# TUNNELING BY TUNNEL BORING MACHINE




By

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1CR12CV057

Guided by:

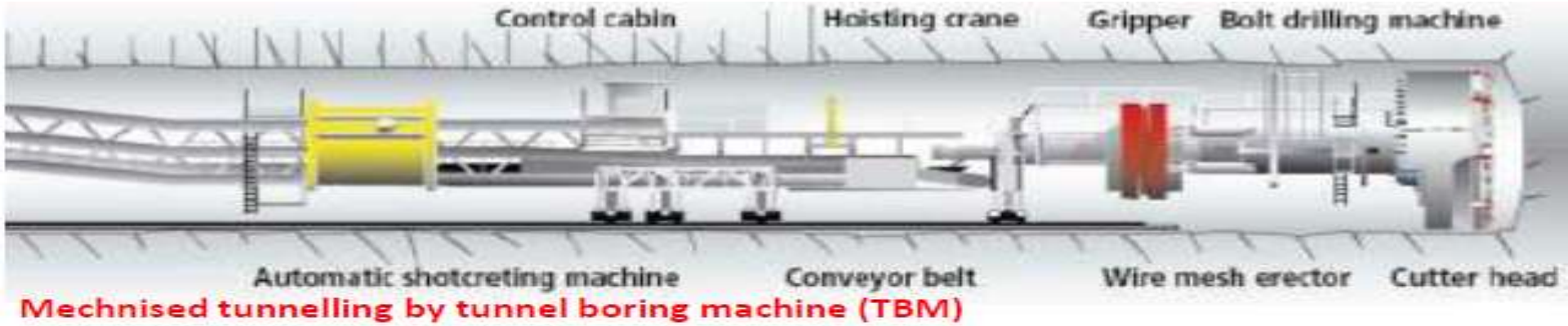
Vibha N. Dalawai

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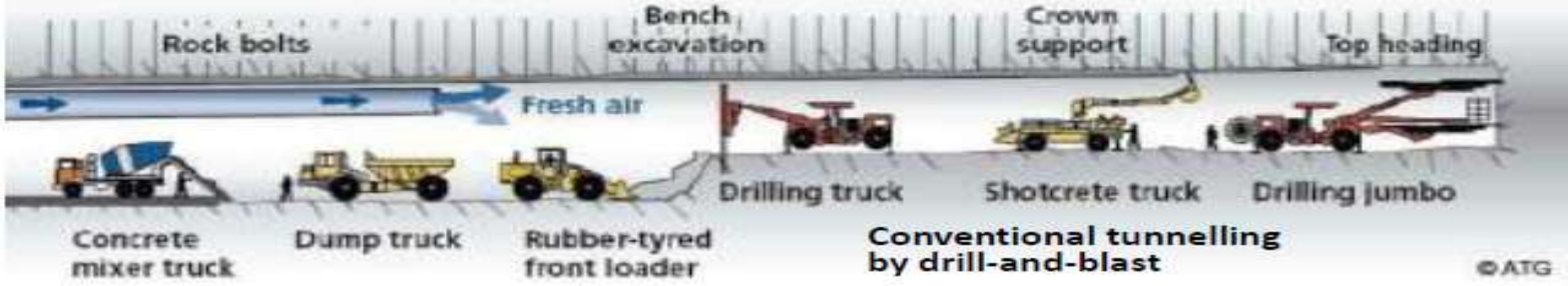

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# INTRODUCTION

- First tunneling shield by Sir Marc Isambard Brunel to excavate under the Thames in 1825.
- Actual boring machine built-in 1845 by Henri-Joseph Maus



