TUNNELLING ASIA 2023
INTERNATIONAL CONFERENCE on CLIMATE RESILIENCE

NOVEMBER 22-23, 2023

HOTEL ITC MARATHA, MUMBAI, INDIA

INNOVATION & CONTRACTING

IN TUNNEL DESIGN & CONSTRUCTION

STRATEGIC MEASURES ON CLIMATE CHANGE

HARALD WAGNER PhD PE

CONSULTING ENGINEER

TUNNEL CONSULTANT - ITACET TRUSTEE & EXCO EXPERT

HARALD WAGNER
BIOSKETCH

Consulting Engineer, PE (Austria), Licenced Master Builder, Expert at Court, Government Counsellor appointed by President of Austrian Republic,
Independent Expert for Underground Infrastructures with more than 50 years in Tunnel Design, Construction and Consultancy.
Assistant Professor, Technical University Graz, Austria (1972 – 1974).
Adjunct Professor for Tunnel Engineering, KMITL Bangkok (2015 – 2023).
ITA VP of International Tunnelling & Underground Space Association (2002 – 2007).
Expert Member of ITA's Executive Council since 2007. ITACET Trustee & Surveyor.
University Lecturer, Arbitrator, Advisor on Dispute Review Boards.

OUTLINE

1. Preface
2. Modern Tunnelling – Evolution
3. Resilience & Climate Change
4. Causality of Climate Change
5. Financing & Contracting
6. Green Transformation
7. Innovative Networks
8. How Can Tunnels Collapse
9. CTM Tunnelling – Strategic Concepts
10. TBM Tunnelling – Strategic Concepts
11. Innovations in CTM Tunnelling
12. Innovations in TBM Tunnelling
13. Uniting Innovation & Technology
14. Summary
15. Concluclusion

1. PREFACE

- **Underground Space,** specifically tunnels, offers sustainable and resilient solutions for generations to come.
- **Energy Supply** based on e.g. innovative use of renewables, is covering up to 10 % of worldwide demand.
- **Green Energy** – Due to increasing population, green energy demand is increasing.
- **Sustainable Infrastructure** - Innovation is for ever challenging young engineers in adaptive and sustainable underground infrastructure.

2. MODERN TUNNELLING – EVOLUTION OF TECHNOLOGY

1975 – **HEP Waldeck II** Germany – Conventional NATM Design. Geomechanic know how from "Mountain Tunnelling" got transferred into "Urban Tunnelling". Experiences with Finite Element Calculations for the design of the Waldeck II Cavern Power House have been used for the design of metro tunnels and metro stations to simulate ground behaviour and to design sprayed concrete support.

1978 – **Mass Transit Construction.** Single Track Tunnels. Previous TBM experiences with one pass precast concrete lining segments have been published following Frankfurt Metro Projects. In Munich, precast single lined designed tunnel segments with unified, auto-connected and double converging segments in both joint types have been used first time. Station cross section has been expanded from 120 m2 (Bochum) to 180 m2 (Munich).

1980 - Findings from the **Geomechanic Technology** of NATM design and construction have been transferred on a global scale into **TBM Technology** with single lined precast concrete segments.

3. RESILIENCE & CLIMATE CHANGE

- **Climate Change** and the threats it brings to urban center in Asia and in the Pacific region are addressed.
- **Asia Pacific Region** remains vulnerable to extreme weather events and climate-related hazards, which carry significant implications for people and urban areas.
- **Urbanization** and its rapid pace, coupled with rising greenhouse gas emissions, inadequate infrastructure, limited financial resources and competing development priorities, complicates efforts to implement effective infrastructures and climate mitigation measures.

4. CAUSALITY OF CLIMATE CHANGE

COP 21 - The Paris Agreement on Climate Change (COP 21) came into force in November 2016 – a landmark moment for the international community committed to collectively accelerating the transition to Green Energy Economy.

