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Integrated Solutions for Complex Structures: Seong-su K project

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Abstract This study presents an integrated structural design and optimization process for an 18-story urban complex building. To resist lateral actions, a high-rigidity system couples a central core configuration with sloped steel-reinforced concrete (SRC) mega-columns. Crucially, eight primary reinforced concrete core walls extend continuously to the foundations to maximize overturning resistance. The superstructure incorporates a three-story macro-module layout separating structural hardware layers and gravity-resisting software layers. Most main columns are engineered as inclined SRC members to eliminate conventional horizontal transfer girders, while a single-story RC transfer wall resolves localized discontinuity at the corner column MC2. Driven by pre-planned bedrock excavation constraints, a transient heavy-duty temporary truss system utilizes a symmetric three-axis percussion rotary drill (PRD) column configuration to safely bypass immense vertical loads during top-down sequences. Linear frame analyses verify temporary column stability under transient unbraced lengths in compliance with KDS 14.

Keywords: Perimeter Cantilever, Vierendeel Truss, Post-Tensioned Beam, Top-Down Construction, Heavy-Duty Temporary Truss

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1. Introduction

Modern multi-functional high-rise developments in dense urban areas increasingly require complex architectural geometries, such as perimeter cantilevers and sloped column configurations. To provide an integrated solution for these complex structures, the target project of this study, Seong-su K-Project, utilizes an 18-story structural framework to counteract seismic and wind actions. To support the massive perimeter cantilever at the lower zones, a two-story podium Vierendeel truss system was successfully introduced. For the main superstructure, the architectural framework incorporates a three-story macro-module layout separating structural hardware layers and gravity-resisting software layers, coupling central RC core walls continuous to the foundations with sloped SRC mega-columns. To accommodate the spatial layout of a lower grand auditorium, a single-story-high RC transfer wall was strategically introduced at the corner column MC2. Furthermore, driven by pre-planned subterranean bedrock excavation constraints under the full top-down sequence, a transient heavy-duty temporary truss system utilizes a symmetric three-axis percussion rotary drill (PRD) configuration to safely bypass immense vertical loads before permanent foundations are poured.

2. Ensuring Structural Safety and Deflection Control of Perimeter Cantilever Members via Podium Vierendeel Trusses

The Seongsu K-Project complex building incorporates a large perimeter cantilever structure at the podium levels to secure architectural openness at the lower floors and organically connect public pedestrian circulations. To eliminate massive diagonal braces that typically obstruct interior finishes and spatial efficiency, a rigid-joint-based Vierendeel truss system was successfully introduced. This rigid frame structure is systematically configured over a two-story height utilizing the floor beams and columns from the 4th to the 6th floors, which directly supports a unique, circular long-span floor plan.

2.1. Deflection Control and Structural Integrity Mechanisms

Operating without diagonal members, the Vierendeel truss carries external gravity loads through strong moment connections established between the chord members (the 4th and 6th-floor beams) and the vertical members. The permanent dead loads and live loads applied to the outer cantilever tip and the circular floor profile induce shear forces and bending moments, which are safely bypassed and redistributed to the central reinforced concrete core walls and main column lines through the rigid joint stiffness. This system thoroughly satisfies the member strength and long-term deflection limits regulated by KDS 41. Furthermore, to completely prevent damage or water leakage risks in non-structural exterior finishes and curtain wall systems, a comprehensive elastic analysis evaluating joint stiffness under serviceability limit states was performed during the detailed design phase, thereby securing permanent structural safety.

