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Braced walls in Korea

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SYNOPSIS : The focus of this paper is to introduce development and performance of braced excavations made for deep building basements and Metropolitan subway in seoul Korea. Geological conditions and ground characteristics are reviewed by regarding the code of practice. Two case studies of recently completed deep excavations in seoul are presented, including earthpressures and braced wall movements. The predicted movement compared to the field measured data.

I INTRODUCTION

The problems associated with deep excavations by braced walls have been call for a great attention in the large cities in Korea due to the following two reasons :

Firstly, extension of subway lines to cope with the rapid growth of traffic.

Secondly, the shortage of land increased the cost there -fore construction of tall buildings required significant space for car parking which result increase of the depth basements.

Although of the most of Korean's major cities have experienced the above phenomena recentely, this report concentrates on the braced walls in Seoul metropolitan area where many of the difficult deep excavations take place.

Since July, 1971, when the construction of Seoul Metropolitan subway started, subway lines 1 through 8 totaling 224Km have been designed and many of them are now in operation. About 112Km of the total lines which adopted the open-cut method, 70Km has been completed and a further 42kms are under construction or in design stage.

The ground formation in Seoul generally consists of a top soil layer and a weathered rock profile becomming less weathered with depth. The ground water table is relatively high.

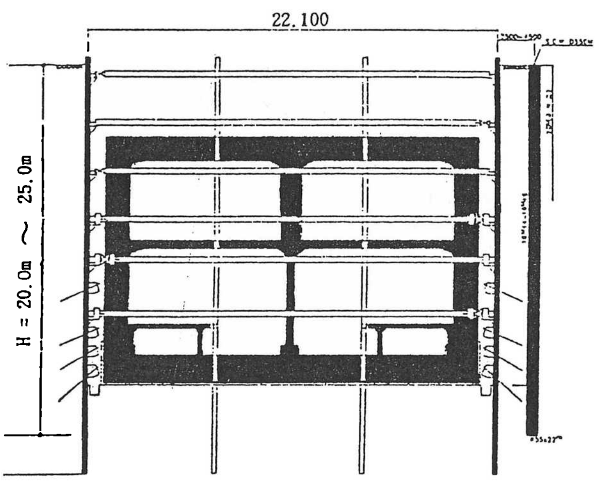


Fig 1. Standard section for Seoul Metropolitan subway

The types of braced walls for the Seoul subway design were selected by considering the ground conditions were H-piles with timber lagging and grouting, Soil Cement Wall (S.C.W), Diaphragm Walls(D.W) in the difficult station areas and limited use of sheet pile wall (SP). The proportion of the wall types applied for the subway to date are 65% for H-pile and timber lagging, 20% S.C.W, 14% D.W and 1% SP type walls.

Earth Anchor or Rock Anchor system was adopted to support the retention walls in good geological and environmental conditions, whereas a strut system was used in difficult ground where the anchor system is inappropriate.

The deep excavation works involving subway construction may be much more simplified and standardized in the size and depth. Compared to that of building basement, although the length is considerably longer. (fig. 1)

Therefore, in recent years, most of the serious problems faced by the Seoul City Authority are mainly concerned with the significant increase in underground parking space required for tall buildings. In this case, plan area of building sites are generally as large as approximately 100m x 100m and with depths from 25m to 35m below ground level is not uncommon.

The number of large scale basement construction projects, classified by the over 11 story high or total floor area over 10,000m^2, in the past 3 years in Seoul metropolitan area were 195

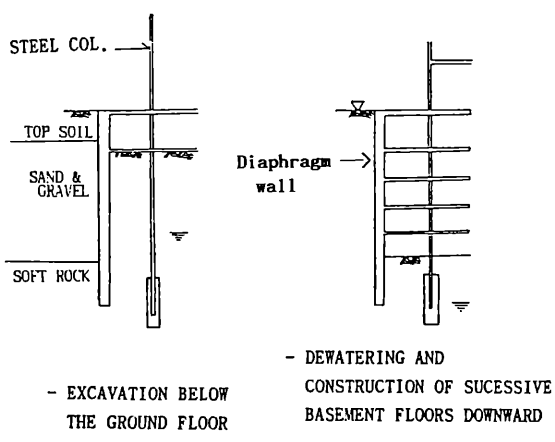


Fig 2. An example of deep excavation for a underground car park in Yoido area (Top & Down Method) Seoul