SDG - The adoption of the United Nations 2030 Agenda for **S**ustainable **D**evelopment and the **S**ustainable **D**evelopment **G**oals also signaled renewed emphasis on the need for affordable, Clean Energy.

COP 26 - held in Scotland, UK, 31/10 - 13/11 2021. The conference negotiated the Glasgow Climate Pact; the first ever climate deal with the aim of reducing coal, the worst fossil fuel for greenhouse gases, the text of which represented a consensus of the representatives of the 197 attending parties.

5. FINANCING & CONTRACTING

- **Financing** plays a pivotal role in advancing progress towards realizing the **S**ustainable **D**evelopment **G**oals in the Asia-Pacific region.
- **Investing** in critical areas, such as underground infrastructure, is vital to achieve sustainable and inclusive development.
- **Crises** continue to stress the financial capacities of governments in the region, leaving limited fiscal space to allocate funds for investment.
- **Innovation** in financing through **P**ublic-**P**rivate-**P**artnership and cooperation can bridge the finance gap and ensure the region's resilience and progress towards **S**ustainable **D**evelopment **G**oals.

6. THE GREEN TRANSFORMATION

Means adapting 5 Critical Components.

- Green **Energy**,
- Green **Infrastructure**,
- Green **Finance**,
- Green **Innovation**, and
- Green **Production**, Consumption & Waste.

Green Transformers need, direct or indirect, input in Innovative Design and Construction from **Infrastructure**.

7. INNOVATIVE NETWORKS

- **Infrastructure -** societies need to transfer information.
- **Network**-of-**Systems/**Communication/Energy/Transportation/Trade/Supply.
- **Communication** – be increasing digitized.
- **Energy -** be based on Renewables.
- **Transportation** - be based on Clean Energy.
- **Supply Chains -** to work without friction between countries and continents.
- **How** shall/can work it together ?
- By **Innovative/Adaptive Underground Networks** !

8. HOW CAN TUNNELS COLLAPSE ?

- **Interaction** between Ground and Initial Support is in need of Verification.
- **Data** verification by means of in-situ monitoring of design assumptions forming integral part of Tunnel **Contracting**.
- **Collapse** happens when unreasonable foreseeability is claimed.
- **Subsurface** data described in tender docs, deemed to be **Foreseeable**.
- Data outside geotechnical conditions defined in tender documents (GBR) are deemed to be **Unforeseeable**.

9. CONVENTIONAL (CTM) TUNNELLING – STRATEGIC CONCEPT

- **Safe Support** to tunnel linings, CTM/NATM is best known of engineering solutions using calculated and empirical real-time measurements.
- **Relaxation & Stress Transfer** by using geological stress of surrounding rock mass, stabilizing the tunnel.
- **Design Parameter** designation shall be carried out by clients engineering team, by consultant's design offices, or by contractors design team.
- **Consultant** is cooperating closely with the client sharing responsibility for design in all phases of the tunnel.

10. TBM TUNNELLING – STRATEGIC CONCEPT

- **Bored Tunnelling** is modern technology, where Tunnel Boring Machines are used working fully mechanized, to ease the entire tunneling process.
- **TBM Tunnel Construction** in urban areas of heavy traffic is preferable and environmentally sustainable.
- **Types** - Tunnel Boring Machines are available at different types and diameters suitable for various ground.
- **Conditions** – TBM's now are used in geological difficult conditions, e.g. below ground water table etc.
- **Repair** – In ongoing working conditions, tunnel workers should not enter pressure compartment except for repair works.

