Frequently Asked Questions

Cost

What is the cost of a tunnel constructed using the hyperTunnel process compared to using a TBM?
For soft rock (e.g. clays, chalks and sandstone), costs are expected to be up to 50% less than a TBM constructed tunnel.

Programme

What is the construction time advantage of using hyperTunnel?
A key aspect of the hyperTunnel method is the use of multiple robots working in all the pipes (the grid) simultaneously. All the robots can pass each other so the supply of materials to a robot is not hindered by other robots. Even taking a conservative view on geology and the number of robots, a tunnel constructed using hyperTunnel would be finished before the TBM was launched.

What is a typical lead time for supply of the hyperTunnel robots?
The robots will be manufactured in the thousands and will be effectively "off the shelf" enabling near immediate mobilisation onto a project.

Embodied Carbon

What are the embodied carbon benefits of a tunnel constructed using this method compared to conventional tunnelling technology for example a TBM?
The following is a qualitative assessment identifying the key differentiators between hT and a TBM.

(i) Energy - the torque required to turn say, an 8m diameter cutting head is far greater than a multitude of low voltage battery driven bots which create the structure.

(ii) Cement – its usage can be reduced due to:

- Thinner tunnel linings as no handling stresses are required in design.
- Greater cement replacement as this form of in-situ construction can allow for longer curing times.

(iii) Geology - for certain materials e.g. chalk which are excavated by a TBM as a slurry, the level of treatment of the excavated material is far greater than for material excavated as part of the hT process given that no treatment is required and the material is extracted as 'natural'. Beneficial reuse is more practical and cheaper.

(iv) Worksite - for hT the tunnelling worksite is smaller leading to less land take and site preparation, fewer personnel travelling to and from site, and smaller site facilities, all of which lead to a lower environmental impact.

(v) All robots are reusable in other projects regardless of tunnel diameter.

Can recycled material be used in the HDPE pipes?
Yes, the pipe supplier has advised that recycled material can be used but the mechanical properties are inferior to a virgin plastic pipe. We are investigating the percentage of recycled material versus the desired mechanical properties of the pipe for our purposes.

Design and Assurance

Will there be a design exercise to determine the geometry, minimum thickness & strength range of the structure required to ensure stability with the appropriate factors of safety?
There will be a full structural design and material specification to meet the relevant codes and to deliver the client's requirements.

What process will be in place to assure the client and end-user that the design and construction meets its requirements?
The process will be no different than any QA scheme. Independent structural checking of the design, checking compliance with the client's requirements and a material testing regime.

Pipe placement

How are the 280mm pipes placed in the ground?
For long tunnels, we would use traditional methods and primarily Horizontal Directional Drilling (HDD) technology although we will bring development here too. For short tunnels (~100m), alternative drilling technologies would be used to install the pipes, for example ODEX.

Please expand on the HDD process. How do you prevent the HDPE liner collapsing when pulling through?
The installation approach is as follows: a pilot hole is drilled to an exit pit, then back-reamed to a larger diameter while pulling in the HDPE pipe. A failure or damage to the product pipe during HDD installation can occur due to an improper ream bore hole, poor workmanship, and improper HDD design. The best approach to avoid pipe failures is to establish conservative design criteria and follow the pipe manufacturer's guidelines.

How do you gain access to carry out HDD at the tunnel elevation - do you need a portal or shaft?
No, a portal or shaft is not essential to launch the HDD. The planned HDD path could start further back and be directionally steered to reach the desired alignment.

Given the use of HDD, what is the maximum tunnel length considered suitable for the proposed method?
1000 metres would be a safe maximum distance to start with, building up to 5000 metres.

What is the minimum radius achievable with the HDD?
On a short HDD, up to 400 metres in length, a midi rig could be used, and the minimum bending radius would be 150 metres. On longer drills using a maxi rig, the minimum bending radius would be 500 metres.

