NATM Tunnelling at Dulles Airport

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ABSTRACT: Tunnel collapse in 2000 during excavation of connection tunnel at Dulles airport causing fatal injury raised the Client's (airport authorities) concerns about construction safety. Ambitious expansion of the airport foreseen for the next decade with airport capacity increase up to 50 mil passengers/year when expansion completed, requires numerous underground facilities to be partly located in mined (both conventionally and TBM driven) tunnels under the airport. All consequent tunnelling works have been set under new systematic supervision scheme including position of a „NATM Engineer" as a part of contractor's team to be present during all excavation & support works. This position has specified strict requirements on experience and qualification of individual experts. Since 2004 to 2006 several conventionally mined (NATM) tunnels have been successfully completed. Paper briefly describes specifics and procedures of some of these drives as well as an experience with the „NATM Engineer" role as part of the Contractor's team.

1 INTRODUCTION

1.1 *Brief Summary*

Washington Dulles International Airport (WDIA) is at present undergoing ambitious expansion, which is enabled by availability of land around the existing airport facilities thanks to the Client - Metropolitan Washington Airports Authority (MWAA) policies in the past. Long term planned modernization includes the construction of a new runway, air traffic control tower, new terminals and service buildings, and also service and transport tunnels.

Construction aspects of these tunnels with emphasis on New Austrian Tunnelling Method (NATM) application and especially on the NATM Engineer role are the main features of the paper.

1.2 *Tunnelling Contracts*

The tunnel construction involves all kinds of tunnelling methods; there are many open cut construction sites serving as starting or receiving pits for either TBM or NATM tunnelling contracts. NATM was used in parts with complicated geological conditions or in tunnel stretches with difficult horizontal alignments and small radiuses.

Construction of mined tunnels started in 2000 with so called "Walkway Tunnel" between the Main Terminal and Terminal B, using NATM tunnelling method. In November 2000 a tunnel collapse, causing death of one worker, happened. The accident and following investigations delayed the construction process; construction of another contract - "West Utility Building Tunnel (WUBT)" was awarded to the Kiewit construction company and construction started in 2004. The part of the contract was 348 m long horse-shoe shaped tunnel with 6 m wide cross section, excavated according to the NATM principles.

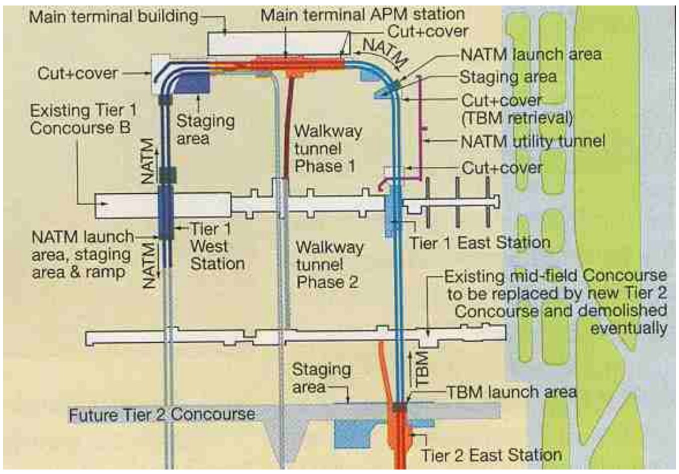

Figure 1. General Dulles Airport Layout

Following contracts included the construction of Automatic People Mover (APM) tunnels, with total length of more than 3 km with four stations built in open cuts, divided into several contracts and awarded to the Clark/Shea JV (east) and Atkinson/Clark/ Shea JV (west). These included open cut, TBM and NATM tunnelling. NATM tunnels were circular, 6.5 m outer diameter tunnels, divided in east and west part (see Fig.1, 2).

