2021).

What makes Aluminium suitable for marine applications?

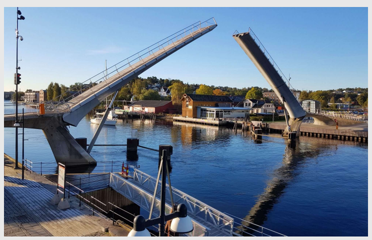
Hydro

Light weight

Functionality

Corrosion resistance

Moving or floating structures



Economy of power during service

In remote places

Transport costs and ease of assembly are important

When maintenance must be limited

Critical infrastructure where downtime must be low

In corrosive environments

Most marine applications

Illustrations: 1) Lifting bridge in Fredrikstad, Sintef (2018) 2) Prefabricated bridge being transported by helicopter, European Aluminium (2020) 3) Sintef 4) Leirvik

Floating solar structures

Floating photovoltaics

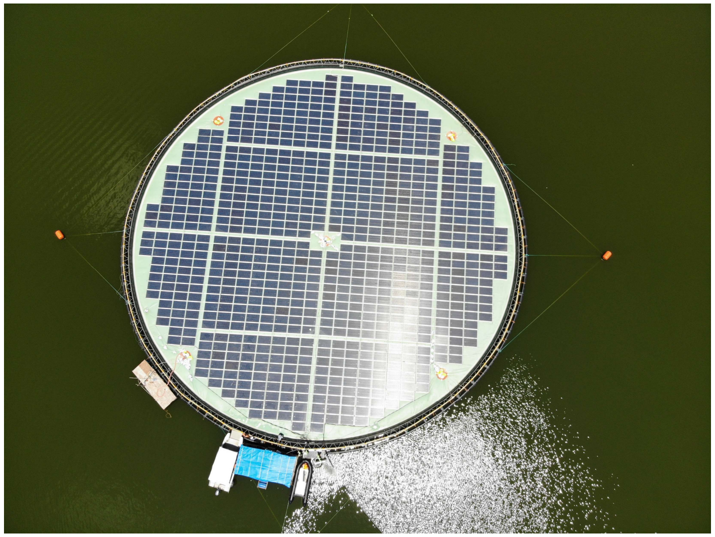
Background

- Global installed capacity:
  - 2016: 132 MW
  - 2018: 1.1 GW
  - 2020: 2.6 GW
  - 2030: 10 GW (World Bank estimate)

- Especially relevant in places with land scarcity (megacities, islands)
- Could be used offshore, for decentralized electrification of petroleum platforms and aquaculture

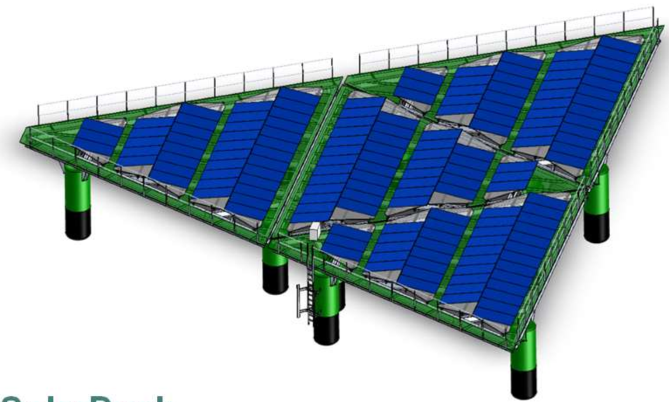
Use of aluminium

- Extruded profiles allow stable and lightweight (floating) designs
- Modular designs from prefabricated parts which are towed to location
- Favorable corrosion resistance
- High thermal conductivity of aluminium construction may be beneficial for cooling of photovoltaic panels, enabling transfer of heat to water



Source: World Bank (2018), Statkraft (2019), Sahu, Yadav and Sadhakar (2016), Ocean Sun (image)

Floating solar structures – Modular concept



Moss Maritime

- Flexible, connected rectangular modules (10x10m)
- Aluminium/steel frame for the modules in some versions of the design
- Modular design gives easy installation and scalability

SolarDuck

- Flexible, connected triangular modules (16 m sides)
- 3.5 tons of aluminium in frame and support pillars of each module
- Platforms elevated 3 meters above water level.
- Complex aluminium profiles allow simple local assembly at pop-up factories, after which the modules are towed to site

