Stability problems effecting the performance of a full face tunnel boring machine in Istanbul – Baltalimani Tunnel

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ABSTRACT: This paper is mainly concerned with the stability problems effecting the performance of a full face tunnel boring machine in Istanbul - Baltalimani sewerage tunnel being constructed in rock formations consisting of, limestone, carboneferous shale, greywackee, siltstone and mudstone. The formations are strongly folded, the joints being generally vertical to bedding planes.

During the tunnel drivage, the machine performance data, the geological parameters, structure and mechanical properties of the rock formations were carefully collected, machine utilization is found to be around 10% in Trakya Formation. Supporting of the caverns due to the collapses took 74% of the machine downtime. All the precautions taken in order to pass the geologically difficult areas are briefly summarized in this paper. The machine was drawn back after a drivage of 1230m and replaced by a shielded roadheader. All the accumulated data given in this paper is believed to be useful and reliable for a succesfull tunnel boring in similar rock formations.

1 INTRODUCTION

Collector tunnels designed to renew Istanbul's inadequate sewerage network and to clean the very polluted Golden Horn (Haliç) are being constructed for sometime by STFA, Construction Co.. The ambitious pollution abetement programme concerning 20 km of circular sewerage tunnels with diameters from 2.2m to 4.5m is funded by World Bank, sponsored by the Istanbul Metropolitan Municipality and engineered by the Istanbul Water and Sewerage Administration (ISKI). The design of the system have been performed jointly by Turkish Consultant UBM and Consultant Taylor Binnie and Partners, who are also responsible for the construction supervision (Bilgin, 1988, 1990).

The general layout of Baltalimani Tunnel which is a part of Istanbul Sewerage Project beeing constructed by STFA is seen in Figure 1. The tunnel having a diameter of 4.5m and a length of 2318m is primarily intended to excavate by a Robbins full face tunnel boring machine. The geological difficulties enforced to withdraw the machine after a drivage of 1230m and it was replaced by a roadheader. All the geological difficulties encountered during the tunnel drivage will be discussed in this paper.

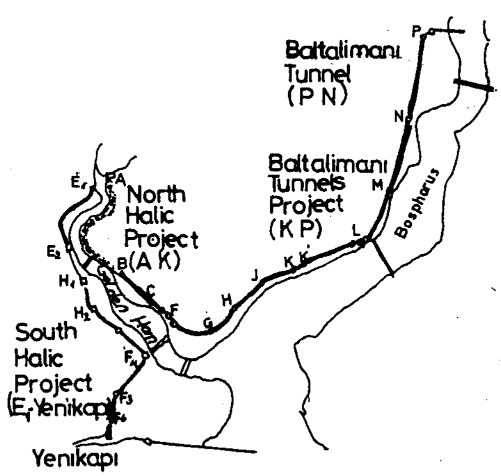

Fig.1 The general layout of the Baltalimani tunnel

2 GENERAL CHARACTERISTICS OF THE TUNNEL SUPPORT AND FULL FACE TUNNEL BORING MACHINE

A typical tunnel support used in Baltalimani is shown in Figure 2. Rock bolts, steel arches and shotcrete were immediately installed after the excavation. Later, the secondary lining has a PVC liner to protect the concrete from corrosion by hydrogen sulphide gases.

A Robbins type 145-168 full face tunnel boring machine is used in Baltalimani Tunnel. Design of the machine was governed by geological requirements and specifications of the project such as tunnel diameter, rock strength and type of

