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TBM excavation ín weak and heterogeneous rock masses for the Athens Metro

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ABSTRACT: Aη engineering geological assessment with respect to the TBM excavation, within a highly heterogeneous system of formations known as the "Athens Schist" is presented. The method considers mainly the rock mass competence οη the basis of criteria related to lithology, tectonic deformation (fracturation-folding-shearing), weathering and rock mass quality as well as geometrical-structural and groundwater criteria. Hence it calibrates the rock mass interaction during excavation using the specific TBM of the Athens Metro project, with an emphasis to potential face failure and overbreaks. It is based οη a statistical-minded extrapolation of factors that govern the behaviour of the ground, when subjected to mechanised boring. The final objective is to identify which tunnel sections exhibit *'friendly', 'moderαte'* or *'αdverse'* tunnelling conditions with respect Io overbreak development and propagation and to provide a basis for the selection of appropriate treatment andJor altemative excavation methods.

RESUME: Une characterisation appliquee a la performance du tunnelier dans des formations tres heterogenes du substratum d' Athenes est presentee. La methode considere la competence de la masse rocheuse suivant sa lithologie, sa deformation tectonique, son alteration, sa classification geotechnique, son developpement geometrique et son milieu hydrogeologique. υη calibrage du comportement de la masse vis a vis a la formation des hors profils par ecroulement du front a travers le disque de la foreuse est donc formule. La methode est basee sur le groupement statistique des facteurs qui controllent le comportement du teπaíη. L' objectif final est de classifier les sections a etre traversees comme d' un comportement "amical", 'mediocre" ou "defavorable", pourvu, le cas echeant, qu' οη decide les moyens des traitements necessaires.

1 GENERAL

The first two fully underground lines of the Athens Metropolitan Raílway are under construction since November 1991. These lines comprise 18km of tunnels, 21 stations, 29 ventilation shafts and various miscellaneous structures. Two 9.5m diameter TBMs, one for each line, were employed ίη order to bore the twin-track running tunnels which are generally located at a depth of lO-20m (measured at the crown). At the time of writing this paper all the stations are excavated, and about 70% of the interstation tunnels are bored with by the TBMs (Hewison, L., 1994).

The objective of this independent tunnelIing assessment is to evaluate whether the tunnelling conditions along the Athens Metro interstations are *'friendly" 'moderαte'* or *'αdverse'* for excavation with the tunnel boring machines (TBM) of the specific project.

The methodology of this analysis has been put ίηIo practise especially for the assessment of the Athens Metro interstations and has provided successful predictions of the behaviour of the ground. This methodology is continuously developing (Marinos, P. et al, 1997), as the experience gained from the works underway lead Io particular adjustments ίη its approach, through a

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better understanding of the engineering behaviour of the rock mass.

2. GROUND CONDITIONS IN THE ATHENS METROPOLIS

The geological substratum of the city of Athens consists, within the depth range of the Metro works, of a series of formations known as the system of the "Athens Schist".

The *'Athens Schist'* is a term used to describe a highly heterogeneous, flysch-like formation of Cretaceous age (Marinos, G. *et. αl,* 1971). Iι comprises schists, phyllites and metasedimentary shales, siltstones and sandstones. Limestones and marls may also occur while igneous activity has introduced peridotitic and diabasic intrusions at places. During the Eocene the 'Athens Schist' formations were subjected Io intense folding and thrusting and subsequent extensive faulting caused extensional fracturing. Widespread weathering and alteration of the deposits are additional controlling factors of the *rock* mass quality. Iη general, sericite metasandstones and schists *form* an upper υηίι, which is underlain by a lower. unit of dark grey clayey and silty shales, phyllites and finer grained metasandstones (Figure 1).

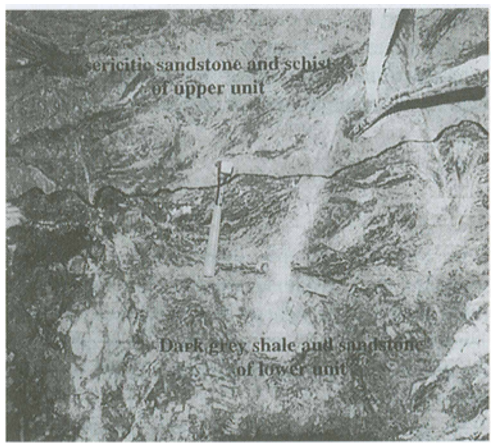


Figure 1: The two units generaHy distinguished ίη the "Athens Schist".

