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Design and Construction of Underground High Speed Railway in Urban Congested Conditions Condtions Public Relation




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1. Introduction

Seoul-Busan High Speed Railway(HSR) 14-3 project employs the method of the As-built Design & Construction. And the total duration of project was 72 months from design step to the completion of construction in July 2009.

Underground tunnel construction in urban environment has a lot of constraints in constructions especially because drill & blast excavation method is used. Due to congested conditions in the site such as existing above-ground railways, office buildings and residential area, special design and construction methods have been applied to minimize complaint from stakeholder.

The purpose of this paper is to suggest a guide of tunnel excavation in urban area. This paper generally introduced the improvement method of tunneling, the complaints, the criteria of blasting in Korea, the auxiliary supporting systems at very weathered ground etc.

2. Design and Construction of HSR Section 14-3

The 14-3 section of the Seoul-Pusan HSR is the final section. This section passes under the ground of Busan

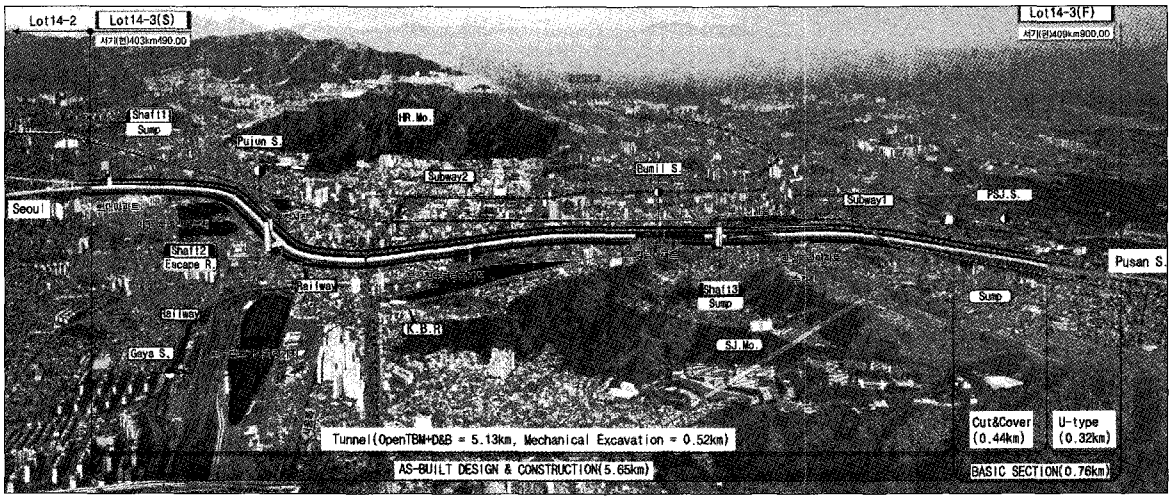


Figure 1. Present state of total HSR 14-3 project

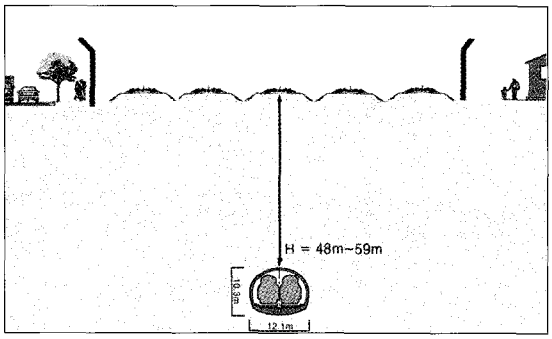


Figure 2. Representative cross section of tunnel

urban area. It is the double track tunnel of 6.41km length.(see figure 1).

As shown in figure 2, this 14-3 section was located 50m under ground level where 1 to 6 railways are running at present. Furthermore, many old houses and large scale apartment units are distributed on the lane of 14-3 project 1).

Important facts for design are as follows;

- Guess the possibility of complaints and countermeasure establishment.
- Establishment of structural stability of HSR 14-3 tunnel passing by the huge Dongrae Fault Zone and the soil layer in thin cover(see figure 3, Section II ~ IV).
- Countermeasure establishment for safety of running trains to all sections.
- Establishment of structural stability of subway 1, 2 passing by the tunnel(see figure 3, Circles).
- Development of automatic instruments for the measure of real-time ground behavior.

