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National report for tunnelling in Korea

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1 INTRODUCTION

The area of South Korea is 99,000km^2, of which about 65% is occupied with mountain terrain. Therefore rail road and motor way could not avoid tunnels. For high speed rail road and highway tunnel portions are increasing.

And more subway lines in 6 largest cities in Korea are designed to be constructed in tunnels due to heavy existing surface traffic. Besides there are several large underground oil or gas storage cavern projects in progress. In large cities major communication and power lines are installed in tunnels. In near future more engineers would be assigned to tunnelling it than ever before.

2 SCHEDULED TUNNELLING

2.1 Highway tunnel

In Korea motor ways are classified according the responsible organization. Highways are constructed and maintained by Korea Highway Coorporation, a government sponsored organization, and rural roads by Ministry of Construction or local governments. The highways are backbone of transportation net work in Korea.(Fig.1)

Therefore only highway construction schedule in near future will be reviewed in this report. From 1993 to 2001 the highways scheduled to be constructed are about 1,925 km(Fig.1), of which 1,344 km will be newly constructed and 581 km widened and improved. Within these highways 116 tunnels are planned. Their total length is 79.8 km. As of February, 1993, 32 tunnels with total length being 17.7 km are under construction and 84 tunnels of 62.1 km are scheduled.(Table 1.)

Most of the tunnels are for two lane highways and some are for four lane highways.

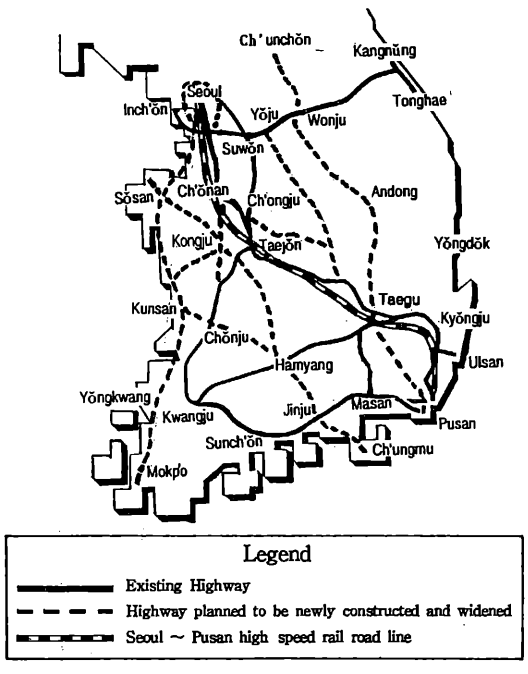

Fig 1. Existing and planned highway net and Seoul ~ Pusan high speed rail road

Table 1. Tunnel construction plan for new highway in Korea
unit:(number/km)

Line	Road	Tunnel (Total : 116/79.785)		Construction period (starting-finished year)
	Length	Under construction	Scheduled design	
Sum	1925.44	32/17.734	84/62.051	
Suburb of Seoul	92.0	1/0.45	5/9.631	1991 - 2001
Western Coast	353.0	-	22/10.215	1990 - 2001
2nd Seoul~Inch'on	15.5	1/1.820	-	1990 - 1994
Inland of Middle Area	154.0	-	15/9.285	1996 - 2001
Taejon~Jinju	161.0	-	13/8.990	1992 - 2001
Ch'onan~Kongju	139.0	-	1/2.200	1996 - 2001
Chungang	280.0	20/7.958	12/12.780	1989 - 2001
Youngdong	97.0	3/2.660	-	1991 - 1996
Taegu~Masan	83.3	3/2.765	-	
Taegu~Pusan	122.64	-	16/8.950	
Namhae	428.0	4/2.081	-	

2.2 High speed rail road

A new high speed rail road are scheduled to be completed by 1998. It starts from Seoul, the capital city of Korea, to Pusan, the southern port and the second largest city(Fig.1). The length is 411.5 km and the maximum operating speed will be 300

km/hr, but the geometry of the double track line and tunnels had been designed for a speed of 350 km/hr.