The 'Athens Schist' rock mass is thus characterised by:

- frequent changes of lithological facies at short distances, further accentuated by an ίπeguIar weathering pattern,
- a variability of materials ranging *from* hard rocks to soils ίη terms of strength (frequently mixed at the sca1e of the tunne1) and
- a highly eπatίc structural' pattern of numerous structural shears and faults.

The tectonic activity whenever assocïated with weak rocks often produces engineering soil materials. The tectonic fabric of the *'Athens Schist'* bedrock also includes mylonite materials that are ηοΙ οηlΥ limited to major fault zones but also rather occur under the *[orm* of gouge infilling of systematic or non-systematic shears. The response of rock mass volumes composed of hard rock and weak rock intercalations to the severe tectonic activity gave rise to dysharmonic folding and faulting that often entailed a clearly visib1e chaotic structure of isolated lensed blocks of hard rock 'floating' within a soft clayey matrix.

The resulting rock mass is highly heterogeneous and anisotropic ηοΙ οηlΥ ίη the macroscopic-geotectonic scale of the Athens basin, but mainly ίη the mesoscopic scale of the tunne1 works. This inherent heterogeneity of the "Athenian Schist" rock masses is a key-factor *for* the generation of overbreak developing conditions during TBM excavation.

In practice, the heterogeneity of the 'Athens Schist' is proved by the uncertainty *for* coπelatίηg adjacent boreholes, a fact which makes the drawing of reliable geological sections more difficult. In the methodology described herein, a 'statistical-minded' extrapolation of the borehole data is employed, instead of compilation of classic geological sections.

Iη the Athens Metro Project the "Athenian Schist" geological formations are being rated by the Contractor according to a *Mass Rating system* (MR), a modification of the RMR classification of Bieniawski. Iη simple terms, the *MR* subdivides the *R.Q.D* and *discontinuity spacing* ratings of the lowest range, and does ηοΙ account *for* the effect of the *discontinuities orientation).*

Since the Athenian Schist rock masses, ίη several cases, exhibit an engineering soil behaviour, the present assessment does ηοΙ rely υροη the rock mass classification ratings Io deduce its stability versus TBM excavation. It is possible that the same MR rating is attributed to formations with totally different behaviour during TBM excavation (e.g. cohesionless soil-like material with frictional characteristics, as opposed Io laminated presheared shales of very Iow frictional strength) or response to strengthening measures ("groutable" or "non-groutable" ground). Nevertheless, the MR-ratings are coevaluated with all other controlling geological parameters of the tunnel's cover zone and face, mainly when MR>22. Οη the *engineering geological profile* the MR-values are shown ίη distinct columns adjacent to the boreholes, thus allowing the facile identification of areas where blocks or lenses of hard rock 'float' within a predominantly weak-rock or engineering soil environment of low MR.

3. POSSIBLE CONSEQUENCES OP TUNNEL BORING: THE NEED FOR A PREDICTIVE METHODOLOGY

The tunnels of the two new Athens Metro Lines are ίη their majority being excavated by means of two identical Tunnel Boring Machines, one per each line. The 9.5m-diameter TBMs are of the shielded type with a cutterhead equipped with disc cutters and drag bits (Figure 2). The uncontrolled muck discharge openings represent about 30% of the total cutterhead area while a series of belt conveyors are used to transport the muck at the back and load ίι Io trains.

Iη principle the Athens Metro TBMs were designed Io deal with various constellations of rock and soil, and their behaviour was indeed very good ίη excavating a major part of the Athenian substratum. However TBM excavation cannot always avoid collapses if the suπouηdίηg material is very poor (Efraimidis, C., 1996). Ground failures may initiate either *from* the face, or, ίη minor extent, *from* the very restricted section of the crown that is temporarily left unsupported at the upper front part of the TBM, as the machine advances. Overbreaks may then develop that could propagate upward.

