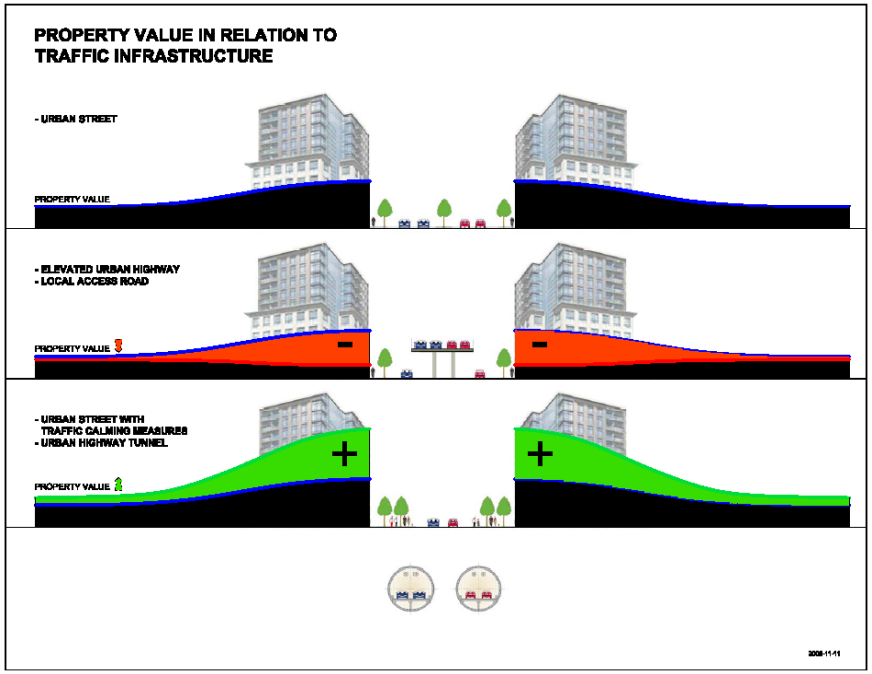
The Spanish experience in large tunnels

A new urban solution

NOW

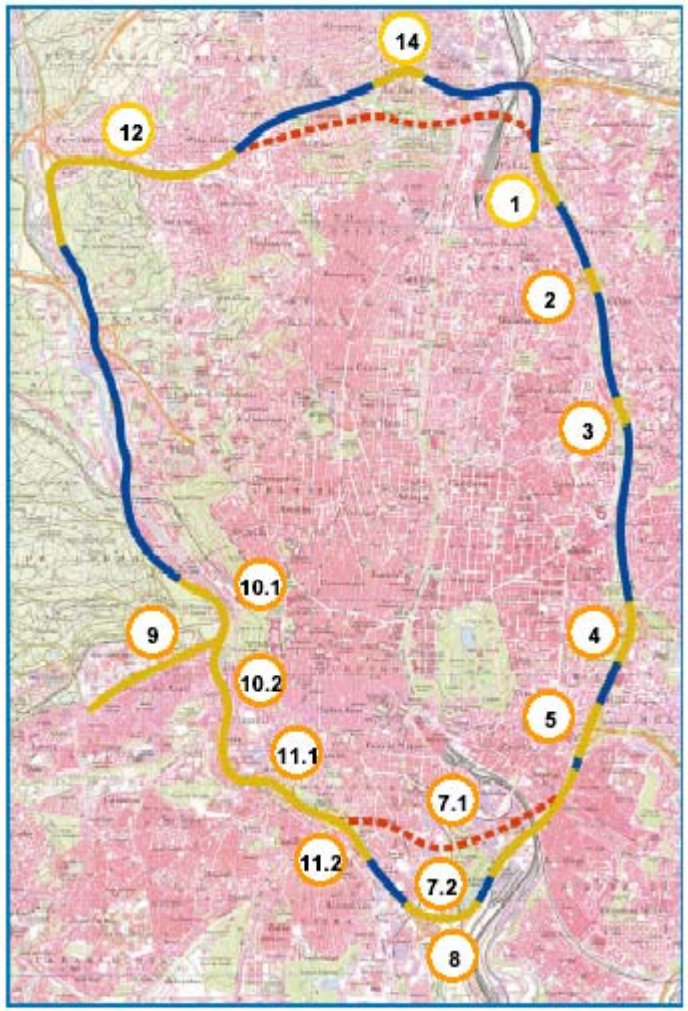
NEW TECHNOLOGIES



- Safer
- Environmental friendly
- Minimize citizen disturbances
- Reducing cost and schedules

MADRID
“CALLE 30”

MADRID “CALLE 30”



3,7 billion euros project

“CALLE 30” Targets

- Move to underground the greatest portion of the road and links. Green areas replace the congested surface
- Increase and improve the traffic flow
- Increase the traffic safety
- Redesign the 6 main links with National roads

MADRID “CALLE 30”

MADRID “CALLE 30”

“CALLE 30” Targets

- **Save 14.000.000 hours in journeys every year**
- **Save 4,5 Million € in fuel yearly**
- **Reduce 35.000 ton yearly in CO2 emissions**
- **Reduce 400 car accidents every year**

MADRID “CALLE 30”

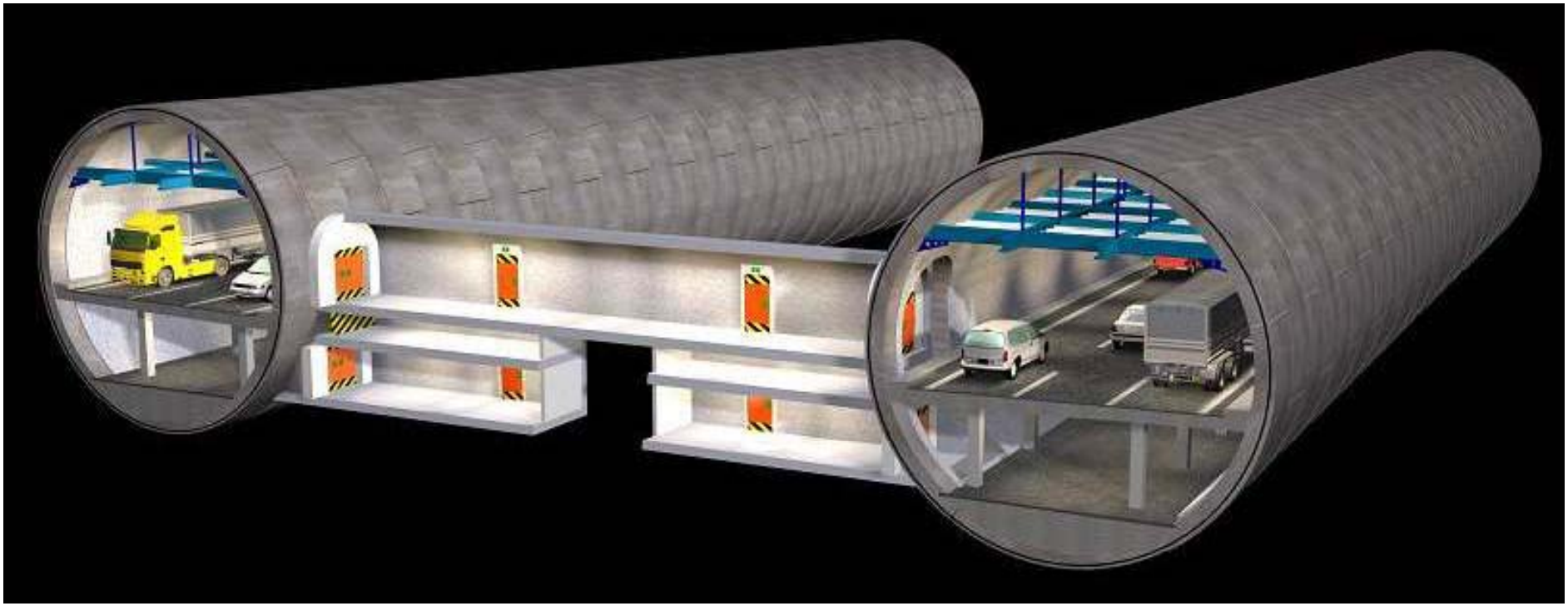
CONSTRUCTION OPTIONS:

- CUT & COVER
- ELEVATED ROAD
- BORE TUNNEL

MADRID “CALLE 30”

CUT & COVER WORKS

MADRID “CALLE 30”



SOUTH BY PASS

SOUTH TUNNEL

Contract price: 410 million € (VAT incl.)

