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SPEEDCORE: Composite-Plate Shear Walls/Conrete Filled Design for Tall Building

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Abstract As the American Institute of Steel Construction (AISC) 360 specification extensively incorporated content on SPEEDCORE in the composite structures section of its 2022 edition, and with the publication of Design Guide 38, the application of SPEEDCORE in high-rise buildings is becoming increasingly active. While most projects are in the design phase, some, as in the case of Taiwan, are already under construction. This study analyzed the merits of applying SPEEDCORE to high-rise buildings, despite the associated increase in construction costs. The investigation was conducted by comparing research findings at the individual member level and by examining the effects of its application to an idealized, simple structure. Based on these results, the effects were further examined by applying the system to a building currently under construction and to typical Korean Flat-Type and tower-type residential buildings. Furthermore, because the core wall is applied on a steel basis rather than a concrete basis, it offers numerous advantages for integration with Off-Site Construction (OSC) items, a recent key topic in the industry. Therefore, a greater advantage lies in this extensibility rather than in the inherent benefits of SPEEDCORE itself.

Keywords: SPEEDCORE, Composite-Plate Shear Walls/Conrete Filled, Composite Shear Walls

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1. Background of Technological Development

In the era preceding the last 30 years, the primary material constituting high-rise buildings was predominantly steel. However, with advancements in concrete materials and the development of pumping technology capable of delivering it to great heights, concrete began to comprise the majority of structural systems starting in the 1990s. During the construction boom in Dubai in the early 2000s, the vast majority of skyscrapers were constructed using post-tension-based concrete and composite structures. As a reflection on this trend, the American Institute of Steel Construction (AISC) initiated a large-scale research project to promote the wider application of steel structures. The main research contents can be summarized as follows.

1.1. Design Procedure for Dual-Plate Composite Shear Walls

Purdue University, 2006-2009: Development of a core wall system for steel structures, aimed at reducing the construction period relative to conventional methods.

1.2. Seismic and Wind Behavior and Design of Coupled CF-CPSW Core Walls for Steel Buildings

Purdue University, 2016-2019: Experimental and analytical investigation of various parameters necessary for design (with findings applied to the Rainier Square Tower).

1.3. R-Factors for Coupled Composite Plate Shear Walls-Concrete Filled (Coupled-C-PSW/CF)

University at Buffalo, 2017–2018: Research on coupled composite steel plate shear walls as a lateral force-resisting system, demonstrating the feasibility of a system with a Response Modification Coefficient (R) of 8.0.

1.4. Performance-Based Structural Fire Engineering of Buildings with Concrete-Filled Composite Plate Shear Walls (CF-CPSW)

Purdue University, 2018-2020: Experimental and analytical investigation of parameters required for the revision of AISC 360-22 Appendix 4 (Structural Design for Fire Conditions) and for performance-based fire-resistance design. This research supported the application of unprotected (zero fireproofing) SPEEDCORE at the 200 Park Avenue project.

Based on these research outcomes, the composite structures section within the AISC 360-22 and AISC 341-22 standards was extensively supplemented. Concurrently, Design Guide 38 was published as a separate volume to provide practitioners with a dedicated design methodology for SPEEDCORE.

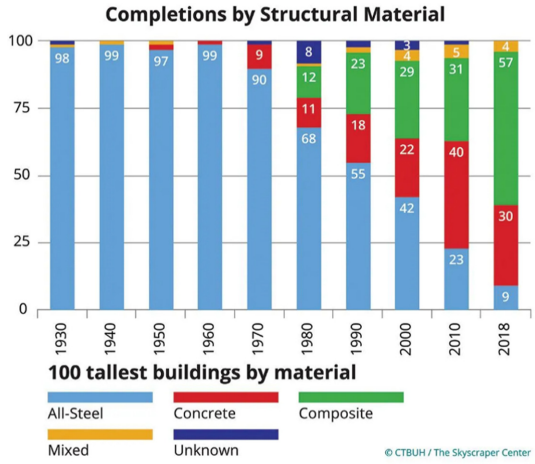


Figure 1. Structural Materials of the World's 100 Tallest Buildings (CTBUH)

Furthermore, under the slogan "Need for Speed," research is currently underway not only on SPEEDCORE but also on the "Fast Floor System" for accelerated floor construction and "Speed Connection" for rapid structural connections. It is anticipated that empirical validation of these technologies will be achievable to some extent by the second half of 2025.

