Concrete Floating Substructures, Aberdeen, Oct 2024

Why make floaters with 3D printed concrete ??

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COBOD

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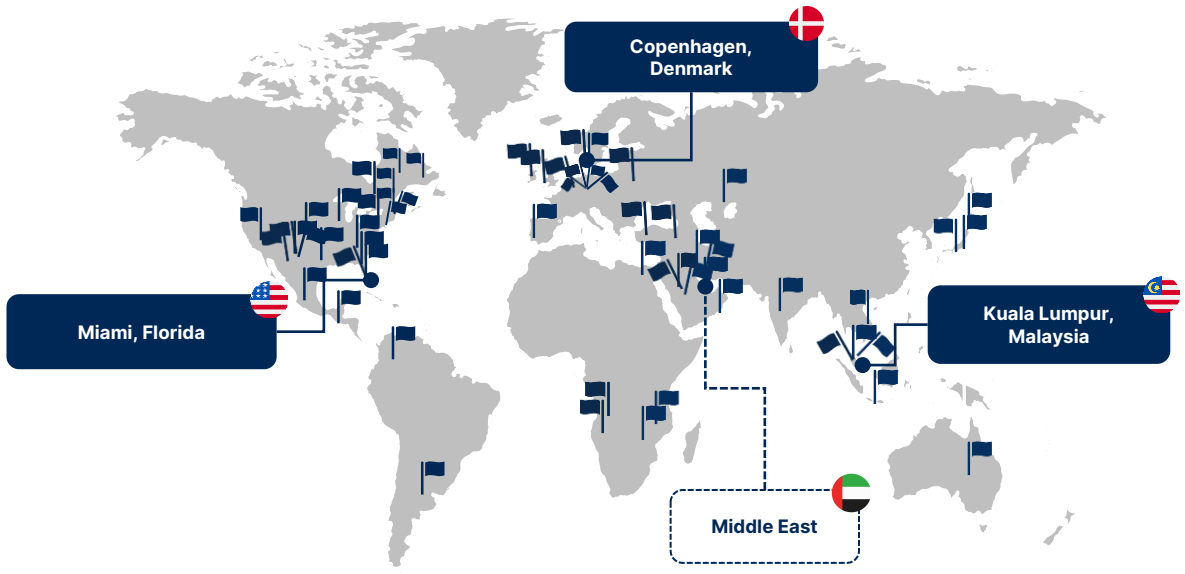
SHORTLY ABOUT COBOD

COBOD basics

Founded in 2018 in Copenhagen, Denmark and later opened regional competence centers and offices in Miami, FL and Kuala Lumpur, Malaysia. Middle-East underway.

Develops, manufactures, and sells 3D printers for the construction sector to developers, construction companies, concrete manufacturers, R&D institutions, etc. (we are not a construction company and only execute R&D projects ourself).



COBOD's global standing

The world's largest supplier of construction 3D printers with 80+ machines sold on 6 continents, more than all other suppliers – combined.

COBOD printers have been applied on +40% of all 3DCP construction sites globally, and are behind all important records for 3DCP projects like for the largest printed building, the tallest, the fasted printed building etc.

100+ employees from +25 different nationalities, incl. engineers, architects, manufacturers, etc.

Backed by our investors General Electric, CEMEX, Holcim, and PERI Group, in addition to the Danish majority shareholder (the founders).

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WHY DOES IT MAKE SENSE TO MAKE FLOATERS WITH CONCRETE NOT STEEL ?

Concrete is cheaper than steel

- Both in absolute prices (tons for tons) and
- In relative prices (given the amount needed to make a structure)

The supply situation for concrete is more attractive than for steel

- Concrete can be sourced in any location and souring skilled concrete workers is easier than sourcing skilled steal workers. Very difficult to source materials and enough skilled people with steel in remote locations, often used for floater deployment
- Cement and concrete prices fluctuates far less than steel prices

Concrete is more suitable material for offshore wind application than steel

- Concrete requires less maintenance than steel
- Concrete is less sensitive to fatigue than steel
- Concrete does not wear & tear to the same degree as steel (less corrosion risk)

Concrete can be shaped into creating any form desired

- As concrete is a fluid material initially it can be given any design or form given the right tools