Can you justify the use of HDPE pipe as liner in HDD pilot hole given that abrasion resistance of HDPE liner is low?
The industry currently uses HDPE liners installed in oversized holes. For example, buried cable ducts from off-shore wind turbines to on-shore. When pulling through the hole, the drilling fluid acts as a lubricant thereby reducing, if not eliminating, contact between the pipe and the inner surface of the bore.

With what level of accuracy can you position the pipes?
The initial index pipe will be steered using an online gyroscopic guidance system. Subsequent pipes can be installed using a wire guided magnetic system using the index bore as the guide. The installed pipe should not deviate from a notional design line by more than a pipe diameter.

What rate of progress might you expect to achieve with each hole in different geologies?
Without stopping to perform any down-hole logging, we expect to progress at around 30 metres per hour through sands and clays. Progress through bedrock varies with the compressive strength of the rock (between 4m and 10 metres per hour). At present, we do not recommend drilling through gravel, man-made ground, or geology containing cobbles or boulders.

Geophysical survey and data compilation

What are your main geophysical survey tools?
The principal tools are Ground Penetrating Radar (GPR) and seismic tomography both of which are being developed to operate from robots operating within a 280mm pipe.

How is the output from the survey tools used?
The survey data is feed into a model or Digital Twin (DT). The DT is initially derived from a CAD/BIM model built with basic site survey and any existing bore hole data. The DT leverages all standard data sources and enhances the geological

map with layers of ground specific geological, seismic and GPR data. When these datasets are combined it provides a unique and detailed insight into the ground conditions that will be encountered during the tunnel construction.

Will GPR data be acquired from multiple modules simultaneously and meshed?
The GPR data from each bore will be meshed together following scanning. As the GPR design is for a combined TX/RX antenna, multiple modules will not run simultaneously in the same geology to avoid interference.

What is the capability of the GPR in terms of identifying details within the geology? Can it identify fissures and voids within and boundaries between geologies?
Resolution is increased by accurate and finely spaced sampling with either step frequency or multiple pulsed frequencies. This is coupled with 3D investigation of geology using multiple viewpoints. Like any GPR system, the physical limitations of radar exist, and as such will not be able to identify variation of grain size within a section of cohesive geology but will be able to identify variation in media size and faults within the geology.

Will GPR data be calibrated against the ground characteristics? If so, how and to what level can this be achieved and relied upon? Is any verification possible?
The GPR can be calibrated in two ways. Firstly, by using the geological core data to identify the ground characteristics immediately surrounding the pipe and secondly by comparing travel times that identify other bores and calibrating this using the known position of each bore. This becomes particularly reliable when the bore locations can be identified from multiple scans, and the dielectric properties can be back calculated by mapping the identified locations to the known locations.

How is seismic tomography being used?
Seismic tomography is being developed as a cross hole survey device which will supplement the data being acquired by the GPR system.

Construction Robots and Geology

There appears to be more than one approach to treating the ground. In what circumstances are these different techniques use?
The approaches are (i) ground treatment prior to excavation, (ii) building the structure in-situ (hyperCast) followed by excavation and (iii) general ground improvement.

All interventions are carried out by specialised robots working from within the placed pipes.

An example of (i) would be a tunnel cross passage where the hT method provides a temporary support system in geology which is not suitable for method (ii).

In method (ii) which we refer to as hyperCast, the construction of the final tunnel structure is carried out in the ground using a robot with a drilling arm which extends from the construction pipe into the ground.

For (iii), general ground improvement would be appropriate for water stopping around tunnels by accessing the geology from pipes placed into the ground and grouting the cavities.

How does hyperCast work?
A robotic arm with a cutting tool spinning at high-speed mills out a small chamber in the geology. The ground is treated and removed possibly as a slurry. The resulting chamber is filled with fibre reinforced concrete. The tunnel is effective built by additive manufacturing.

How is the hT method applied to the range of geologies (below) assuming that the permanent tunnel lining is being built?

Silty sands:
We would apply pre-treatment to the ground to consolidate it and then use hyperCast to form the permanent structure.

Soft clays:
We would use hyperCast to form the permanent structure.