2. Case Study

2.1. Unit Member Case Study

To evaluate the structural characteristics of SPEEDCORE walls in comparison to conventional Reinforced Concrete (RC) walls, an investigation was conducted on unit members and simple structures. The unit member analysis was performed by varying the member's aspect ratio (length-to-width) to 1:1, 2:1, and 1:2 to assess both in-plane and out-of-plane stiffness. For this analysis, the steel plate ratio was assumed to be approximately 6% of the concrete cross-sectional area.

The analysis was carried out using ETABS v21, which is capable of modeling SPEEDCORE members. The results confirmed that variations in the aspect ratio led to a 25% increase in in-plane stiffness, whereas the out-of-plane stiffness exhibited a more substantial improvement, showing a 60% increase.

2.2. Structure-level Case Study

A case study was conducted to preemptively identify potential errors that may arise during the analysis of SPEEDCORE. For this study, a square-shaped, center-core floor plan of a building actually designed and constructed in Busan, Korea was modeled with variations of 20, 40, and 60 stories. Furthermore, the study investigated the degree to which the increases in in-plane and out-of-plane stiffness, observed at the unit member level, are enhanced in an actual structure.

The floor plan measures 34 m by 34m with a 16m core. In the original 60-story building, this corresponds to a core-to-floor area ratio of 22%. Although the core ratio should decrease as the number of stories is reduced, this factor was disregarded; only the member sizes were scaled

Table 1. Comparison of Key Application Cases and Features of SPEEDCORE 1.0 and 2.0

RAINIER SQUARE (58 stories, construction started in 2017)	200 Park Avenue (19 stories, construction started in 2019)
SPEEDCORE 1.0, 32 months → 22 months (10-month reduction)	SPEEDCORE 2.0
12 in. cross-tie spacing	18 in. cross-tie spacing
Link beams are reinforced with rebar	Unreinforced link beams
SPEEDCORE is connected to the foundation.	Connection of SPEEDCORE to special shear walls on above-grade floors
Spray-applied fireproofing is applied.	No spray-applied fireproofing applied – based on subsequent research from Purdue University
14-foot (story height) Korean-made plates are used	Use of 10-foot plates with welded splices
	

down to approximately reflect the design results. The building's location was also changed to Seoul for the analysis. The floor plan and member sizes are as shown in the figure below.

Despite the square plan, the Y-direction behaved as the weak axis due to the location of the main core entrance. It was confirmed that the increase in lateral stiffness provided by the SPEEDCORE system in the weak axis was approximately 10%. For this analysis, the steel plate ratio was approximately 4%.

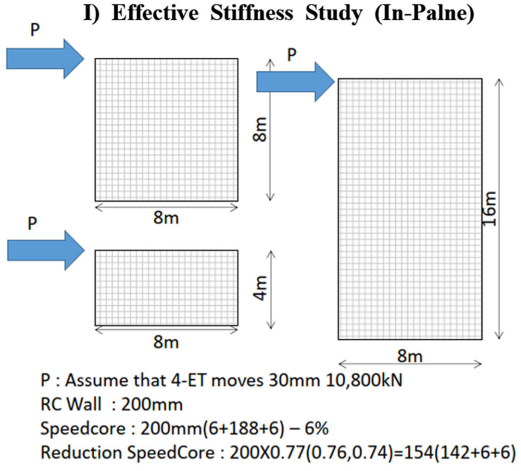
3. Pilot Project

To verify its applicability in actual buildings, an alternative design study was conducted on Flat-Type and tower-type apartment buildings. The study targeted moment-frame apartments based on recent floor plans from a construction company, which feature composite structures without interior columns. The Flat-Type building is 35 stories above grade and 4 stories below grade, while the tower-type is 59 stories above grade and 4 stories below grade. For these apartments, which were based on the construction company's standard design documents, only the core walls were replaced with the SPEEDCORE system to evaluate its effectiveness.