Contract schedule: 30 month

MADRID CALLE 30

CROSS SECTION

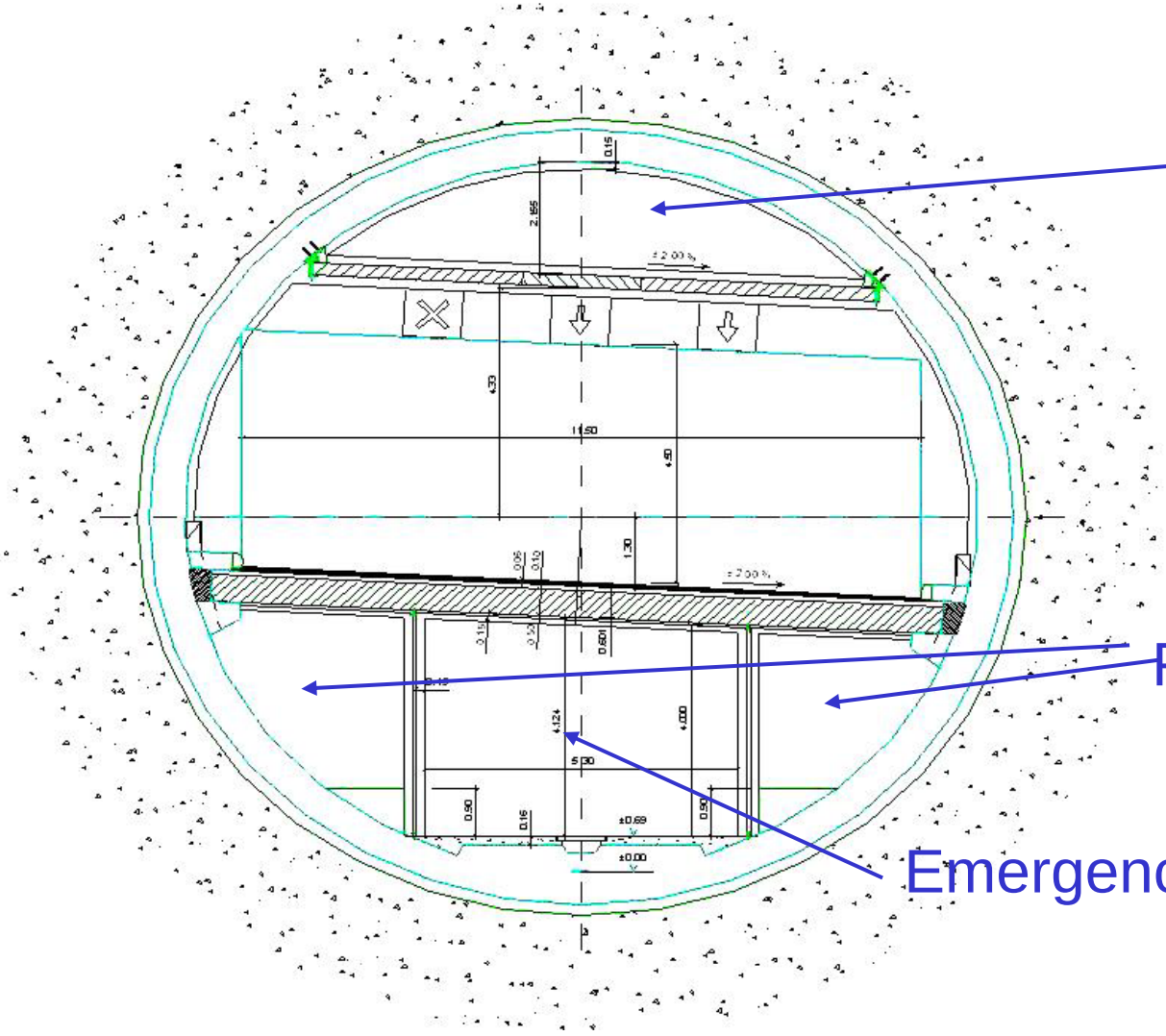
- 3 lanes 3.5 m for heavy and light vehicles
- Emergency gallery
- Ventilation and facilities

1 VENTILATION SHAFT

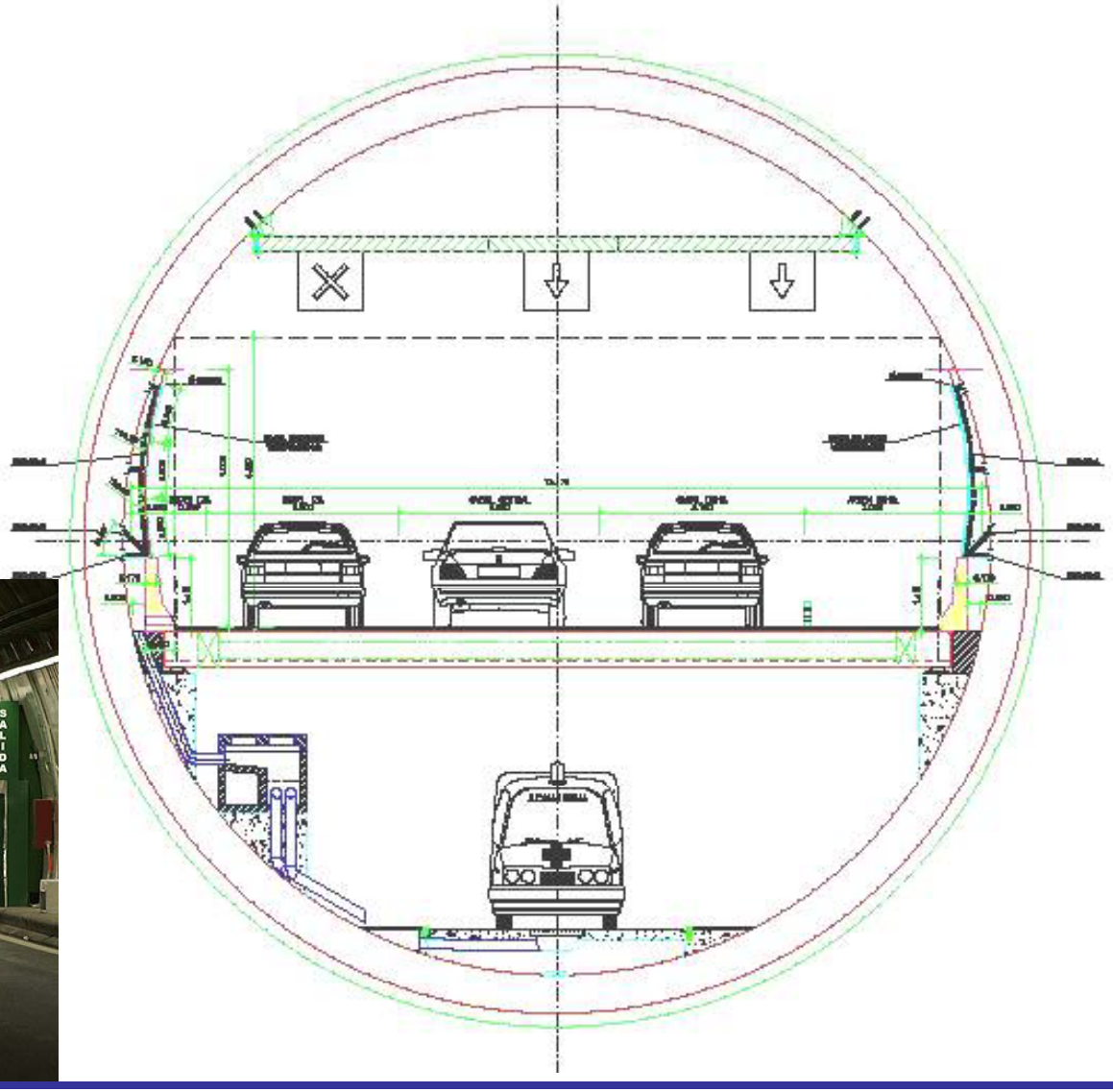
CROSS PASSAGES (every 300 m)

- 3 Vehicle galleries
- 5 Pedestrian galleries

MADRID “CALLE 30”



FINAL CROSS SECTION



MADRID CALLE 30

- Tunnel length…… 2.24 miles
- Excavation diameter……49.25 feet
- Excavation volume……831,856 cy
- Inner diameter……44.13 feet
- Segments tickness……1.97 feet
- Segments length.....6.56 feet

MADRID “CALLE 30”

- Ground conditions:
  - Deposit materials from 0 to 66 feet
  - 80 to 100 feet of sandy clay (Peñuela)
  - 66 to 80 feet of hard clay with Gypsum levels
- Maximum overburden 213 feet
- Average overburden 100 – 115 feet

MADRID “CALLE 30”

PRELIMINARY DESIGN

METRO MADRID

- The first stretch of the Madrid Metro (2.5 miles) was opened in 1919

- Extension 1995 - 1999
  - **35 New miles in 2 track tunnels, 37 Stations and 4 interchange**
  - **Length of the network after extension: 109 miles**

  .
- Extension 1999 – 2003
  - **34 miles**
  - **39 stations**

- Extension 2003 – 2007
  - **49 miles**
  - **80 stations**

- Current length in 2009 is 193 miles (310 km)

Earth Pressure Balance (E.P.B.)