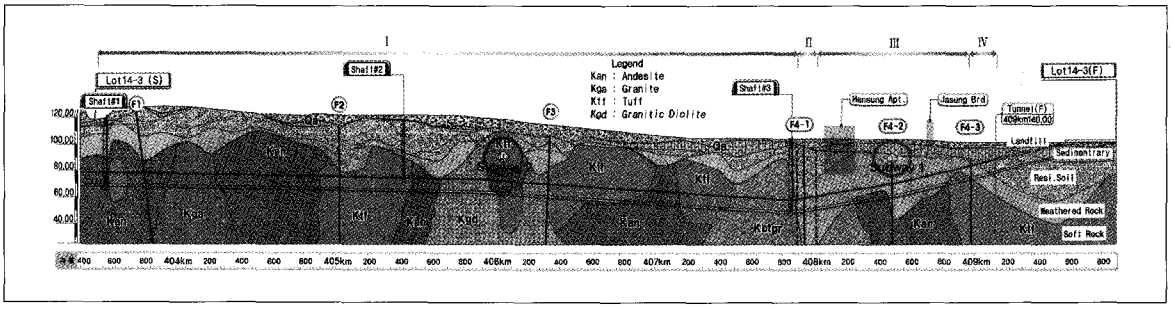


Figure 3. Geological map of tunnel alignment

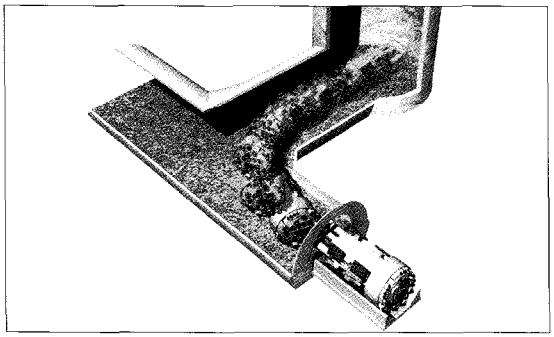
3. Tunnel Excavation Methods

3.1 Hard and Soft Rockmass

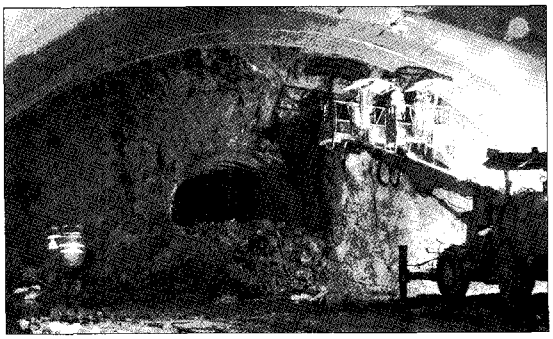
To blast in hard rock section of HSR 14-3 particularly, we have applied the various blasting method like [Open TBM + Enlargement(D&B)], [PLHBM(Pre-Large Hole Boring Method) + D&B] and [Pilot D&B] etc. which being satisfy the criteria of blasting vibration. It is appeared the used excavation methods at figure 4.

When it must blast in rock mass, the best way of minimizing blasting vibration is mixing a pilot tunnel and Drill&Blasting. In this project, we used the open TBM of diameter 5.0m(see figure 4.(a)) for pilot tunnel. After penetration of TBM was done, as in figure 4.(b) for the purpose of blasting, holes of 1.0~2.0m in diameter were drilled according to rock classification in parallel with the axis of pilot tunnel 2).

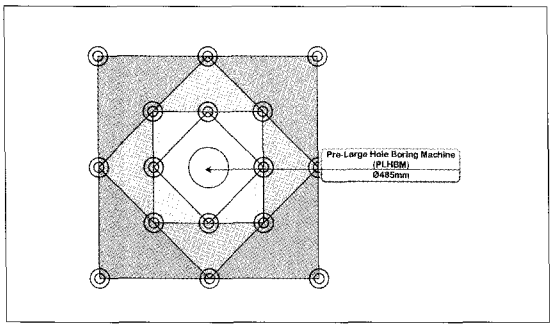
Figure 4.(c) shows the Pre-Large Hole Drilling Method(PLHBM) which was applied to decrease blasting vibration at center-cut section of tunnel and shafts for launching TBM. We also prepared a extra blasting method shown in figure 4.(d), that is, Pilot & Multiple Stage Drill and Blasting to be used in more serious re-