Challenges

- Connections between modules must allow some movement, and still resist wave loads.
- Connecting structural elements (aluminium and steel/polymers) within a module and avoiding galvanic corrosion

Source: solarduck.tech , mossww.com, Delhaye et al. (2021)

Floating solar: Membrane concept

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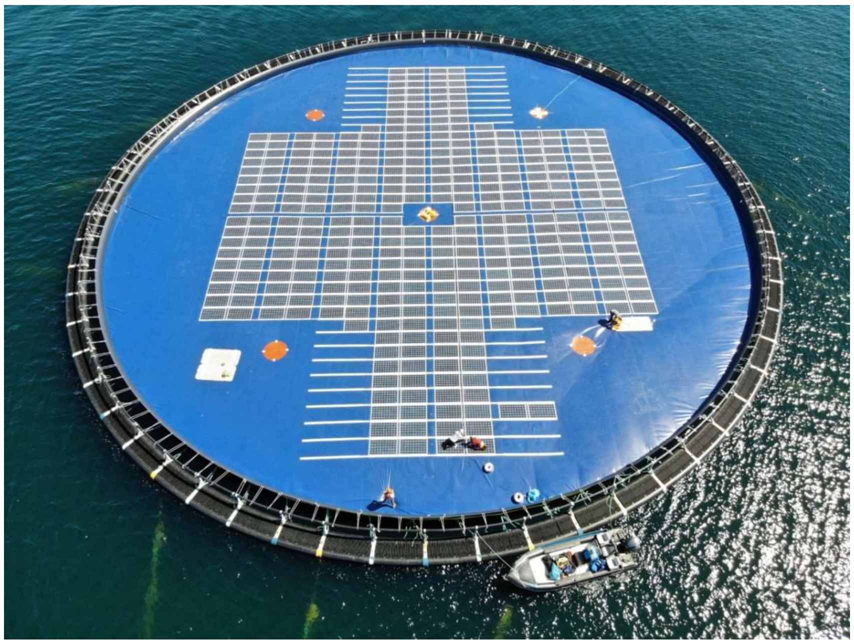


Ocean Sun

- Panels on a flexible polymer membrane attached to a buoyant ring
- Aluminum rails used to attach panels to membrane, allowing for easy attachment and replacement
- The durability of connection (glue) between aluminium and polymer membrane is important
- Al could potentially also be used on fixation elements between membrane and buoyancy ring

Source: Oceansun.no

Floating wind

Floating wind

Current standards limit use of aluminium in primary construction elements.

DNVGL-ST0119: Floating wind turbine structures

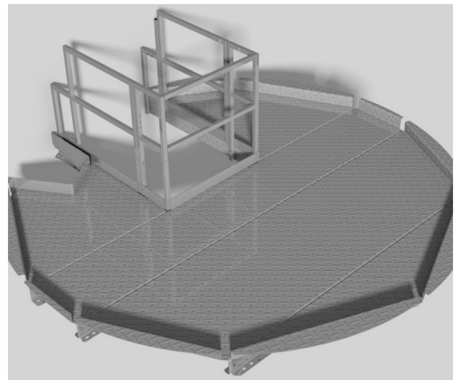
6.2.2.5 Aluminium shall be of seawater resistant type. Aluminium alloys shall comply with the requirements set forth in DNVGL-OS-B101. Aluminium shall not be used as construction material in load-bearing structures.

Sources: DNVGL (2018)

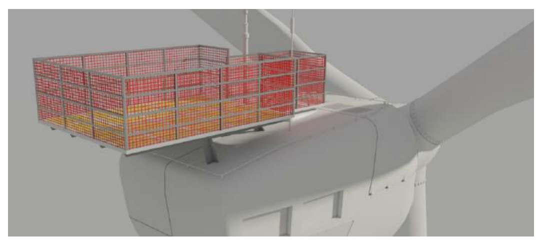
Floating wind structures – Secondary elements