Since it passes through mountainous country, 153.9 km, 37% of the total length, is built on bridges and 138.6 km, 34% of it, in tunnels. (Table 2). The tunnel will be for double tracks.

Table 2. Classification of Seoul~Pusan high speed rail road

Classification	Length(km)	Ratio(%)
Total	411.5	100
Surface work	119.0	29
Bridge	153.9	37
Tunnel	138.6	34

2.3 Subway lines

Due to increasing population in urban area with industrial development, in most of the big cities traffic is one of the most important social problems.

Therefore mass transit transportation systems have been developed in 6 largest cities. In 2 cities subways are now operating and its expansion works are in progress. In one city subway construction started last year and other 3 city governments have finished preparing preliminary subway designs.

The plan for mass transit systems in 6 largest cities in Korea are shown on Table 3.

Table 3. Scheduled subway in Korea (the late 1991)

unit: km

City	1991					Plan(2011)		
	Population (thousand)	Number of car (thousand)	Line number	Length (km)	Daily traffic passenger (thousand)	Line number	Length (km)	Daily expected passenger (thousand)
Seoul	10,622	1,375.2	4	123	3,084	8	415	17,659
Pusan	3,800	340.5	1	26.7	497	5	135.2	4,490
Taegu	2,282	256.4	-	-	-	6	126.8	1,572
Inch'on	1,860	191.0	-	-	-	3	81.8	2,445
Kwangju	1,202	104.4	-	-	-	5	102.1	1,613
Taejon	1,062	90.0	-	-	-	5	80.0	700

In Seoul, the largest and capital city of Korea, the construction of subway systems are divided into 3 phases of construction. In the first phase, which had been completed in 1985, 4 lines of total 116.5 km had been constructed. And in the second phase 4 lines of 168.4 km will be under construction from 1990 to 1996. The third phase, which is planned during 1994~1999, including additional 4 lines of about 120 km.(Table 4, Fig.2)

Table 4. Status quo' of Seoul subway and construction plan

Classification	Construction period	Line number	Length
Phase 1	1971-1985	4	116.5
Phase 2	1990-1996	4	168.4
Phase 3	1994-1999	4	120.0

As the surface traffic problem has became severe, the construction method has been changed accordingly from open-cut method, which is more economical for shallow depth box structures, to tunnels. It is shown on Table 5 that the portions of tunnel for later subway lines are markedly increased.

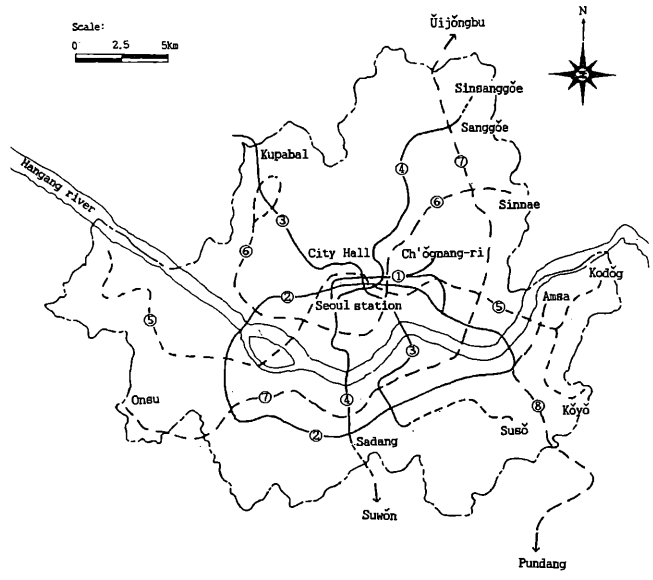

Fig.2 Seoul subway(phase 1,2)