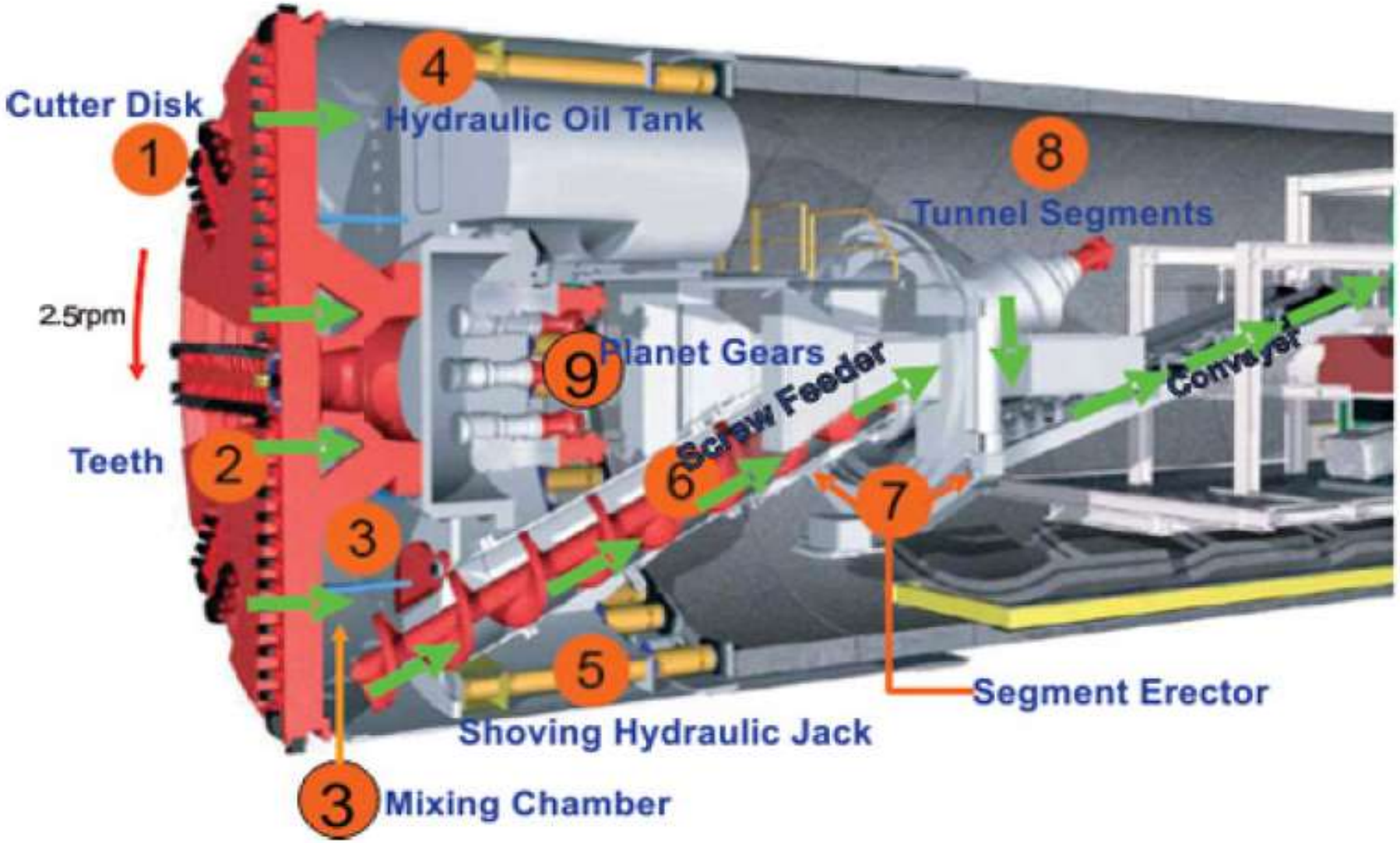

Mechnised tunnelling by tunnel boring machine (TBM)



# OBJECTIVES

- To give an understanding of what is a TBM.
- To build up an awareness of the wide variety of perils TBMs are exposed to.
- Role of civil engineers in this machine tunneling work.
- How we utilizes our geotechnical and survey knowledge.

# MAJOR COMPONENTS OF TBM



# TUNNEL LINING

- 5 segments and 1 key segment, each 1.2 and 1.5 m long and 275 mm thick.
- The segments were precast with M50 grade concrete at the casting yard



