Title:	**Structural Design of SK Euljiro Headquaters**
Authors:	Jidong Kim, Chang Minwoo Structural Consultants Jinkyong Kim, Chang Minwoo Structural Consultants Jongho Kim, Chang Minwoo Structural Consultants
Subjects:	Building Case Study Structural Engineering
Keywords:	Façade Foundation Structure
Publication Date:	2004
Original Publication:	CTBUH 2004 Seoul Conference
Paper Type:	1. Book chapter/Part chapter 2. Journal paper 3. **Conference proceeding** 4. Unpublished conference paper 5. Magazine article 6. Unpublished

Structural Design of SK Euljiro Headquaters

Jidong Kim[1], Jinkyong Kim[2], Jongho Kim[3]

[1,2,3]Chang & Minwoo Structural Consultant, Seoul, Korea

Abstract

This building planning to be used for SK-Telecom headquarters has 36 stories (include roof floors) above and 6 stories below grade, and the building features uniquely shaped exterior of two sloping facade on the south side of the tower, as well as the top portion of the north side sloping.

As the project site is located in one of the busiest business district in the city of Seoul, careful consideration and planning had to be made, to cope with the surrounding conditions such as little allowance for construction space and project duration. Hence so-called 'Top Down' construction method was employed, which possess advantages to maximize the usage of the ground space, as structure gets erected above and below ground simultaneously. In other words, NSTD (Non Supporting Top Down) method was applied for building of substructure to further reduce construction duration. To maximize the floor-to-floor height in basement levels, two-way slab system with "Wide Girders" were chosen. Above ground, lateral loading is to be resisted by reinforced concrete core system to withstand all of the imposed loading. Steel framing around the cores was designed to solely resist gravity loads, with pinned connections to simplify the structural design and fabrication process.

Keywords: sloping facade; top down; NSTD; wide girders; pinned connections

Introduction

This building located in Euljiro, Jung-gu, Seoul plans to be used for SK-Telecom headquarters. The design phase was done by the collaboration between RAD(Research Architecture Design) and Jung-lim, Jin-ah Architecture. Ove Arup & Partners Hong Kong Ltd. carried out schematic design phase, whereas Chang & Minwoo Structural Consultants did the final structural design phase and design for construction. SK construction co. was the construction manager of this project. The construction kicked off in 2001 and building of the primary structural framing has been finished in 2003; the completion is expected at the end of year 2004. The General View of the SK headquarters under construction is shown in Fig. 1 and 2.

SK headquarters has 90,748m^2 gross area, and 36 stories (include roof floors) above and 6 stories below grade, which typical story height is 4.0m. The project comprises a steel structural building measuring 148.1m, in which the width-to-length aspect ratios are 2.15:1 and 2.94:1 for 15th and 33rd respectively. And also the height-to-width aspect ratios are 2.1:1 and 2.8:1 for 15th and 33rd respectively.

6th below grade is used for instrumental room, electric room and water tank, 3rd~5th below grade are used for parking areas, and 1st~2nd below grade are used for retail facilities. 1st~33rd floors above grade are used for office facilities, and the rooftop is used for instrumental room and water tank.

For the primary lateral load resisting system, the core shear wall system is adopted to withstand all of the lateral loading imposed. For the design of reinforced concrete, design standard using Ultimate Strength Design Method was employed; steel design and SRC(Steel Reinforced Concrete Structure) design were done conforming to Standard for Structural Calculation of Steel Structures and Standard for Structural Calculation of Steel reinforced Concrete Structures respectively; serviceability limitations were set according to National Building Code of Canada (NBCC). Design loads set for this building are summarized in the following Table 1.

Contact Author: Jongho Kim, principal, PE,
Chang&Minwoo Structural Consultants,
Youngil Bldg, 4~5f, 12-7, Yangjae-Don, Seocho-Gu, 137-30, Seoul, Korea
Tel: 82-2-571-1961 Fax: 82-2-578-0425
e-mail: jhkim@minwoo21.com

Fig. 1. The General View

Fig. 2. The Front View

Table 1. Design Loads Used.