Table 5. Applied method in Seoul subway unit: km

Classification		Length	Open-cut	Tunnel	Surface
Phase 1 (1971 ~1985)	Line 1	9.5	9.5(100%)	-	-
	Line 2	54.3	35.8(66.0%)	4.6(8%)	13.9(26.0%)
	Line 3	28.9	14.9(52.0%)	10.1(35%)	3.9(13.0%)
	Line 4	30.3	18.3(60.0%)	6.0(20%)	6.3(20.0%)
Phase 2 (1990 ~1996)	Line 5	57.9	21.9(37.8%)	35.4(61.2%)	0.6(10.0%)
	Line 6	34.1	1.5(4.4%)	24.3(71.3%)	8.3(24.3%)
	Line 7	44.2	12.8(29.0%)	27.8(62.9%)	3.6(8.1%)
	Line 8	19.7	14.0(71.1%)	4.2(21.3%)	1.5(7.6%)
	Expanded line2	3.0	3.0(100%)	-	-
	Expanded line3	8.2	4.9(59.8%)	3.3(40.2%)	-
	Expanded line4	1.3	0.3(23.1%)	-	1.0(76.9%)
Sum		291.4(100%)	136.6(46.9%)	115.7(39.7%)	39.1(13.4%)

For instance the whole track of subway line 1, which was completed in 1974 was constructed by open-cut method, but the major lines(line 5, line 6, line 7) in the second phase consists of more than 60% of tunnel portions. The tunnel portion of 8 subway lines of the first and second phase constructions are 115.9 km out of total 291.4 km, which is about 40%.

In Pusan, the second largest city, one subway line is operating and another under construction. For these two lines 25.5%(18.48 km) of total 72.35 km will be constructed in tunnels. Three more

subway lines are planned. The portion of tunnel in those lines would surely be much larger than the previous lines. In each of other 4 big cities 3 to 6 subway lines, ranging from 80 km to 127 km are scheduled to be completed by the year of 2011. Tunnel portion of those lines in these cities would be increased as those in Seoul.

3 PROBLEMS IN TUNNELLING

3.1 Geology

About 65% of all nation is mountainous area, of which only 2.4% has slope less than 15%. The northern and eastern part of the country are covered with high mountains and low and flat area are formed in western and southern parts. Therefore most big cities are located either in western or southern part.

Granite, granite gneiss and gneiss cover more than half of the nation. In some parts sedimentary rocks and their metamorphic derivatives are also found. The alluvial deposits in inland area are less than 10 m to 20 m thick. In coastal areas the thicknesses become larger, but most of the cases they never exceed 30 m with rare exceptional cases.

3.2 Highway and rail road

Most of the tunnels for highway and rail road are excavated in rock mass with deep covers above tunnels. Therefore construction conditions are favorable for tunnelling. Not much problems for double track rail road or two lane highway has been encountered. But during construction of four lane highway tunnel in gneiss and schistose gneiss great cares had to be taken.

3.3 Subway in cities

Subway tracks in cities run in shallow depth. If they could be constructed by open cut method more economically than by tunnelling. But due to heavy surface traffic more portions of subway are built by tunnelling in big cities. Since tunnels are in shallow depth, tunnelling has become more difficult. Normal double track subway tunnel is about 8.5 m high and 10 m wide forming horse shoe shape. In Seoul downtown area a 10~20 m fluvial deposits cover bedrocks. Therefore in many cases tunnel crowns have only 5~10 m completely or highly weathered rocks cover. In the neighborhood of the Han river the weathered rock covers sometimes become less than 5 m.(Fig.3)

The tunnel spring lines in either highly weathered or moderately weathered rocks. Therefore about upper half of the tunnels are in completely or highly weathered rocks and the lower half in the moderately weathered rocks.

Such complex subsurface conditions put some limits on choice of tunnelling method.

4 TUNNELLING METHOD

In most frequently applied tunnelling method a primary support system which consists of shotcrete, rock bolt and steel rib is installed right after excavation. Then a permanent secondary lining is formed on it.