First EPB in Madrid (1993)

(Railway administration)

Single track tunnel (24.2 feet)

TBM 30.8 feet diameter

Double track tunnel

Metro Madrid

THRUST REQUIREMENTS

- Avoid horizontal deformation in the front face
- Balance the ground effective horizontal pressure
- Balance the water pressure on the ground
- Avoid the vertical settlement on surface in front of the excavation
- Shield friction during the excavation

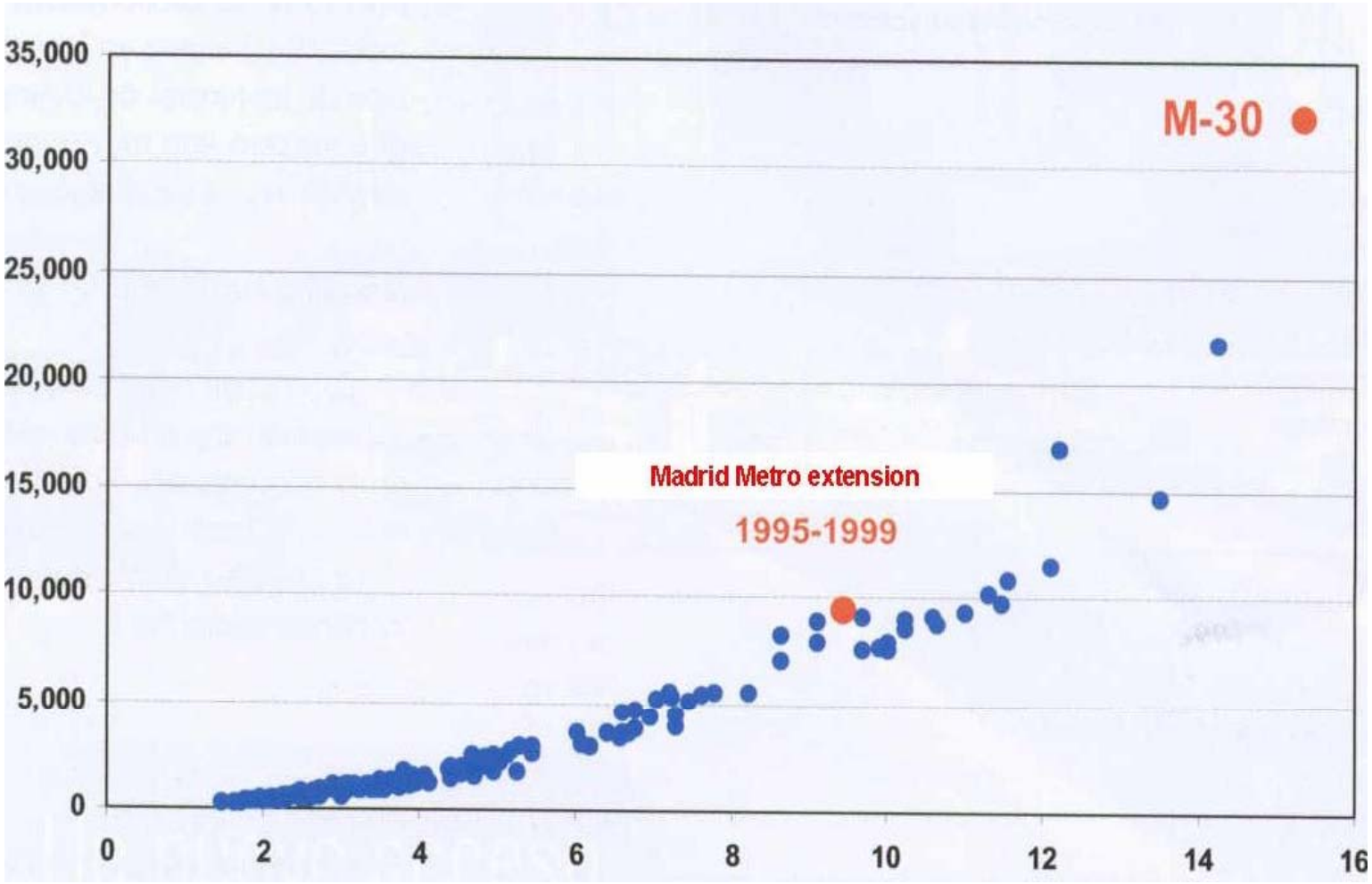
THRUST REQUIREMENTS

CROSS SECTIONS COMPARAISON

1-2,5

- **THRUST TBM METRO 10.000 TON**
- **THRUST TBM “CALLE 30” 25.000 TON**

TBM comparaison



TORQUE REQUIREMENTS

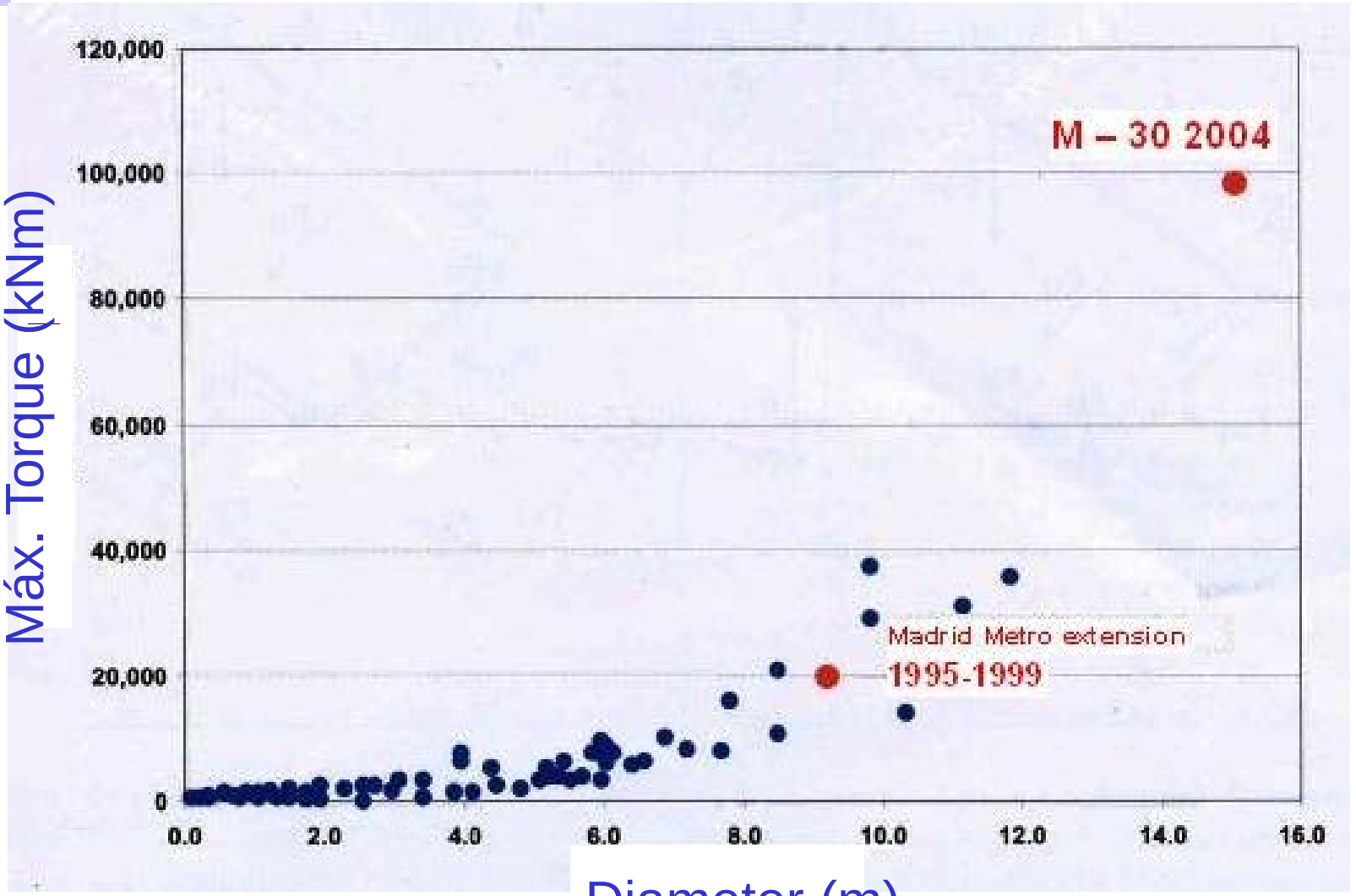
- Dig the ground with cutter tools (pics)
- Friction between ground and cutterhead
- Radial and tangencial forces applied in the main bearing
- Friction on sealing lips
- Mix the soils inside the chamber

