hyperTunnel press kit – technical overview

hyperTunnel develops completely new way to build, repair, enlarge and monitor underground construction

Tunnels are 3D-printed in the ground using robots, making building underground faster, cheaper, safer, more environmentally-friendly and with less project risk than current methods.

“We’ve brought together extraordinary technology breakthroughs from a wide range of industries and integrated them with proven methods to create a radical new method. This approach is enabling us to rethink how new underground space is planned, designed, constructed, operated, and maintained.” Steve Jordan, co-CEO, hyperTunnel.

The approach to building underground has barely changed in 130 years. Though the machines deployed for surveying, constructing and excavating tunnels have evolved and improved, methods remain fundamentally the same as they were in Victorian times. Complexity, cost and project risk have remained stubbornly high, as has carbon footprint. In this emerging era of digital transformation and technology transfer, hyperTunnel is initiating a revolution.

hyperTunnel has devised a new smart, scalable system for the construction, repair, enlargement and maintenance of tunnels and underground structures. Fit for the 21st century, the patented hyperTunnel method combines proven construction techniques from other industries with innovative digital technologies.

The hyperTunnel method at-a-glance

Whereas the conventional method is to dig a hole then build the tunnel, hyperTunnel first builds the tunnel, then digs the hole. The structure is constructed in the ground before the tunnel (or another underground asset) is excavated.

Another significant break from convention is that the hyperTunnel method does not create the hole by pushing through the ground with a cylindrical boring machine or drill-and-blast. Instead, hyperTunnel 3D-prints the structure inside the ground, working to a digital twin created using completely new levels of data generated by hyperTunnel’s digital ground surveying techniques.

Using horizontal directional drilling (HDD), a series of construction bore pipes are drilled in the geology to form the perimeter of the structure. Then the shell is created by sending semi-autonomous robots through these bores to deploy a chamber-cutting and filling tool called hyperCast. Casts formed in situ in the chambers join to form segments of the shell, and the segments meet up with each other to form the complete shell. The permanent lining is formed by the bots in an additive manufacturing process similar to 3D printing.

After the geology within the shell is disrupted, spoil is removed with a remote-controlled excavator. A continuous concrete layer can then be sprayed onto the shell and the construction completed, if required, with custom linings. Secondary bore pipes are used to house monitoring technologies which improve long-term maintenance and safety.

hyperTunnel's radical but practical system will make underground construction easier, quicker, safer for personnel, less expensive, less financially risky, and more sustainable. It radically improves how existing tunnels are enlarged, strengthened, repaired, maintained and monitored. And because the system is flexible, modular and fully automated, any underground construction company can quickly commission, deploy and integrate hyperTunnel into a new project, anywhere in the world.

Phase 1: Preparation – with HDD and a digital twin

"To make the radical hyperTunnel method possible requires absolute precision backed up by a level of knowledge of the geology that simply hasn't been available before in underground construction. It's why building information modelling and digital twinning are at the very heart of the method and the digital twin dictates everything," says Director of Engineering, Patrick Lane-Nott.

Traditionally, to acquire a detailed understanding of the geology, information is limited to what's available from geological mapping (if any exists) and by dropping vertical boreholes along the planned tunnel path up to 500 metres apart. Because geology can change over such a distance, this method forms an incomplete picture, putting the project at risk of unanticipated difficulties and delays during construction.

With the hyperTunnel method, investigations during this preparation phase are much more thorough. Using technology proven in the oil and gas industry, core geology samples are taken along the entire tunnel path, providing, for the first time in tunnelling, a complete picture. This is made possible by horizontal directional drilling (HDD) index bores at the centre of the tunnel. There are typically three index bores, though the precise number depends on the geology and the diameter of the tunnel. These bores are lined with High-Density Polyethylene (HDPE) pipe, approximately 280 mm in outer diameter, to maintain their integrity and create a clean working space.

The core samples are supplemented by standard information sources such as the geological map and any existing bore hole data. Additional data is gathered by running a proprietary 3D ground-penetrating radar (GPR) system along the bores.

GPR data is expected to have significantly better resolution and reliability than traditional techniques because of hyperTunnel's methods of collection, meshing, and antenna design. Resolution is increased by accurate and finely spaced sampling with either step frequency or multiple pulsed frequencies. To further enhance visualisation, seismic, tomographic and thermal imagery data can also be meshed together.