The stiffness of the SPEEDCORE system was determined in accordance with Design Guide 38. For all other members, the design was based on ACI 318, with separate models for serviceability (displacement checks) and strength (member design). The member design was conducted using an in-house tool, which was verified by comparing its results with manual calculations from design examples.

The core wall thicknesses were assumed to be identical to the original reinforced concrete walls, with maximums of 400 mm and 800 mm for the Flat-Type and tower-type buildings, respectively. Steel plate thicknesses of 10 mm and 12 mm were applied. For both cases, a tie spacing that precludes any strength reduction was used. The remaining structural system consisted of long-span slabs with perimeter beams. The thickness of the steel plates was governed by fabrication, lifting, and casting considerations rather than structural capacity. The boundary element plates were planned at 19 mm and the closure plates at 13 mm (to account for bottom-up concrete pumping pressure), eliminating the need for additional ties. For the coupling beams, a continuous web plate connection was applied in accordance with AISC 341.

Assuming a location in Seoul, a basic wind speed of 28



	Displacement [mm]	Ratio	Remark
4-GEN	30.6	102%	
8-GEN	101.8	102%	
16-GEN	520	101%	
4-ET	30	100%	
8-ET	100	100%	
16-ET	515	100%	
4-ET-S	23.2	77%	
8-ET-S	76.2	76%	
16-ET-S	383	74%	
4-ET-SC	27.4	91%	154mm
8-ET-SC	90	90%	152mm
16-ET-SC	450	87%	148mm

16-ET-S
Blank : RC Wall, S:Speedcore
SC : Reduction SpeedCore
Gen: Midas/gen, ET:ETABS
Height 16, 8, 4m

	Displacement [mm]	Ratio	Remark
4-GEN	32.6	108%	
8-GEN	282	118%	
16-GEN	2652	139%	
4-ET	30.0	100%	
8-ET	238	100%	
16-ET	1908	100%	
4-ET-S	11	36.7%	
8-ET-S	88	37.0%	
16-ET-S	703	36.8%	
4-ET-SC	19	63.3%	74mm
8-ET-SC	151	63.4%	74mm
16-ET-SC	1210	63.4%	74mm

16-ET-S
Blank : RC Wall, S:Speedcore
SC : Reduction SpeedCore
Gen: Midas/gen, ET:ETABS
Height 16, 8, 4m

Figure 2. Speedcore Single Wall Case Study.

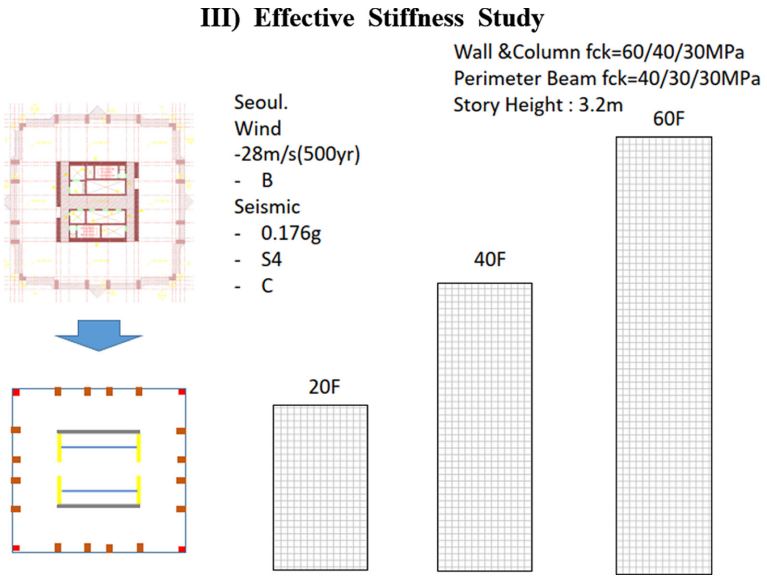
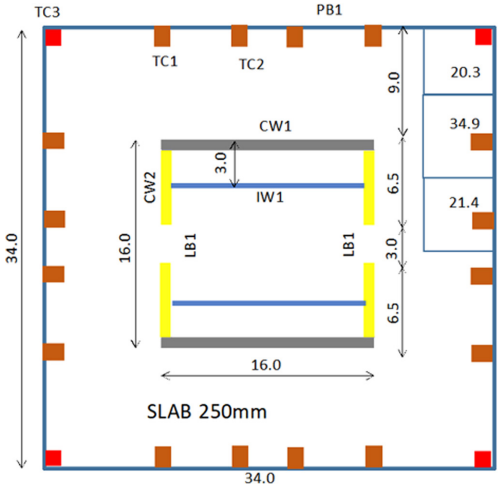


Figure 3. Analysis Models of Composite Steel Plate Shear Walls by Number of Stories.