REINFORCED CONCRETE IS CHEAPER THAN STEAL BOTH IN ABOSOLUTE AND RELATIVE TERMS

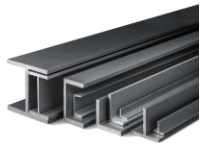
15 MW STEEL FLOATER EXAMPLE

Unit price per tons, EUR

Relative amount needed for structural applications, tons

Total materials price, EUR

Steel



€2.500

4.000

€10.000.000

X/20

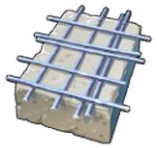
Price of reinforced concrete typically is 1/20 (5%) of the steel price

5X

A concrete sturcture typically requires 5 times more material than the same structure made in steel

-75%

Reinforced concrete



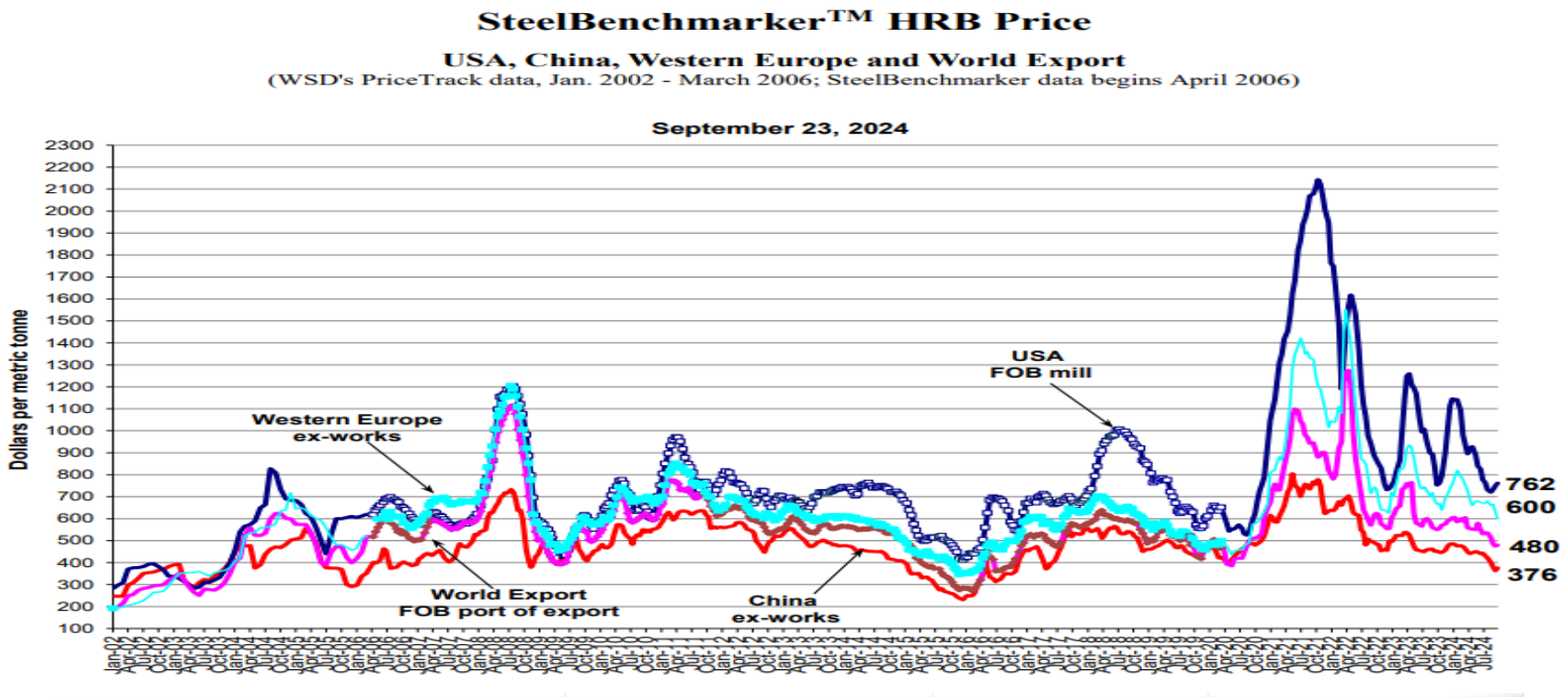
€125
200 (high strength)