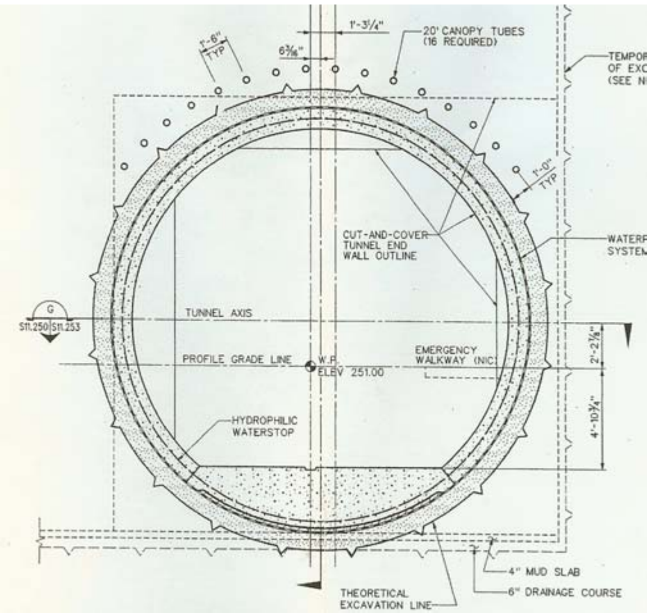

Figure 1. Typical Cross Section of NATM APM Tunnel

1.3 *Contract Stipulations – NATM Engineers*

Due to the problems experienced with the first contract, the Client's requirements defined specific position as a part of the Contractor's team designated as "NATM Engineer". Contract stipulations called for permanent presence of NATM Engineers, with sufficient experience of the method application.

The situation in the US tunnelling market driven by the low cost rule, with few NATM tunnels, resulted in shortage of suitably qualified engineers and tunnel workers. Even the largest companies are commonly hiring external specialists for tunnelling contracts.

Position of NATM Engineers for both mentioned contracts were subcontracted to the Austrian tunnel consultants D2 Consult, and through its daughter company D2 Consult Prague, several Czech tunnel engineers worked on the project as a part of the contractor's teams.

2 TUNNEL CONSTRUCTION

2.1 *Geological and Hydrological Conditions*

Geological conditions for the tunnel construction are relatively favourable. The bedrock, in which the tunnels have been predominantly mined, consists mainly of competent hard mudstone and claystone, with few sets of joints and UCS range between 20 – 40 MPa. Only at limited locations rock weathering process created softer soil with clay characteristic.

Figure 2. Typical Face Conditions

The earlier conventional tunnelling at the airport was performed using drill&blast excavation technique, with large amount of explosives used, significantly disturbing the surrounding rock. As a result, when crossing in the vicinity of previous construction works with newly built tunnels, excavation and support installation have to consider earlier affected broken rock conditions.

Massive mudstone and claystone were during excavation relatively dry, the water penetrated into the excavation only through joints and was related to surface precipitation.

2.2 *TBM Tunnelling*

There were several contracts, in which TBM tunnelling with bolted precast segmental lining assembled in the TBM shield has been used. The latest technology for the segment production has been introduced; for the tunnel lining water tightness the modern sealing systems with rubber sealing gaskets have been applied.

2.3 *NATM Tunnelling*

2.3.1 *Generally*

Designed support classes (I – III) for the tunnel excavation and support were applied according to the NATM Engineer's decision.

Both, horseshoe and circular tunnels were excavated in two steps. Firstly, the top heading was excavated and support measures as specified for the initial lining applied. In the second step the invert was excavated and initial lining completed.

2.3.2 *Excavation*

The excavation in all contracts was done by roadheaders, blasting was strictly prohibited. There were several types of roadheaders, mostly Voest Alpine models AM 75 for large profiles and AM 50 for e.g. invert and final profiling.

2.3.3 *Support Classes*

The following description is related to the APM contract.

The round length was corresponding to the applied Support Class. In the Support Class I, which was used for massive sound rock, this length was 1.5 m; and at the same distance lattice girders were erected. Initial lining was formed by 15 cm thick shotcrete with steel fibres.

In the Support Class II, applied for jointed rock, 4 m long spiles were installed in each round to prevent loosening of the rock blocks and their falling from the excavation roof. Round length was 1.2 m, shotcrete thickness 20 cm, lattice girders at 1.2 m distance. Probing ahead of the face was performed every fourth round, the length of probe drill hole was 12 m.

Support Class III was applied when the tunnel profile entered into the area of heavily weathered rock having character of clay. The round length was 0.9 m and the pre-support measure consisted of grouted steel pipe umbrella length of 9.0 m. In some cases the Support Class III was applied during tunnelling under other structures or utilities as a safety precaution measure.

Bolting was considered as an additional measure, bolts installation was based on NATM Engineer's decision. SN bolts installed into boreholes fastened with resin cartridges have been applied.