Member Size

	20F	40F	60F	Remark
CW1	200	400	600	
CW2	250	500	800	
IW1	0	0	0/250	
LB1	Wx600	Wx600	Wx600	
TC1	600X800 2.8%	800X1000 3%	800x1100 2.8%	
TC2, 3	400X800 3.0%	600X1000 2.8%	800x700 2.7%	
PB1	1000x600	1000x600	1000x600	
fck Wall, Col.	30	40	60	
fck PB	30	30	40	

Figure 4. Floor Plan and Member Sizes for Analysis Models by Number of Stories.

m/s and a ground acceleration of 0.176 g were applied. The lateral force-resisting system for both towers was governed by seismic loads. The analysis results showed that, compared to the concrete core walls, the wind drift for the strength-design model decreased by 20-30%, while the serviceability model showed a reduction of approximately 10%. However, the application of SPEEDCORE had no discernible effect on the natural period. This is judged to be due to a highly conservative estimation of SPEEDCORE stiffness, suggesting that the design manual was written with a sufficient margin of safety.

	Displacement X Dir. [mm]	Ratio	Remark
20GEN	7.6	100%	
20ET	7.6	97%	
20ET-S	4.7	60%	
40GEN	57.7	100%	
40ET	57.6	96%	
40ET-S	46.1	71%	
60GEN	185	100%	
60-GEN-I	171	92%	
60ET	185	100%	
60ET-S	163	88%	

	Displacement Y Dir. [mm]	Ratio	Remark
20GEN	15.5	100%	
20ET	15.4	100%	
20ET-S	10.6	69%	
40GEN	79.5	100%	
40ET	79.5	100%	
40ET-S	67.5	85%	
60GEN	227	100%	
60-GEN-I	217	96%	
60ET	223	98%	
60ET-S	199	88%	

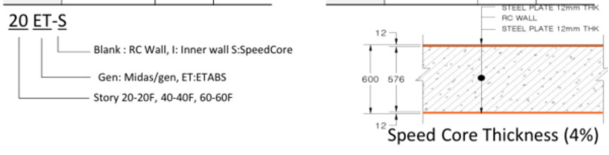


Figure 5. Comparison of Lateral Displacements by Building Story According to Structural Analysis Models (GEN, ETABS, SPEEDCORE)

4. Pilot Project: Performance-Based Fire Design

4.1. Selection of Members for Performance-Based Fire Design

For a 42-story office building, the subject of an alternative design, a performance-based fire design was conducted at

