THE REDUCTION IN EFFICIENCY AND THE EXCAVATION DIFFICULTY DEPENDING ON ROCK CLASSES IN TUNNELS

Bülent ULUKAN [1], Nefise AKÇELİK[1] , Çetin FIRAT[2]

SUMMARY

Motorway tunnels , which have large excavation crossection with two tubes and three lanes, are excavated by New Austrian Tunneling Method in Turkey. Factors such as driving techniques (drill and blast method, mechanized etc), excavation and support sequences, staged excavation, maximum advance length, which change due to rock classes, influence tunnel excavation cost and working program depending on excavation time.

In this study reduction in efficiency due to difficulty of excavation are studied by evaluating site records held in motorway tunnels during driving. Information about equipment and excavation techniques used in excavation of different rock classes are collected and variation of excavation and support application time due to advance rate. As a result of study, in tunnel excavations, it is seen that efficiency reduces with decreasing rock stability different from open cuts.

1. INTRODUCTION

Construction time and final cost of tunnels have been affected by driving techniques, excavation sequences, time of application of supports, maximum round lengths. In this study site records taken from five motorway tunnels in Turkey with a total length of 22 km are considered and effects on construction efficiency and excavation difficulty are evaluated depending rock classes. It is seen that the efficiency reduces five times more for squeezing type rocks (C2 rock class) compared to stable type rocks (A rock class) classified according to ÖNORM B 2203 (classification used by NATM).

2. EXCAVATION DIFFICULTIES DEPENDING ON ROCK CLASSES

In the study, excavation difficulties were evaluated using standard excavation forms, geological maps from tunnel face, design drawings of excavation and support systems and all factors , which bring reduction of construction efficiency.

Bolu Tunnels, TAG Motorway tunnels (P1, P2,P3) and Selatin Tunnels located on highway arteries were selected for this study.

---

1. Civil Engineer (M.Sc.) General Directorate of Highways, Turkey
2. Civil Engineer (M.Sc.) LMK Joint Venture, Turkey

The main factors and operations for each advance round are concerned in evaluation as follows.

- -Excavation geometry, sequences of excavation and supports depending on rock classes
- -Driving techniques (drill and blast, mechanized excavation)
- -Characteristics of drilling and/or excavation machine
- -Blasting Pattern (diameter, depth of drills)
- -Type and amount of blasting materials
- -Period for cleaning of face and preliminary works before blasting or excavation
- -Period for workmanship and machines and drilling for blasting, ventilation, loading of loose material
- -Geological mapping and geotechnical monitoring

In stable rock conditions like A1-A2 type classes, even full face excavation is possible, due to large crossection of motorway tunnel staged excavation (top heading-bench) is preferred practically by concerning especially necessity of huge equipment contrarily to stable and weak rock classes. However in C1-C2 type rock classes multistage (sometimes side drifts) is required for stability of tunnel. In addition to all these factors, there are support application which are necessary for each excavation stage due to varying rock conditions. Without completion of support application for each round advance to the other round is not possible.

All this operations and difficulties following each other and cause delay in advance have affected the efficiency of excavation.

In Table 1, each work and its duration in a round are described depending on rock classes. Duration for works in top heading-bench-invert excavation are given totally. Using these data time period and round length of a full face advance are determined for different rock classes changing from A1 to C2. According to results given at Table 2, a 1.39 m advance for C2 rock class can be realized in 39 hours, while a 1.6 m advance in 27 hours for A1 type rock class.

TABLE 1 Excavation and Support Works and Their Application Time according to Rock Classes