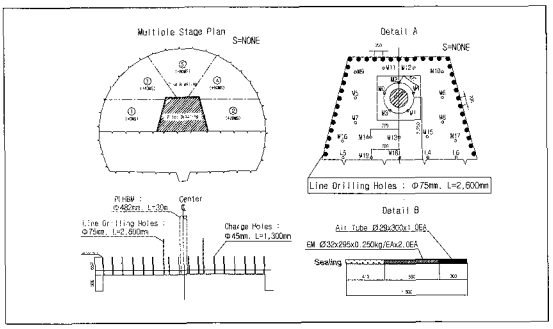
(a) Open TBM



(b) Drill and Blasting



(c) PLHBM(L=50m) + Drill and Blasting



(d) Pilot Drill and Blasting

Figure 4. Methods of Drill and Blasting used in HSR 14-3 project.

Table 1. Criteria of blasting vibration in Korea.

Object	Velocity of vibration(cm/sec)	Note
Human Body	0.3	Law of Noise Shock Regulation
Existed building	0.5	Korea Design Standard of Tunnel
Underground structure	2.0	
Concrete in curing	0.254	ASCE

gion. For reference, table 1 is the criteria of blasting vibration of objects in Korea.

3.2 Very Weathered Rockmass and Soil

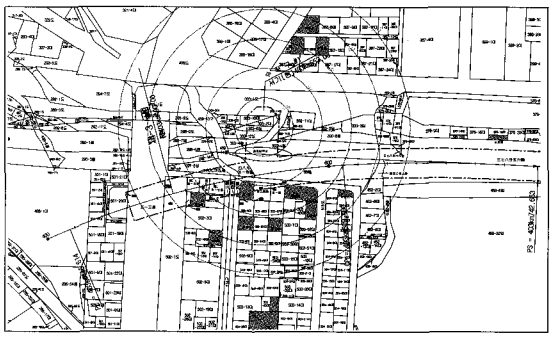
For tunnel excavation in deep soil section, we applied mechanical excavation method and supporting conception of NATM in SFRC(Steel Fibre Reinforce Concrete). Furthermore, the various auxiliary supporting systems such as RPUM(Roof Pipe Umbrella Method) of Ø112mm by self drilling, MFG(Micro-cement Fissure Grout), Foot Piles and Temporary H-300-beam Struts between Spring Lines, etc. were used for the minimization of tunnel deformation.

4. Analysis of Complaints Tendency by Section

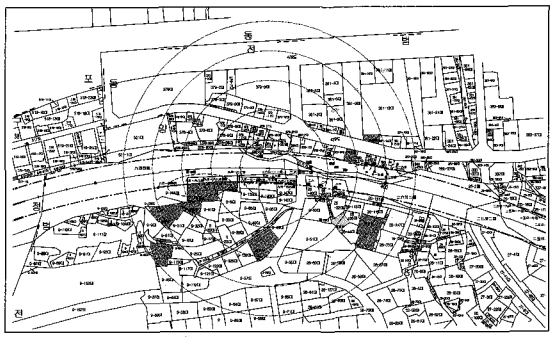
4.1 Drill and Blasting Section (403k490~407k690)

Because of the excavation of tunnel by D&B, the range of complaints in 403k409~407k690 appeared as shown figure 5. From the result, the range extended to 100m which is more than that evaluated in design phase. In this section, from the results of monitoring as shown in table 2, the crown settlement of tunnel slightly developed by about -2 to -21mm according to rock classifications, and the surface settlement developed by about -1 to -24mm which is similar to crown settlement.

