TBM EXCAVATION AND TUNNEL DESIGN FOR ROCK TUNNELS UNDER HIGH COVER IN CRITICAL GEOLOGICAL CONDITIONS

Remo Grandori_Swiss Tunnel Society – September 2010
TBM TUNNELING
SCIENCE TECHNOLOGY AND ART

- Soft ground TBM tunnelling
- Rock TBM tunnelling
SOFT GROUND TUNNELING

Mix of science and technology

• Ground normally homogeneous
• Shallow cover and water pressure
• Risks more predictable, limited to man made actions/objects
• Procedures and discipline in operation and maintenance
ROCK TUNNELING

Technology, art and small science

• No homogeneous (Rock to mud)
• High cover and water pressure
• Risks difficult to be predicted (poor science)
• Force of nature may become impressive, normally were not expected
EXAMPLE OF EXTREME EVENT IN ROCK TUNNELLING

The GIBE II CASE
The Gilgel Gibe II Hydro-Power Plant, 240km from Addis Ababa, in Ethiopia, between Gibe and Omo Rivers.

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Figure 1. Typical lining section
EVENT AT THE CHAINAGE 4+196 FROM INTAKE HEADING

- The tunnel face moved towards and pushed back the TBM at 40-60 mm/hour.
- The measured pressure of mud was 40 bars
TBM SHIELD DEFORMED
BORE HOLES FOUND MUD AT 40 BAR AND OVER 40c°

Figure 6. Mud poured out from one of the borehole
BY PASS TUNNEL AND BACK CHAMBER
MUD EXTRUDED AND FLOWING INSIDE THE LEFT BY PASS TUNNEL
Extruding mud in the Exploratory Adit
Figure 12. Extruding mud in the Exploratory Adit
Figure 13. Extruding mud at the Adit Portal
Extruded mud at the Adit Portal
Extruded mud in the Power Tunnel
Consolidated mud filling the Power Tunnel
FOR N.3 TIMES THE LEFT ADIT AND THE TUNNEL WERE FLOODED BY THE MUD

Pressure variation measured in the Back Chamber
A NEW STRATEGY WAS DEFINED

- the mud was removed from tunnel
- the Back-Up was extracted to portal
- new drainage drilling performed
- Exploratory Adit on the Right side (40m behind)
Rescue Chamber to recover the TBM
BY PASS TUNNEL SCHEME

- TBM ri-assembly tunnel
- By pass tunnel
- Concrete Plug
- Fault
PRODUCTION AFTER RESTART OF EXCAVATION.

Figure 28. TBM production chart after the excavation resuming.
The Tunnel excavation completed on June 6th 2009, the two TBMs meet at the ch.: 8+520,8
EVENT OCCURRED AFTER START OF OPERATION

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ALMOST 10,000 CM OF MUD, SAND, BOULDERS AND BLOCKS ENTERED THE TUNNEL

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FROM A SECTION OF 10 – 15 m OF TUNNEL
SO WE WERE AGAIN IN THE........TO THE NECK
SIX MONTH AFTER... ALMOST OUT
NEVER GIVE UP

• EVEN THE WORSE SITUATIONS CAN BE OVERCOME BY ENGINEERING SPECIAL MEASURES AND DEDICATED EXPERT CREWS

• THIS IS WHAT MAKES TUNNELLING SUCH A WONDERFUL WORK
DON’T STOP TBM DESIGN PROGRESS

• THE PROGRESS IN TBM DESIGN WILL MORE AND MORE LIMITS THE NECESSITY OF SPECIAL MEASURES TO VERY EXTREME AND RARE EVENTS
DOUBLE SHIELD DESIGN EVOLUTION

- 1983-1993 - Increase capacity in Hard Rock boring
- 1995- Increase Torque and Auxiliary Thrust
- 2001-2005 New DSU TBM design
- 2005-2010 – Dual mode EPB DSU
TODAY STATE IN ROCK TBM DESIGN

- Short shields
- Conical shields
- Extended overboring & overcutting
- Extended ground and face treatment
- Torque and thrust same of EPB TBMs
- Double mode capacity (with no stand by time) were required
- Improve cutterhead design to cope with widest range of geological applications
The fact that TBMs are and will be more and more capable to bore through extremely bad ground under high cover and water pressure will move the criticality to tunnel lining and support design.