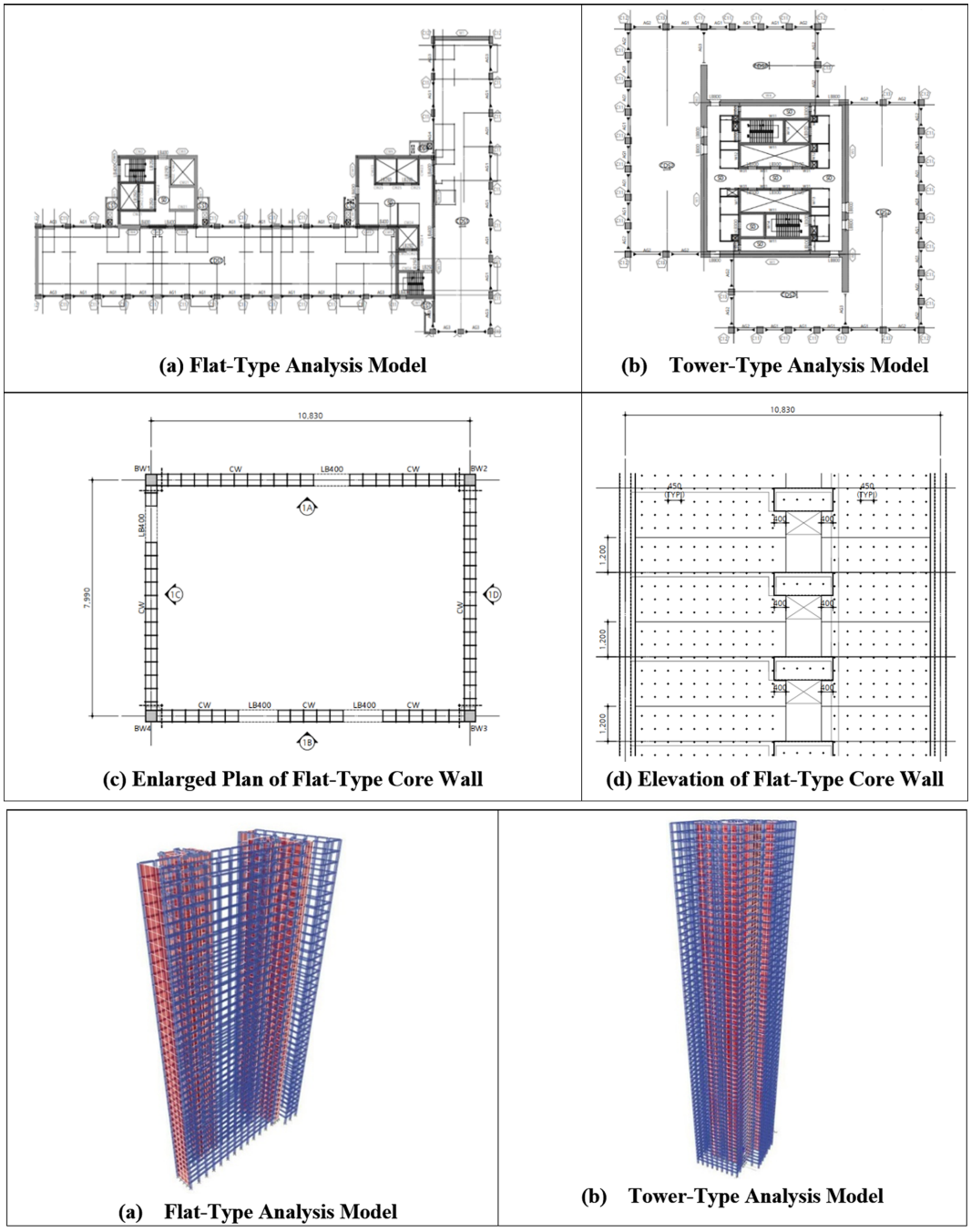


Figure 6. Analysis Models.

the member level for the SPEEDCORE walls in the lower stories, which have relatively small member sizes and are subjected to high axial loads. In the revised standard (AISC 360-22), under 'Fire Conditions', the calculation for SPEEDCORE walls can be performed using key variables such as wall length, axial load ratio, and thickness. If the axial load is low, a sufficient fire-resistance time is generally secured.

On the other hand, in performance-based fire design, since a fire load is input, and this fire load itself incorporates a time component, it is only possible to verify whether the target fire-resistance time is achieved. To enhance the reliability of the finite element analysis, the input variables were matched with the results from research papers, and the investigation was conducted reflecting this.

The subject member for the analysis was OW15 on the first floor (800 mm thickness, 12 mm steel plate), and the investigation was performed with variables including steel plate thickness (12 mm and 21 mm) and fire load (standard indoor fire load, design fire for office facilities - compartment fire). The analysis was conducted using ABAQUS/CAE-2024. The applied loads were a dead load