Segment Yard



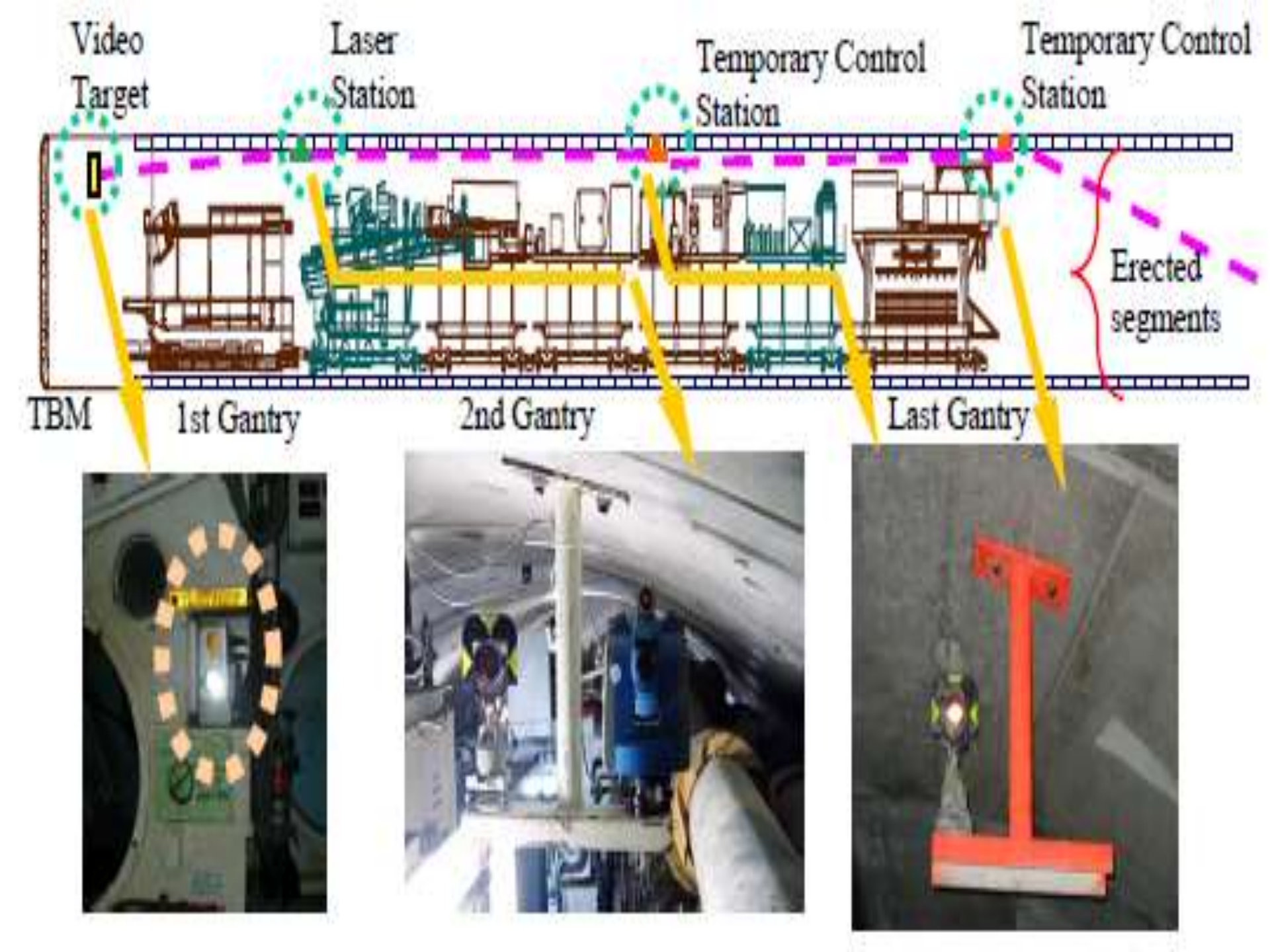
# SURVEYING

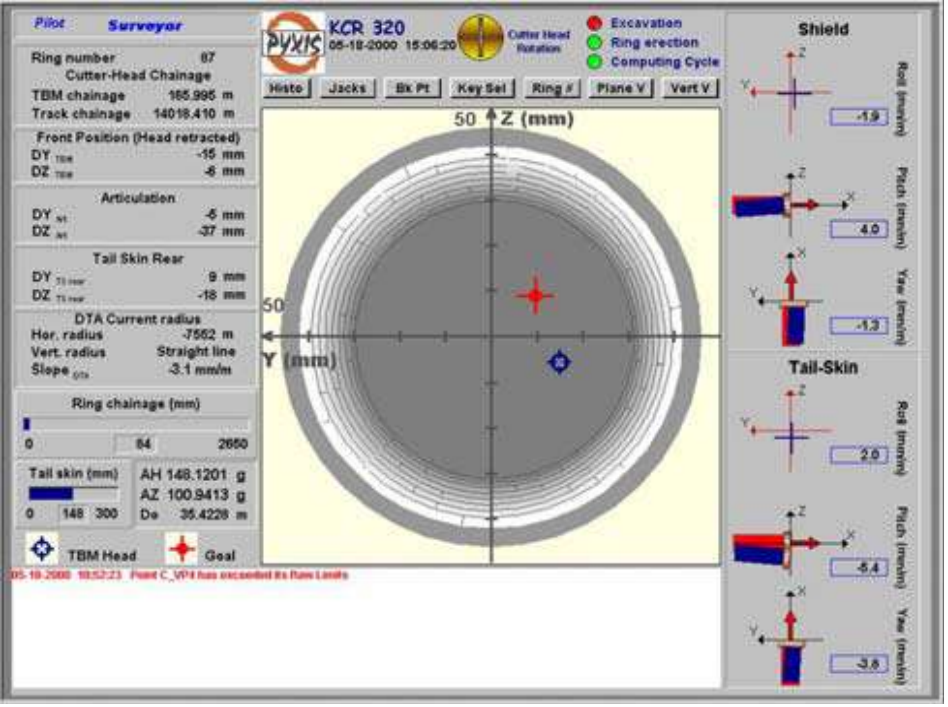
- After doing general survey i.e. identifying geographical extent of the construction work, reconnaissance survey, establishing new survey stations from known control stations.
- Computation of global coordinates of control stations are performed
- Secondary control station established for TBM launching shaft at surface & then transfer that to tunnel control station at underground level