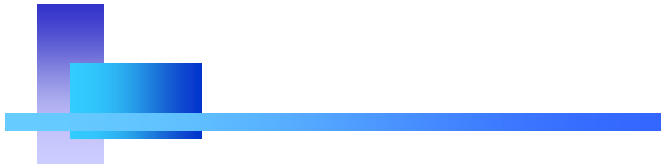
TORQUE REQUIREMENTS

VOLUME COMPARAISON

- **TORQUE TBM METRO 2.000 TON x M**
- **TORQUE TBM “CALLE 30” 8.240 TON x M**

TBM comparaison

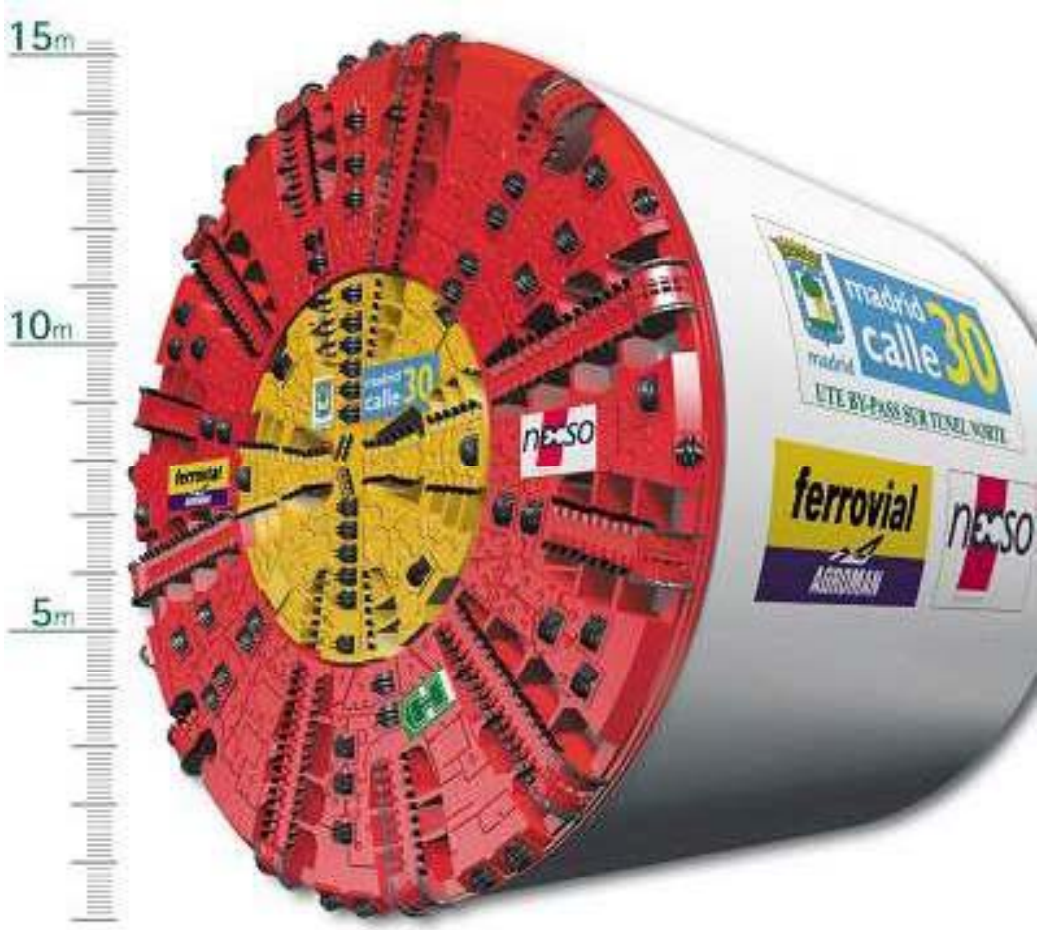




GERMAN CONCEPT

HERRENKNECHT DESIGN

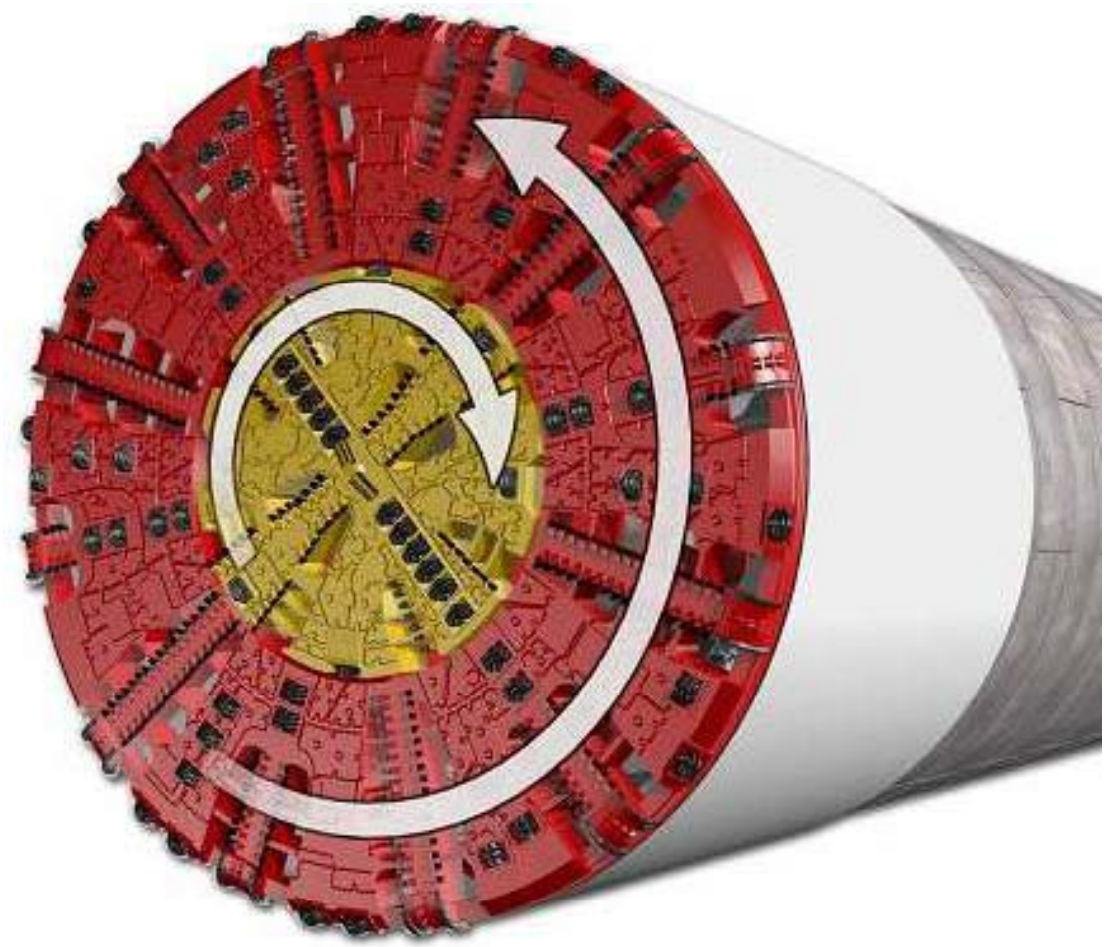
DOUBLE
CUTTERHEAD



HERRENKNECHT DESIGN

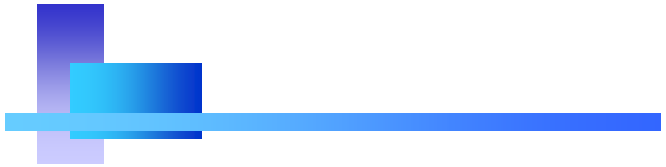
INVERSE

ROTATION



HERRENKNECHT DESIGN

3 SCREW CONVEYOR



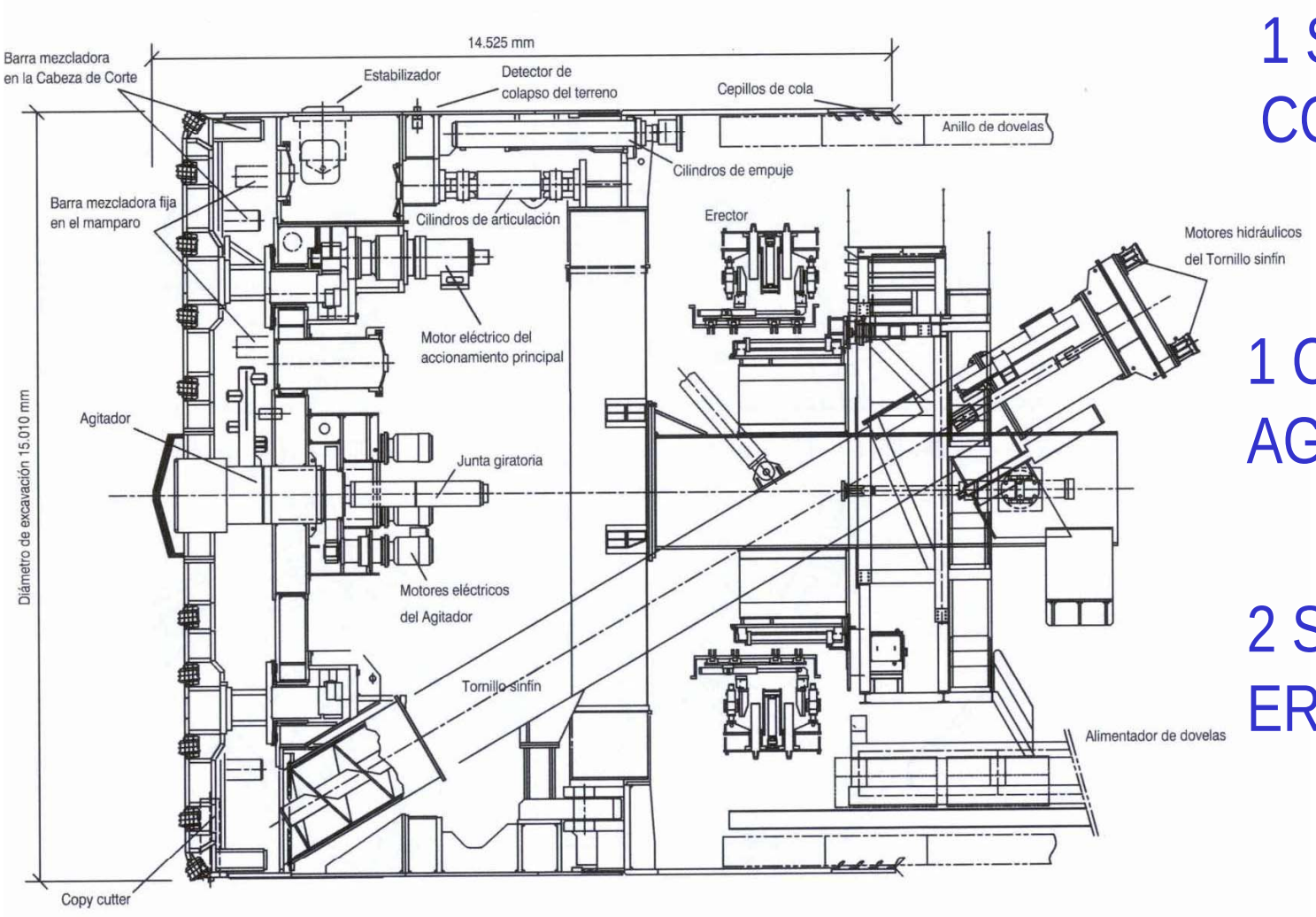
JAPANESE CONCEPT

MITSUBISHI DESIGN

SINGLE

CUTTERHEAD

MITSUBISHI DESIGN



1 SCREW CONVEYOR

1 CENTER AGITATOR

2 SEGMENT ERECTORS

SEGMENT ERECTION

MADRID “CALLE 30”

Model	MHI -DF
Diameter	15,010 m
Length TBM	13,075 m
Weigth TBM	2,700 T
Length Back-up	150 m
Minimum horizontal radius	350 m
Maximum working pressure in chamber	6 bar
Maximum Thrust	317,000 kN
Cutterhead power	9,800 Kw.
Maximum torque at 1,05 r.p.m.	85,700 kNm
Rotation speed	0,1 / 2,43 r.p.m.

