Subaquatic 3D printer for building a tunnel

Aveiro - Innovative Design

Team - ECT Sub23:

André Clérigo, Cláudio Asensio, Edgar Sousa, Hugo Domingos

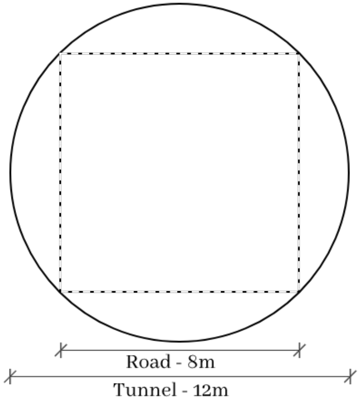
TOC

Introduction

In this presentation, we will explore the dream of Högafflel and Fysse to connect Gothenburg, Sweden, and Frederikshavn, Denmark through an underwater tunnel. Our objective is to develop a 3D printer that can build a sustainable underwater tunnel for road connection between these two cities.

Tunnel Specifications

The tunnel as a road width of 8 meters and maximum vehicle height of 5 meters and must be capable of operating at a depth of 150 meters. With that said the diameter of our tunnel will be 12 meters. Since the deepest point of Kattegat is 109 meters there are other 31 meters of soil, using a safety factor of 2 we determine that the tunnel must maximum load of 265 tons per linear meter.



$$d = \lceil \sqrt{(8^2 + 8^2)} \rceil$$
$$= 12 \text{ meters}$$

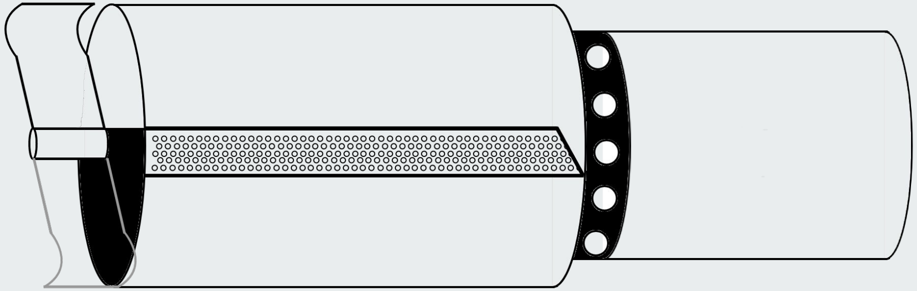
- Diameter: 12m, Area: 113.1 m^2
- Concrete strength: 50 MPa
- Soil pressure: 0,558 MPa, Water pressure: 1,069 MPa
- Total pressure: 1,627 MPa
- Safety factor: 2
- Max Load: ~268 tons/linear meter

Tunnel Specifications

The 3D printing process involves the layer-by-layer deposition of concrete and reinforcement materials. To ensure structural stability, we will continuously monitor and test the strength and quality of the concrete. Given the rough calculations done previously we determined that the thickness of concrete should be around 1,5 meters.

- Max Load: 268 tons/linear meter
- Safety factor: 2
- Factored Load: 5196 kN/m
- Max Shear Force: 2598 kN/m
- Max Bending Moment: 7794 kNm/m
- Concrete strength: 50 MPa, Reinforcement: 2%
- Permissible stress: 0,45 MPa
- Estimated Thickness: ~1,5 m

3D Printer Design



The design is a combination of a Tunnel Boring Machine and a 3D printing extruder. It is composed of 2 cylinders, the drill and the extruder and the difference in diameter of these 2 dictates the thickness of the concrete wall.

The head collects the debris and pans the usable materials to create the concrete directly (usable on the bottom and unusable on the top).

The unusable material will be pushed to the tail which is opened and deposit the material to later be used as road pavement and the other material will be mixed with additional elements to create concrete that will be pumped to the extruder chamber.

The displacement of the tube is based on a Pump-Dry-and-Push mechanism.

Material

Used for prototype

- Cardboard
- Hot Glue
- Foam board
- Duck tape
- Play Doh
- Syringe
- PVC tube
- Steel hooks
- String

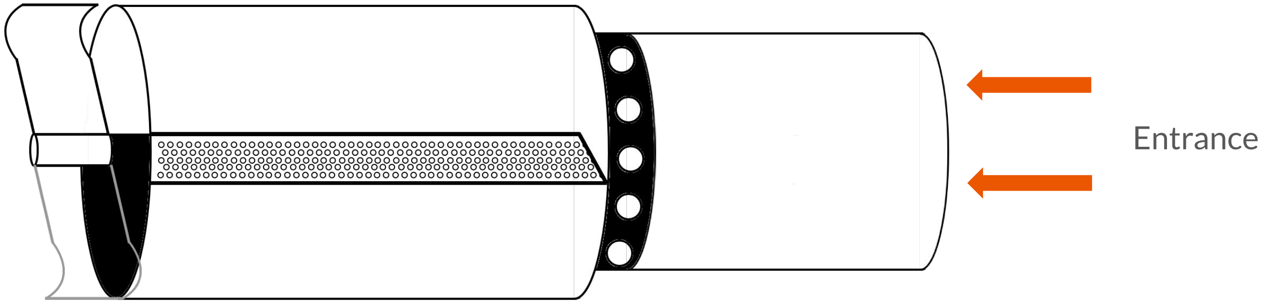
Envisioned for final product

- Recycled steel for the drill shovel
- Recycled aluminum for the structure
- Biodegradable lubricants for the drill's moving parts
- Recycled plastic for non-structural components such as control panels, handles, and protective covers.
- Recycled rubber for components like seals and vibration dampers

Maintenance and Repair

For maintenance and repair of the extrude holes we have an entrance that is located in the back of our drilling system, this enables the workers to fix any issues with the extrude holes (material that is stuck).

To replace the material that will be used by the drill and cannot be extracted by the drilling of the soil we can also use the back entrance to insert the material needed.



Environmental and Economic Considerations

Since our design envisions a tunnel that is underwater and under the seabed the disturbance in the wild aquatic life is minimal to none, the only ecosystem that will be disturbed in the underground bug life.

By using the drilled soil to create the concrete, using the unwanted material to create the ground for the road pavement and by having a displacement of the tube based on a Pump-Dry-and-Push mechanism there is a lot of cutted corners in terms of costs of operation and materials for the structure.

On top of that we also use reused material for the whole drilling structure which will reduce the environmental impact.

Scalability and Transportability

Our design is adaptable for different working conditions, with a modular approach for varying tunnel depths, if a tunnel requires a bigger or shorter thickness of concrete the only thing we have to do is to change the diameter of the second cylinder module. The disassemblable components and transport system (hooks) ensure that the 3D printer is easy to move from one location to another.

The human interaction is minimal because the printer only needs maintenance when the material to create the concrete finishes.

Conclusion

We have presented an innovative and sustainable solution for underwater tunnel construction successfully that meets the objectives and sub-objectives for connecting Denmark and Sweden. Besides the objectives of this challenge some potential benefits of this project include improved regional connectivity, economic growth, and cultural exchange between the two countries.

References

https://upload.wikimedia.org/wikipedia/commons/8/88/2014-06-30_7356x4904_chicago_tbm.jpg

https://www.sciencedirect.com/topics/engineering/underwater-concrete

https://www.structuralguide.com/underwater-concrete/

https://en.wikipedia.org/wiki/Channel_Tunnel#:~:text=The%20tunnel%20consists%20of%20three,diameter%20service%20tunnel%20in%20between

https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/mindmap_es.html