The ground conditions ahead of the TBM are assessed ίη terms of overbreak risk that induces surface settlements jeopardising the stability of surface structures, or occasionally propagates ιο surface collapse with inestimable consequences ίη the worst case scenario.

Indeed, certain ground conditions can easily induce such collapses, by 'ravelling' of loose fine-grained material or by 'flowing' of soil or crushed rock, or by slippage of 'flakes' of tectonically disturbed phyllite. In other words, the aforementioned phenomena are favoured by 'passages' with low modulus of deformation (E), or ίη presheared formations of low strength with closely spaced foliation.

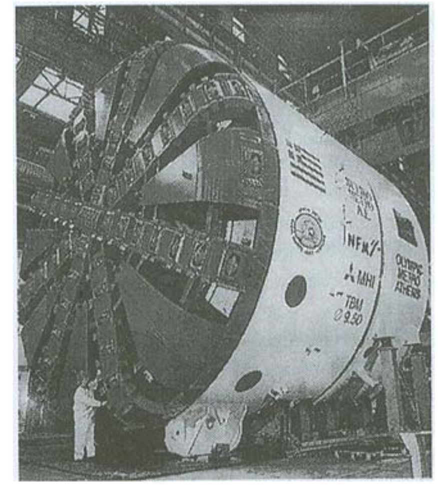


Fig. 2: The Athens Metro open cutterhead shielded TBM

Iη the special case of mixed face conditions where sizeable blocks of competent hard rock (of the tunnel's scale) are isolated ίη a sheared weak clayey rock environment, overbreak may initiate when the blocks are rotated and displaced rather than cut by the TBM cutter head.

Overbreak developing conditions are further aggravated by the presence of water. During tunnelling with a TBM, the unlined front part of the tunnel constitutes a medium of infinite permeability. Iη general, vertical drainage towards the tunne1 cannot be intense due to the overall moderate to low permeability of the 'Athens Schist' rock masses and therefore overbreak due to intemal erosion is ηοΙ a typical mode of failure. However, the *rock* mass becomes softer and weaker when saturated with water, and the discontinuity condition is radically downgraded, especially ίη the case of completely weathered or presheared clayey shale with gouge infillings of low friction.

Aι this ροίηι it should be stressed that the encounter of ancient or antique (empty or backfilled) wells and cistems, may constitute an imponderable failure factor at the tunnel face and cover zone. Aside from the uncontrolled flow of water and mud from the well itself, the suπoundíng rock mass tends Io be softened and disturbed and is generally liable Io collapse from the rapid drawdown. Weakening may also occur due Io leakages from overlying old sewage pipes.

Additionaly, there is always the problem of predicting and avoiding tunnel-induced settlements οη the surface of the urban area of Athens.

4. BOREHOLE INFORMATION AND THEIR ASSESSMENT

Borehole infoπnation is the main core of the present methodology. A solid basis of all necessary geological and geotechnical information is first compiled, ίη the form of *'geological sections lor engineering purposes'* οη which the key parameters for the evaluation of the ground conditions are depicted.

4.1. *Engineering geological characterization OI the borehole materials*

Detailed logs of the boreholes are prepared, following careful inspection of the cores, mostly collected with the split baπel drilling technique. The geological material is described and classified ίηIo distinct *engineering geological lormations,* ηoI according Io strict classic petrographical criteria but combining basic engineering geological data such as:

- the type of tectonic deformation, i.e. brecciation, intense fracturing, compact endogenetic breccias,
- the type of infilling material of the discontinuities, i.e. soap-like clayey coatings or thick compressible gouge infillings of low friction angle,
- the presence or absence of slickensides (lines or striations) along the discontinuity surfaces and susceptibility of the foπnations Io shear failure,
- the degree of participation of loose rock material and susceptibility of the foπnations Io ravelling failure,
- the degree of participation of engineering soil material, which may occur ίη the forms of completely weathered rock (residual soil) or discontinuity infilling material or fill material ίη the voids or mylonitic clay along zones of intense tectonic shearing,
- the presence of blocks of very hard rock within a very weak, sheared and laminated mass that exhibit differential behaviour during excavation (incapability of the cutters Io break the floating blocks).