MADRID “CALLE 30”

Number of drag bits	472
Number of knife edge bits	226
Number of disc cutters (triple)	44
Number of trim bits	32
Number of thrust cylinders	57
Central agitator diameter	5 m
Screw conveyor diameter	1.5 m
Total Power installed	14,300 kW

MADRID “CALLE 30”

This is a guy!!!

MADRID “CALLE 30”

Monitoring and Technical Control Unit MTCU

- Building characterization study
- Monitoring plan
- Installation of the instrumentation
- Instrumentation reading frequency
- Data interpretation and report generation

Integrated Monitoring System IMS

•Instrumentation Unit**:** Centralizes, stores and shows all the readings taken from the installed devices. It shows the state of the sensors in comparison with the adopted alarm thresholds

•Building Unit**:** Centralizes, stores and shows all the information related to each inspected building. It also shows the registered movements by the instrumentation installed in them

•Execution Unit**:** Allows visualizing, consulting and monitoring the job advance degree in its different areas

•Documentary Unit: Centralizes, stores and shows the job most interesting information

LAUNCHING SHAFT

LAUNCHING SHAFT
300 x 150 feet

CONTROLS DURING EXCAVATION

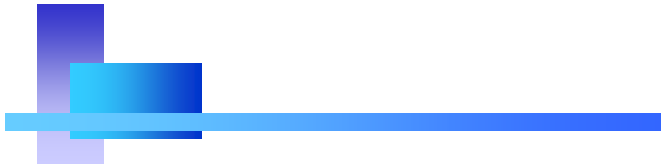
> Front face support pressure

> Mortar injection pressure and volume

> Cumulative weight and volume of extracted material from cutterhead chamber

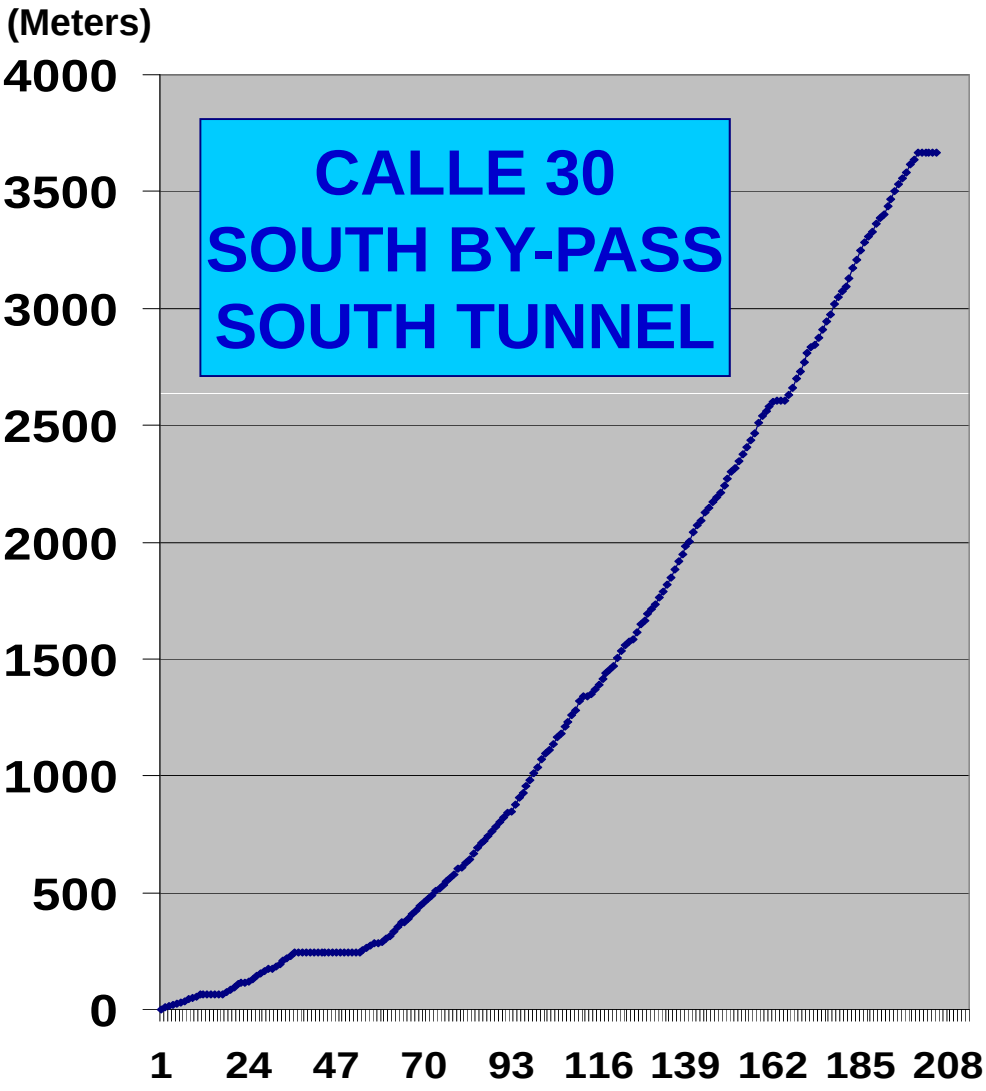
> Ground conditioning agents

> Particular events to be controlled during excavation (Cutterhead blockage, Gas, Water seepage…)