The result is a uniquely detailed insight into the ground conditions that will be encountered, including geology changes or features such as fissures, voids, or water.

These multiple layers of information are incorporated in a fully parameterized 3D model – a digital twin – of the tunnel and the geology immediately surrounding it, supplemented by building information modelling (BIM). Using virtual reality (VR) and augmented reality (AR) technology, it is possible to take a virtual walk through the digital twin on a computer screen to examine key features in the tunnel environment.

The reliance on digital twinning to define and guide every step in the tunnel's construction, though innovative in this context, is a discipline well understood in Formula 1 motorsport.

"Creating an F1 car's digital twin entails bringing together numerous digital twins, each representing a discrete section of the vehicle, such as the engine, chassis and bodywork, and each usually developed by a different department or supplier. The processes necessary to ensure flawless coordination between these various parties are transferable to construction, so that the building, tunnel or structure's digital twin can be formed seamlessly, avoiding the oversights and mismatches which too often waste time and money on site," explains Patrick Lane-Nott.

The digital twin is also used in the preparation phase to customise the tunnel design. Using AI machine-learning techniques, the geology of every millimetre of the underground path is matched exactly to the chemistry that will best stabilise the structure.

The final step in the preparation phase is to define the tunnel profile. Now a series of HDD construction bores – typically about 24 to 40 of them – are drilled around the periphery to define the dimensions and temporary workspace for construction. These construction bores – guided with exceptionally high positional accuracy by the magnetic field from an electrified wire in the initial bore – can also be used to gather more geological information to add further detail to the dynamic digital twin.

The unprecedented accuracy of hyperTunnel's surveying and deployment methods is well-suited to dealing with a range of geologies along a tunnel's proposed path. This will be especially advantageous if, as predicted, the world's increasing need for more tunnels leads to more being constructed through challenging geologies or soft ground.

When all this is done, the index bore pipes are ready to serve as a grid or scaffold in the construction phase and to be populated by robots, called hyperBots.

Phase 2: Construction – with a hyperSwarm of hyperBots

For the construction phase, building the finished structure in the ground *before* excavation, hyperTunnel has again transferred methods from other industries. Semi-autonomous robots called hyperBots – as used, for example, in warehouse picking-and-packing, bridge-building and pipe maintenance and repair – are sent into the lined construction bores to perform a wide range of tasks including drilling, chamber-cutting, micro deep-mixing cement, and chamber-filling to form the shell. Each hyperBot can carry a 20-litre cartridge of industrial chemicals.

In this revolutionary method, the hyperBots carry in their payload bay a tool called hyperCast for the chamber-cutting and filling. First the hyperBots drill through the construction bore's skin into the surrounding geology to deploy a conduit called hyperDock. Then hyperCast sends a continuum-style robotic arm through the hyperDock to cut a chamber in the outer geology, removing any liquids or slurry from the chamber through a continuous loop back to the bot. Next, hyperCast casts a concrete block into the chamber, deploying chemistry appropriate to the local geology. These casts ultimately form the segments of the shell, and the segments form the complete structure.

By using hyperSwarm technology managed by standard industry software, hundreds or even thousands of hyperBots can work simultaneously at different locations, resulting in extremely high productivity. hyperBot technology gives almost complete freedom to position deployment points, radially and axially, through the bore wall and into the surrounding geology. The hyperBots are dispatched, monitored and coordinated according to a construction plan created by hyperTunnel Artificial Intelligence. This plan provides all the key construction data, such as material strength, chemical volume, and location.

Despite their versatility, the robots are not complex or costly, and are reusable from one project to the next. When the structural shell is complete, it is time for the untreated geology within the shell to be disrupted. As the first step in this process, the original index bores are reamed-out to facilitate a slump of the spoil. Then the spoil is disrupted by the technique best-suited to the geology and ground conditions. Disruption can be achieved by perforating guns, as used in the hydraulic fracturing industry; by targeted, shaped charges for hard ground; or by hydraulic or sonic fracturing. Disrupting the geology so effectively makes the next phase, excavation, easier.