4.2. *Assessment OI geologic conditions lor TBM excavation*

The assessment described herein, is based οη the identification and the grouping of the participation of the above mentioned rock mass types (Figure 3).

The main poίηι of interest is the proportional participation and the geometrical structure of the *'competent'* (rock-like) and *'non- competent'* (weak rock or soil-like) ground materials, both ίη the cover zone and the tunnel face. The relevant information originates from the cores of the boreholes. The rock mass classification ratings of the cores and the hydrogeological measurements and test results are also taken ίηIo account; the overall assessment is counterbalanced with an empirical estimation of the behaviour of similar rockmasses, as witnessed during inspection of both TBM and conventional excavations ίη the completed tunnels of the project.

<u>Cover zone</u>

Of interest here are the following parameters:

I) The depth of the tunnel crown.

2) The *participation OI the various weak materials,* i.e. alluvium, backfill, mylonitic material, brecciated rock, loose rock fragments ίη a matrix of soil, shale and any other type of geological material that simulates Io soil *(engineering soil).*

3) The *participation OI rock-like materials* ίη a 6-metre zone immediately above the tunnel crown. This 'factor' is considered as indicative of the capability of the cover zone Io bridge over a progressive overbreak and prevent its propagation towards the surface.

<u>Tunnel face</u>

Regarding the tunnel face, the rock mass is assessed both ίη teπns of differential behaviour as of its hardness and ίη teπns of potential slippages or ravelling behaviour. The parameters which are examined are:

I) The participation of *rock-like against soillike material,* at the *lull section* of the tunnel.

The *rock-like* material at the face may represent distinct layers with sufficient thickness and lateral persistence ίη the scale of the tunnel. In case such rock layers prevail within the section of the tunnel face, the conditions of excavability are favourable with minimum or total absence of overbreak.

The *soil-like* material at the face is mainly represented by the presheared black shale or phyllite of the lower unit. Horizons of highly fractured and loose rock, or mylonitized or highly weathered rock ίη the upper unit, are also considered as soil-like material.

2) The participation of *rock-like against soillike* materials ίη the *upper half* of the tunnel face, since this very part is the most prone Io facecollapse and overbreak initiation..

BOREHOLES	AKS 102	AKS 103	SYO 409
Chainage (m)	4216	4231	5445
Distance from TBM tunnel axis *1m)*	5.5	20	5.6
COVER ZONE INFORMA TION			
ΤυΠΠθl crown deoth (m)	15.8	15.8	19.8
Alluvium - FiIII'!o)	8.9	10.1	17
Comp/ete/y Weathered Rockl ΕΠΟΙΠθθΓίπa Soil (%)	3.8	6.3	19
Seήcitíc schist with black shaleI'!ol	O	O	O
Breccia ('!ol	O	26.6	32
B/ack Sha/e(%)	O	O	15
voidr;;)			
Total cummulative percentage ol weak mateήal ίπ the cover ΖΟΠθ, alluvium excluded *l'!o)*	3.8	32.9	66
T otal cummulative percentage OI weak mateήal ίπ the cover ΖΟΠθ ('!o)	12.7	43	83
Percentage ol soil-like material ίπ the 6-m ΖΟΠθ above the tunnel crown ('!o)	3	35	73
FACE INFORMATION			
Full face: Soil-like mateήal ('!o)	10.4	28.1	68
Upper half ol face: Soil.like mateήal ('!o)	O	29.2	48
ASSESSMENT FOR TBM EXCAVATION	F	M	A

Fig. 3: ExampIes of the engineering geologicaI assessment of borehole cores for TBM excavation. Typical cases of boreholes for which the material both of the cover zone and of the tunnel face are characterised as P: friendIy, M: moderate, A: adverse for TBM excavation. Iη those cases where a different characterisation is assigned ιο the cover zone and Io the face

The *geometrical distribution and structure* of the various materials at the face obviously contributes Io the stability factor. The simultaneous presence of 'competent' and Ωoη competent' members iS responsible for the differentiality of the rock engineering behaviour of the face.