PROGRESS RATES

PRODUCTION



Av:60 feet/day

9 Oct 06: 151 feet

Oct 06: 865 yards

22/9-21/10: 1,015 yards

BREAKTHROUGH SOUTH TUNNEL

INTERMEDIATE SLAB

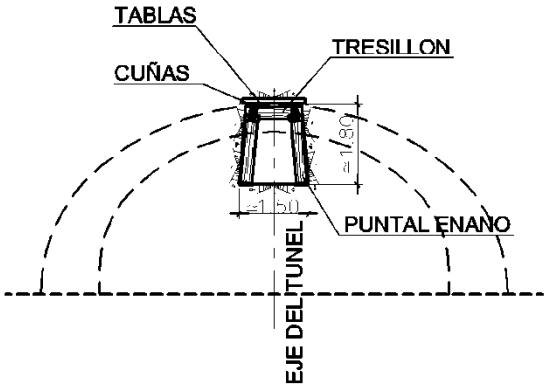
Cantilever formwork

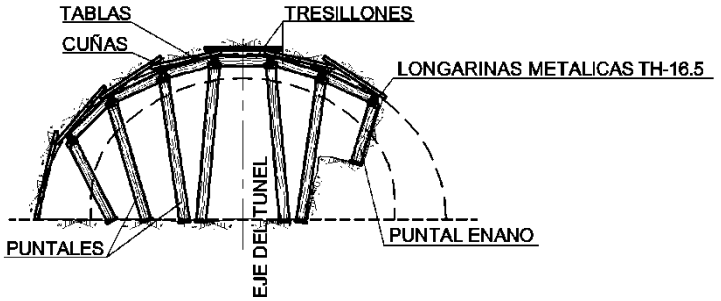
Precast slab installation

following the TBM progress

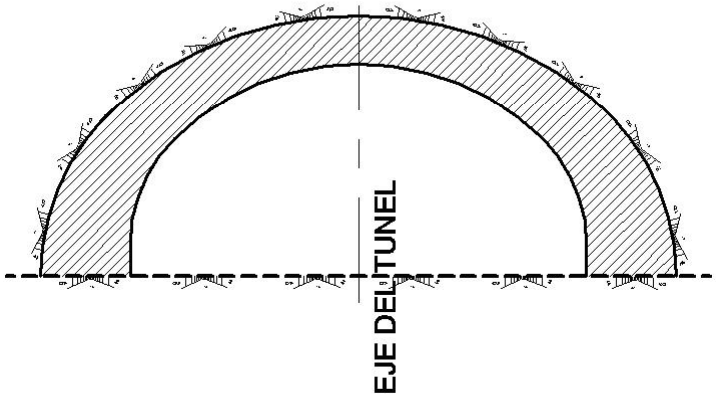
CROSS PASSAGES

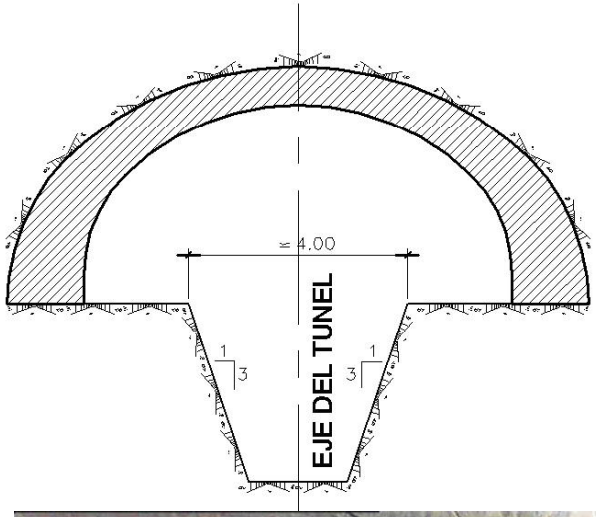
MADRID Method



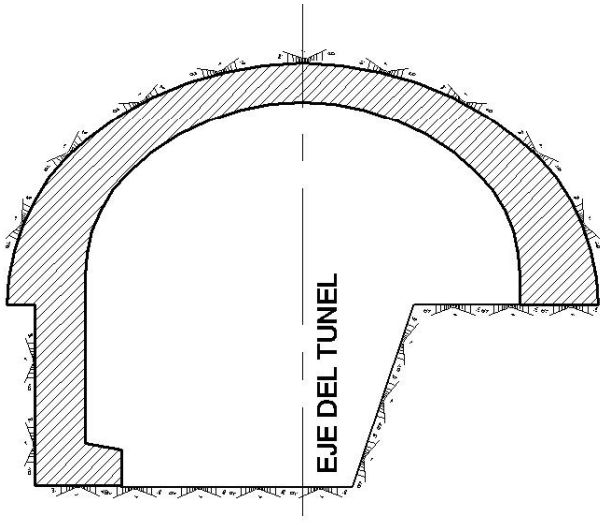


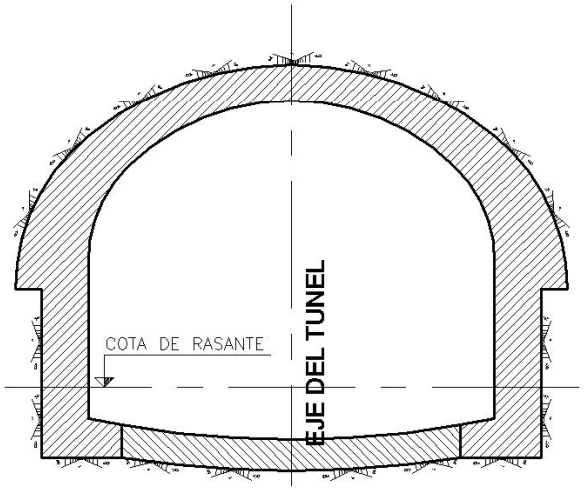
MADRID Method





MADRID Method





MADRID Method

LESSONS LEARNED

>TBM CURRENT TECHNOLOGY ALLOWS LARGE BORE TUNNEL DESIGNS

>PROPER TBM DESIGN IN ACCORDANCE WITH GROUND CONDITIONS IS THE KEY ISSUE FOR SUCCESS

>EXPERIENCED TEAMS ARE HIGHLY RECOMMENDED

> INTENSE SUPERVISION AND MONITORING TOGETHER WITH INMEDIATE REMEDIAL PROCEDURES REDUCE DISCOMFORT TO THE NEIGHBORHOOD (MTCU)

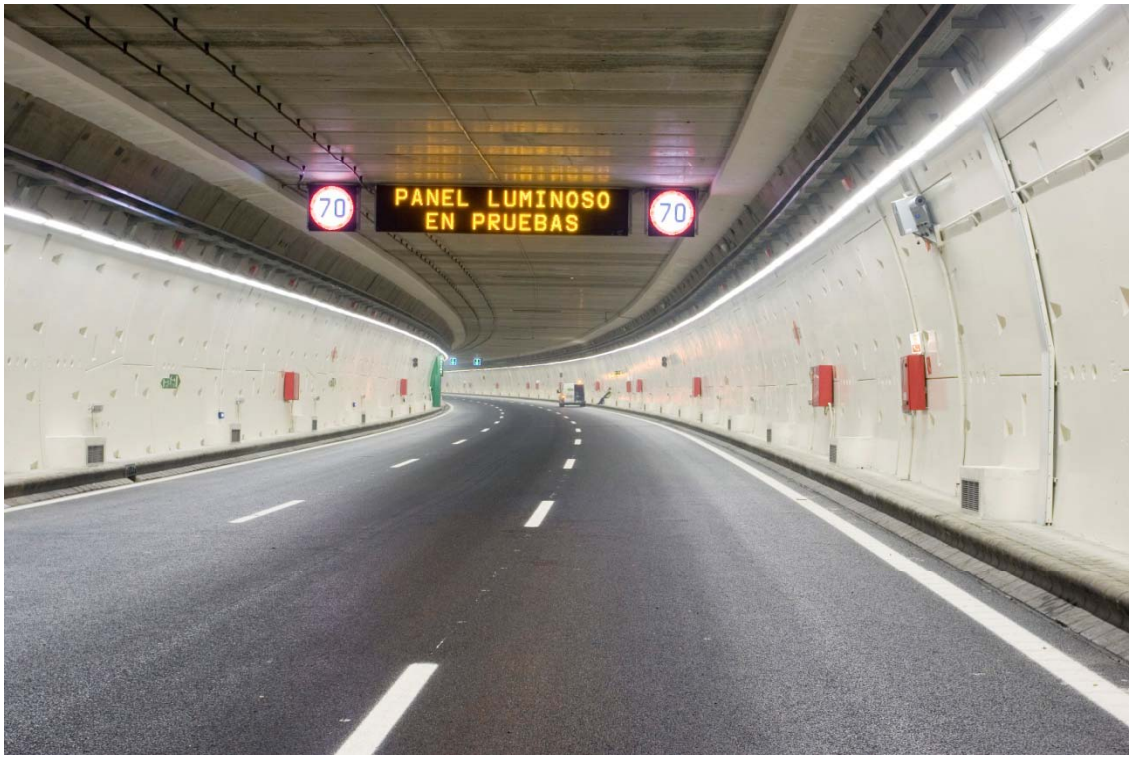
>CLOSE RELATIONSHIP WITH THE CLIENT AND DESIGNERS ALLOWS TO RESOLVE THE PROBLEMS EVEN BEFORE THEY OCCURS