cases in 1990, 206 cases in 1991 and 163 in 1992 (the year in which restrictions have been imposed).
Selection of braced wall type such as CIP (cast-in-place), SCW and D walls for the deep excavations in Seoul, which may be similar to the subway construction case is influenced by the ground characteristics and the function of cut-off requirement to prevent the surrounding ground loss.
H-piles with timber lagging and grouting type walls can be applied to the building sites where the depth of excavation is relatively shallow and it is environmentally acceptable.
The area of Seoul known as Yoido was originally an island in Han River which flows through the central part of Seoul. The geology consists mainly of alluvial sediment underlying a thin veneer of fill . There are other areas in Seoul like Yoido especially near to the Han River where the high water table and very permeable granular deposits makes traditional type of braced walls in appropriate.
Therefore the basement excavations for some of the tall buildings in Yoido area have been carried out by a "Top-Down" method in which floor slabs were cast as the excavation proceeds within a previously constructed diaphragm wall enclosure. Fig 2 shows an example of deep basement excavation to provide space for car parking yoido area in Seoul.
Though Earth Anchor or strut system to support retention walls seems to be the most popular choice, but combination of the both above techniques and Island method can be adopted in areas where adjacent structures need to be secured.
As discussed previously, the ground conditions in Seoul, consists of a veneer of fill overlying various types of weatherd rock layers, which may be classified as soft ground due to highly broken and weathered nature of the materials particularly the upper part of the highly weathered thick zones above the bed rock. The type of rocks in this region are typically banded biotite gneiss, granite gneiss and biotite granite and more details are given in later discussion.

2. CODE OF PRACTICE

Four standard codes of practice for braced excavtion are available from Seoul and Pusan Metropolitan Subway Bureaus, the National Railway Authority and the Building Code.
These codes of practice differ slightly depending on the ground condition, but this paper will be restricted to the codes of Seoul Metropolitan Subway Bureau and General Building Code for the design of deep basements in the Seoul region.
In order to understand the background of these code of practice used in Seoul region, a general study of geological conditions and ground characteristics in Seoul would be necessary, and is discussed in this section whilst the design codes will be introduced in the next section.

2.1 Geological conditions and ground characteristics in Seoul

The area is characterized by the low relief of the mountain ranges to the south of the Han River where gniesses are distributed throughout the region.
To the north of the Han River the granites outcrop where the relief is high with gneisses again found to the north. The Han River flows westward through the centre of Seoul forming a wide and thick alluvial deposits.
A geological point of view as shown in fig.3, the northern and southern region of Han River composed of banded biotite gneiss, granitic gneiss and small amout of limestone and amphibolite formed in the Pre-cambrian age, late plutonic and instrusive rocks of the Mesozoic age and alluvial deposits of the Quaternary age.
The biotite gneiss (so-called Seoul granite) and porphyritic