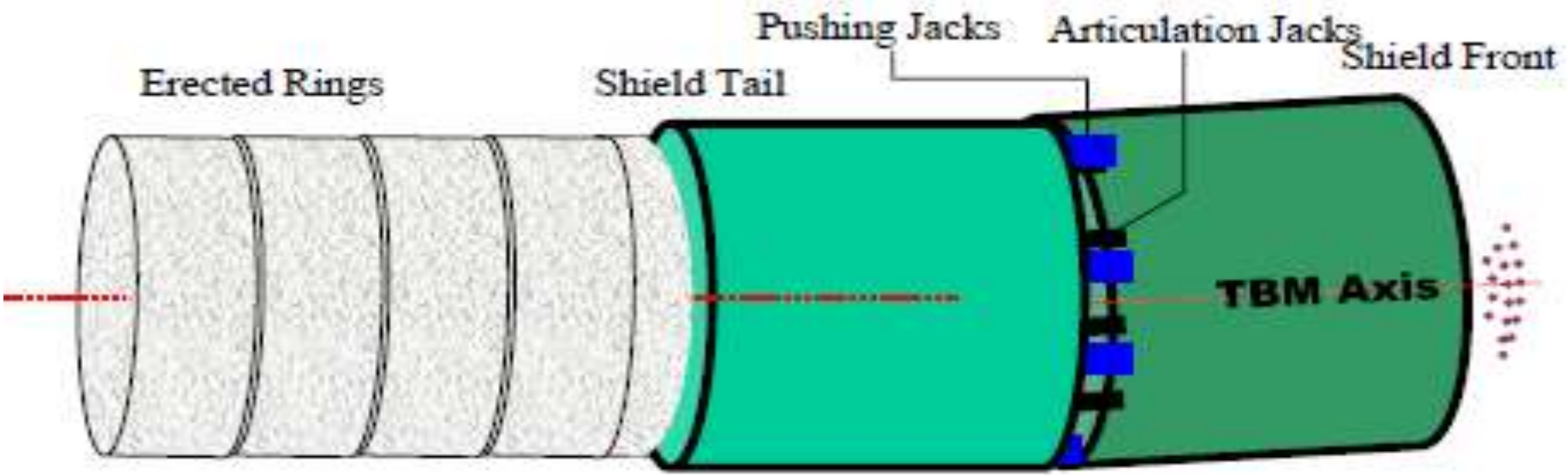

**Figure 7**
Transfer of control station at surface




Video Target
Laser Station
Temporary Control Station
Temporary Control Station
Erected segments
TBM
1st Gantry
2nd Gantry
Last Gantry


Pilot
Surveyor
Ring number 87
Cutter-Head Chainage
TBM chainage 165.995 m
Track chainage 14018.410 m
Front Position (Head retracted)
DY -15 mm
DZ -6 mm
Articulation
DY -5 mm
DZ -37 mm
Tail Skin Rear
DY 9 mm
DZ -18 mm
DTA Current radius
Hor. radius -7562 m
Vert. radius Straight line
Slope -3.1 mm/m
Ring chainage (mm)
0 84 2650
Tail skin (mm)
0 148 300
AH 148.1201 g
AZ 100.9413 g
De 35.4228 m
TBM Head
Goal
KCR 320
05-18-2000 15:06:20
Cutter Head Rotation
Excavation
Ring erection
Computing Cycle
Histo
Jacks
Bk Pt
Key Sel
Ring #
Plane V
Vert V
50 Z (mm)
50
Y (mm)
Shield
Roll (mm/m) -1.9
Pitch (mm/m) 4.0
Yaw (mm/m) -1.3
Tail-Skin
Roll (mm/m) 2.0
Pitch (mm/m) -5.4
Yaw (mm/m) -3.8