TO BE CONSIDERED IN PRELIMINARY DESIGNS

>VENTILATION

>FLOODING

>FIRE



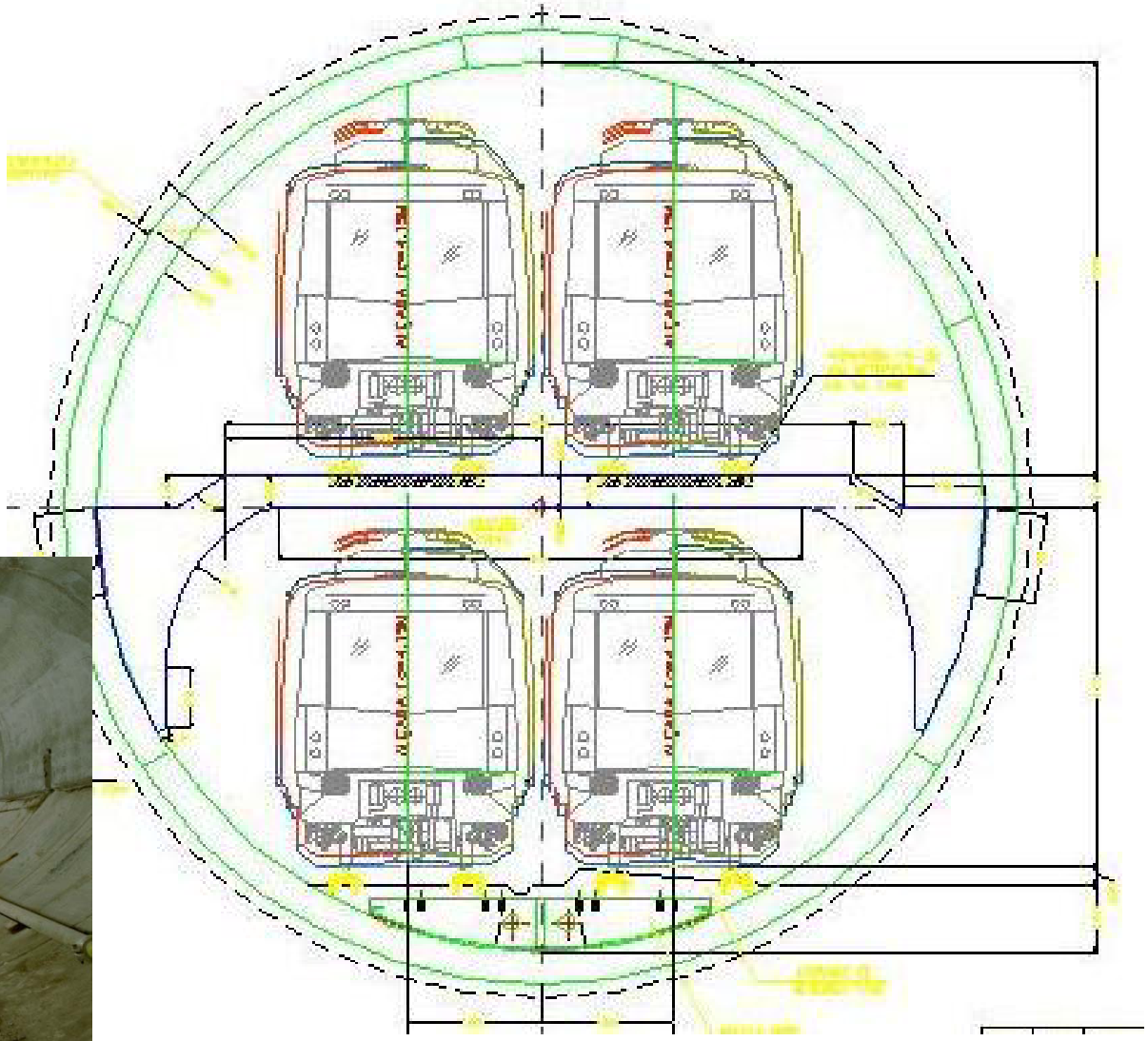
>EVACUATION ROUTES

BARCELONA METRO LINE 9

GEOLOGY

- Paleozoic and Tertiary formations covered by Pleistocene and Quaternary materials
- Miocene. Gravel with clay matrix
- In Delta rivers, pliocene alluviums

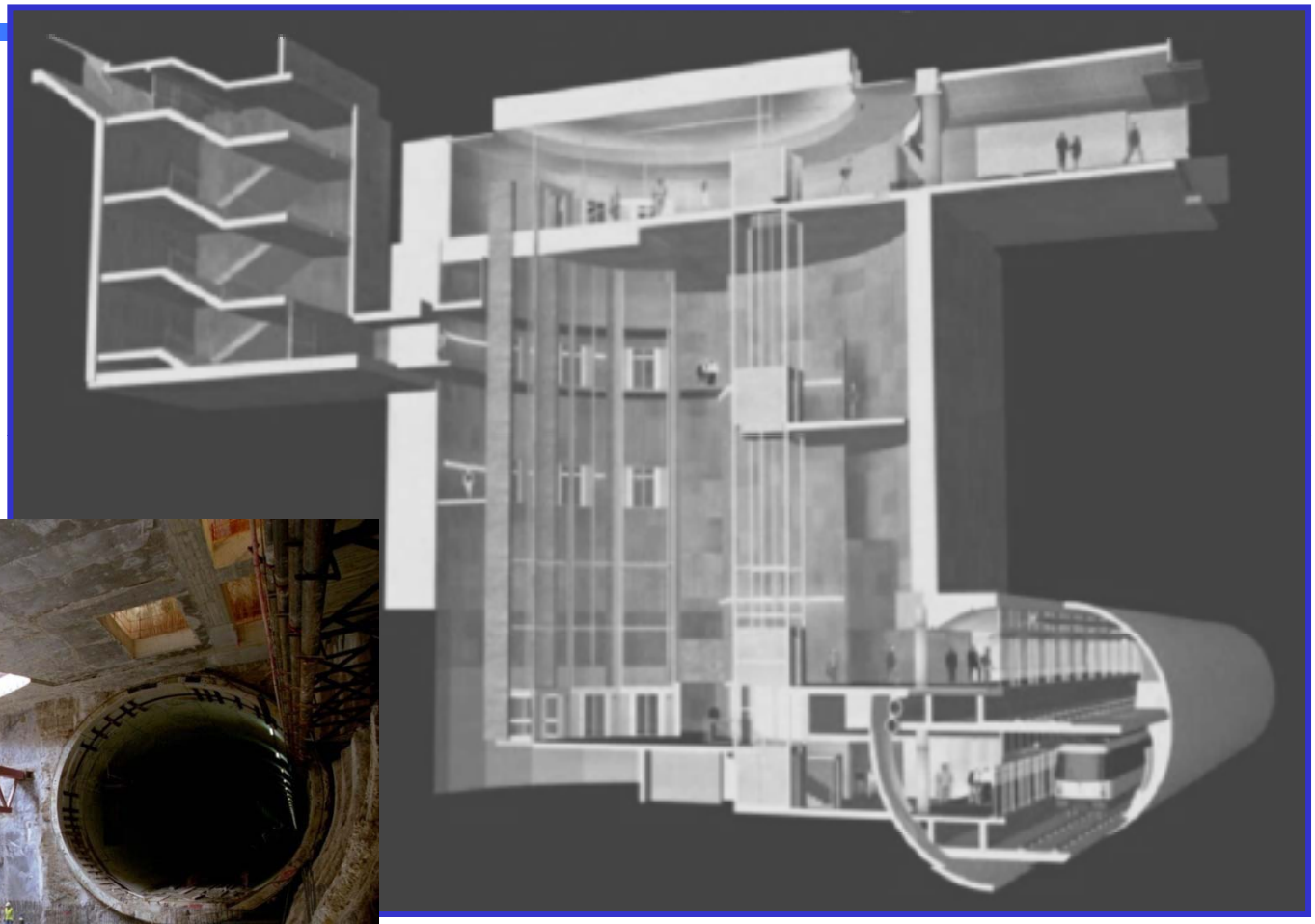
CONTINUAL STATION



CONCEPTUAL DESIGN
LINE 9

- Reduce surface disturbance
- Less subsidence in deep tunnel (2 D cover)
- Station platforms inside the tunnel
- Crossing other underground facilities
- Four track capacity