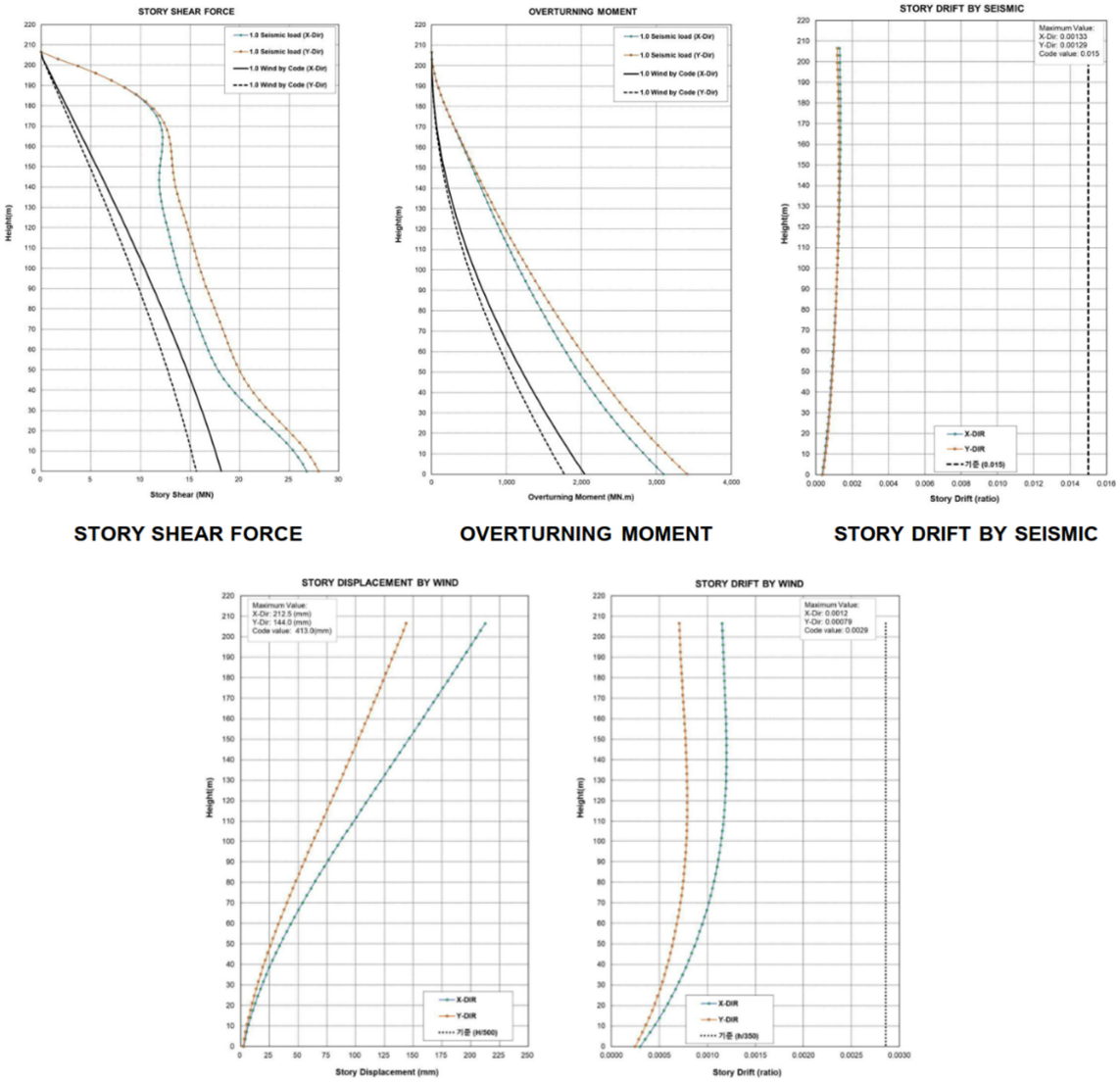


Figure 7. Results of Lateral Force Comparison and Serviceability Check for a Tower-Type.

of 26,287 kN, a superimposed dead load of 7,088 kN, and a live load of 7,203 kN.

4.2. Fire Load

For the fire load analysis, the ISO 834 standard indoor fire curve was applied. Additionally, a detailed design fire load for an office facility was also investigated. The detailed fire load for the office facility was selected based on the fire scenario for a typical office building, as provided in the design examples of the fire-resistance design guidelines. This design fire corresponds to an equivalent fire-resistance time of approximately 60 minutes when converted to the standard fire exposure.