Phase 3: Excavation – with the new dragline hyperShield

To break away and excavate the spoil from small underground structures and smaller tunnel enlargements, hyperTunnel uses a standard excavator. For larger projects, however, the company is developing a new dragline shield technology, called hyperShield, utilising techniques used in open-cast mining. This makes it possible to complete the excavation in one pass. The spoil is not dug or drilled, but gathered and removed, which is much easier and requires significantly less energy.

“Tunnellers see removing spoil from a tunnel as a problem, but if you are an ore miner, that spoil is your revenue stream. It made sense to go and talk to the mining and oil and gas industries and ask how they reduce cost and increase efficiency by getting it out of the ground as quickly as possible. That has inspired our methodology,” says hyperTunnel Co-CEO, Steve Jordan.

The hyperShield is pulled along the tunnel’s path by cables that run through the HDPE pipes previously used for constructing the shell. Using probes with cameras and LiDAR scanning systems as steering guides, hyperShield is controlled by operators located externally. This greatly reduces human risk. At no stage during preparation, construction, or excavation is it necessary for people to enter the potentially dangerous environment of the incomplete structure.

An array of tools mounted on the leading edge of the hyperShield cut the precise interior shape between the HDPE pipes, defining the tunnel profile and base dimensions. Loose debris is scooped up, channelled through the back of the hyperShield excavator, and removed by autonomous electric trucks cycling under the type of drop-box loader routinely used to fill wagons with ore or coal. Removed earth is recycled on site, reducing the time, costs, and environmental impacts involved in processing and transport.

The hyperShield can also prepare and incorporate systems for the installation of a secondary lining during the next phase, completion.

Notably, the hyperTunnel method itself reduces the amount of spoil that needs to be removed and because the spoil has not been chemically treated, it is in a much better state for recycling.

Phase 4: Completion – with a digital twin to simplify handover

This final phase entails the installation of tunnel linings, if required, and of equipment such as sensors to continuously monitor the tunnel for predictive maintenance.

Once the hyperShield has excavated the disrupted material, other machinery such as robotic sprayed concrete lining machines or slip formers can follow it through to install the type of secondary lining that meets the need of the application. Depending on the geology, the hyperTunnel method may provide the opportunity to use non-sacrificial bores for additional strengthening, for monitoring technologies (such as non-intrusive inspection with GPR), or for use by third-party services such as fibre optics.

Because a digital twin has been created, handover of the tunnel is simplified. The data gathered for the digital twin (logged using blockchain encryption) provides a ‘single truth’ database of construction details to enhance future asset maintenance and management.

The hyperTunnel method in summary

Phase 1 Preparation:

- Continuous **core sampling** of index bore for detailed geological data
- Patterned **directional boring** using HDD technology
- GPR facilitates visualisation of the geology interfaces and obstacles
- Development of **digital twin**
- **Virtual Reality** imagery and building information modelling (BIM)

Phase 2: Construction

- Structural preparation via **chemical injection** deployed by a **hyperSwarm** of **hyperBots**
- Post-injection **structural assessment** using complementary techniques such as GPR and core sampling
- Initial **‘slump’ creation** through index bore reaming
- Further **spoil disruption** using hydraulic and/or soundwave fracturing

Phase 3: Excavation

- Single-pass **dragline shield** technology maximises efficiency
- Safe **remote excavation** with no need for workforce in workspace
- **Spoil recycled** without need for reprocessing
- Option of simultaneous **sprayed concrete lining**

Phase 4: Completion

- Customised **lining** (if required)
- Digital twin facilitates sign-off
- Remaining bores useable for monitoring and predictive maintenance; third-party services; additional reinforcement for specific overburden

The hyperTunnel difference

The hyperTunnel method outlined has multiple advantages to underground construction contractors:

- Costs are greatly reduced throughout the process, from labour and consumables to the project cost gain of a shorter project duration.
- Construction design is more accurate and therefore less risky. Geological certainty provides full knowledge of the tunnel path.