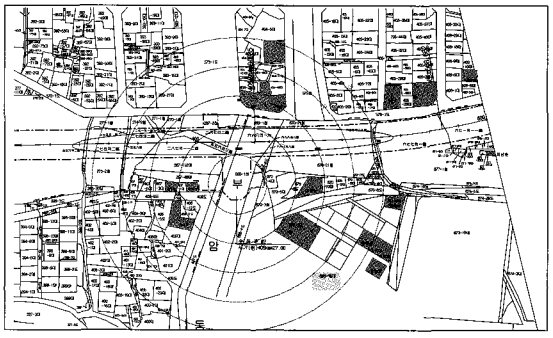
And the groundwater level was fallen by about 33m



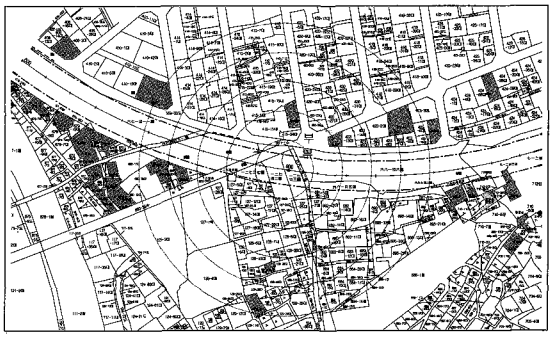
(a) Shaft 1



(b) Hard Rockmass

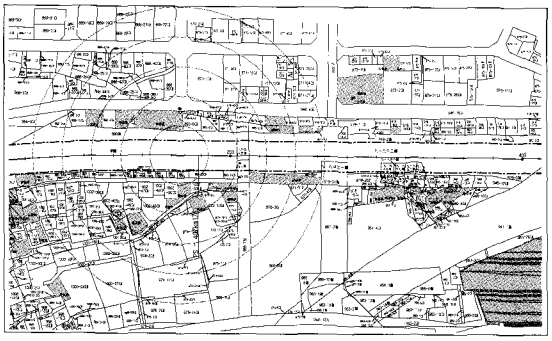


(c) Shaft 2



(d) Soft Rockmass(old buildings)

Figure 5. The developed range of complaints in 403k409 ~ 407k690(계속)



(e) Soft rockmass(shopping street)

Figure 5. The developed range of complaints in 403k409 ~ 407k690

from G.L-2.0m to G.L.-35m because of groundwater inflow in tunnel. The groundwater behavior in this section is as follows;

- G.L. -0 ~ -2m : Landfill / G.W.L.- 2m : before tunnel excavation
- G.L. -2 ~ -10m : Residual Soil
- G.L. -10 ~ -40m : Weathered Rock / G.W.L.-35m : after tunnel excavation
- G.L. -20 ~ -60m : Soft & Hare Rock / G.L. -45m : average S.L. of tunnel

4.2 Mechanical Excavation Section (407k690~409k140)

Many weathered grounds in this section developed as shown figure 6.

A huge Dong Rae fault zone with the width of several hundred meters and length of several ten kilometers was formed by mechanics of strike slip. A mixed zone and a thin soil cover zone were also included in this section.

Considered these conditions, excavation method was decided. We showed the range of complaints which developed in this section in figure 7. As shown in the figures, the range extended from 40m to 60m as anticipated by evaluations in design phase and it decreased by less than 403k490 ~ 407k690. Because the tunnel alignment is included in highly weathered rockmass and thin soil cover, from the results of monitoring shown in table 3, the crown settlement of tunnel seriously developed by about -14mm to -107mm, and the surface settlement developed by about -19mm to -140mm which is similar to crown settlement 3).

Table 2. Representative settlement of surface and tunnel crown in soft and hard rock(C.T.C 100m)

STA.	Settlement of Tunnel Crown	Surface Settlement	STA.	Settlement of Tunnel Crown	Surface Settlement
403K600	-7.0	-20.0	800	-11.0	-11.0
800	-6.0	-5.0	406K000	-15.0	-14.0
404K000	-2.0	-2.0	200	-8.0	-11.0
200	-4.0	-1.0	400	-14.0	-15.0
400	-5.0	-7.0	600	-14.0	-17.0
600	-5.0	-9.0	800	-14.0	-21.0
800	-8.0	-7.0	407K000	-15.0	-17.0
405K000	-5.0	-4.0	200	-15.0	-12.0
200	-15.0	-15.0	400	-16.0	-16.0
400	-16.0	-17.0	600	-21.0	-24.0
600	-16.0	-10.0			

From these result, we can confirm facts as follows;

- Settlement of surface slightly developed because tunnel alignment is included in rockmass and consolidation developed in soil layer.
- Therefore we knew that complaints in rockmass section were caused by the vibration because of a psychological anxiousness even if it satisfied the criteria.