Combinations of stiff clays and saturated fine sands, or soft clays and silts:
We would apply pre-treatment to the ground to consolidate it and then use hyperCast to form the permanent structure.

Soft Rock with fissures and voids which may be an unfavourable discontinuity geometry and clay filled fractures:
We would treat it using (iii) to fill discontinuities & fissures and then use hyperCast to form the permanent structure.

Soft Rock with larger voids/discontinuities/karst (or large voids around existing tunnels, bottoms of poorly backfilled shafts originally used for construction):
We would treat it using (iii) to fill the voids with grout then use hyperCast to form the permanent structure.

What monitoring and feedback will be available during operations and how will it be used to control the process as it proceeds?
We will maintain surveillance of the operations in real time and update the DT continuously.

How is water prevented from entering the HDPE pipe when the drill bit or robotic arm penetrates the pipe wall?
The drill bit and shaft (hyperBit) is drilled through the pipe and self-taps into the HDPE wall thereby sealing the construction bore from ingress of water or other material. Deployment of chemistry into the geology is through the hyperBit which incorporates a one-way valve and outlet hole(s).

For hyperCast, the principle is the same. The robotic arm moves through a seal in the pipe wall.

Is there a risk of blow outs when chemistry is deployed in areas with low cover?
The hT method delivers low-pressure and low volumes so areas with low cover or adjacent services will not be impacted.

Is one robot size applicable to all types of ground, the only change being the type of chemical adopted to create the structure from inside the plastic 280 mm pipes?
Yes, all the robots are built to fit the 280mm pipe. The one significant variable in the process is the volume and type of material deployed. All the equipment is the same for each project. The equipment used for excavation will depend on the scale of the project.

Can you provide details in case of breakdown of bots how to handle substitution/recovery and continuity of works?
The robots are inexpensive (100s of USD each) so replacement is easy and relatively trivial in cost terms. There will be robots whose role is to recover broken down machines.

Can you provide more details with regards to logistics: batteries, material reload (chemical deployments)?
In principle, the deployment robots are serviced by robots that deliver replacement chemical cartridges. It is important to note that all the robots can pass each other within the pipe so that supply can be kept up with deployment progress.

Excavation

What plant do you use for excavation?
The choice of excavation plant will depend on the size of project. For small projects e.g. tunnel cross passages we would use small remote control breakers / excavators. For large diameter tunnels, we would use a bespoke piece of equipment based on the principles of drag-line buckets and using autonomous trucks to remove material as the tunnel is excavated.

Are the holes at the centre of the tunnel the same diameter of the peripheral HDD holes?
Initially yes. However, in the excavation phase these initial index bores will be reamed-out to a larger diameter to enable the collapse of the tunnel material.

How will the disruption of material be focused on the material to be excavated and not affect the treated ground or tunnel lining?
The level of intervention to disrupt the material e.g. by fracking will be designed to achieve the objective of no cracking of the structure already formed.

How will water ingress be addressed to allow the removal of tunnel material?
The process of forming the tunnel structure will form a water seal around the tunnel from end to end. Any water within the future tunnel perimeter can drain through the initial index bores.

How does the system affect surface ground loss which is an important consideration in urban environments?
The approach is that all initial intrusions into the ground for installing the construction pipes, the bores are stabilised using drilling fluids and / or a casing. Removal of material for building the structure is carried quickly (possibly under pressure) and in small volumes. There will be some axial shortening of the tunnel lining when the tunnel is excavated and the lining supports the overburden.

In service

Has consideration been given to other potential uses of the construction bores in the operational phase of the tunnel?
If the bores remain after construction, then they could be used for dewatering, non-intrusive inspection by remote survey equipment and other condition monitoring during the operational lifetime of the tunnel as part of a structural health monitoring programme. The monitoring will be non-disruptive to operations.

In addition, there is an opportunity to use the redundant HDPE pipes embedded in the geology around the tunnel for installing pipework for ground source heat pumps. It is acknowledged that this application is geology dependent i.e. one with sufficient heat diffusion and recharging.