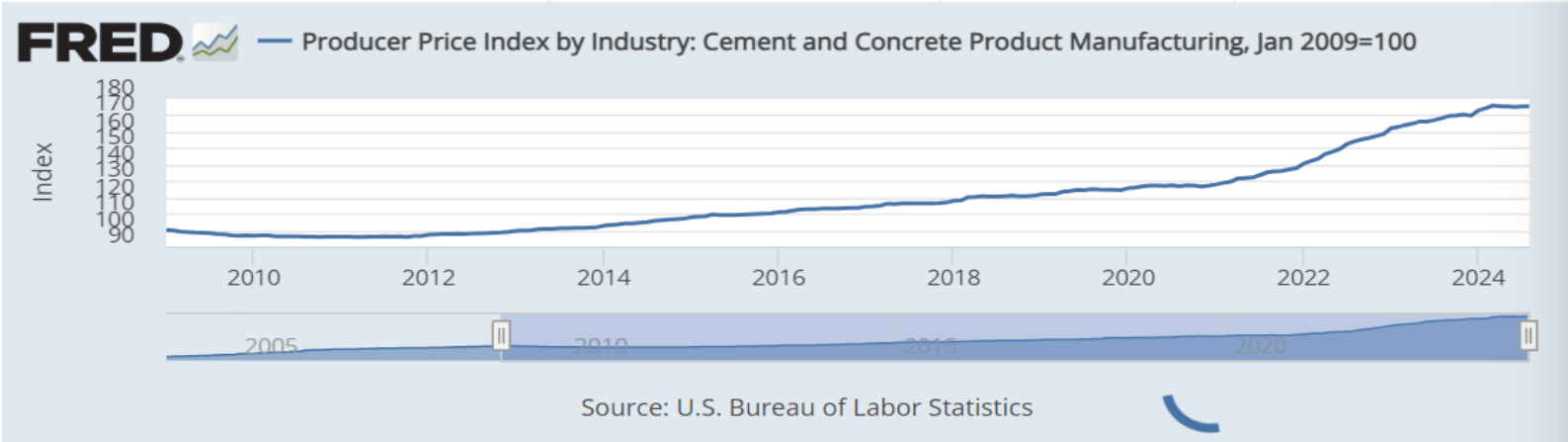
20.000

€2.500.000
(4.000.000 high strength)

Source: COBOD study (2023)

STEEL PRICES FLUCTUATING MUCH MORE THAN CEMENT/CONCRETE DAMAGING PREDICTABILITY





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WHY USE THE 3D PRINTING TECHNOLOGY FOR THE CONCRETING

➢3D printing is faster, a.o. because no formwork is needed

- For most on site casting, the formwork is what takes 80% of the time of the concreting job
- Multiple 3D printers can be used on same structure to speed up execution

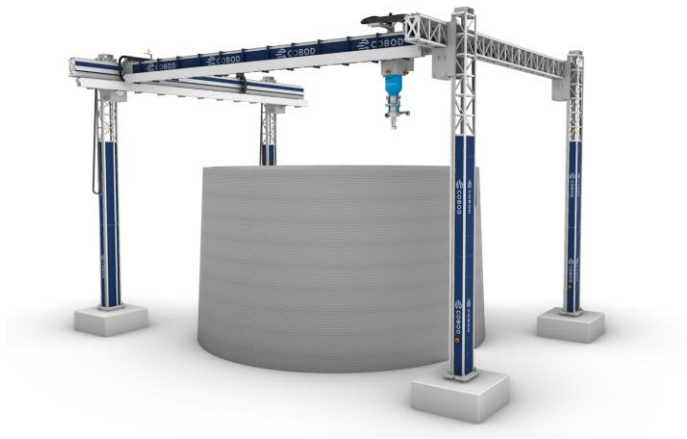
➢3D printing is less costly due to lower manning