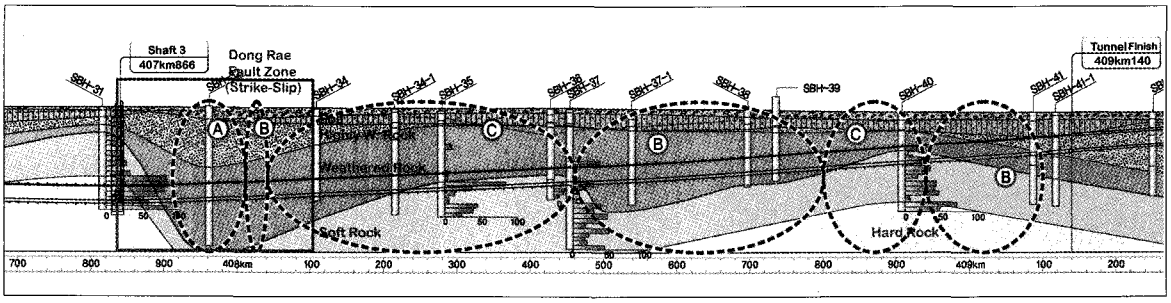


Figure 6. Geological map of the section 407k690~409k140

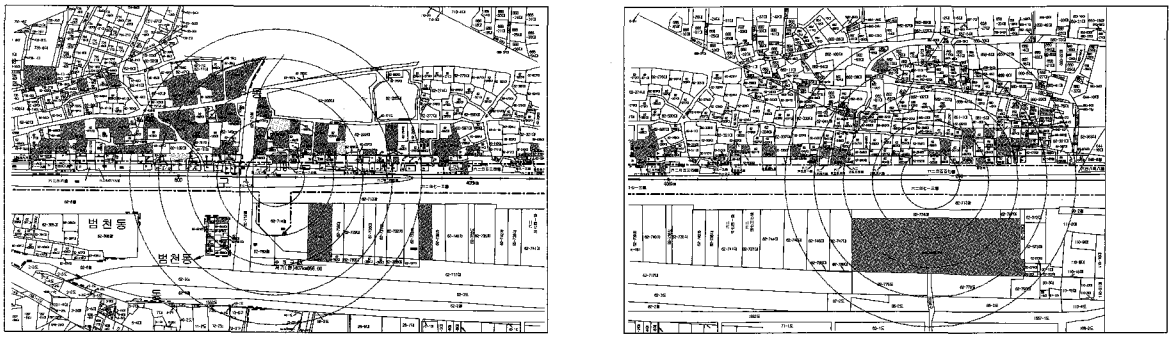


Figure 7. The developed range of complaints in 407k690 ~ 409k140

We compared the settlement of tunnel crown with surface according to distance from tunnel face as shown in figure 8. From the result, we could confirm the plasticity behavior of ground which simultaneously developed surface settlement by tunnel excavating and the high correlation between them 4).

The groundwater level was fallen about 17m from G.L-3.0m to G.L.-20.0m which is less than in rockmass section because of the limited groundwater inflow in tunnel due to many fault clays. The groundwater behavior in this section is as follows;

- G.L. -0 ~ -5m : Landfill / G.W.L.- 3m : before tunnel excavation
- G.L. -2 ~ -30m : Residual Soil / G.W.L.-20m : after tunnel excavation
- G.L. -2 ~ -30m : Residual Soil(Finish Point) /

Table 3. Representative settlement of surface and tunnel crown in highly weathered rock(C.T.C 100m)

STA.	Settlement of Tunnel Crown	Surface Settlement	STA.	Settlement of Tunnel Crown	Surface Settlement
407K700	-22.0	-19.0	408K500	-14.0	-28.0
800	-99.0	-61.0	600	-14.0	-27.0
900	-49.0	-55.0	700	-17.0	-34.0
408K000	-55.0	-64.0	800	-24.0	-64.0
100	-53.0	-34.0	900	-49.0	-129.0
200	-15.0	-24.0	409K000	-107.0	-140.0
300	-14.0	-28.0	100	-32.0	-65.0
400	-14.0	-26.0			