Pushing Jacks
Articulation Jacks
Shield Front
Erected Rings
Shield Tail
TBM Axis

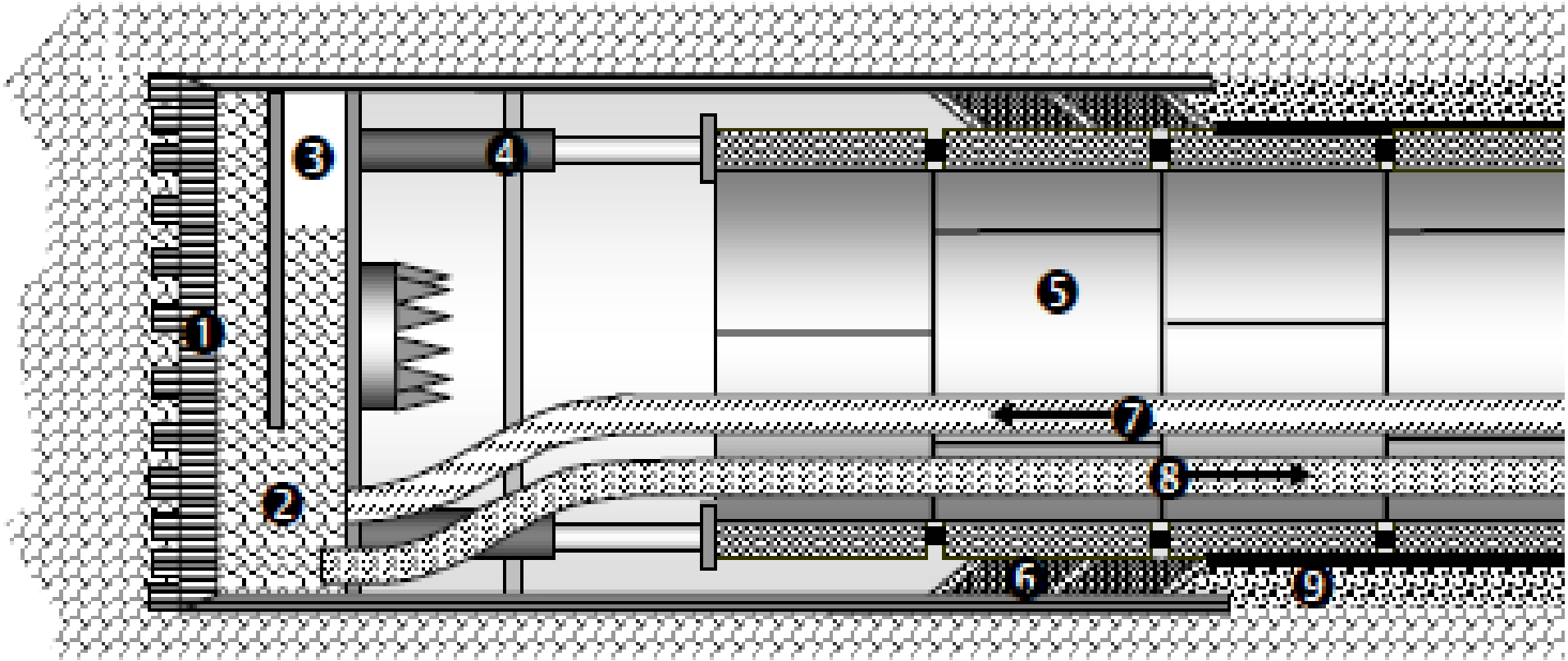
# GEOTECHNICAL CONSIDERATION

| *Soil characterisation* | *Rock characterisation* |
|---|---|
| - *soil density, wet and dry* | - *rock density* |
| - *water content* | - *petrography* |
| - *grain size distribution* | - *abrasiveness, content of quartz* |
| - *pore volume* | - *mineralogical analysis – where relevant* |
| - *abrasiveness (grain shape and hardness)* | - *elastic modulus and Poisson ratio* |
| - *Atterberg limits (when clay is present)* | - *cohesion* |
| - *mineralogical analysis – where relevant* | - *permeability* |
| - *elastic modulus and Poisson ratio* | - *angle of friction* |
| - *cohesion* | - *Unconfined compressive strength* |
| - *permeability* | - *Tensile splitting strength* |
| - *angle of friction* | - *triaxial strength* |
| - *undrained shear strength* | - *swelling capacity* |
| | - *schists / bedding* |
| | - *fissuring* |
| | - *Stability* |
| | - *RQD-value* |

**Rock-quality designation** (**RQD**) is a rough measure of the degree of jointing or fracture in a rock mass, measured as a percentage of the drill core in lengths of 10 cm or more. High-quality rock has an **RQD** of more than 75%, low quality of less than 50%.