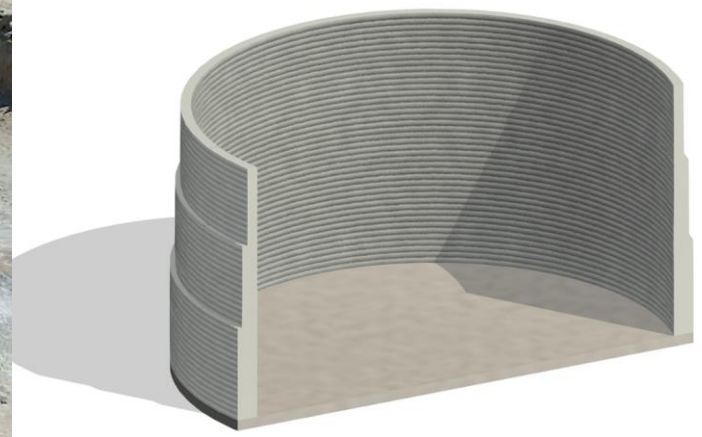
- A 3D printing crew of 4-6 people can make the same as 10,15, 20 or even more concrete workers
- On top is the savings in labor due to no need of formwork activities

➢Conventional concreting methods have limitations whereby excess materials are used

- Only limited complex molds can be made with formwork (or precast), including slip forming
- Hereby the geometry that provides the best support to the structural integrity is often excluded
- 3D printing comes with form freedom, such that designs that provide the geometry with the biggest support to the structural integrity can be made leading to a lower need for concrete and reinforcement

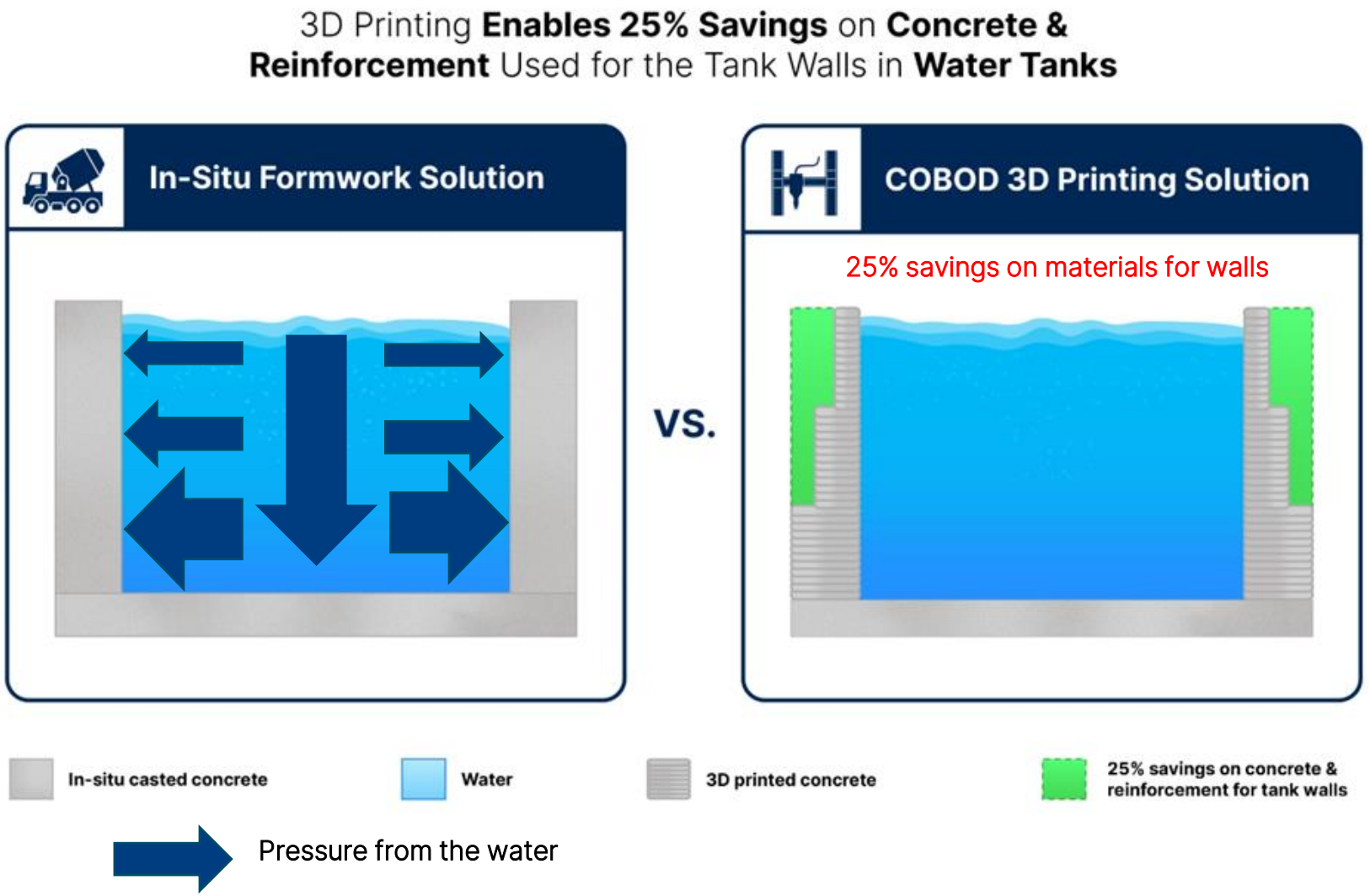
3D PRINTING CAN MAKE THE GEOMETRY WITH THE MAXIMAL SUPPORT TO THE STRUCTURAL INTEGRITY, WHEREBY MATERIALS ARE SAVED (LIQUID TANKS CASE)