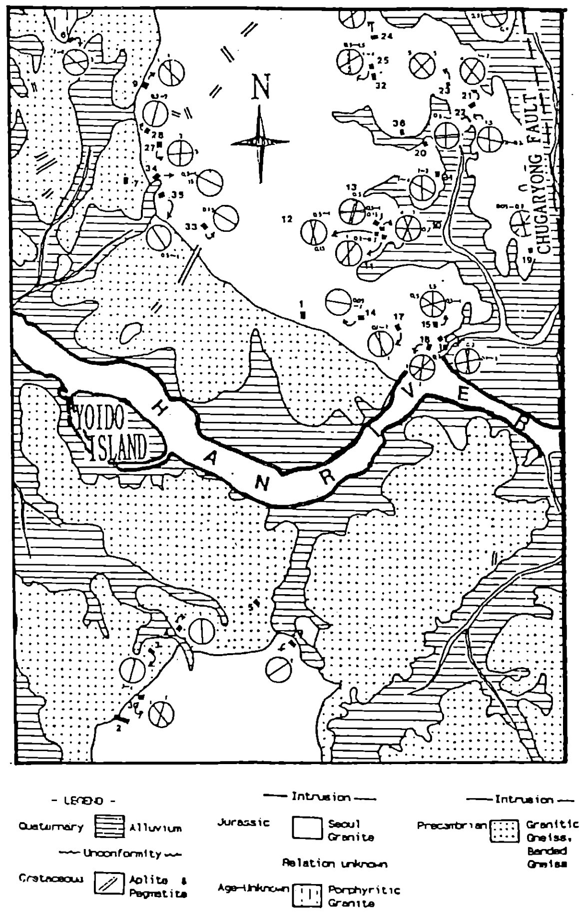


Fig. 3 Geological Map of Seoul

granite are distributed in the central part of Seoul city which is located slighty Northwards of Han River.
The soil profile within the metropolitan area is relatively uniform and consists of a typical weathered sequence from residual soil near to the surface to the unweathered bedrock at depths between 15 and 20 metres. Weathered rock layers underlying the residual soils become progessively stronger with depth.
The excavation works to the south of the Han River may be classified as a soft ground operation because of the biotite gneiss distributed over the whole region forming layer about 30m thick of fractured rock in which highly weathered biotite mica zones are found in layers as the result of severe folding activities.
Therefore the movement along the highly weathered mica surfaces generates larger lateral pressures than those found in soft ground. This phenomenon creates many difficult problems for designers as well as constractors.

2.2 Design code of Seoul subway

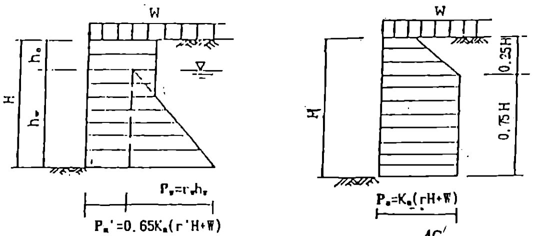
1. Temporary Earth retaining structures : - H-piles with timber lagging, sheet pile, continuous pile walls(contiguous tangent or secant layout), Diaphragm wall, soil improved walls.
2. Permanent or combind wall type : - Diaphragm walls of 60cm to 80cm thickness or D wall plus concrete internal walls.
3. Bracing system of retention walls : - Earth Anchor, struts, top-down method or combind supporting system.

4. Type of wall selection dependng on size of excavation, ground condition, ground-water level and settlement of the adjacent ground etc.

5. Earth pressure :

a) Sands — ○ cut-off type walls

b) Clays — ○ $K_a \geq 0.4$ Case



$$K_a = 1 - m\frac{4C'}{\gamma H}$$

$m = 1.0$ Except as noted

Fig4. Apparent Earth Pressure

6. Analytical Method : - Simple and Continuous beam analysis, Beam on elastic foundation analysis, Elasto-plastic soil-structure interaction analysis and F.E.M analysis (These methods consider the movement of the adjacent structures).

7. Control of ground settlment : - Grouting or Column zet grouting, structural cut-off walls key into the impermeable layers and grout curtain.

2.3 Design Code of Building Basement Excavation

1. Type of retention walls : - Basically cut-off wall types are recommendable.

2. Wall bracing system : - Earth Anchor, struts, top-down or combind supporting system.

3. Earth pressure : - Apparent pressure diagram (Empirical Method), surcharge and water pressure considered, soil-structure interaction model ($K_a \leq K \leq K_p$), Finite Element Method, Elasto-Plastic model including Cantilever stage as well as construction sequence.

4. Protection of adjacent structures :

a) An estimation of settlment caused by neighboring excavation and assessment of damages to the adjacent structures as well as underground services.

b) Movement of surrounding ground associated with the inward movement of the vertical walls, settlement due to dewatering and loss of the ground between walls should be accurately predicted.

c) Noise and Vibration assessment induced by the site activities.

d) Analytical Method : - Numerical Analysis including FEM, adjacent ground surface settlement can be evalueated by peck, caspe and clough etal. methods etc.

e) Measures for protecting the adjacent structures : - Application of the most appropreate techniques such as ground improvement by grouting, satisfactory quality control of grouting (grouting pressure, quantity and gel-time etc) to cope with the main cause of the ground movement.

2.4 Instrumentation

The conseqence of poor performance of a deep excavation in urban area can lead to severe damage to neighboring structures and may on occasion be catastropic. Therefore instrumentation and monitoring of ground movement and ground water level is essential.