- The hyperTunnel process can cope with all geologies and all kinds of specifications relating to e.g., watertightness or durability.
- It's safer – the tunnel is structurally sound before a human enters it.
- There is better control of ground movement compared to conventional tunnelling methods, without the need for costly preventative works.
- After construction, infrastructure can be used to carry state-of-the-art smart sensors that monitor its condition 24/7.
- There is a much lower environmental impact and CO2 footprint compared to conventional methods.
- The hyperTunnel method offers smaller work sites that can be accessed away from the confined space of a city centre.
- There is no need for road closures and no disruption to traffic.
- Spoil can be reused or removed far away from the city centre.
- It can be used in a number of different applications beyond new build and repair including slope stabilisation, dam fixing, hazardous waste containment and underpasses.

Environmental benefits

hyperTunnel's technique is much more sustainable than current methods because it:

- reduces energy consumption
- Reduces amount of concrete used
- reduces water consumption
- reduces air pollution
- reduces waste and uses raw materials more efficiently
- reduces impacts on protected and sensitive environments
- reduces disruption to local communities, by reducing the size of construction sites and removing the need for wide-load lorries to pass through, for example.

The hyperTunnel system also offers secondary environmental benefits because it:

- enables an affordable construction underground that can reduce journey times
- lengthens the lifecycle and improves the safety of existing infrastructure
- makes sustainable energy solutions such as tidal-range tunnels far more feasible
- can contribute to critical energy industries, such as nuclear.

Economic impacts

hyperTunnel-enabled underground construction projects can help grow economies by:

- Speeding up infrastructure development and driving down costs

– Providing new solutions for big national and local challenges
– Transforming how cities are designed and developed
– Creating jobs and investment in high-value skills training.

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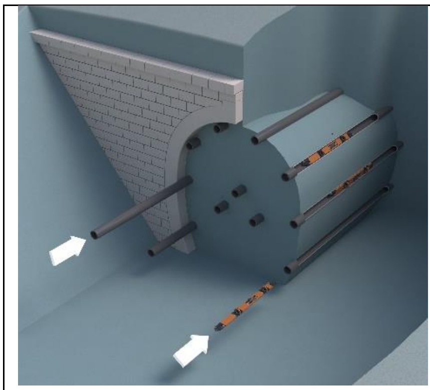
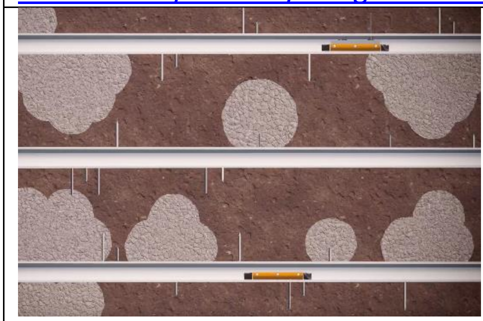
September 2022

Images

 https://hypertunnel.sharepoint.com/:i:/s/hTMediaMaterial/ESJ-1ELe1WFIhPmjLFhYd78BC-GJ_MWBT3yZ0nXnXyrhWg?e=adVk5h	The hyperTunnel method: rather than digging through the ground with a tunnel boring machine or using a traditional drill-and-blast technique, the hyperTunnel method uses a simple horizontal directional drilling (HDD) rig to install a network of HDPE pipes to provide access to the whole tunnel length so that a swarm of multi-function robots can 3D print the tunnel.
 https://hypertunnel.sharepoint.com/:i:/r/sites/hTMediaMaterial/Shared%20Documents/HyperTunnel%20Images/The%20hyperTunnel%20process/Stills%20from%20video_John%20Nix/Folder%20A/Screenshot%202022-02-14%20at%2014.45.23.png?csf=1&web=1&e=M62zxC	The hyperTunnel method: Swarms of hyperBots are sent into each construction bore to build the tunnel's structural shell, deploying an additive manufacturing process, which uses the same principle as 3D printing.
	

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 https://hypertunnel.sharepoint.com/:i:/s/hTMediaMaterial/ETqhrpGHdHJMhK7SWW80OgEBXOq7l8ALYHTomYqRrFrxQQ?e=UyerXv	Steve Jordan, co-Founder and co-CEO of hyperTunnel.
 https://hypertunnel.sharepoint.com/:i:/s/hTMediaMaterial/EVon3sYuqC1Cv3aqw01v4rIBXkHtvZFVMo78maS3hV6Qxw?e=EevXOj	Jeremy Hammond, co-Founder and co-CEO of hyperTunnel.
	Patrick Lane-Nott, Director of Engineering at hyperTunnel.

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