CONTINUAL STATIONS

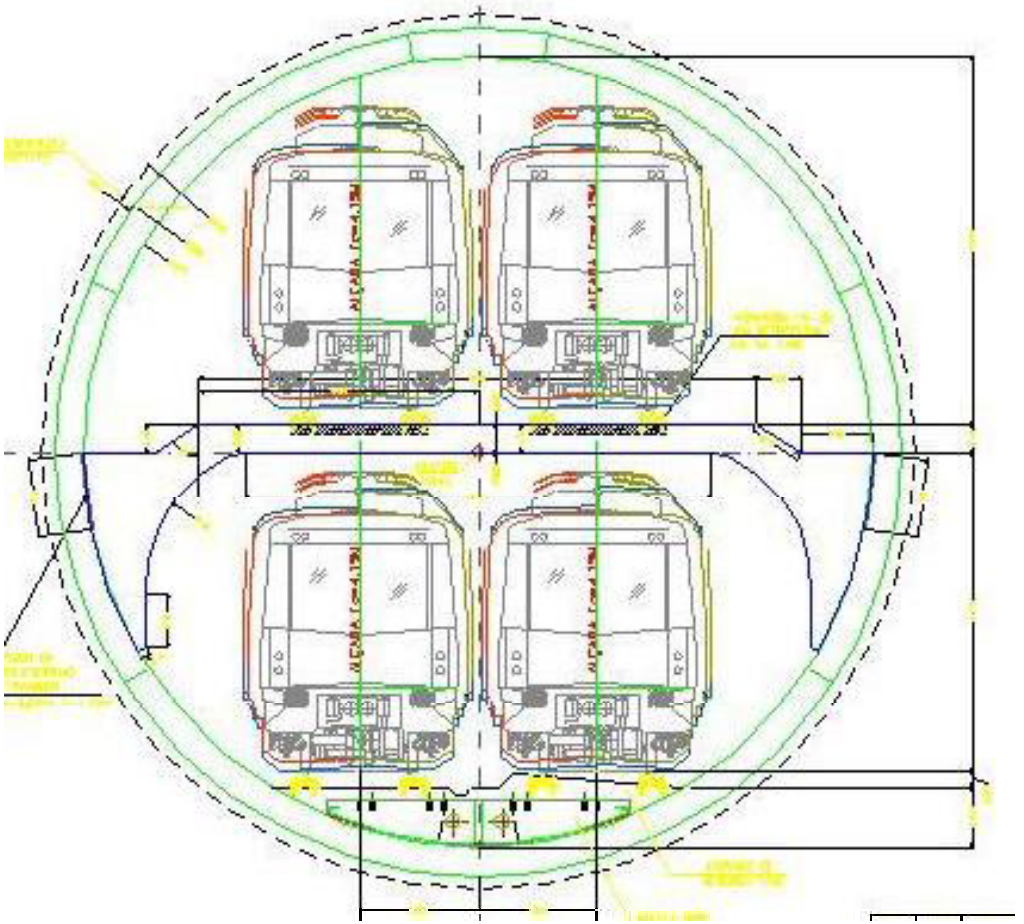


2 X E.P.B. 39’ 5’’ diameter

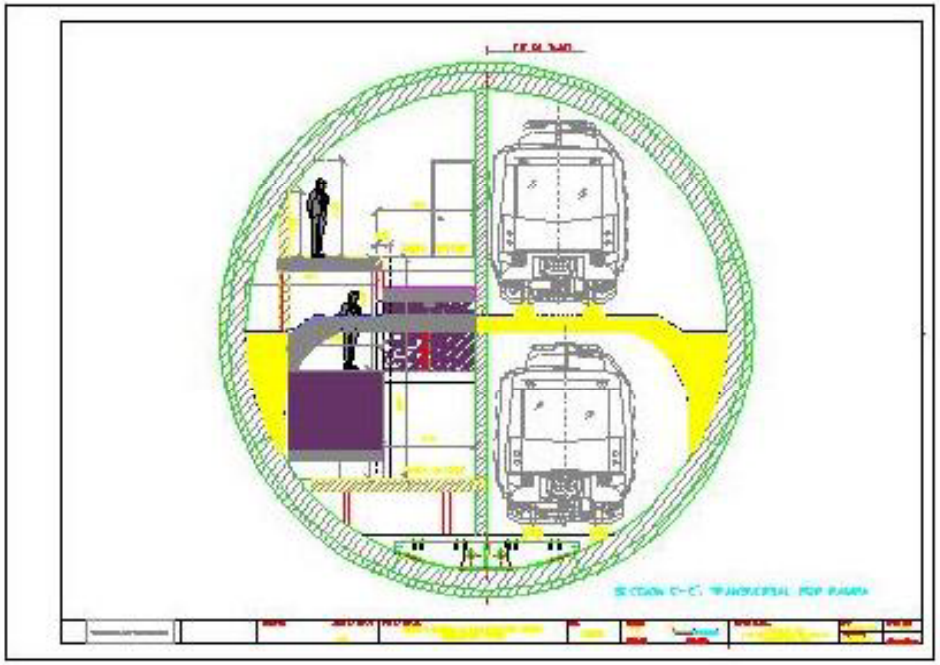
SEGMENT RING

- Inner diameter…….35.8 feet
- Thickness……..1.3 feet
- Length…… 5.9 feet
- Bolted and center bars between segments
- Bolted and connectors between rings

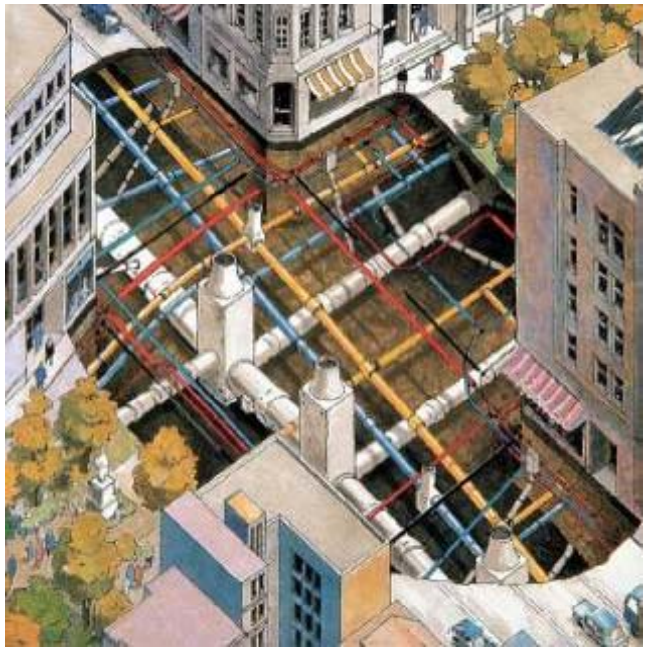
INTERMEDIATE SLAB



SLAB IN STATIONS



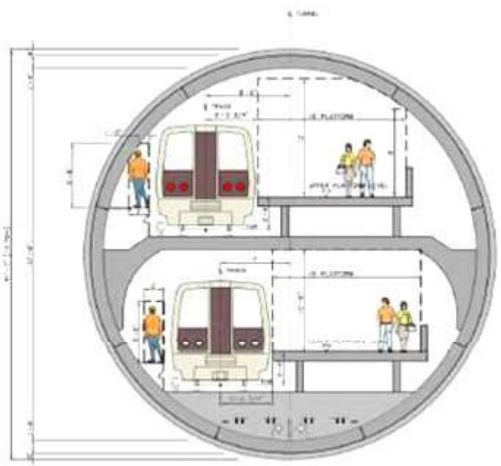
THE CITY BELOW THE CITY

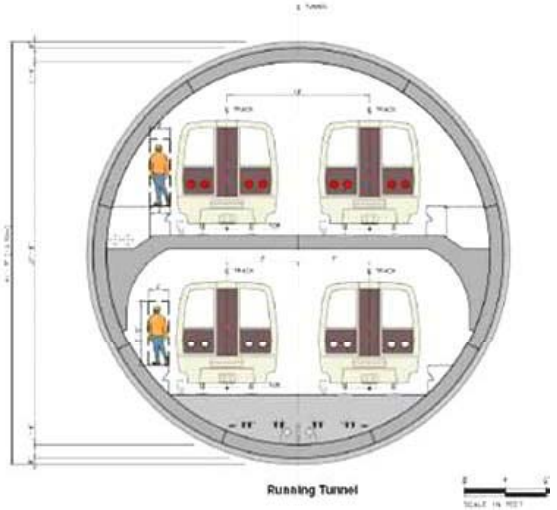


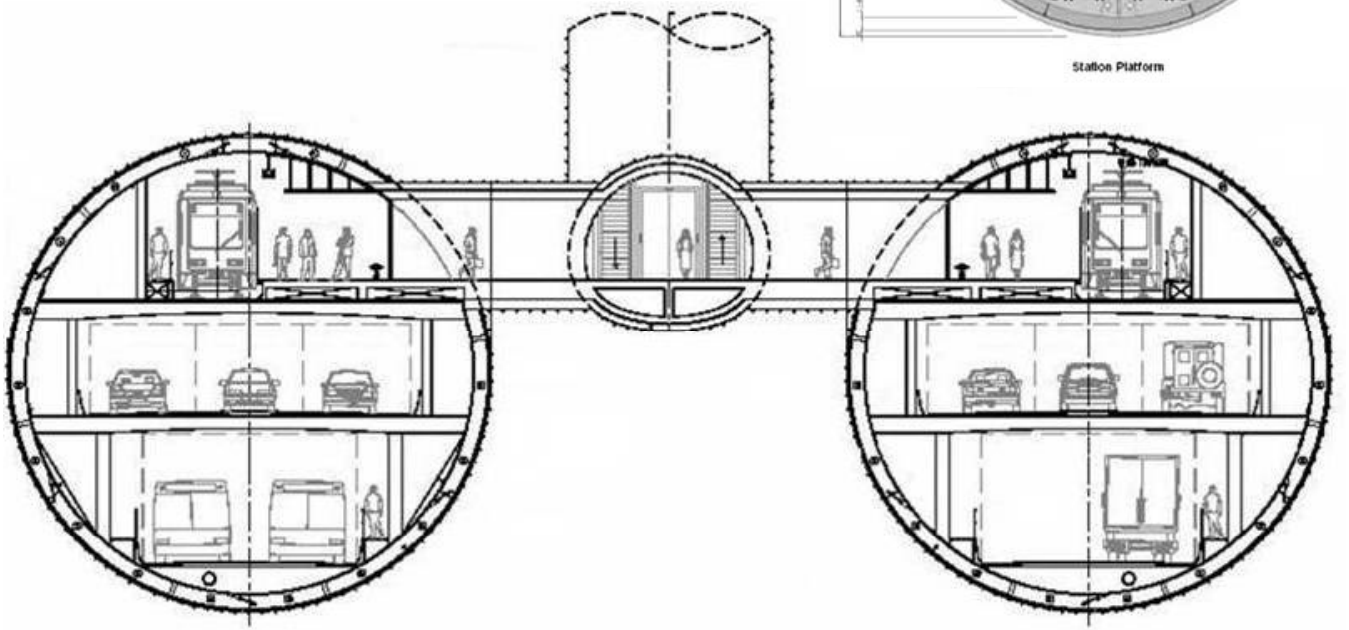
NEW TECHNOLOGIES

- See through ground
- Environmental friendly ground treatments
- Sophisticated TBM's
- Monitoring on - line
- Muck materials recycling
- Fire resistant lining materials
- Arrangement of underground space

OTHERS PROPOSALS



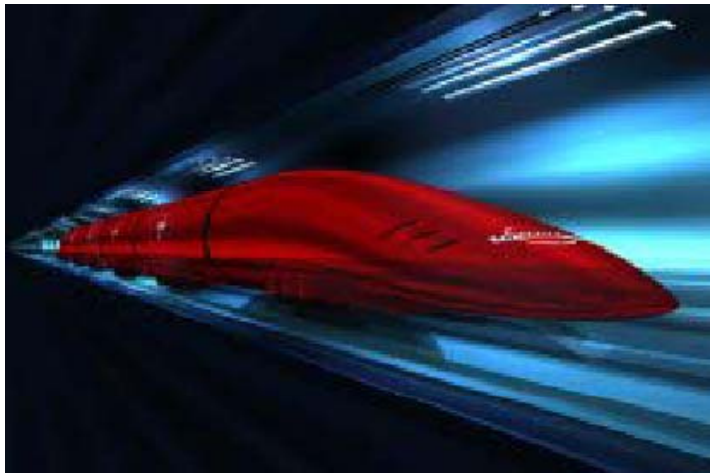




UNDERGROUND SPACE

SOCIAL BENEFITS

- New open mind of the citizens related to the underground space
- Create more green areas at grade removing existing infraestructures
- Increase the transportation network and reduce the journies
- Increase the companies competivity
- Nouxious gases reduction
- Noise reduction



THANKS SO MUCH