Description	Design Loads (kgf/m2)
Roof	500
Office	400
Storage, Mechanical and Electrical Rooms	1500
Retail	700
Underground Parking	600 / 400
Heliport landing	500

* Wind Load : Basic Wind Speed V=30m/sec
Exposure Category = B
Earthquake Load : Earthquake Zone Factor (I),
Earthquake Area Factor (A = 0.12),
Importance Factor (I_E = 1.2)
Soil Profile Factor (S = 1.2)
Response Modification Coef. (R = 4.0)

Structural plans and elevation

Typical frame plans for lower and upper portions of the building are shown in Fig. 3 and 4. Elevation view through vertical section is also illustrated in Fig. 5.

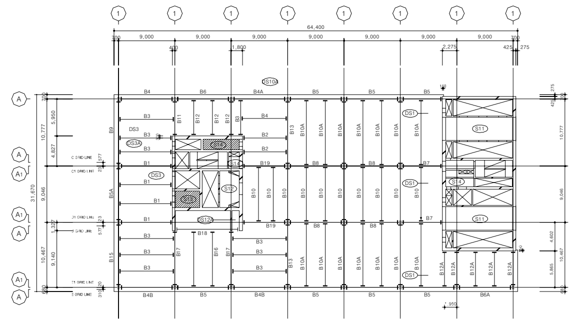


Fig. 3. Lower Floors Plan (15th)

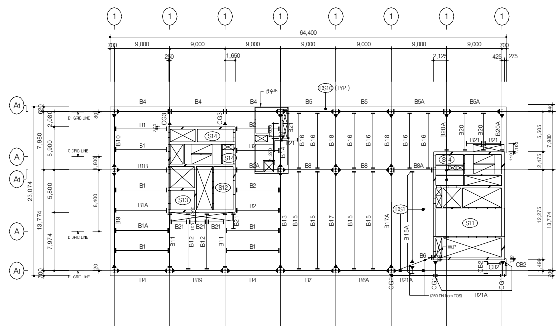


Fig. 4. Upper Floors Plan (33rd)

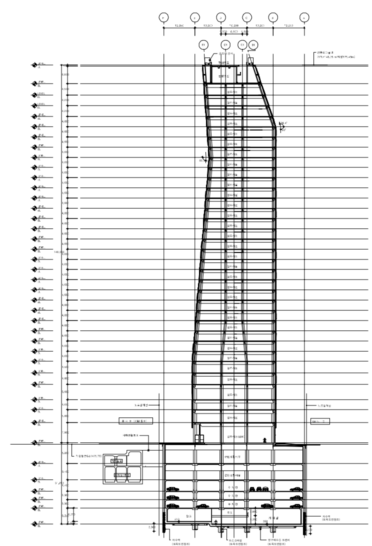


Fig. 5. Vertical Section

Strength of structural material and wall thickness

Structural material is shown in Table 2 and 3.

Table 2. Design Standard Strength of Concrete

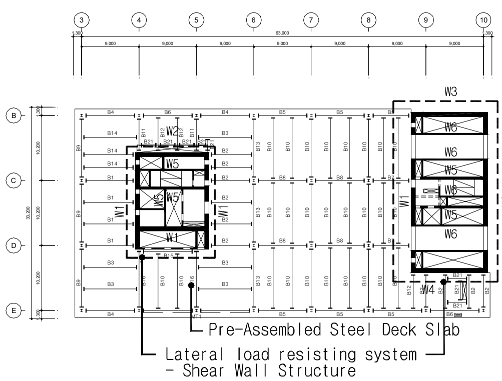
Description	Design Standard Strength (kgf /cm2)
Slab, Beam	240
Core Wall, Link Beam	240 / 350 / 400
SRC Column	300

Table 3. Material and Strength of Steel

Description	Material and Strength
Beam	SS400 / SM490A (Fy = 2400 / 3300 kgf/cm2)
Column	SM490 / SM490A TMCP (Fy = 3300 kgf/cm2)
Brace	SM490A (Fy = 3300 kgf/cm2)

The shear walls thickness to mainly resist the lateral loads, are shown in the Table 4.

Table 4. Wall Thickness



	B6~6F	7F~22F	23F~RF		B6~6F	7F~22F	23F~RF
w1	t=650mm	t=500mm	t=350mm	w4	t=650mm	t=500mm	t=350mm
w2	t=650mm	t=500mm	t=350mm	w5	t=350mm	t=350mm	t=350mm
w3	t=650mm	t=500mm	t=350mm	w6	t=200mm	t=200mm	t=200mm

Structural Design

Gravity and lateral load resisting system

As the project site is located in one of the busiest business district in the city of Seoul, careful consideration and planning had to be made, to cope with the surrounding conditions such as little allowance for construction space and project duration. Hence The Construction method was employed, which possess advantages to maximize the usage of the ground space, as structure gets erected above and below ground simultaneously.