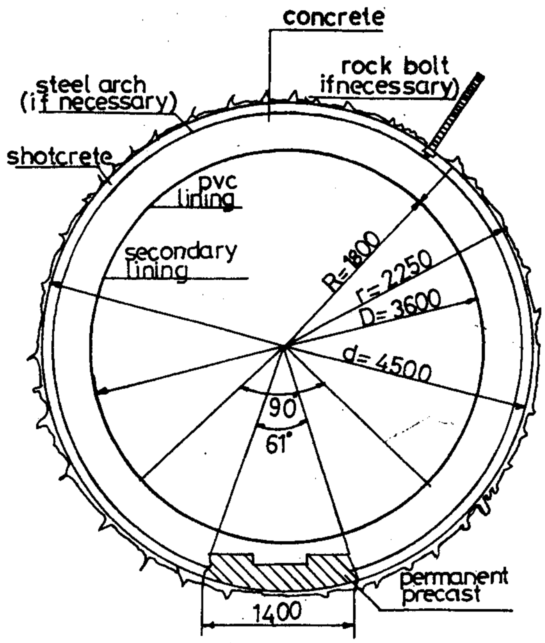

Fig.2 The support used in Baltalimani Tunnel

Table 1. The characteristics of the Robbins full face tunnel boring machine

Model	: 145-168
Refurnishment	: Herrenknecht
Machine Diameter	: 4500 mm
Propel Cylinders	: 4 pieces
Gripper Cylinders	: 4 pieces
Side support Cylinders	: 2 pieces
Roof support Cylinders	: 8 pieces
Primary Conveyor Cylinders	: 2 pieces
Gripper Piston Shoes	: 2 pieces
Cutterhead Power	: 7x125=875HP
Hyd.Pump Propel and Low Pressure +First and Third Conveyor	:100 HP
Hyd.Pump Gripper	: 50 HP
Second Belt Conveyor Motor	: 50 HP
Transformer	: 2x600 kWA 6000 V
Electric Current	: 380 V -50 Hz
Disc Cutters Number	: 35 (4No:12",31No:15.5")

support. The characteristic of the machine are summarized in Table 1.

3 THE GEOLOGY OF THE TUNNEL AREA

Paleozoic rock formations representing a continious sedimentation from lower Devonian to Middle Carboniferous are found in the tunnel side. These are locally covered by 5 to 15m thick Neogen Deposits of clay, silt, sand and boulders of 2-30m. Devonian and Carboniferous Buyukada and Trakya Formations which form the bedrock are cut by andesite and diabase dykes of 1-30m thickness.

Buyukada Formation of Upper Devonian Age consists of micritic and nodular limestone and carbonately rich shale. It is strongly folded, little jointed and has massive apperance. The joints are generally vertical to bedding and have vertical to subvertical dip.

Trakya Formation consists of mudstone, shale-graywackee and conglomerate units. It is closely jointed and strongly folded. RQD in Trakya Formation is comparetevely very low.

4 MACHINE PERFORMANCE IN STRUCTURALLY TWO DIFFERENT ROCK FORMATIONS

Machine performance in Buyukada and Trakya Formation are summarized in Table 2 and Figure 3. Some data on geological conditions such as RQD, RMR, Q, overbreake and rock mass quality values are also given in Figure 3. As one can easily notice in this table, the machine utilisation in Trakya Formation is 4 times less than Buyukada Formation, the main reason of this fact being very bad ground conditions (Cigla,1991).

The support of the caverns at crown and sidewalls took 74% of the machine downtime during the excavation through Trakya Formation. High pressing loads of gripper

Table 2. Machine performance in Buyukada Formation

Machine Utilazation	28.50 %
Machine Downtime	71.50 %
Net Cutting rate	1.22 m/h
Progress Rate	0.35 m/h
Average Shift advance	3.15 m/shift
Best Shift Advance	11.50 m/shift
Lowest Shift Advance	0.60 m/shift
Average Daily Advance	7.18 m/day
Best Daily Advance	20.0 m/day
Lowest Daily Advance	0.22 m/day
Average Weekly Advance	43 m/week
Best Weekly Advance	76 m/week
Lowest Weekly Advance	9.95 m/week
Average Monthly Advance	197 m/month
Best Monthly Advance	261.48 m/month
Lowest Monthly Advance	56.2 m/month
Total Adv.in Büyükada Formation	683 m

Machine Downtime	
Disc Changing	16.84 %
Disc Control	3.05 %
Support	14.04 %
Mucking and Waiting for Wagons	14.47 %
Mechanical Breakdown	5.11 %
Electrical Breakdown	1.21 %
Ground Conditions	3.00 %
Crane Failure	4.20 %
Conveyor Failure	0.88 %
Ventilation Failure	0.31 %
Maintanence	2.00 %
Others	6.39 %
TOTAL	71.50 %