11. INNOVATIONS IN CTM/NATM TUNNELLING

- CLAY/SILT – Soil Stability Improvement (Soft Ground Anchoring),
- DOUBLE DECK - for Transport Tunnels (Oswaldiberg Tunnel Austria),
- STEEL ARCHES - Inclined settlement control (U-Bahn Bochum, Los A3/A5),
- LOAD DISTRIBUTION - Rails and Shotcrete (Stadtbahn Bochum Los A2),
- FINAL LINING - with Shotcrete (Stadtbahn Bochum Los A3/A5) ,
- MULTIPLE DRIFT - Binocular Metro Stations (Metro Munich Los 5/9-5),
- WATERPROOFING - Sprayed Membrane (U Bahn Nuremberg Hasenbuck Tunnel)
- HYBRID - Shallow Tunnelling (Pfaender Tunnel, Brettfall Tunnel, Austria)
- STEEL FIBER - Reinforced wet Shotcrete (London Heathrow Terminal 5)

12. INNOVATIONS IN TBM TUNNELLING

- VERTICAL TRENCH - with prefabricated one pass D-Walls, (Metro Ankara, Turkey)
- UNIVERSAL RING - Precast one pass liners (Metro Munich Section 2)
- CONTROLLED KINEMATIC – Connectors (Metro Munich Section 5/9-9)
- SIMULTANE TUNNELLING - Dig/Support (Metro Mexico, Linea 7 y 3 Sur)
- FLAT JOINT DESIGN – for stress transfer (LA Metro HB 1/5, California)
- SEALING Tunnels - with Precast Segments (Berlin Sewer Collector, Germany)
- CAVERN Construction - with Machines (Waldeck 2, Germany)
- SINGLE PASS - unified precast segments (WMATA, Washington, USA)
- UNIFIED Circumferential Joint – Connectors (Metro Munich, Section 2)
- UNIFIED L-Joint Sliding - Guiding Rods (Metro Munich Section 5/9-5)
- CONTRACTS - integrating GBR & RMP (Innovative Contracting).

13. UNITING INNOVATION & TECHNOLOGY

- **Unification** - Protruding merit has been achieved by Uniting Technologies and Geomechanical Principles in Tunnelling.
- **Tunnelling** - CTM/NATM Conventional Tunnelling supplementing TBM (Mechanized) Tunnelling.
- **Innovations** reflecting ground Support in both Technologies, as well as implementation of new **Contracting Practices** (GBR, RMP).
- **Innovations** in NATM/CTM and TBM challenging project evaluation.
- **Evolution** of Technology and subsequent Decision.
- **Technology Approximation** accompanied by advanced, integrated in situ Observation & Monitoring, happened.

INNOVATION & CONTRACTING

- **Innovative Contracting** - orienting the contract for the construction works of tunnels using NATM and TBM Technologies considering **FIDIC** features with implementation of **Geotechnical Baseline Report** and related **Risk Management Plan**.
- **Construction** to include permanent geological mapping of the rock mass in the cross section. Preparation of reports with the proposal for carrying out other investigation activities (**Geotechnical Daily Report**).
- **Geological Mapping** of excavated area including lithological structure determination, comparison with geological profile and geotechnical model from the geotechnical documentation of the Main Design, macroscopic evaluation of the basic Engineering and geological properties, selection of samples for further testing.

14. SUMMARY

- **Innovative Tunnel Contracting** shall start with strategic, comprehensive investigation of ground conditions.
- **Investigation** of various routes, horizontal and vertical alignments optimization of best ground conditions and water influence.
- Independent from **Tunnelling Technology**, tunnel designers are advised to start e.g. using "Stand-up time" being the amount of time a newly excavated tunnel face can support itself prior to any added structural support.

15. CONCLUSION

- **Key Parameters** – Knowing KP's allows to determine, how far an innovation concept can proceed before support is installed, affecting **Contracting**, speed, efficiency, and cost of construction.
- **Experience** - Contractor is presumed to be experienced and able to implement support at conditions specified in contract.
- **Conditions** encountered at tunnel face and defined in the GBR (Geotechnical Baseline Report) are to be compared and evaluated.
- **Tunnel Consultant** – Finance Institutes to engage competent / experienced Consultants to review **Innovations**, Management and process in respect to **Contracting** Schedule & Risk Management.