Above ground, steel framing around the cores was designed to solely resist gravity loads, with pinned connections to simplify the structural and constructional process.

In addition, NSTD (Non-Supporting Top Down) method (Fig. 6) was applied for buildings of substructure to further reduce construction duration. To maximize the floor-to-floor height in basement levels, two-way slab system with "Wide Girders" were chosen.

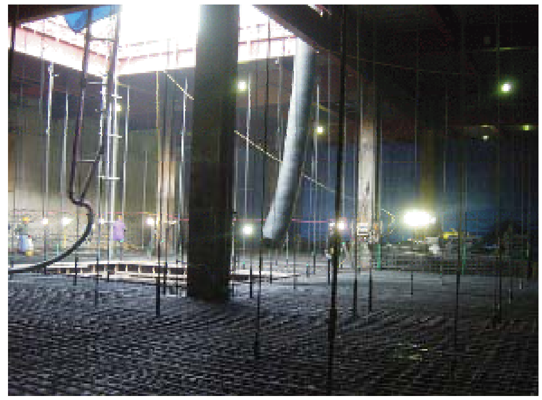


Fig. 6. Construction in Sub-ground Levels with NSTD Method hanged with ϕ25mm

For the stability of structure for lateral load, the core walls of concrete were designed as mainly resist the lateral load. The steel frame was constructed using after construction of the both towers in constructional process. (Fig. 7)

Fig. 7. Towers during the Construction in 2003,7

Structural Design Outline in the Main Constructions

Slab

Pre-Assembled Steel Deck system was employed for the superstructure slabs, and RC slabs were used for the sub-ground levels. (Fig. 8)

Fig. 8. Pre-Assembled Steel Deck System

Beam

Reinforced concrete beams were used for sub-ground levels, and steel beams are applied for all the floors above ground.

Column

Columns from the foundation level up to 2nd floor are made of SRC sections except for a few steel columns. Four of the long columns (L = 22.9m, 1st to 4th floor) in front were also designed as SRC sections, and all columns above 3rd floor are steel members. As the building from 7th to 27th floor slope by 5 degrees, sloping columns were used. (Fig. 9, 10, 11)

Fig. 9. Construction of Sloping Column in the Front Side 7th Floor

Fig. 10. Weld Size Examination of Column Connection

Fig. 11. Construction of Sloping Column in the West Side 7th~11th Floors

Foundation

At the foundation level, 800mm thick RC slab is used with mixture of RCD piers and isolated footings.

Allowable bearing capacities used in design were 1500tonf/EA, 2000tonf/EA, and 2500tonf/EA for RCD piers depending on the pier diameters used, and 200tonf/m2 for isolated footings depending on weathered rocks. In addition, dewatering system was applied to withstand possible buoyancy pressure from the groundwater for the design foundation floor. As the water pressure 3.0tf/m2 applies during the design of floor resisting water pressure, the building withstands water pressure rising.

Structural Design and Construction Feature in the Others

Choice of constructional methods for normal construction of underground core during top down constructional process

After the sheathing work for core wall was constructed, the erection column is established for frames of 1st floor. And while core was constructed from basement level to 1st floor, the construction using the RCD column of top down construction and the erection column was carried out in below ground.