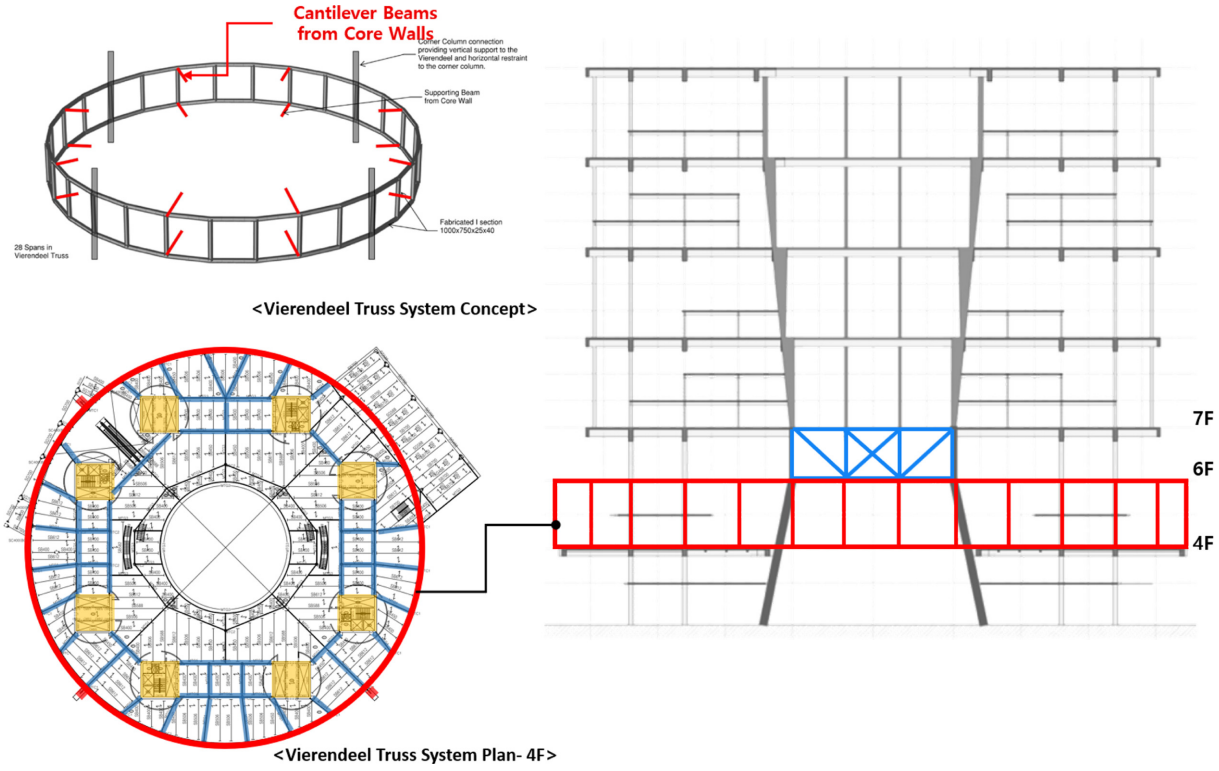


Figure 1. Vierendeel Truss System at Podium Level.

3. Structural Hardware and Software Layers, Inclined Mega-Columns, and Transfer Mechanisms

To accommodate the spatial and elevation requirements of the office and mixed-use facilities, this project incorporates an innovative structural configuration where three floors are grouped into a single macro-module and repeatedly stacked. The base floor of each macro-module—specifically the 7th, 10th, 13th, and 16th floors—functions as a **'Hardware Layer'** equipped with mega-column structures and massive frames to simultaneously resist both lateral and vertical gravity loads. Conversely, the two upper floors stacked above the hardware layer (e.g., the 8th–9th floors, 11th–12th floors, etc.) serve as a **'Software Layer'** designed exclusively to carry simple gravity loads without complex lateral-force-resisting components, thereby enabling an optimized, column-free open office layout.

The gravity loads, including dead loads and live loads generated within the software layers (such as the 8th and 9th floors), are directly transferred to the floor beams and girder-column lines of the immediate underlying hardware layer (the 7th floor). The heavy macro-frame structures integrated into the hardware layer consolidate these accumulated vertical gravity loads, establishing a well-defined load path that safely distributes and bypasses the forces toward the central reinforced concrete (RC) core walls and mega-column systems.

3.1. Inclined Mega-Columns and Transfer Systems for Lateral Load Resistance

To safely resist the immense wind and seismic actions exerted on the 18-story superstructure with a maximum height of 87.25 meters, a robust lateral force resisting system was established by coupling central core configurations with steel-reinforced concrete (SRC) mega-columns. Crucially, the eight primary RC core walls, which act as the main lateral-load-resisting elements, are designed to be fully continuous down to the lowermost substructure foundations without any structural interruption, thereby maximizing the shear resistance and overturning moment capacity against lateral forces.

To eliminate the severe stress concentrations and excessive headroom losses typically caused by traditional large-scale transfer girders, the majority of the main columns were engineered as inclined columns aligned with the architectural building envelope to completely bypass general transfer member configurations. However, at one specific corner main column location where direct vertical support from below was structurally unfeasible, a single-story-high RC transfer wall was strategically introduced inside the auditorium zone to safely transfer and distribute the upper column actions down to the lower structural framing.