2 chicken drinking water tanks, 4,5m tall and 7m diameter. Kuwait.

3D PRINTING CAN MAKE THE GEOMETRY WITH THE MAXIMAL SUPPORT TO THE STRUCTURAL INTEGRITY, WHEREBY MATERIALS ARE SAVED (LIQUID TANKS CASE)



Logic

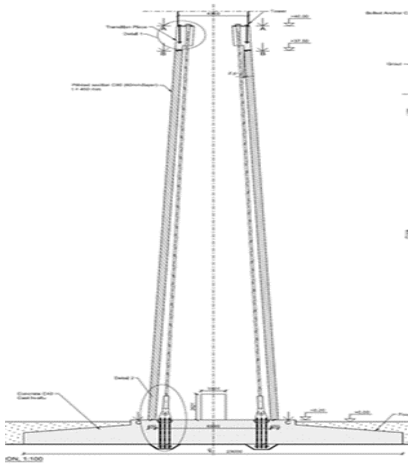
As the pressure from the water is decreasing with height, it makes no sense to make the walls with the same thickness all the way up.

With in-situ formwork it is not possible to variate the wall thickness, but with 3D construction printing technology it is.

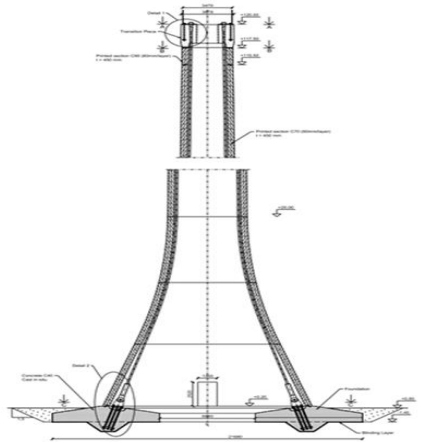
The tanks were reinforced by 3D printing concrete, **which contained (0,95%) macro fibers and no hard reinforcement.**.

3D PRINTING CAN MAKE THE GEOMETRY WITH THE MAXIMAL SUPPORT TO THE STRUCTURAL INTEGRITY, WHEREBY MATERIALS ARE SAVED (TRUMPET SHAPE VERSUS CONICAL)

Traditional cone-shaped design



3DCP wider trumpet-shape



40% saving on materials for foundation

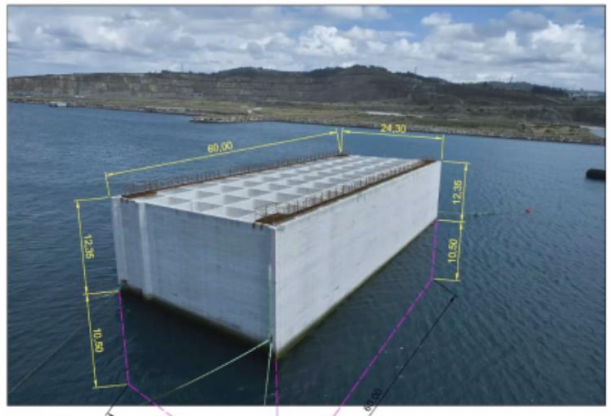
Logic

Wide diameter means that the foundation can be made as a strip foundation instead of being massive, **leading to a 40% saving in the amount of concrete and reinforcement used for the foundation.**

The trumpet shape cannot be made with precast and in situ casting soluions, **as the mold would be too complex**.