# DIFFERENT TYPES OF TBM

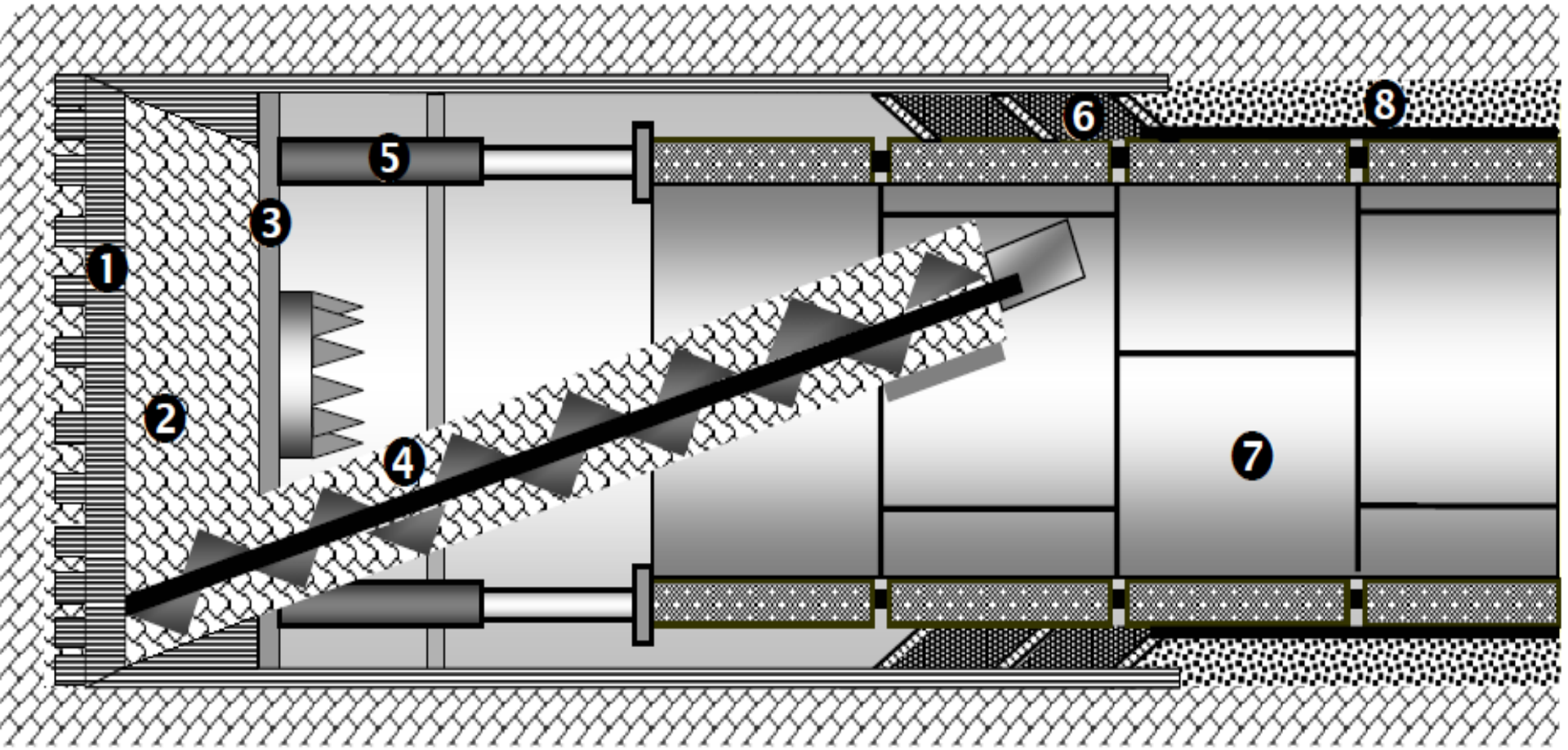
- 1. SLURRY SHIELD TBM



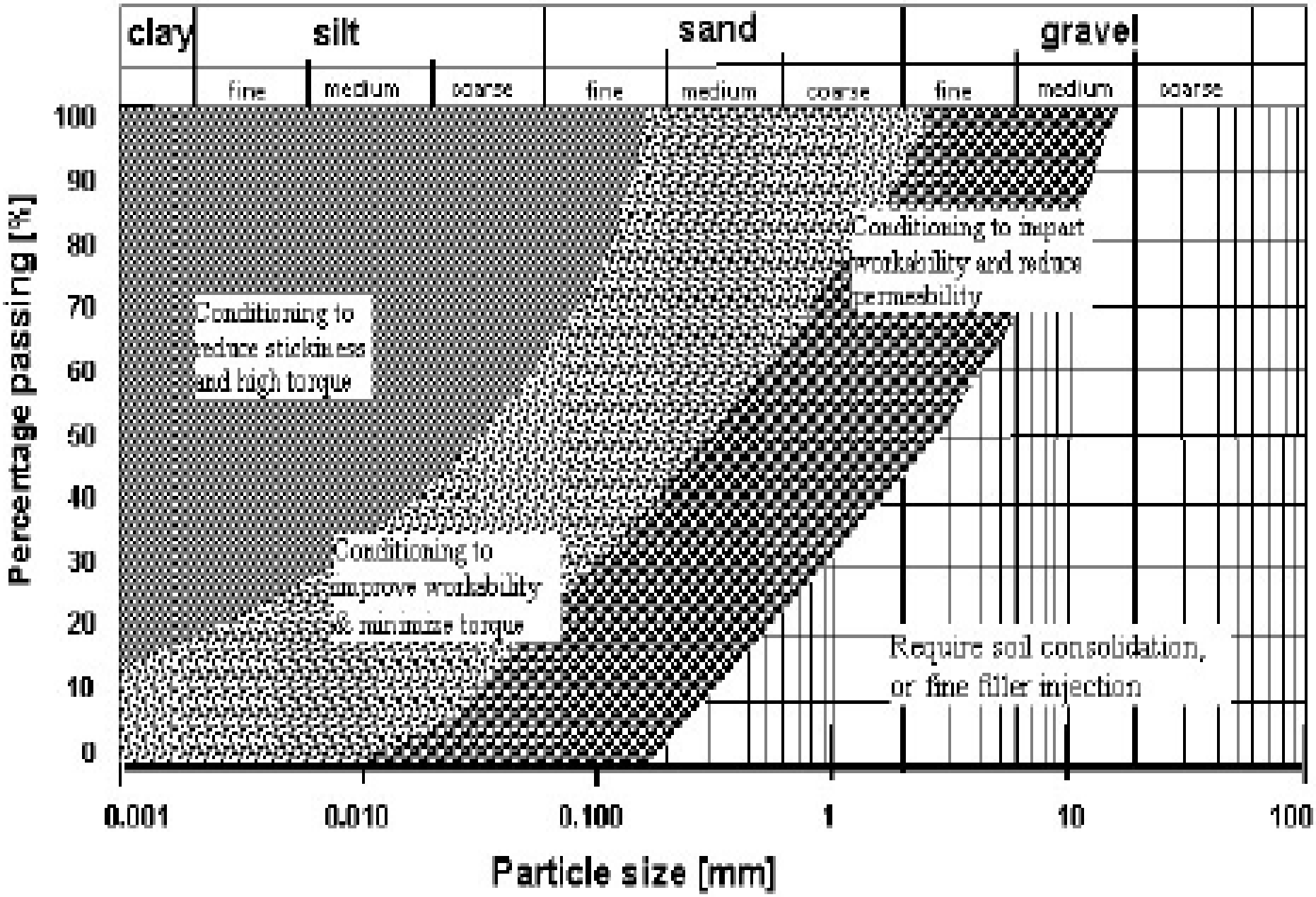
| Characteristic | units | Test method | Type of test |
|---|---|---|---|
| Density - $\rho$ | $kg/m^3$ | cylinder + scales | laboratory / site |
| Solids content | % | oven drying | laboratory |
| PH | - | test paper or meter | site |
| Marsh fluidity - $t_M$ | s | EN ISO 13500 | site |
| Plastic Viscosity - $\eta$ | Pa.s | EN ISO 13500 | laboratory – rarely measured |
| Yield value - $\tau$ | Pa | EN ISO 13500 | site |
| Filtrate water | $m^3$ | EN ISO 13500 | laboratory / site |

slurry test programmed will generally include the above parameters[ 2]