Fig. 12. RCD Column of Top Down Construction and 1st Floor Steel Construction

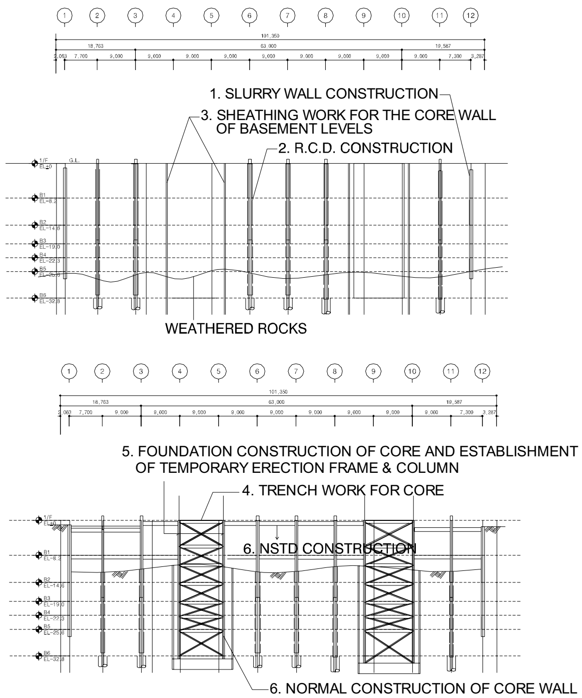


Fig. 13. Constructional Diagram of Core Normal Construction

Design consideration for vertical structural irregularity and associated stability issues

The building features uniquely shaped exterior of two sloping facade on the south side of the tower, as well as the top portion of the north side sloping. In order to achieve overall stability, selected frames above 27th floor were considered as rigid frames in structural design, and slab systems in the vicinity were thoroughly checked against associated horizontal shears to implement required reinforcements. Figure 7 illustrates the rigid frame installed on the 33rd floor of the building.

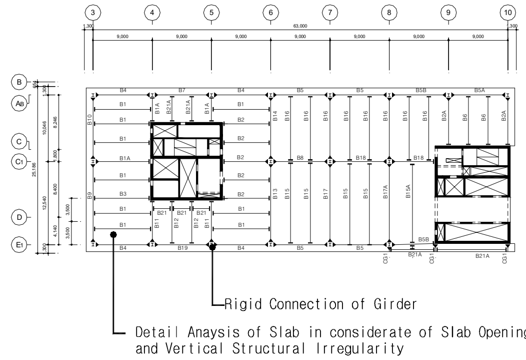


Fig. 14. 33rd Structural Plan

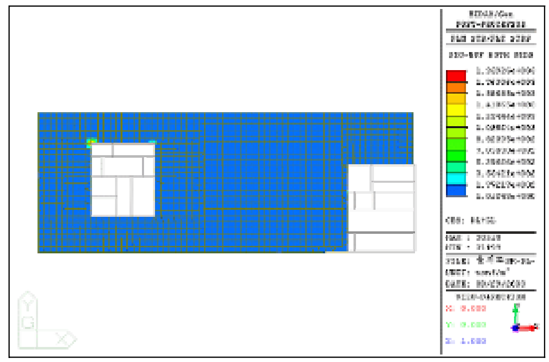


Fig. 15. The Detail Analysis of Slab

Design issues associated with sloping columns from 7th to 11th floors

Span length between grids C1 and D1 changes from 10.2m on 7th floor to 6.6m on 11th floor. As the columns slope along those locations, and careful consideration must be made to account for horizontal components of the column axial forces. Thus, horizontal braces were added on the 7th and 11th floors to ensure adequate load paths, as shown in Fig. 16 and 17.