Since deep tunnels for railroad, highway, waterway, communication lines and power lines are dug in rock formations, excavation is usually done by blasting. But for shallow tunnels for subways excavators and breakers are more common excavating equipment.

When an upper part of tunnel is in soft rock and a lower in hard rock, a modern excavating equipment, such as roadheader is less efficient. Therefore in subway construction in Korea conventional excavation equipment are more favorably used.

Tunnelling machine such as TBM started to be used only a few years ago. And the cases for large highway or rail road tunnels are rare because large diameter TBM had not been efficient in biotite gneiss, schist and banded sedimentary rock formations. But use of small TBM less than 4.5m in diameter are increasing in the area of waterway, communication and power line tunnels. Small TBM is also used in excavating pilot tunnel for large tunnel.

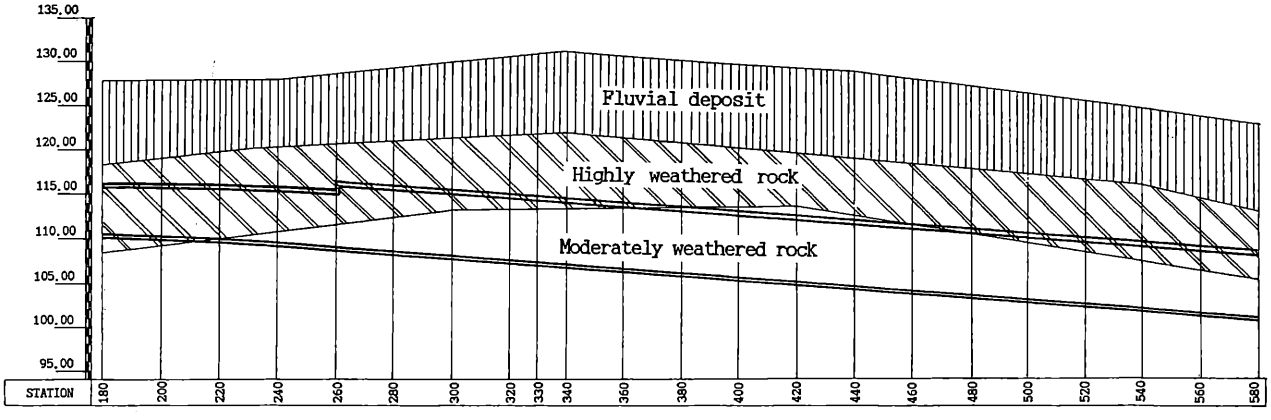

Fig. 3 Typical longitudinal subsurface for subway in Seoul

Tunnel through purely soil formation is very rare in Korea. Only a few cases in coastal area for communication lines were reported. Therefore shield for soft soil has not been used in Korea.

Instead rock shield has begun to be used for small diameter tunnels in Pusan, the southern coastal city. Recently large diameter rock shield for double track subway tunnel has been attempted. As of now no subway tunnel is yet designed to use rock shield. But if machine tunnelling is going to be adapted in large cities in Korea, it would be more like rock shield.

5 SUMMARY

The foregoing review could be summarized as follows.

1. During the years from 1993 to 2001 116 highway tunnels of 80 km total length are scheduled to be completed. And 138.6 km of rail road tunnels are also planned to be finished by 1998.
2. More subway lines in large cities are planned to be installed in tunnel due to heavy surface traffic. In Seoul alone, the capital city of Korea about 100 km subway tunnels should be completed by 1996.
3. Most common tunnelling method in Korea is conventional method, in which tunnel support system consisting of shotcrete, rock bolt and steel rib is installed right after excavation. This method is most flexible for very irregular subsurface conditions.
4. The use of TBM is limited to deep tunnels with small diameters for waterway, communication lines, power lines, pilot tunnels for large tunnels.
5. Soft soil shield has not been used in Korea upto now. Instead the use of rock shield is expected to be increasing in small diameter tunnelling as well as subway tunnelling.

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