# 2. Earth pressure balance TBM



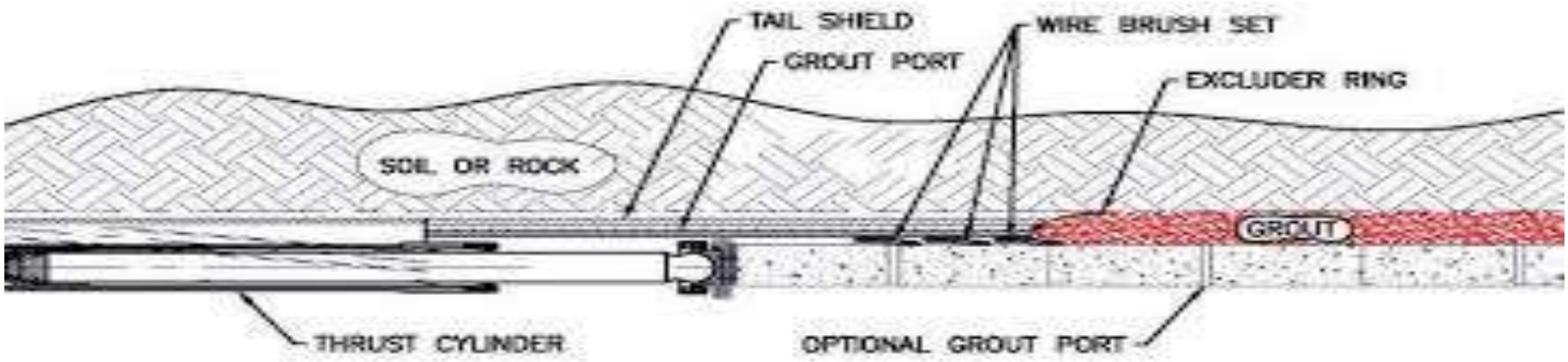

❶ Cutterhead
❷ Working Chamber
❸ Pressure Wall
❹ Screw conveyor
❺ Thrust Arm
❻ Tail sealant
❼ Segments
❽ Annulus Grout




indicates typical particle size distributions for the use of EPBM[ 3 ]

# ANNULUS GROUTS & MORTARS

- To prevent flotation and heave
- To prevent surface subsidence
- To prevent misalignment of the segment rings
- To bond the soil and segments into a single component



# THE TUNNEL BORING MACHINE

**What is a tunnel boring machine (TBM)?**

A tunnel boring machine (TBM) is like a giant drill, but one that builds as it drills.

The TBM arriving in Auckland in July is going to drill two holes, each big enough for a three lane motorway. It will first travel north from Owairaka to Waterview to dig one tunnel, then turn around at Waterview and begin its journey back to Owairaka.

**Why is the tunnel boring machine referred to as a TBM?**

Saying the words tunnel boring machine is a bit of a mouthful so we call it a TBM for short.

**Why do we need the TBM?**

By digging the tunnel and taking the motorway underground for 2.4 kilometres, we save the existing roads, parks, rivers, houses and businesses that are along the route.

It's a practical solution to easing traffic congestion and building new roads, though an extremely challenging one. The Waterview Connection is a Road of National Significance, meaning the benefits of the motorway go beyond the use of people in Auckland. All of New Zealand benefits as it will be a major road that is used to transport goods and services around the country.

WELL-CONNECTED ALLIANCE

If you want to learn more about New Zealand's 11 Roads of National Significance visit www.roadsofnationalsignificance.govt.nz




## HOW DOES IT WORK?

**The simple answer is that the TBM is like a giant drill and it will drill the two holes that will be the north and southbound tunnels.**

The front section of the TBM is called the shield. At the front of the shield is the cutting face. The cutting face is like a giant, round circular cheese grater.

The shield has two jobs. It drills through the ground to create a large hole which it then lines with concrete segments to form complete rings. These concrete segments are 2 metres wide and 450 millimetres thick.

So the TBM could also be called a TMM – a tunnel making machine because it not only digs the tunnel, it also lines the hole that it has dug with concrete segments and completes the process of making the tunnel.

TOP SPEED:
**8CM PER/MIN**

**How fast does it go?**

Depending on the ground strength the TBM can travel at a top speed of 8 centimetres a minute, but like any new engine – it is going to need to be broken in and gradually taken up to reach all its top speed. Eight centimetres a minute is also the top speed of a snail.

DRILL TO THE CENTRE OF THE EARTH:
**2655 YEARS**

**If our TBM was to keep straight down into the earth, how long would it take to reach the centre of the earth?**

It is going to take about a year for our TBM to travel 2.4 kilometres. This includes downtime while the machine is being maintained.

The centre of the earth is approximately 6371 kilometres down. If we take the TBM to be moving at the same speed that it will be travelling while it digs the Waterview tunnel, then it would take approximately 2655 years for the TBM to travel a distance to the centre of the earth.