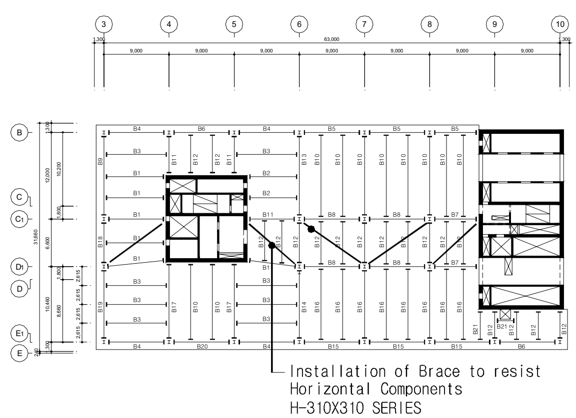


Fig. 16. Structural Plan of 11th Floor

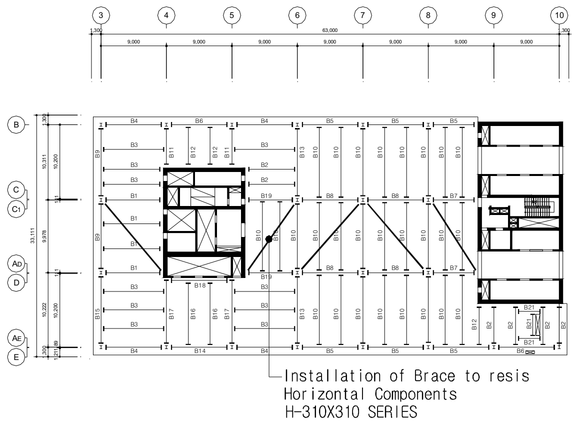


Fig. 17. Structural Plan of 7th Floor

Treatment of connection with walls

For the overall stability of structure, the cores were designed as RC shear walls. To improve the connections details and construction of steel beams framing into the RC core walls in the superstructure, steel plates were embedded during the construction of the core walls to provide simple fabrication of pinned connections. In addition, the connection between slab reinforcements and RC walls was constructed with embedding coupler in below ground and 'Halfen Box' in above ground respectively. (Fig. 18)

Fig. 18. Tension Test of Reinforcement Embedded in Halfen Box

Design consideration for serviceability

Serviceability limitations of overall building displacement and inter-story drift ratio were analyzed complying with the National Building Code of Canada (NBCC).

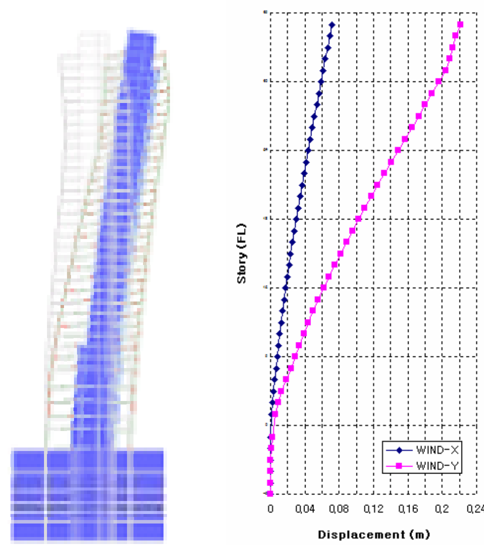


Fig. 19. The Maximum Horizontal Displacement by a Wind load

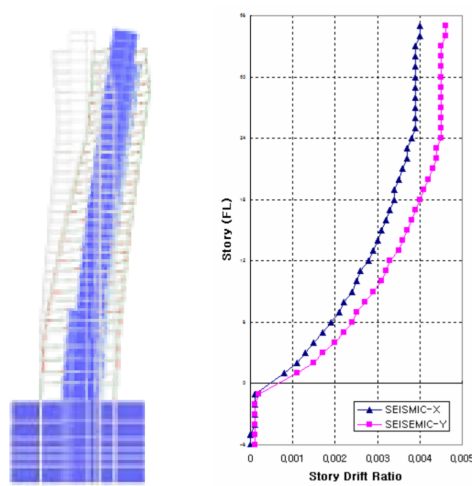


Fig. 20. The Story Drift Ratio by an Earthquake Load

1) The Maximum Horizontal Displacement by a Wind Load

Direction	Horizontal Displacement	Target of Horizontal Displacement (H/500)	Remark
X-DIR	6.89cm	29.58cm	OK
Y-DIR	20.85cm	29.58cm	OK

2) The Story Drift Ratio by an Earthquake Load

Direction	Story Drift Ratio	Allowable Story Drift Ratio (0.015)	Remark
X-DIR	0.0061	0.015	OK
Y-DIR	0.0062	0.015	OK

3) The maximum Acceleration Ratio examination at a Rectangular and Parallel Wind Direction

Direction	Acceleration Ratio		Serviceability limitations (NBCC)	Remark
	X-DIR	Y-DIR		
Rectangular Wind Direction	6.65 mg	7.72 mg	30 mg	OK
Parallel Wind Direction	5.36 mg	7.26 mg	30 mg	OK

Conclusion

This building plans to be used for SK Telecom headquarters. At present, the underground path, which connects number 2 line Subway, is designing in 1st floor below grade, so matters relevant to the open of slurry wall are being consulted with constructor and garden plaza is being constructed. The curtain wall construction has been almost finished, and the building now awaits the final touches. (Fig. 21)

Fig. 21. Curtain Wall Construction in NOV., 2003

It underwent several major design revisions and rigorous fast-track project schedule, so I think that efficient cooperation among engineers, designers, and constructor is very important.

New constructional method of underground floors and lateral load path mechanism of sloping column were used in SK Telecom headquarters, so I think that this building solved well structural matters of geometric shape, and will be landmark building in Seoul city.