Type of instruments most widely used in korea are as follows :

1. Settlement Points by surveying method
2. Inclinometers to monitor deformation of soft ground
3. Multipoint Borehole Extensometers measuring relaive movement of rock

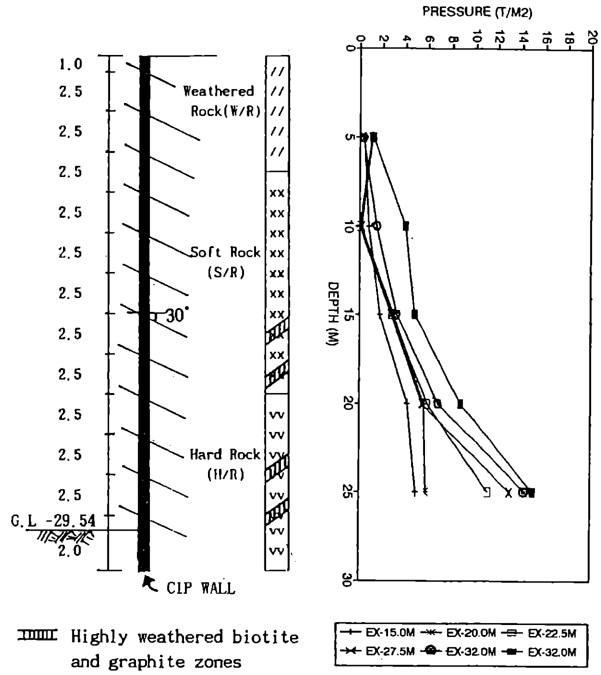


Fig.5 Latteral pressure measured by pressurecells at various excavation stage

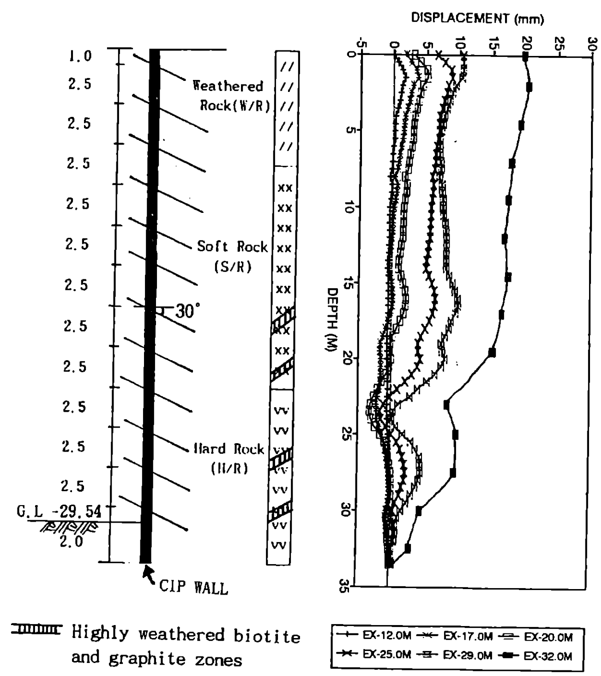


Fig.6 Horizontal displacement of the CIP wall measured by Inclinometers

4. Strain gages and Load cells to measure stress in or loading on supports and walls

5. Ground water pressure by piezometers or observation wells

6. Crack gages and Tiltmeters to check the change in width of cracks in structures and tilt of buildings alongside excavations

3. CASE RECORDS OF EARTH AND WATER PRESSURE ACTION ON BRACED WALLS

The basements of POSCO's (PoHang Iron and, Steel co.) intelligent building which has a 120m x 138m plan area and extends to 30 ~ 34m below existing ground level, required careful consideration of the environmental influence of the construction on adjacent buildings and underground utilities in Kang Nam area south of the Han River.

A tieback (ground anchors) system for supporting the CIP Walls of an excavation 31m deep in biotite or graphite gneiss with cleavage fracture overlain by top soil and a thick layer of weathered rock. Fig.5 shows measured earth pressure in various construction stages.

It can be recognised that the measured pressure and the deflection of the wall in the relatively strong banded gneiss layer increased constantly with depth as well as time.(Fig. 6)

This implys that lateral rock pressure exist in the banded biotite and graphite gneiss layers which has been subjected to very high horizontal forces in the past.

4. CASE RECORDS ON GROUND MOVEMENT ASSOCIATED WITH BRACED WALL CONSTRUCTION AND EXCAVATION.

The New Christian Council Building is being constructed on the site of the councils previous building in the central district of Seoul.

The New building area of 3400m^2 with depth varing from 17.0m to 27.0m is located in very difficult conditions for deep excavation due to the close proximity of neighboring tall building and old houses.