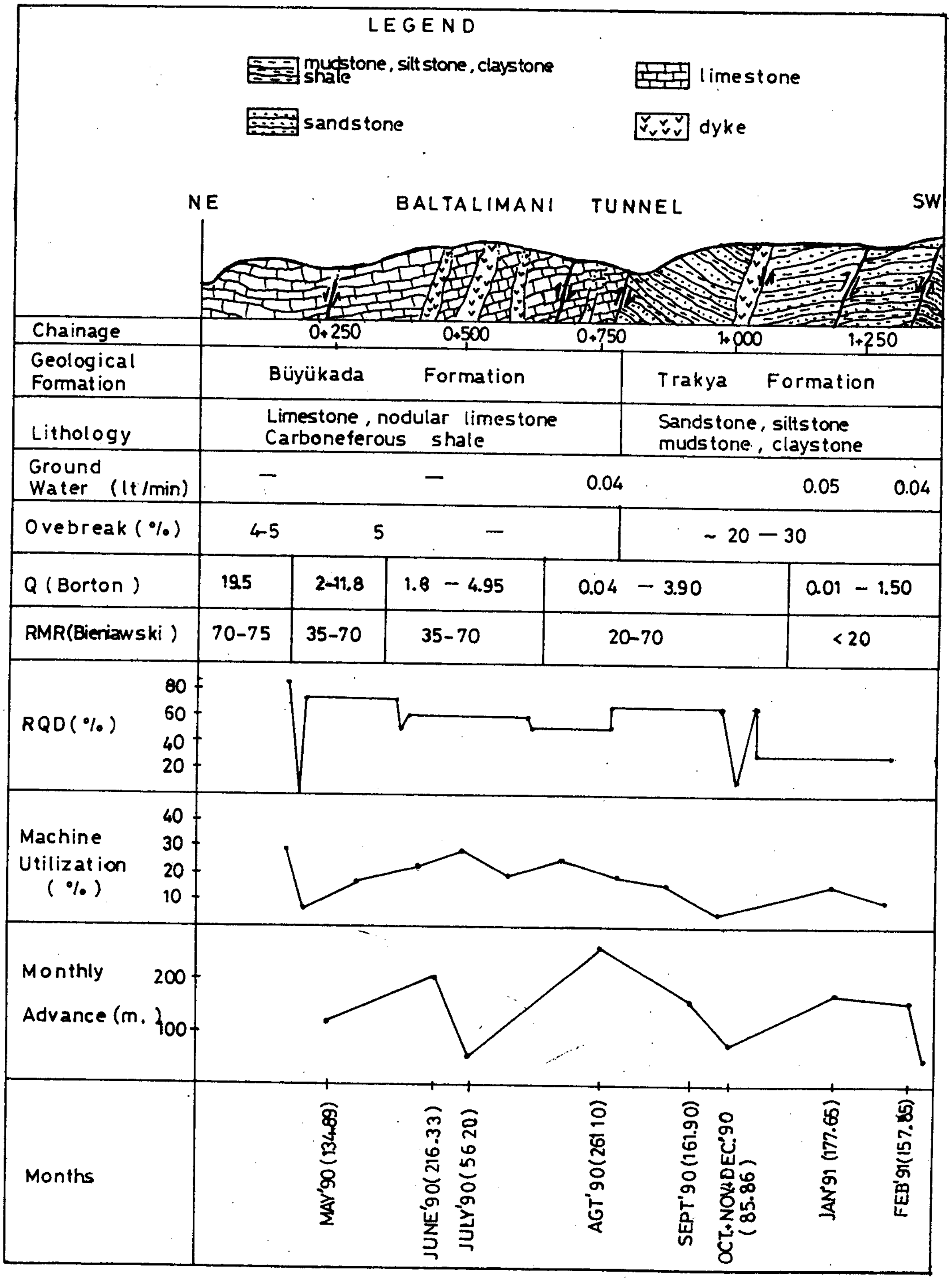

Fig.3 The summary of geological conditions and machine performance in Baltalimani Tunnel

Table 3. Machine performance in Trakya Formation

Machine Utilazation........	7.20 %
Machine Downtime...........	92.60 %
Net Cutting rate	1.70 m/h
Progress Rate	0.13 m/h
Average Shift advance......	1.24 m/shift
Best Shift Advance.........	9.57 m/shift
Lowest Shift Advance	0.20 m/shift
Average Daily Advance	3.12 m/day
Best Daily Advance....... ..	16.5 m/day
Lowest Daily Advance.......	0.50 m/day
Average Weekly Advance......	21.0 m/week
Best Weekly Advance	66.0 m/week
Lowest Weekly Advance.......	1.90 m/week
Average Monthly Advance.....	84.0 m/month
Best Monthly Advance...... .	177.65 m/month
Lowest Monthly Advance.....	17.33 m/month
Total Adv.in Trakya Formation	586.24 m

Machine Downtime	
Support	44.58 %
Ground Condition...........	29.39 %
Mucking and Waiting for Wagons	4.34 %
Mechanical Breakdown..........	.3.00 %
Electrical Breakdown...........	1.39 %
Crane Failure	0.25 %
Disc Changing	0.80 %
Disc Control	0.17 %
Belt Conveyor Failure	1.75 %
Ventilation Failure	0.52 %
Maintanence	0.58 %
Others.........................	5.83 %
TOTAL..........................	92.60 %

pads from 690 to 1100 tons caused also the deformation of the support system and cracks on the shotcrete cover. When encountered with highly crushed zones or clay bands, the pads entered into the sidewalls due to weak ground conditions, so wooden blocks were placed between gripper pads and support system to distribute the load coming to the sidewalls.