4.3. Performance-Based Fire Design Results

A performance-based fire design was conducted for the subject member, OW15, in accordance with the methods presented in the Korean Design Standards (KDS), which are based on the Rules on Building Structural Standards. The performance evaluation method adopted one-sided heating as stipulated by the Korean Industrial Standards (KS). The fire-resistance analysis was performed using a general-purpose finite element analysis program, and the reliability of the proposed finite element model was secured by comparing its results with those of existing experimental research.

1) When one side of member OW15, an 800 mm thick SPEEDCORE wall with 12t steel plates, was subjected to the standard fire, the maximum temperature on the unexposed side was 20.08°C, the axial deformation was 3.00 mm, and the rate of axial deformation was 0.143 mm/min.

2) When one side of member OW15, an 800 mm thick SPEEDCORE wall with 21t steel plates, was subjected to the standard fire, the maximum temperature on the unexposed side was 20.00°C, the axial deformation was 5.71 mm, and the rate of axial deformation was 0.199 mm/min.

Table 2. Comparison of Flat-Type and Tower-Type Structural Analysis Models

No	Model	Period (sec)			Max. Wind Displacement (mm)	
		1st	2nd	3rd	X Dir.	Y Dir.
1	Model 1	6.75	5.96	3.23	288.5	204
2	Model 1-SC	5.96	5.21	3.06	208.3	153.9
3	Model 2	5.81	5.1	2.72	213	151
4	Model 2-SC	5.63	4.93	2.66	188.8	136.4
5	Model 3	3.88	3.05	2.61	46.3	232
6	Model 3-SC	3.47	2.88	2.43	37.8	179.5
7	Model 4	3.25	2.54	2.19	33.8	170
8	Model 4-SC	3.18	2.52	2.18	31.4	155

3) When one side of member OW15, an 800 mm thick SPEEDCORE wall with 12t steel plates, was subjected to the design fire, the maximum temperature on the unexposed side was 20.09°C, the axial deformation was 3.65 mm, and the rate of axial deformation was 0.918 mm/min.

4) In all three cases above, the results satisfied both the integrity criterion (temperature rise on the unexposed side below 140°C) and the load-bearing capacity criterion (axial deformation below 82 mm). Therefore, it was concluded that the OW15 member of the Yeouido Teachers' Pension building achieves a 3-hour fire-resistance rating without any applied fireproofing.

4.4. Comparison between the Standard (AISC 360) and Performance-Based Fire Design

The primary factors considered in the standard are the wall height (length), the axial load ratio, and the thickness. It was observed that as the thickness increases, the fire-resistance time also increases. This relationship was incorporated into a program for calculation, and it was confirmed that the fire-resistance time of the alternatively designed member is approximately 5 hours.c

4.5. Mock-up

4.5.1. Overview

A mock-up was constructed for a portion of the alternatively designed core. In addition to the SPEEDCORE

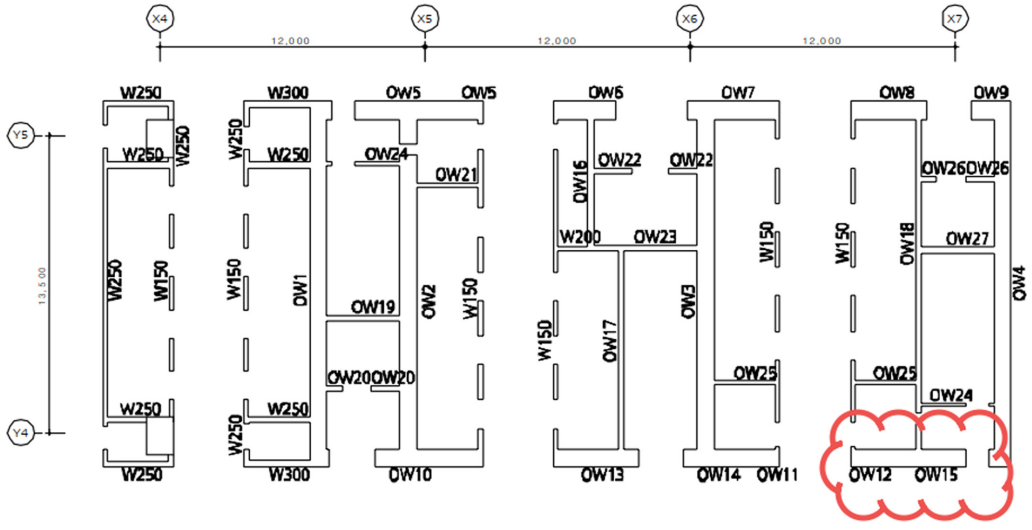


Figure 8. KEY PLAN for First Floor.