<u>Ratinf!s</u>

The parameters discussed ίη the previous paragraphs are co-evaluated, ίη order Io provide an assessment of the expected engineering geological conditions for TBM excavation. Such an assessment iS of practical value if ιt identifies *distinct areas along the drive* and suggests the *likely precautions* Io be taken before, or during, the passage of the TBM. These precautions will be first aimed at eliminating any possible risk of damage Io the urban environment, such as settlements, surface collapses and associated damages. Additionally, they will be aimed towards guiding an efficient, trouble-free and thus rapid excavation procedure.

Individual ratings (ίη the foπn of symbols *A* for *adverse, M* for *moderate* and *F* for *Iriendly)* are assigned at each borehole, based οη the cover zone quality, the face quality and the MR va1ues (Figures 4, 7). As a rule, the meaning of these ratings is the following:

<u>*Friendlv:*</u>

No significant overbreaks are expected due Io the good quality of the rock mass.

<u>*Moderate:*</u>

Case I: Incompetent rock may exist at the tunnel face, but the quality of the cover zone impedes the upward propagation of extensive overbreaks.

Case 2: The face consists of competent materials but the cover zone is partly intensely broken (brecciated etc.). Iη this case ιt is difficult Io have initiation of extended overbreaks by a face instability. If, however, an overbreak occurs, then the cover zone may ίη principle have some ability of bridging, since ιt does ηoI consist of the black shale ravelling flakes, but of angular portions of fractured or brecciated layers.

<u>*Adverse:*</u>

Predominance of the black shale or of veryweak material at the face, associated with material of similar weakness at the cover zone, over a significant height above the tunnel crown. The latter material might be very weathered or intensely brecciated rock of the upper unit, or transitional material from the upper Io the lower unit. The enhanced presence of groundwater dramatically downgrades the condition of the discontinuities, which generally bear clayey coatings, and as a rule contributes to *adverse* conditions. Overbreaks may easily initiate from the tunnel face and propagate towards the surface.

The presented geologic assessment was proven Io be ίη good agreement with the performance of the TBM; as a rule, ίη areas where the borehole information indicate the extended development of soil-like materials, frontbreaks or overbreaks have appeared. Failure events were much less, or totally absent, ίη areas where rock-like material prevails. However , a number of failures are often caused by other reasons, such as the encounter of leaking sewers or aqueducts associated with TBM stoppages and provoking. occasionally internal erosion of the ground.
Although the borehole information is most valuable other data is required ίη order Io get a more realistic feeling for the ground behaviour during excavation.

5. OTHER SOURCES OF INFORMATION

5.1. *Hydrogeological information*

AII the available information, such as the water level drawdown during drilling, the ground water piezometric data, the ίη situ permeability tests, the hydrographic info οη watercourses or preferential surface runoff ίη the broader area *of* the alignment, are compiled οη distinct hydrogeological profiles along the drive.

These allow the evaluation *of* the hydrogeological conditions *of* the overburden deposits and *of* the 'Athens Schist' bedrock. In the former case, the presence *of* alluvia or *of* deep buried channels that could approach the tunnel or tunnel crown elevation, are *of* major significance. Ιη the latter case, particular importance is attributed ιο perched water tables above the tunnel or to sections with enhanced permeability that could induce increased water inflow. The presence *of* water ίη poor quality formations is responsible for a further degradation *of* the ground as already mentioned.

5.2. *Information on voids andlor buried antique features*

It is common knowledge that as the TBM is driving through the substratum *of* the city *of* Athens there is an inherent high risk *of* encountering old pre-existing voids and/or other buried structures, either empty or filled with loose material. Among others *one* could indicatively mention the ancient hydraulic structures (wells, shafts, aqueducts and galleries either isolated or ίη complex systems) or the fortification wall *of* Athens (moat, trenches and galleries). Buried features and voids *of* the modem times are also concerned (known or unknown utilities' networks).

More specifically, the presence *of* voids may not prove to be sufficient to induce dangerous overbreak, where these are are found 'isolated' ίη a *'friendly'* environment *of* good rock. Οη the other hand, the same ground response cannot be anticipated ίη the case *of moderate* or adverse *conditions.* If however these voids do not represent individual 'isolated' features but rather they form part *of* a combined system *of* wells, aqueducts or galleries, the danger *of* extensive overbreak exists ίπeSPectίve *of* the nominal geotechnical conditions for TBM excavation.