2.3.4 *Shotcrete*

There were batching plant directly on the site; mixing of the wet shotcrete mix was done in truck-mixers. From the trucks the shotcrete was delivered to the stable pump located on the surface. From the pump the shotcrete was pumped by delivery line (slick line) to the shotcrete spraying robot with remote control, close to the tunnel face. Accelerator was delivered to the nozzle by small pump at accelerator storage tank.

2.3.5 *Final Lining*

Final lining was made of reinforced cast in situ concrete of 30 cm thickness. Specific feature was universal use of corrosion protection coat of all reinforcement bars. Between shotcrete and final lining a waterproofing membrane was installed.

Figure 3. Finished Final Lining of East APM Tunnel

2.3.6 *Problems during Tunnelling*

The biggest problem encountered during tunnelling was shotcrete delivery to the tunnel face. Due to the pump location on the surface, the delivery lines were long, with many bends. They were also exposed to the heat or cold conditions and as a result there were many blockages on the lines, leading to delays in shotcrete delivery. Very often the problems with accelerator dosage caused delays during shotcrete application.

The biggest problem, from the NATM Engineer's point of view was long time period required for shotcrete support application in the cases of unstable rock conditions.

Another problem was presence of water in the tunnel, affecting the conditions of the temporary top heading invert. The water was mainly technological water from the roadheader spraying the face during cutting; the water used for cleaning and in some cases the water coming from the portal areas. As a result there was permanently thick layer of mud on the tunnel invert, making the working conditions difficult.

Application of roadheaders for the tunnel excavation did not allow for partial suitable excavation of the face. In some cases, it would be advantageous to excavate only top part of the face and apply shotcrete layer to support unstable rock. With the roadheader, the excavation had to start at the lower part to create the space for roadheader apron, to allow cutting boom reaching the top of the face.

Typical tunnel worker has not NATM tunnelling experience and is trained for required specific skills before project starts. Also Trade Union labour rules make it rather difficult to use available labour force in tunnel with required flexibility and efficiency.

3 NATM ENGINEER POSITION

The NATM Engineer is a specific position, present in the moment only on the USA tunnelling market, therefore brief explanation of his position and role follows, together with few comments based on experience gained on the Dulles Airport contracts.

Generally, the NATM Engineer could be characterized as bearer of NATM know-how, who is responsible for effective and safe application of the method. There are strict criterions stipulated in the contract documents as far as the NATM Engineer qualification and experience is concerned (years of experience, type of works done, both design and site experience requirement, etc.).

Actual role of the NATM Engineer on Dulles Airport tunnelling contract encompassed few more tasks. NATM Engineer provided also geological mapping of tunnel faces and monitored probe drilling in relevant support classes. He was taking decision on what support class will be applied for given conditions and also about any additional measures required (additional shotcrete, bolting). Part of his responsibility was evaluating the results of geotechnical monitoring (deformation measurements) and proposing relevant measures to react on the results.

NATM Engineer was an important partner during technical discussions and negotiations with the Client's Representative, who was at Dulles Airport project called Project Management Consultant (PMC). In the PMC team there was highly qualified international staff with long term experience regarding NATM tunnelling.

Two years project experience demonstrated importance of the newly established position. Responsibility of the NATM Engineer was quite high and his activity significant, especially in the case of worsening geological conditions and a need to take and imply quickly the decisions in respect of changing to another support class or to apply additional support or excavation measures. Although a part of contractor's team, quite understandably sometimes the priorities of both subjects (NATM Engineer vs. Contractor's management) were slightly different. This fact was also confirmed at the meetings with PMC an/or Client, where NATM Engineer's position and reasoning were considered by the parties as rather neutral and objective, not much affected by project economical interests.

From the personal experience, a serious problem for the NATM Engineer was to get support measures done as fast as possible and in required quality. This is valid mainly for the timely shotcrete delivery in the case of unstable rock conditions. To improve and accelerate this process was beyond the NATM Engineer capability and competence, although he was generally responsible for proper and timely application and safe and stable conditions.

4 CONCLUSION

The presence of "NATM Engineers" on the Dulles airport tunnelling contracts definitely contributed to safe realization of WUBT and APM conventionally driven tunnels. European tunnelling experts experienced working in different contractual environment and different working conditions with respect to local workforce experience with NATM, tunnelling qualification, and local practises. It is probable that on follow up tunnelling contracts on Dulles extension, the same or similar model of NATM expert working directly for contractor shall be applied.