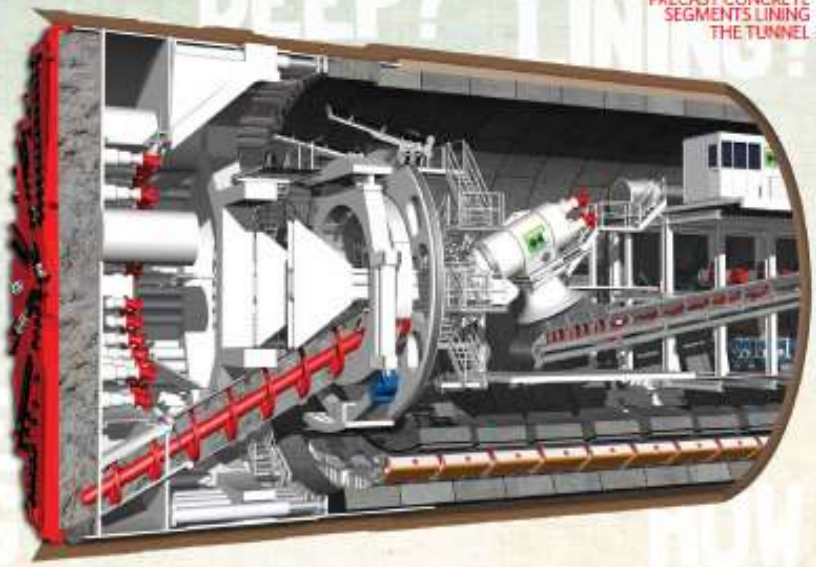
**INJECT FOAM**
INTO THE SOIL

**What happens if the cutting face gets stuck in the ground?**

This won't happen as a material that has the consistency of foam is injected into the soil through ports in from cutting head, along with water, to help turn the soil into a slurry which can then be more easily excavated.

**How deep underground does the tunnel go?**

The tunnels start in a maximum of 43 metres below ground at certain points of the TBM's journey. The TBM will travel beneath a layer of ice-cold(ish), hard volcanic rock, formed by the eruptions of a volcano in the region a long, long time ago.



**24,040**
PRECAST CONCRETE SEGMENTS LINING THE TUNNEL

**Where does the lining come from?**

A purpose built facility in East Tamaki will make the 2 metre wide segments. The steel segments are made by casting concrete in a reusable steel mould. Concrete is poured into the mould and then cured in the heat conditioners to ensure that it is strong. Curing concrete does not mean we heat it or what with it, but we make it stronger than it would be if it was just cured. We take the utmost care to properly cure the concrete so that it achieves the required strength and hardness.

The moulds are then used over and over again to cast the rest of the segments and ensures that all the rings will be of the exact size.

There will be 24,040 concrete segments in total used to line the tunnel.

**16**

**How many people do you need to work the machine?**

At any one time there will be about 16 people working in the TBM. It will house a crew – comprised of the TBM pilot in the machine's operating cabin.

**800,000M³**
OF SOIL TO WIRI QUARRY

**What happens to the soil that is removed from the tunnel?**

The soil that has been ground away by the TBM is referred to as 'spoil' and it is taken out of the tunnel on a conveyor belt to a special building made just for it.

It sits in this building for 10 hours while the water that was sprayed into the ground along with the foam, slowly comes out of the spoil. Once it has 'de-watered' the spoil is then trucked to a quarry in Wiri, South Auckland.

So many trips makes that the TBM progresses, that in the width of one tunnel ring, the TBM will remove approximately 330 cubic metres of spoil.

When the TBM has done its job, it will have excavated 800,000 cubic metres of ground. That is enough to fill 320 Olympic sized pools.

AS HEAVY AS
**5.25** AIRBUS A380s

**How big is the machine?**

The machine has a diameter of 14.4 metres, which is larger than the trunk of Sam Manuela, New Zealand's oldest and biggest Kauri tree, and about the same height as a four storey building.

The TBM is the size of a Waterview mall on the largest tunnel boring machine (TBM) ever used in Australasia.

The TBM will weigh about 3,000 tonnes, that is equal to 3,000,000 kilograms or 750 elephants. Or the same as 5 and a quarter Airbus A380s.

The total length of the TBM is 87.7 metres, almost as long as a rugby field.

## DID YOU KNOW?

**Who is building it?**

The New Zealand Transport Agency has commissioned the Well Connected Alliance to build the Waterview Connection. The Well Connected Alliance is a group of leading engineering companies that are working closely together on their seven teams.

**Why must the TBM have a female name?**

This tradition dates back to Saint Barbara who is the patron saint of the artillerymen, armourers, military engineers, gunsmiths, miners and anyone else who worked with explosives and explosives.

Tunnellers, as underground workers, look to Saint Barbara for protection and as a result machines that work underground are always given female names.

**How much does it cost?**

The machine cost $100 million dollars to build and transport to New Zealand. It has been built by Herrenknecht, a leader in manufacturing this type of machine, in their plant in Guangzhou, China and arrived here China in July 2010.

**When will it start work?**

It starts work in October, after it has been assembled and tested in Waterview (NOT!). It will take three months to put it together after it arrives in Auckland, having been broken down into parts to be transported to Auckland.

**Will people be able to cross over from one side of the tunnel to the other?**

People who work in the tunnel will be able to use one of the emergency cross passages that will connect the north and south bound Waterview tunnels.

**What is it made of?**

The machine is made from a number of materials but the main ones are:

- the cutting head is made from a special kind of steel that has been made to handle extreme pressure
- the wiring and motor cables are all made of copper and weigh about 70 tonnes alone
- gears, driving the computer systems and programmable controllers
- concrete bolts are made from layered rubber with steel wire reinforcing for strength.

**If it isn't the largest machine of its kind, what is the largest in the world?**

The TBM that is going to be used in Waterview is the fifth largest in the world with a diameter of 14.40 metres. The largest machine is from 2012 has a diameter of 17.526 metres and is currently in Seattle becoming more beneath the ground.

THE BIGGEST: **17.526m**
JOHN BIGGEST: **14.46m**

# REFERENCES


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Thank
you