Advantages of aluminium

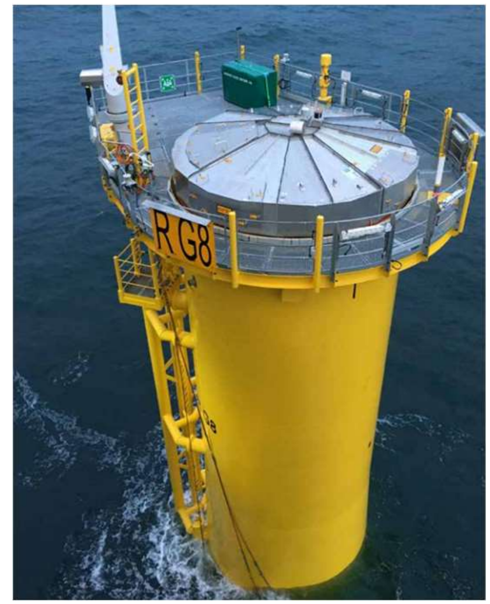
- Easy to install and ship due to low-weight prefabricated modules
- High corrosion resistance and no need for paint, reduced maintenance costs
- Functionality of extruded parts allows specialty and modular designs



Internal tower platform (AluWind)



Platform on top of nacelle (AluWind)



Temporary transition piece cover (AluWind)

Sources: DNVGL (2018), SAPA (2012), aluwind.com
Illustrations: AluWind

Floating wind – Turbine blades

Aluminium could replace fiberglass/polymer turbines in some select cases

Advantages of replacing fiberglass with aluminium

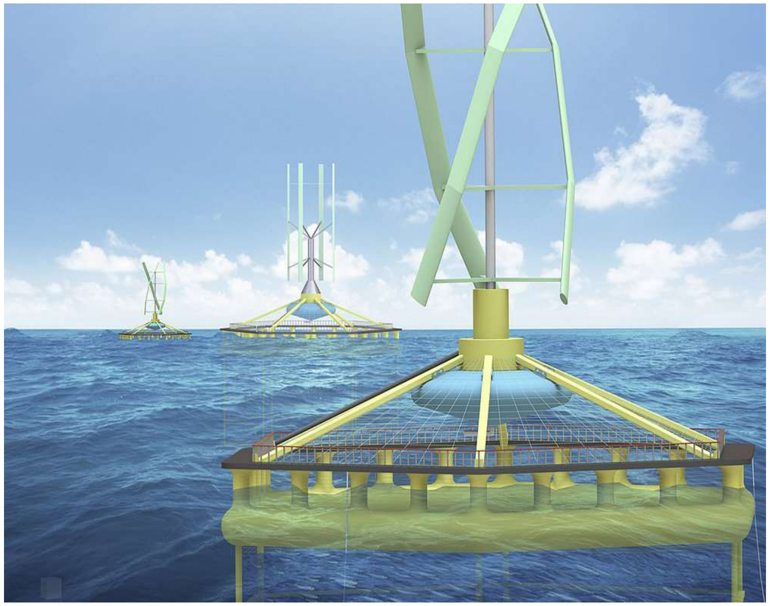
- Lower maintenance
- High structural properties - avoid erosion in high wind
- Lower life cycle costs

Challenges

- Poor fatigue properties over long period of cyclical stress
- Heavier than fiberglass
- Blades cannot be made in one piece due to extrusion press size. Requires weld or rivets across entire length of turbine blade

Pocket floating wind structures

- Off-grid electrification
- Miniaturization of turbine blades reduces loads and the need for connecting multiple parts
- Vertical axis wind turbines may be more relevant in these type of concepts



Hybrid wind/aquaculture structure concept (Red Dot)

Sources: Delhaye et al. (2021), Möllerström et al. (2016) Red Dot (2017)

Aquaculture

Aquaculture structures

Current use of aluminium

Current floating aquaculture systems largely use polymer materials for e.g. the floating collar and net, and steel where a higher load resistance is required. However, several suppliers use aluminium in various applications, including:

- Railings/platforms etc.
- Feed distribution systems (silo, selector, spreader)
- Work boats

Examples of aluminium applications, from AKVAgroup:

Feed silos

Feed selector

Rotor spreader of feed

Work boat cabin

Source: Delhaye et al. (2021), akvagroup.com

Closed aquaculture systems

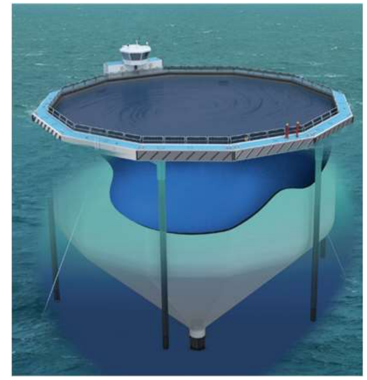
Closed aquaculture systems

- A second cage outside normal fish farm net pens, limiting water exchange with the environment
- Floating closed pens can no longer allow currents and waves to pass through, so stronger structures are needed.