5 PRECAUTIONS TAKEN IN ORDER TO PASS GEOLOGICALLY DIFFICULT AREAS

Collapses and overbreaks were major problems faced during the tunnel drivage through Trakya Formation. Collapses took place in different rock conditions such as faulted, crushed, fractured or highly altered zones. Special support systems were applied in each case according to the form of caverns. These are briefly summarized below.

5.1 Collapse Between Chaniage 0+895-0+935

The collapse occured in very crushed and fractured interbedded siltstone-mudstone zone. It started from right shoulder and enlarged towards the left shield of the machine. The support system used in this collapse area is described in Figure 4.

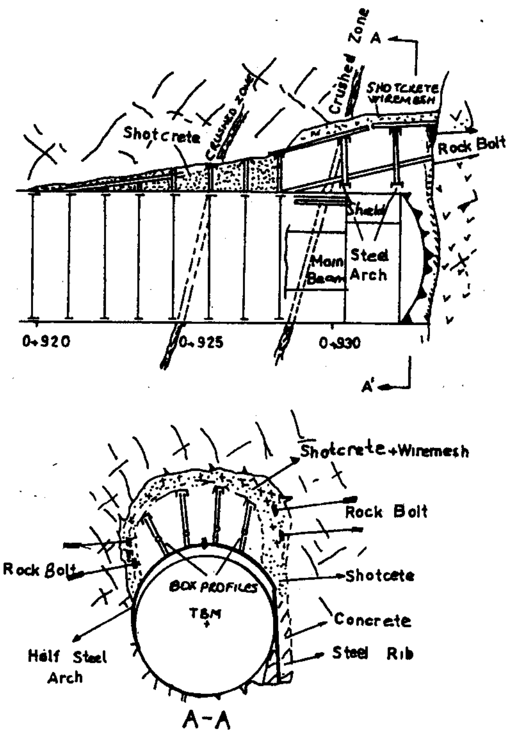

Fig.4 Collapse and support system used between chainage 0+928-0+935

5.2 The Collapse Between Chainage 0+965-0+982

Geological and structural conditions produced severe stability problems within 10m of collapsed area. Extensive overbreak from left wall and roof caused some caverns of 1 to 1.5m in dimension. Well developed medium closely spaced joints (20-50cm max.) and other nonsystematic discontinuities seperated the rock mass into rock elements of 5-20cm. The suppport system used was smilar to previous one.

5.3 The Collapse Between Chainage 0+965-0+982

The collapse happened in mudstone of Trakya Formation which is green to grenish gray coloured, moderatély hard, heavily jointed and fractured, with clay filled shear zones. The fault zone having 20-30cm clay gauge, making an angle of 40-50° with tunnel route caused the collapse in this area. Rock material of 40-50m³ filled the face and burried the cutterhead of the machine. A shematic presentation of the collapse area and thge support system used is given in Figure 5.