At specific discontinuous locations where the internal main columns transition from vertical configurations to modified sloped directions along the elevation layout, robust transfer truss systems were concentratedly deployed

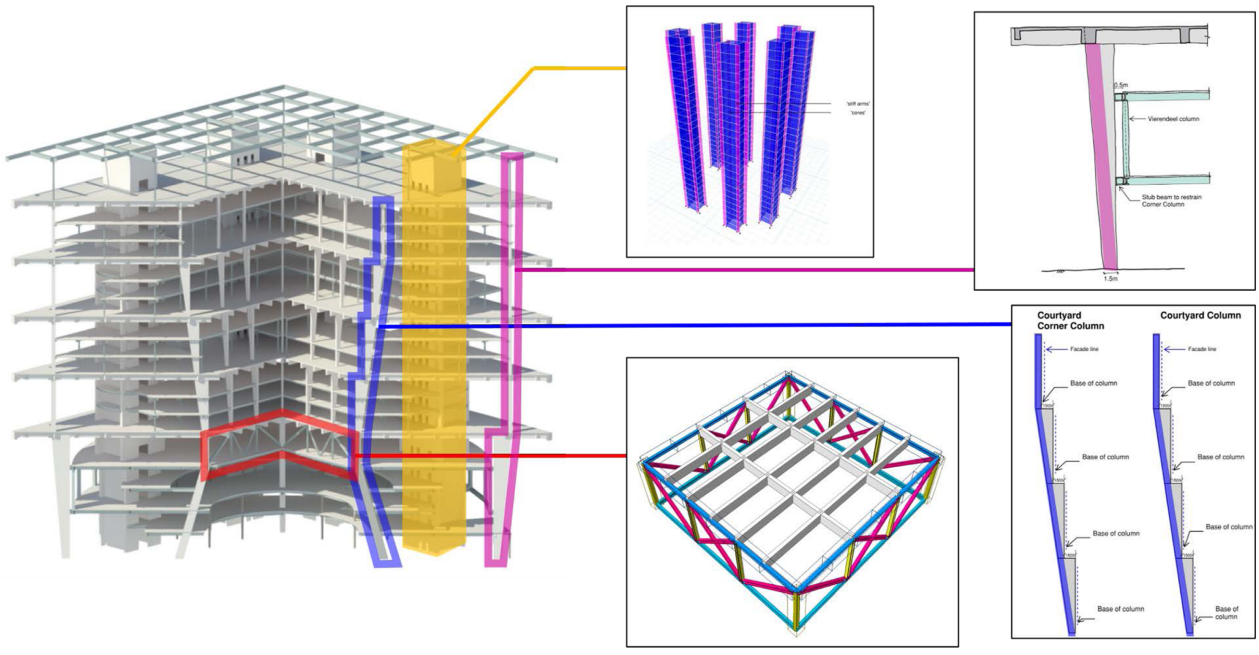


Figure 2. Structural components of the lateral force resisting system: central cores, mega-columns, and transfer trusses.

to eliminate buckling risks and local stress concentrations caused by the abrupt directional shifts, successfully securing overall structural stability.

4. Top-Down Construction Sequences and Temporary Structural Systems

4.1. Stability Evaluation of Temporary Columns During Full Top-down Erection

This project is actively being executed using the Full Top-Down construction method, where underground excavation and superstructure framework erection progress simultaneously. Before the lowermost underground floor excavation is finalized, the upper structural dead weights are consecutively accumulated. Consequently, the temporary percussion rotary drill (PRD) columns and permanent PRD columns acting under transient stages must sustain the entire cumulative gravity loads of the superstructure under transient, long-column conditions governed by the excavation depth.

To thoroughly control the structural buckling risks of these columns throughout the excavation advancement, the maximum effective unbraced lengths were meticulously calculated in strict compliance with the KDS 14 structural criteria (establishing a maximum unbraced length of 14.70 meters during the 1st-floor temporary stage and 11.25 meters during the lowermost excavation phase). The temporary structural safety was successfully verified by reviewing the stress ratios against the nominal axial compressive design capacities of the temporary members via comprehensive frame analysis models.

4.2. Heavy-Duty Temporary Truss Systems for Load Transfer of Mega-Columns

The lateral-force-resisting system of this superstructure relies entirely on the sloped mega-columns (SRC structure) and the RC core walls. Based on prior geotechnical investigations, the presence of a hard bedrock layer in the subterranean zones was clearly recognized during the design phase. Due to the predetermined prolonged duration required for this rock-crushing process, a high-load stacking sequence was planned where the entire superstructure skeletal framework is topped out and the exterior curtain wall finishes are fully applied prior to the completion of the lowermost permanent foundations. Under this specific construction stage, the immense cumulative vertical actions descending from the podium and subterranean mega-columns far exceed the design axial capacity of a single permanent PRD column alone in the absence of permanent foundations. To safely support and distribute these anticipated heavy structural actions, a heavy-duty temporary truss system composed of structural H-sections was strategically implemented into the underground layout.