Ecomerden concept

A flexible polymer bag outside net pens, supported by a rigid floating collar of 6082 aluminium.

- High strength and buoyancy
- Able to withstand high wave and current loads
- Standardized pontoon modules
- Supports secondary functions



Ecomerden R

Ecomerden S

Ecomerden S20 deployed for broodstock production in Sognefjorden. Note color difference due to high algae concentrations outside cage and no algae within

Sources: Delhaye et al. (2021). Ecomerden.no

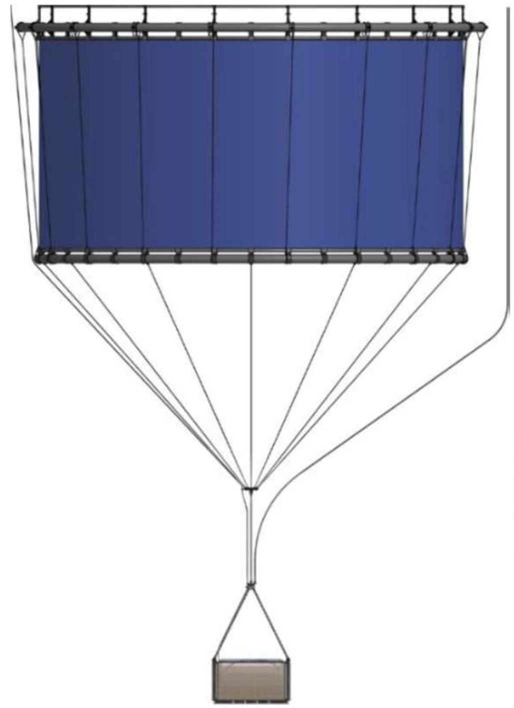
Aquaculture – potential structural applications

Regulation may incentivize use of more environmentally friendly materials.

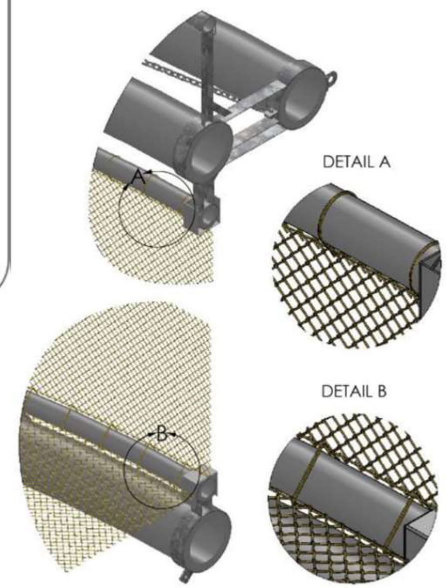
Potential aluminium applications

Several structural applications of other materials could be replaced by aluminium (suggestions from Delhaye, 2021)

- Floating rings around fish net
- Nets and wires
- Structural pipes and support pipes
- Brackets, connecting parts
- Platforms and handrails



Copper cage and wires (EcoSea)



Handrail, structural pipe, and support pipe, made of high density polyethylene (Akvagroup)