The information used ίη this assessment derives from geophysical surveys (ηoI always very effective), from boring and mainly, where possible, from pilot tunnels.

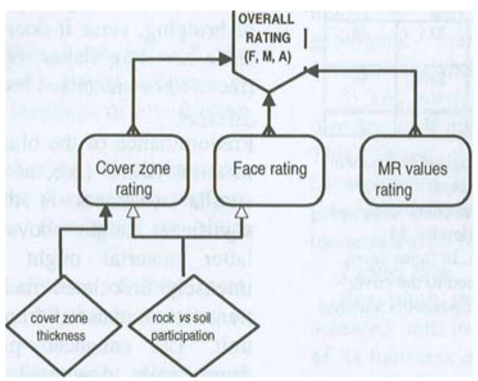


Fig. 4: Ratings *of* boreho\e cores for the assessment *of* the geo\ogical-geotechnica\ conditions for TBM excavation. F: friend\y, M: moderate, A: adverse IO TBM boring.

5.3. *Pilot tunnel inf(πmαtion*

The need for further investigation by means *of* ρίΙoι tunnels emanated from the detection *of* adverse zones through the described assessment, ίη which poor ground prevailed increasing dramatically the risk *of* TBM failures. The frequent and random occuπeηce *of* ancient wells and voids constituted a another basic reason.
Pilot tunnels (usually *of* 0=3.0m and located 1.5m below the TBM crown) proved Io be valuable sources *of* information, since, apart from the accessibility for undergroung treatment *of* the rock mass (if and where necessary), they allowed:

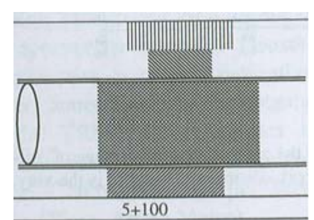
a) the compilation of a continuous engineering geological profile along the tunnel drive,
b) the encounter *of* wells and other preexisting voids that intersect the tunnel or lie ίη its close environment (probehole detection),
c) the drainage of the rock mass (locally weepholes contribute significantly to water pressure relief),
d) the observation *of* the rock mass behaviour during excavation and identification *of* potential modes of failure.

The above categories *of* pilot tunnel data are added to the drawing *of* the engineering geological section ίη the form *of* 'bars' (Figure 5) that enable the quick visualisation *of* hazardous zones.

6. FINAL ASSESSMENT: 'FRIENDL γ', 'MODERATE' & 'ADVERSE' CONDΙΙΙΟΝS FOR THE TBM

The final assessment results from the co-evaluation *of* the borehole core ratings along with the available pilot tunnel information, the hydrogeological information, the presence *of* buried disturbing structures and the overall sensitivity *of* the area.

The geotechnical conditions for TBM excavation are again assigned the characterisations *'friendly' (low* risk), *'moderate' (medium* risk) and *'adverse' (high* risk) (Fig. 7). These characterisations are an index *of* geotechnical hazards and consequent overbreak risk, now ίπ
conjuction also with the vulnerability *of* the area (sensitivity *of* buildings, presence *of* ancient structures, wells & underground chambers, sewers, utilities, etc.)



Shaded areas indicate:
<- significant water int10w <-
overbreaks/failures
pίlσι tunnel section: <- zones of weak material (shear & mylonitic)

<- MRΩ2 <-
chainage

Fig.5: PίloI tunne! information οη the hazardous zones. Details are reported οη the finaI engineering geo!ogica! section (see fig. 7)