The deployed subterranean temporary truss system functions as a powerful structural load-bypassing mechanism that intercepts the massive vertical axial forces concentrated at the tip of each mega-column due to the superstructure framework and finish loads, dispersing them into three distinct underlying column axes. To overcome the structural capacity limits of a single support, one permanent PRD column was rigidly coupled with two additionally deployed temporary PRD columns at the lower joints of the temporary truss frameworks.

The vertical and lateral actions traversing the sloped

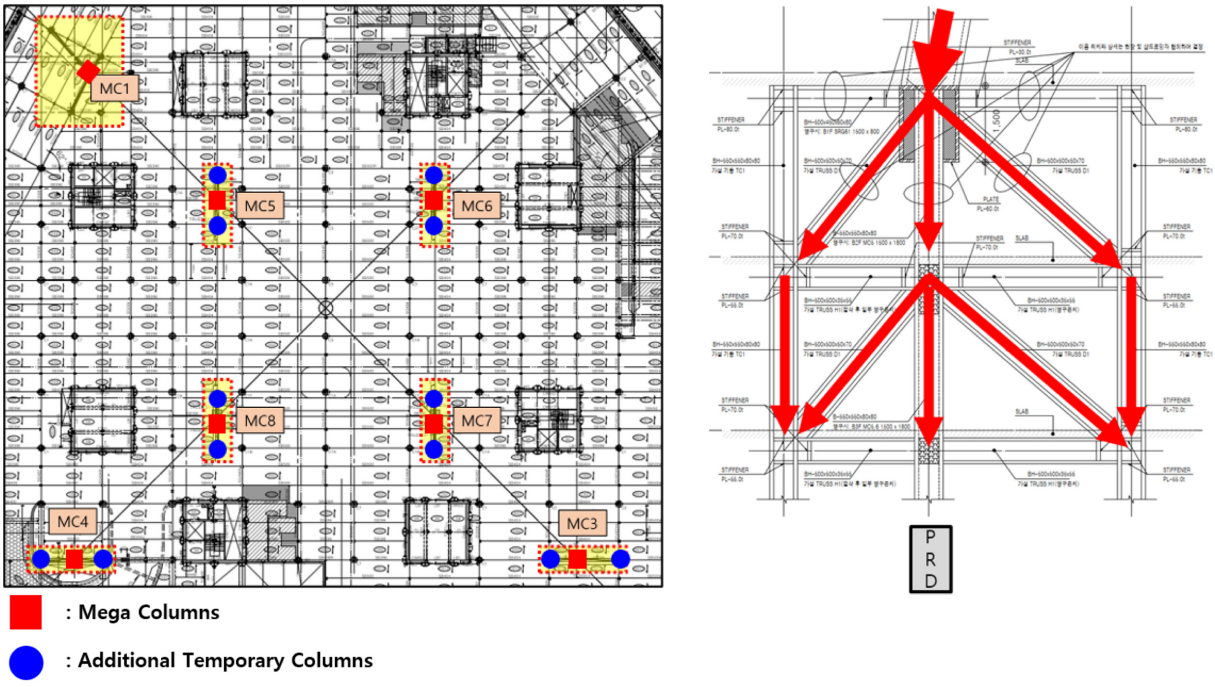


Figure 3. Temporary truss system and three-axis PRD configuration for vertical load transfer.

mega-columns are uniformly partitioned through the diagonals and chords of the truss, successfully distributing the loads via a three-axis configuration comprising permanent and temporary PRD columns down to the subgrade. This configuration was rigorously verified under the temporary construction load combinations of KDS 41 using precise frame analyses, thereby confirming the structural safety during construction.

5. Conclusions

This study successfully verified an integrated structural design and construction optimization process for an 18-story urban complex building. To secure open lower-level space without obstructing interior finishes, a rigid-jointed two-story podium Vierendeel truss was introduced, and elastic analyses confirmed it safely redistributes perimeter cantilever loads while satisfying KDS 41 criteria. For the main superstructure, a three-story macro-module separating hardware and software layers was implemented to achieve column-free office layouts, establishing continuous load paths by coupling central core walls with eight sloped SRC mega-columns arranged symmetrically in the inner and outer zones, while mitigating local stress concentrations via an RC transfer wall at the MC2 column. Furthermore, to resolve vertical capacity limits caused by pre-planned bedrock excavation delays under full top-down sequences, a heavy-duty temporary truss system was deployed. By rigidly coupling one permanent and two temporary PRD columns, this configuration safely bypassed immense vertical loads down to the subgrade, and its buckling safety was comprehensively validated in compliance with KDS 14 throughout the construction phase.