Sources: Delhaye et al. (2021), akvagroup.com, ecoseafarming.com

Bridges

Bridge superstructure: Deck and girders

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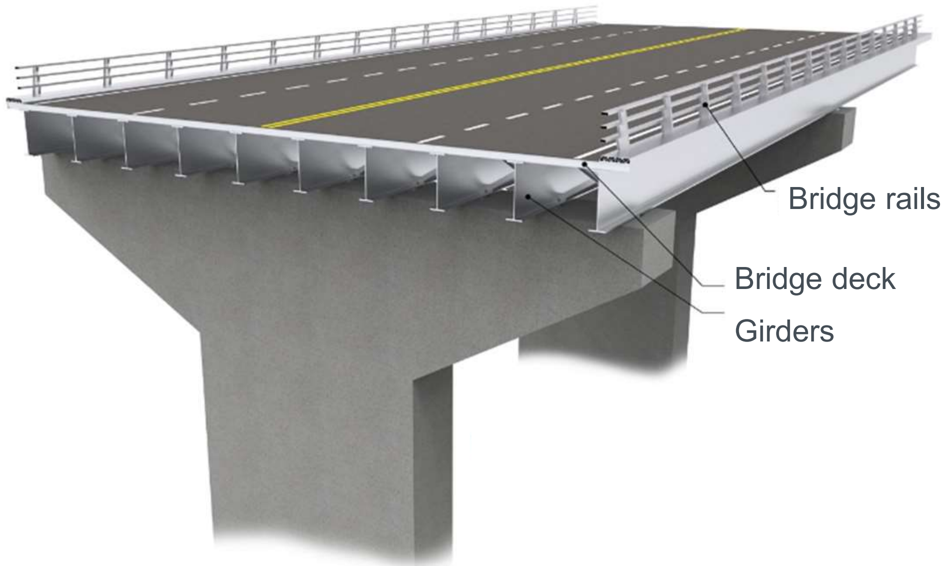
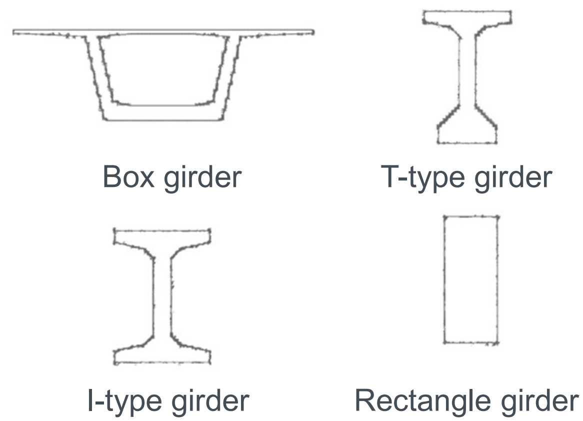


Cross section of a road bridge with aluminium deck and girders (MAADI Group). This is known as the superstructure of the bridge, and is the main use area of aluminium (as opposed to the supporting substructure like abutements and pillars)

The bridge deck/slab itself serves as the main load-carrying component for bridges up to 300-500 meters – longer bridges must have a box girder

Examples:



Source: MAADI Group (2012), NPRA (2020), Hydro (2021a).

Aluminium in bridge constructions

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Advantages

- Light aluminium superstructure can reduce dimensions required for supporting structure (towers, cables etc.)
- High corrosion resistance
- Standard, light-weight extruded parts allow for quick and easy installation
- Reduced maintenance and quick installation

Challenges

- Higher initial cost than steel and concrete
- Relatively low stiffness compared to steel
- Dimensions of available extrusion presses limits size of profiles used for decking.
- A well-established market, with design and functionality standards made for concrete and steel bridges.

Opportunities for aluminium in bridge construction

- New bridge constructions, all parts of the superstructure
- Aluminium decks for retrofitting existing bridges
- Rapid bridge replacement
- Deck widening or sidewalk/bike path addition

Source: MAADI Group (2012), NPRA (2020), Delhaye (2021)

Market potential of aluminium in Norwegian bridges

Summary of market analysis carried out by Hydro

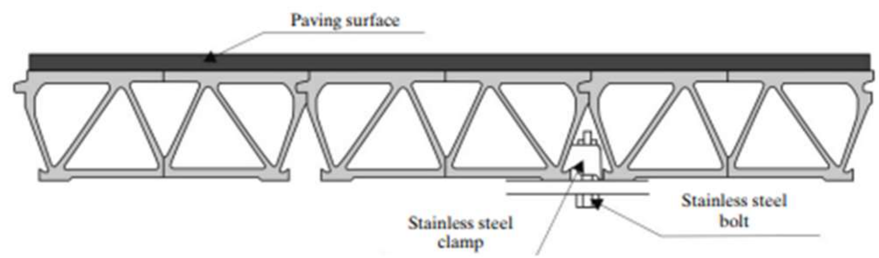
- There are over 14,000 bridges in Norway. Many of these are undergoing significant decay, with a maintenance backlog estimated at 14.4 billion NOK by the Norwegian Public Road Authority (NPRA).
- A typical design life of older bridges is 50 years. 22% of the bridge area on Norwegian national roads was more than 50 years old, and 50% was more than 40 years old.
- In the National Transport Plan (NTP) for 2018-2023, construction of 70 new bridges, and rehabilitation/maintenance of 155 existing bridges is prioritized.
- Public funds do not yet match the need for rehabilitation of bridges, but this will likely be given higher priority in the NTP after 2023.
- Maintenance is prioritized on longer bridge spans, as these are the most expensive to replace, while the decay on shorter bridges continues and will **eventually lead to more bridges in need for replacement.**
- The **NPRA are looking at alternative materials** (including aluminium) from a cost-savings perspective
- The lack of established standards for, and familiarity with, aluminium within the industry is a major challenge. Close collaboration with decision makers in the NPRA, contractors, designers and engineers is needed.