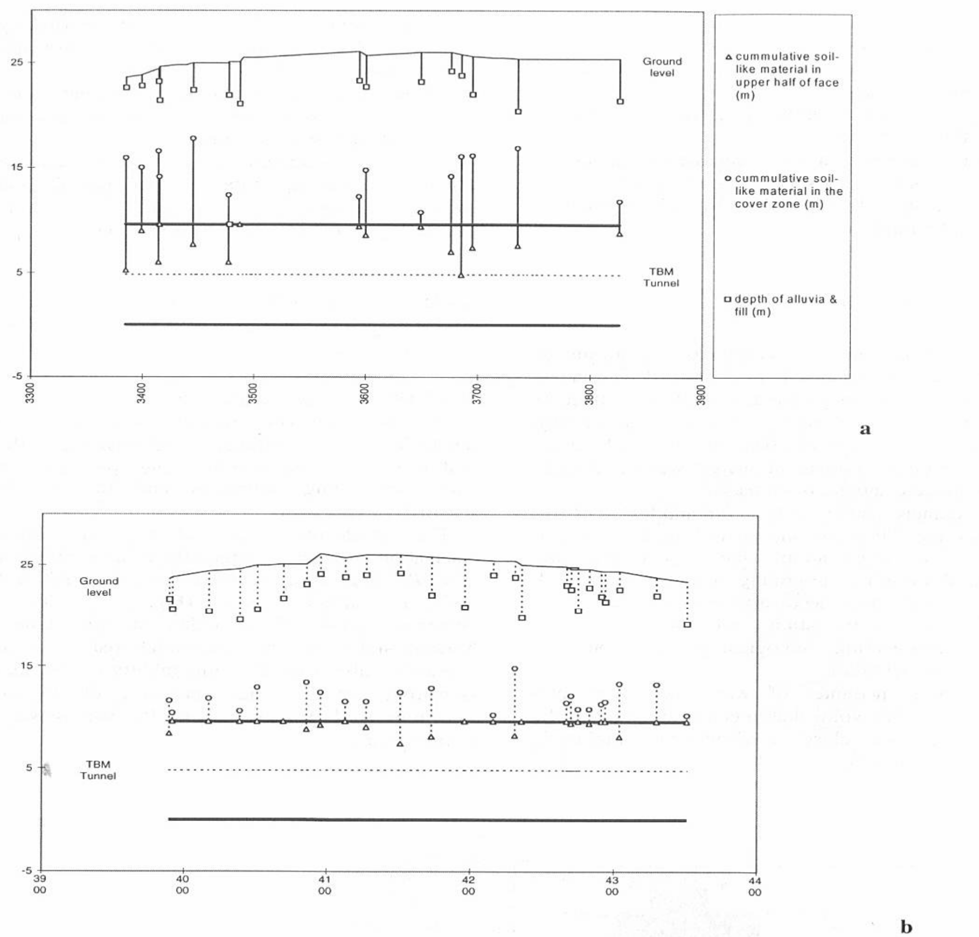


Fig. 6: Assessment of borehole materials for TBM excavation,in terms of the cummulative percentage of soil-like materials. a) interstation where overbreaks have occured, b) interstation with no overbreak occurrence. Notable is the very limited presence of weak black shales at the tunnel face in case b.