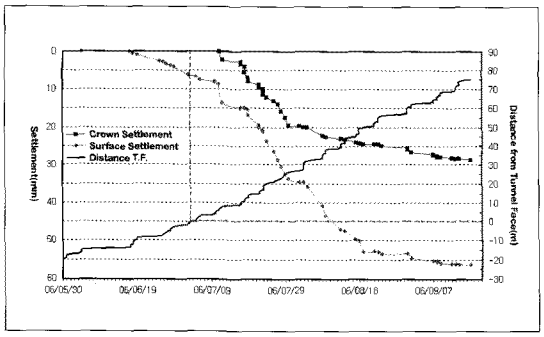


Figure 8. The time history curves of a distance, settlement of crown and surface at 407k900

G.L.-25m : average S.L. of tunnel

- G.L. -10 ~ -80m : Weathered Rock(Fault) / G.L.-45m : average S.L. of tunnel
- G.L. -40 ~ over : Soft Rock / G.L.-40m : average S.L. of tunnel

From these result, we can confirm facts as follows;

- Settlement of surface developed more higher than rockmass section.
- We knew that complaints were mostly caused by the settlement of surface.
- The range extended 40m to 60m which decreased less than 403k490 ~ 407k690.
- Because the tunnel alignment is included in highly weathered rockmass and thin soil cover.

5. CONCLUSIONS

This paper highlights the construction methodology considering public relation and restriction in worksite in downtown. When drill & blast excavation is used for the whole planned tunnel sections, vibration and noise could affect aboveground area very much. Therefore, special excavation method by combining TBM pilot tunneling and drill & blast enlargement was applied to control vibration and damage which can affect aboveground structures. Pre-Large Hole Boring Method was also applied considering the complaint in several sections. Comprehensive study of possible public complaints has been carried out in advance, and corresponding measures were derived.

Blast vibration and settlement along routes have been controlled systematically during the whole periods of construction, and all feedback to stakeholders has been carried out.

According to the project experiences, it can be concluded that drill & blast method can also be efficiently adopted in urban complicated environment once geology and public relations problem are solved.

- Settlement of surface was slightly developed because tunnel alignment is included in rockmass and consolidation just developed in soil layer.
- Therefore we knew that complaints in rockmass section were caused by the vibration because of a psychological anxiousness even if it satisfied the criteria.
- Settlement of surface developed more higher than rockmass section.
- We knew that complaints were almost caused by the settlement of surface.
- The range extended from 40m to 60m which decreased less than 403k490 ~ 407k690
- Because the tunnel alignment is included in highly weathered rockmass and thin soil cover.

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연약지반기술위원회 현장견학 안내

연약지반기술위원회에서는 웅동지구 준설매립토 개량 건설현장을 방문하여 최신 연약지반개량 공법에 대한 세미나와 현장견학을 아래와 같이 실시합니다. 관심 있는 회원님들의 많은 참여를 부탁드립니다.

1. 목　적 : 부산 웅동지구 견학을 통한 연약지반 개량기술 습득 및 정보교류
2. 일　시 : 2010. 5. 14일(금)
3. 장　소 : 웅동지구 3공구(대우건설), 2공구(한라건설)
   (경남 진해시 안골동 790번지)
4. 집결장소 및 시간 : 서울출발 ⇒ 강남고속버스터미널 앞, 오전 7시 정각(버스)
   부산출발 ⇒ KTX 구포역 주차장, 오전 11시20분(버스)
5. 견학 주요 일정

시 간	내 용	비 고
~07:00	서울 강남터미널앞 집결	BUS로 이동(예약회원)
11:20~11:30	KTX 구포역 주차장 집결 및 추가인원탑승	BUS로 이동
11:30~12:40	이동 (구포역 → 웅동지구 3, 2공구 현장)	
12:40~14:00	점심식사	
14:00~15:00	세미나 - 웅동지구 건설사업 소개 (3, 2공구 현장담당) - 세미나 (개별진공압밀공법 소개, 한상재 박사)	진행위원
15:00~17:00	현장견학	현장 담당자
17:00~17:20	이동	
17:20~19:20	저녁식사 후 해산	

- 회비 : 2만원(소요경비 등)
- 참가희망자는 4월 30일까지 우리 학회(02-3474-4428, 박소영님)로 사전 연락을 주시면 버스, 점심 준비 등에 도움이 됩니다.
- 문의 : 김윤태(부경대, 010-7568-1488), 차경섭(대우건설, 031-250-1172)

연약지반기술위원장 이 강 일