Number of bridges in Norway by type

Source: Hydro (2021a)

Retrofitting bridges: Replacing decks

- Replacing concrete decks with aluminium plates
  - Reduces weight 50-90%
  - Increases capacity
  - Rehabilitiation of old bridges
  - Cost-competetive
- Rapid deck replacements are possible (down to 24 hours), reducing social costs of closures and detours.
- Increased durability due to corrosion resistance
- Challenges include fatigue verification of the finished deck system. The dimensions of extruded deck panels are limited by diameter of the extruder, typically around 5 meters.



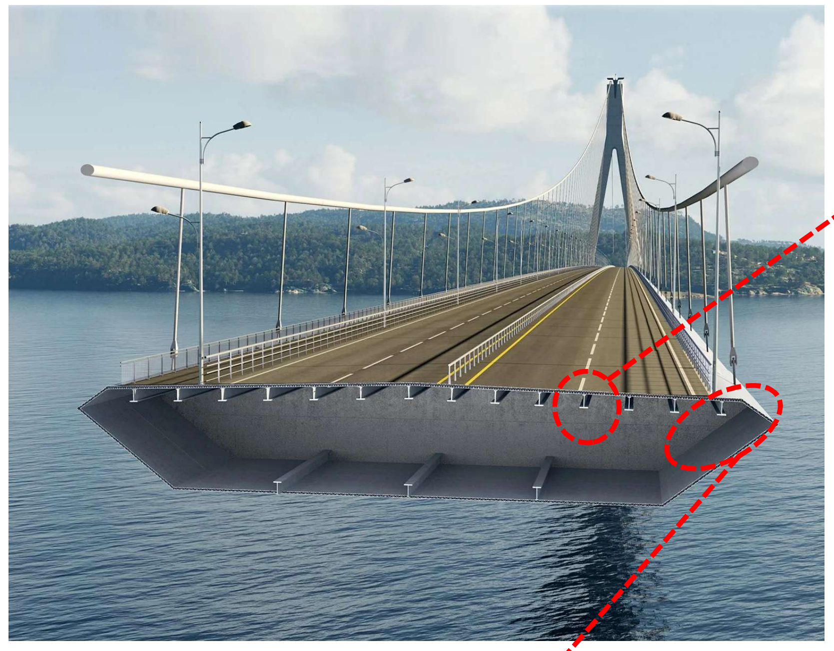
SAPA FRONT aluminium bridge deck product, which has been installed on at least 70 bridges in Sweden (Siwowski)

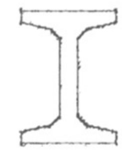
Source: MAADI group (2012), Siwowski (2006)

Large bridges: Langenuen concept

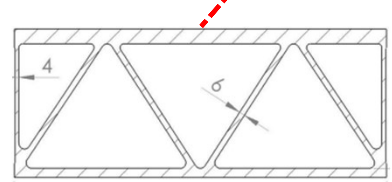
- An aluminium motorway suspension bridge concept for the E39 road.
  - Longest Al-bridge in the world, 1250 m span
  - 8-10 thousand tons Al
  - Concept meets all criteria, including design, stability, fatigue, stress levels and serviceability deflections with a lifetime in excess of 100 years

- Extruded profiles joined by FSW
- Similar in cost to steel





Longitudunal I-beams supporting deck-panel. Positioned underneath car wheels to reduce stress



Hollow «sandwich» profiles for sides, deck and bulkhead.

Source: NPRA (2020)

Secondary bridge components

- Secondary bridge components are frequently made of aluminium, due to light weight, corrosion resistance and extrudability
- Established standards and guidelines exist for design of light poles, sign supports, and bridge rail products
- Pedestrian or cycling lanes have lower load requirements, making light-weight aluminium sections especially competitive

Cross section of a road bridge with aluminium superstructure and secondary components (MAADI Group).

Source: MAADI group (2012)

Conclusion

Aluminium shows great potential in maritime settings where its light weight, corrosion resistance and functionality gives it advantages.

Some industries that are expected to grow with the green transition were identified as potential applications of aluminium.

Main challenge: Corrosion in joints between Al and other materials

Familiarity, standards and knowledge is needed!

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Industries that matter