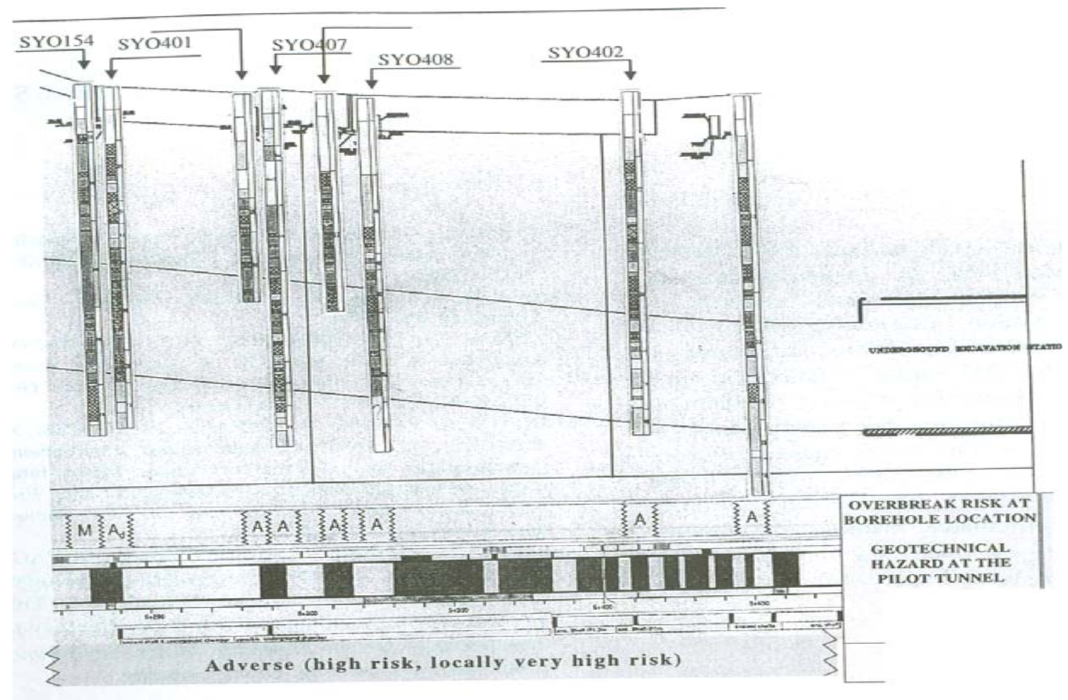


Fig.7: Engineering geo!ogica! section ίη the area of *Plaka,* an old central Athens quarter with vulnerable historical buildings (part of SYO interstation, line 2). The area was already assessed as *"adverse"* from the boreho!e data a fact which was confirmed by the ρίlοι tunne! constructionThe cover zone was thus reinforced through the ρilοι tunne! with grouted fiberglass nails, prior ιο the TBM advance.

7. FACING THE ADVERSE CONDITIONS

Aη early assessment of the tunnelling conditions to be encountered during TBM excavation allows the contemplation of appropriate remedial measures and altemative engineering solutions, particularly since face treatment cannot easily be implemented through the specific TBMs. The measures are designed and implemented by the parties involved ίη the project (the Contractor, Olympic Metro Consortium, and the Client, Attiko Metro).

'Adverse' conditions for TBM excavation denote the inabi1ity of the machine to excavate through these ground conditions, without inducing extensive overbreak that cou1d possibly propagate to surface collapse. The range of solutions is then levelled as follows:

J. If adverse conditions prevai1 over significant lengths of a tunnel drive, or if significant structures are to be underpassed by the TBM, then the *realignment of the tunnel,* where feasible, is a way of bypassing the problem. This was the case with the realignment of the Metro tunnel beneath the Archaeological Site of Keramikos (P. Marinos et a1., 1997).

2.a If the tunnel alignment cannot be modified, then treatment is required. . In this case *pilot tunnels* driven ahead of the TBM are considered highly beneficial, because:

- they allow the detection and filling of pre-existing voids (wells, galleries, e.t.c.) which are often the basic imponderable factor for triggering fai1ures
- they drain the rock mass

- they permit the implementation of rock mass strengthening techniques ahead of the TBM, where the rock mass is susceptible Io treatment (e.g. grouted fiberglass nails).
- by means of the support measures for their own temporary stability (e.g. fiberglass reinforced shotcrete), they reduce the possibility of face failures during TBM excavation.

2.b .If the rock mass can be sufficiently treated from surface, then the implementation of appropriate ground treatment methods is considered (grouting, jet grouting, piling).

3. The aforementioned solutions are aimed at ensuring safe TBM boring by preconditioning the ground. However, if none of them is feasible (i.e. due Io the underpassing of buildings or Io the predominance of ηοη-treatable ground ίη the pilots), then a change of method was ίη some cases seriously considered. Alternative methods may include the use of an open shield machine or conventional tunnelling ("stiff NATM" or forepolling).

CONCLUSIONS

The assessment presented ίη this paper is based οη an engineering geological classification of a complex geologic formation, that takes ίηΙο account the particuJarities of the behaviour of the specific boring machine for the construction of the Athens Metro. This classification distinguishes the various members of the 'Athens Schist' by means of petrographic characteristics, tectonic fatigue, weathering and groundwater conditions through the geotechnical grouping process and assumes their behaviour (rock-like or soil-like) during excavation with the TBM. The final risk evaluation takes ίηΙο account man-made particuJarities of each area and may be supported by information from ρίΙοι tunnel. This method is intented for the works of Athens Metro; however, the same principles of assessment can also be applied Io other projects and different ground types, given that the sensitive parameters for a particuJar method of excavation are properly recognised.

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