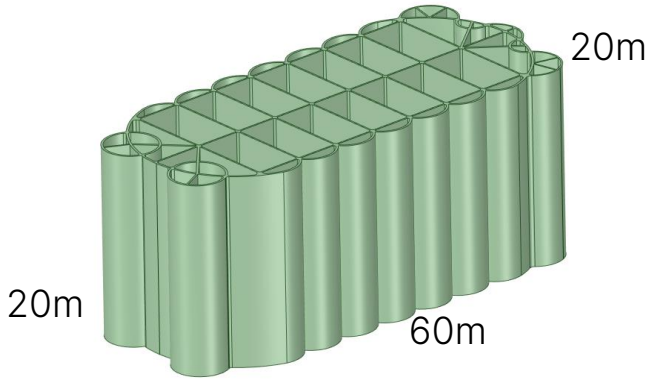
3D PRINTING CAN MAKE THE GEOMETRY WITH THE MAXIMAL SUPPORT TO THE STRUCTURAL INTEGRITY, WHEREBY MATERIALS ARE SAVED (CAISSONS CASE)

Traditional form work design (Acciona)

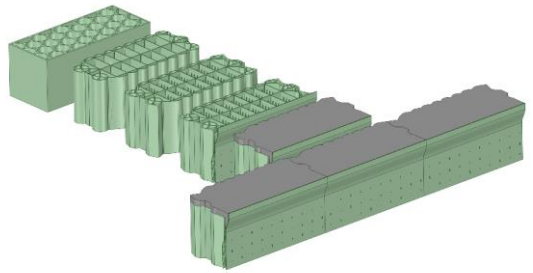


7.700 m3

3D printed caisson (COBOD)



3.600 m3 – 53% reduction



Description

Caissons (under water foundations), also called **box caissons**, are typically made with straight exterior sides and square boxes inside.

The caissons are mainly exposed to forces from the water from the outside.

The straight walls does not provide optimal support from the geometry leading to the need for **thick walls and many support walls when using formwork.**

By printing the walls **round** on the exterior side and thereby **provide maximum structural support from the geometry**, the thickness of the walls and the need for support walls can be dramatically reduced, leading to a **53% savings in amount of concrete and reinforcement used**.
By 3D printing the caissons it is also possible to cerate holes, carves out and other features **to improve marine life**.

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WHAT IS THE PRESENT STATUS AND WHAT IS NEXT