EXCAVATION AND SUPPORT WORKS*		TIME PERIOD FOR EACH WORK ACCORDİNG TO ROCK CLASSES (HR)				
		A2	**B1**	**B2**	**C1**	**C2**
1-Excavation Area (m2) and round length (m)	Top Heading	57,75/3,00	58,86/2,85	59,26/2,30	60,50/1,15	61,50/1,10
	Bench	69,54/4,50	70,10/3,80	72,68/3,25	74,70/1,50	75,27/1,10
	Invert	-	-	18,0/13,5	18,00/13,5	18,00/13,5
2- Ventilation		1,5	1,5	1,5	1,0	0,5
3-Forepoling		-	-	-	2,0	2,5
4-Cleaning of Face		1,5	1,5	1,0	0,5	0,5
5-Drilling for blasting		6,0	5,5	4,0	-	-
6-Drill-blast or mech. exc.		4,5	4,25	4,0	4,5	5,0
7-Moving loose material		2,0	2,0	1,0	-	-
8-Loading and transportation		5,25	5,25	5,0	-	-
9-Shotcrete		3,5	4,5	5,0	5,5	6,0
10-Wiremesh		2,5	3,0	3,0	3,75	5,0
11-Steel ribs		-	-	2,5	3,5	4,5
12-Drillings for bolting		0,5	1,5	2,0	3,25	3,75
13-Bolting and injection		0,5	1,0	1,5	3,0	4,5
14-Geological Mapping		1,5	1,5	2,5	4,0	4,0
15-Geotechnical Monitoring		0,5	0,5	1,0	1,5	2,0

*time for excavation and supporting is given totally concerning time passed for top heading-bench-invert

At different motorway constructions, technology of sprayed concrete application (dry or wet), overbreaks affect application time. In stable rocks due to condition of discontinuities, necessity of additional bolting and wire mesh and increasing time for cleaning loose material at face are the most important factors which bring delays. In squeezing and weak rocks temporary shotcrete, wire mesh, bolting or injection at face, additional geotechnical investigations (sometimes boreholes drilled at face, lab tests etc) and low frequency of geotechnical measurements, reprofiling due to large displacements cause delays.

To evaluate the time for different rock classes at the same base, a 24 hour advance length as full face is determined. Advance length for a day is 3 m for A2, 0.80 m for C2 class rock. If excavation in underground is taken account as 1.1 for A1 this coefficient is five times more for squeezing rocks.

TABLE 2 Coefficient of Underground Working and Advancing Difficulties depending on Rock Classes

ROCK CLASS	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**
Av. advance length for staged exc. (m) **time (hr)**	4,60 27	3,80 30	3,25 32	2,50 33	1,80 36	1,30 39
full face advance length in 24 hour	4,20	3,00	2,40	1,80	1,20	0,80
coefficient of underground work and advancing difficulties	1,10	1,40	1,75	2,30	3,50	5,25

Coefficient of underground working difficulty as showed 1.1 (4.60m/4.20 m) for A1 represents only underground difficulties. Coefficients given for other rock classes provided by the ratio of 24 hour advance length of each rock group with advance length of A1 type rock (For example: 4.20 m for A1 /0.80 m for C2= 5.25).

3. CONCLUSION

Reduction of efficiency and factors should be investigated realistically at design and construction stage and difficulties should be described, in order not to have delay in construction time and program, reprofiling and repairments

In this study it is seen that time and length of advance for a tunnel and final efficiency for tunnel construction are affected by difficulties, excavation and support application changing according to characteristics of rock. In unstable, weak and squeezing rock conditions difficulties increases and efficiency reduces 5 times compared to stable rocks.

Before and during the construction, geotechnical investigations selection of construction equipment and its convenience to soil/rock conditions, geotechnical measurements and modifications of excavation and support systems by concerning site requirements has great importance for a high efficiency.

As stated before, this study based on site records from motorway tunnels. For the last five years there are many tunnel construction on state roads. These tunnels are 2 lane tunnels and have smaller crossection compared to motorway tunnels. It can be concluded that reduction of efficiency is less for decreasing rock stability compared to motorway tunnels. This difference is due to smaller crossection and conservative determination of rock mass classes in state road tunnel constructions. According to the experience from these tunnel constructions this study should be renovated considering new site records.

REFERENCES

1. KGM, (1994) Technical Specification of Underground Works, General Directorate of Highways, Ankara
2. ÖNORM B2203 (1994) Austrian Rock Classification Standard
3. KGM, (1996) Site Records of Excavation and Support Design from Motorway Tunnels, General Directorate of Highways, Ankara