Therefore a rigid CIP (drilled tangent piles) wall was chosen to cope with the settlement limit of surround ground. The cast in-place piles(CIP) were typically 40cm diameter drilled shafts filled with H - shape steel piles(H-300 x 200 x 9 x 14) at an interval of 80cm and structural concrete .

L.W grouting work has been carried out at the pile joints to control the ground water level outside the site. The rigid temporary retention walls were supported by ground anchors at a space of 2.5m vertically.(Fig 7.)

The installed instrumentations in this site to control the ground movement are inclinometers, piezometers, load cells, tiltmeters and crack gages.

As previously described that the ground profile in Seoul Metropolitan area is relatively stiff. For that reason, surface settlement gages are not so popular thus site measurement data seldom available.

During the excavation of the adjacent SAMYANG existing building side, the 11 story concrete building has been subjected severe settlement as the result of considerable retention wall displacement as shown in fig.7 and 8.

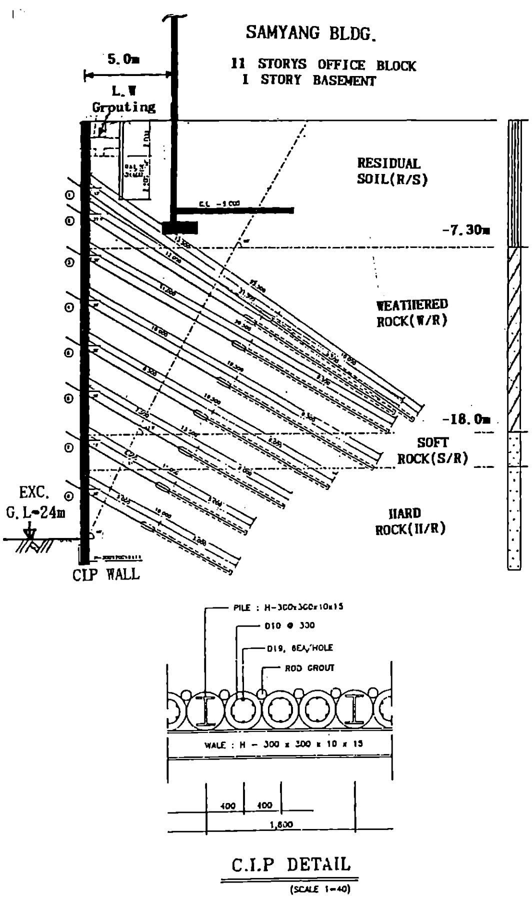


Fig.7 Section through CIP Wall on SAMYANG BLDG. Side

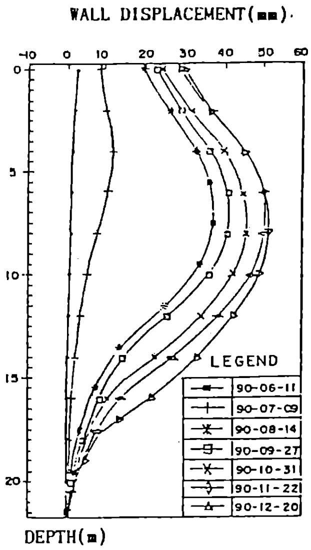


Fig.8 Horizontal Movement of the wall measured by Inclinometer

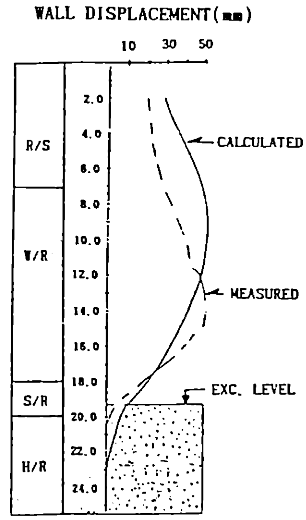


Fig.9 A Comparison between Predicted and Actual Field Measurement of wall Displacement

5. CONCLUSIONS

Selection of the braced wall types in urban area is influenced by many factors involving ground conditions with water table, adjancent structures, noise and vibration, cost and construction safety etc.

Monitoring and observation are eccential part of deep excavation projects in built up areas where the ground movement is restricted.

The lateral pressures measured by pressurecells at POSCO site have increased constantly in the banded biotite and graphite gneiss layers, implying some movement take place.

The rigid CIP walls for the New Christian Building deflected 50mm due to the over excavation and heavy rain fall. The predicted wall displacement is in good agreement with measured one.