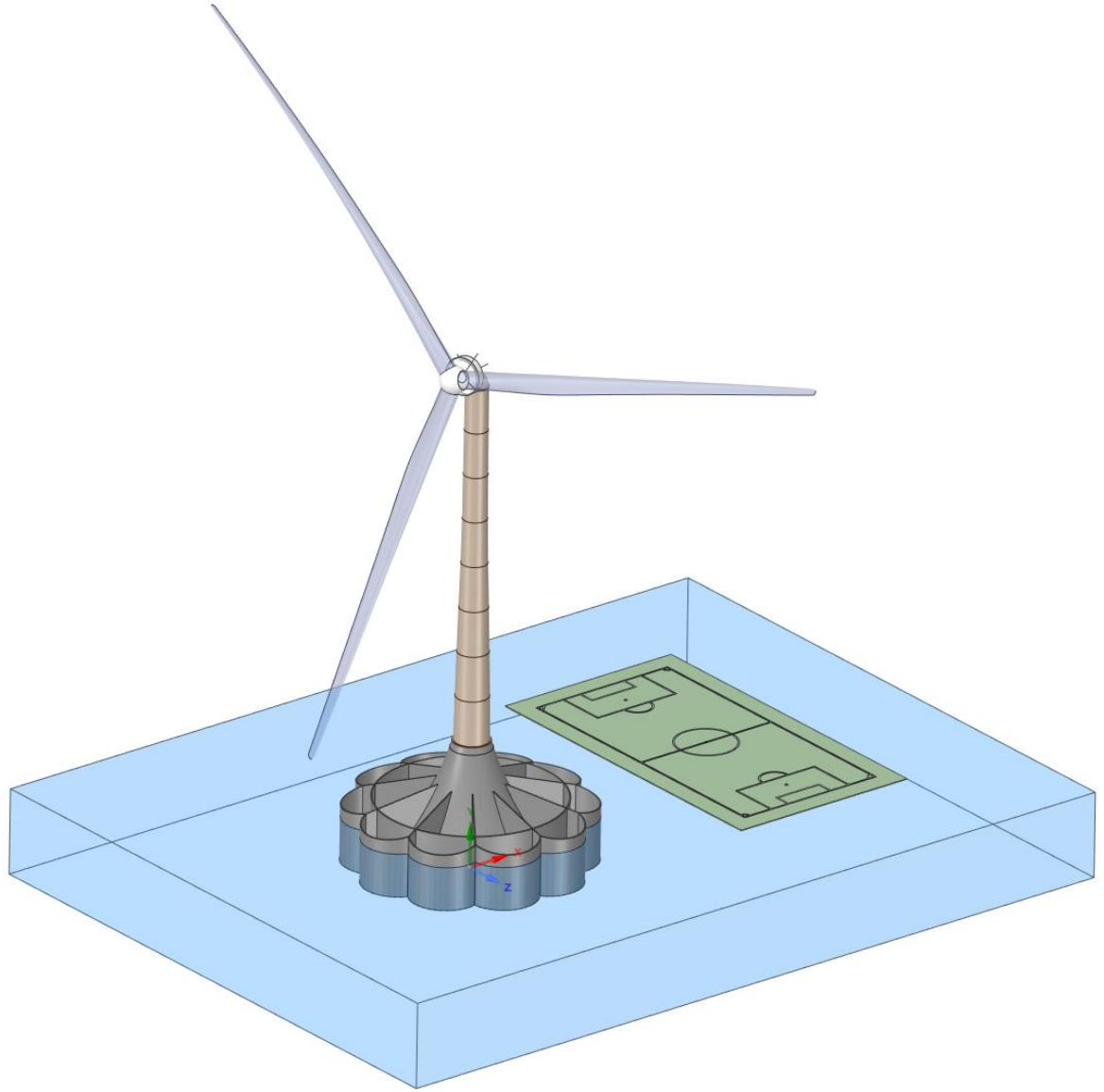
3D printing status relevant for floating wind

- Printing with real concrete (8 mm) since 2020, hose size 50mm.
- Promising trials with 16mm particle size in 2024, hose size 75mm. Final solution to be validated.
- Printable high strength concrete recipe developed (70 and 90 Mpa)
- Concrete can be made in local batch plant or delivered by RMC truck
- Steel fibers 20-80 kg per m3 can be included in the concrete materials. X-raying concrete samples to determine alignment of fibers. Nozzles to be optimised to align fibers in the print direction.
- Nozzles allowing printing of 50 cm width by 8 cm height made
- Output is presently up to 6 m3 pr hour. Targeting 15 m3 pr hour.
- Printers with 50m length and 30m width is under production. Can be 25m tall.

WHAT IS THE PRESENT STATUS AND WHAT IS NEXT

Proposal for floating wind solution

- Proposal made with DTU Wind and Ramboll
- Use “flower design” inspired by the caissons case for the base structure
- Use trumpet design inspired by the onshore wind case for the connector piece
- Put steel tower on top (and tendons inside for vertical reinforcement)
- Open to any suggestion for cooperation on other shapes



Concluding remarks:

The inherent limitations of the concrete construction methods of the past have meant that for decades less energy efficient, and materials and co2 inefficient constructions have been made.

With the new 3D construction printing ability, not only can we make entirely new solutions enabling constructions the industry has been wanting to do for years, but there are so many new possibilities for optimizing the geometry to enable that the geometry provides maximum support to the structural integrity, thereby limiting the need for using excessive materials and constructing much more sustainable !

Sustainable construction of wind energy solutions for the future through 3D construction printing!

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