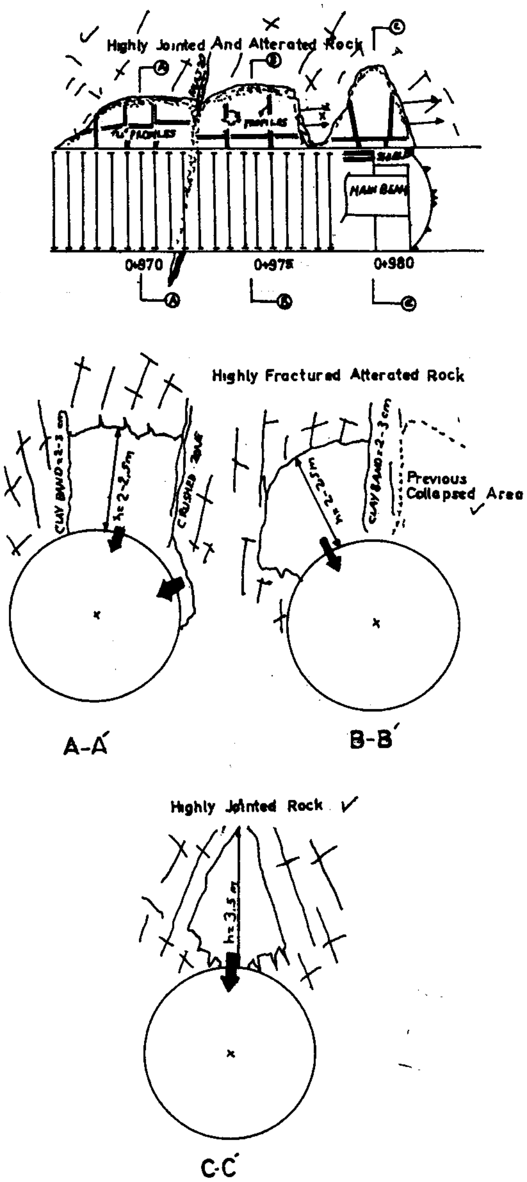

Fig. 5 The Collapse Between Chainage 0+965-0+982

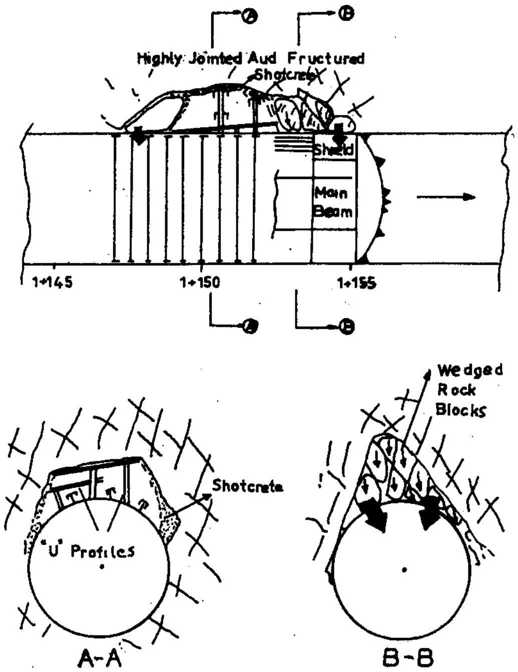

Fig.6 Wedged rock blocks between chainage 1+148-1+155

5.4 The Collapse Between Chainage 1+148-1+155

Highly jointed and fractured rock with clay filled siltstone, mudstone of Trakya Formation were encounterd in this area. Rock blocks collapsed on the shield due to the presence of joint sets as seen in Figure 6.

5.5 The Collapse Between Chainage 1+220-1+235

The main rocks at collapsed area are sitstone and mudstone, although not obvious some sandstone bands have been recorded. Trakya Formation in this area is intensely jointed and fructured. Joints are generally filled with clay or calcite. Nearly at the chainage at the 1+210 an overbreak occured due to the loose fructured rock on the left hand wall, later a big collapse occured when a fault zone was encountered.

6 CONCLUSIONS

A Robbins full face tunnel boring machine was used in Baltalimani Tunnel which is a part of Istanbul Sewerage Project. Buyukada and Trakya Formations exist along the tunnel road. Machine utilization is found to be 28.5% in Buyukada Formation and less than 10% in Trakya Formation.

Trakya Formation is closely jointed, locally strongly folded and faulted. The biggest and most important problem encountered through this formation are support installation in front of the gripper pads, overbreaks at crown and sidewals of the tunnel, sometimes collapses especially crushed and faulted zones.

Overbreaks and collapses from 10 to 250 m^3 occured at different chainages. The

support of theese anomalies, passing through them caused the machine advance rate to decrease very much. Besides, pressing of the gripper pads on the steel arch+shotcrete caused another big problem, when clay bands exist.
Excessive disc wear, supporting works and bad ground conditions were the reasons for low machine utilization time. Especially, supporting of the caverns in Trakya Formation due to the collapses took 74% of the machine downtime. Difficulties encounterd in geologically difficult ground and precautions taken are briefly summarized in this paper.

REFERENCES

Bilgin,N.,Seyrek,T.,and Shahriar,K.,1988, Golden Horn Clean contributes valuable data, Tunnels and Tunnelling, Vol.20, No.6, 41-44

Bilgin,N.,Seyrek,T.,Erdinç,E.,and Shahriar,K.,1990, Roadheaders glean valuable tips for Istanbul Metro, Tunnels and Tunnelling, Vol.22, No.10, 29-32

Çiğla,M.,1991, Effect of Geotechnical Properties on the Cutting Performance of a Full face Tunnel Boring Machine, Istanbul Technical University, Institute of Technology and Science, 161