Table 3. Section and Material Properties of SPEEDCORE

No.	Member Section (mm)	Legnth (mm)	Steel Yield Strength (N/mm^2)	Concrete Strength (N/mm^2)	Load (kN)	Tie Bar
1	12-776-12 (800 mm)	8,200	355	60	36,564	φ24@300
2	21-758-21 (800 mm)	8,200	355	60	36,564	φ24@500

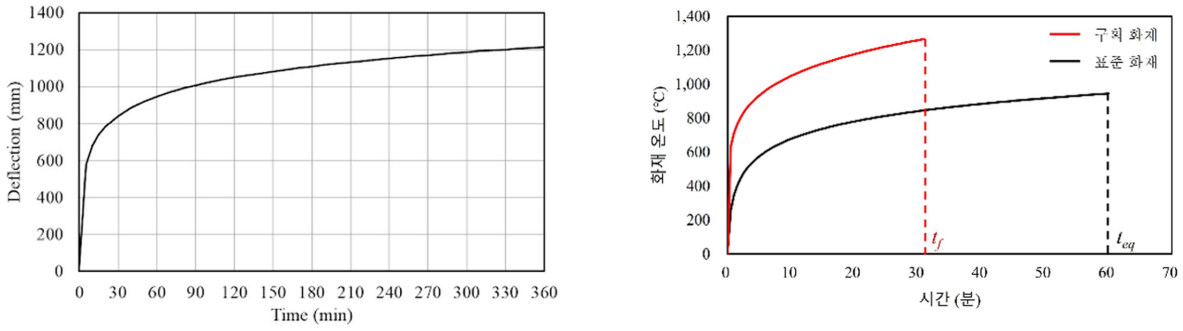


Figure 9. Fire Curve or Time-Temperature Curve.

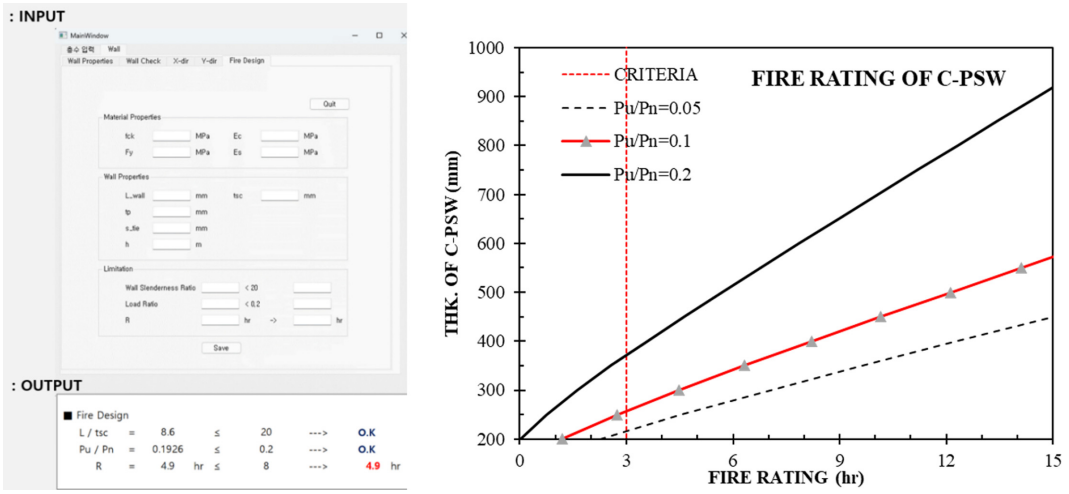


Figure 10. Calculation Results for Fire-Resistance Time as a Function of Thickness (at a 10% Axial Load Ratio).

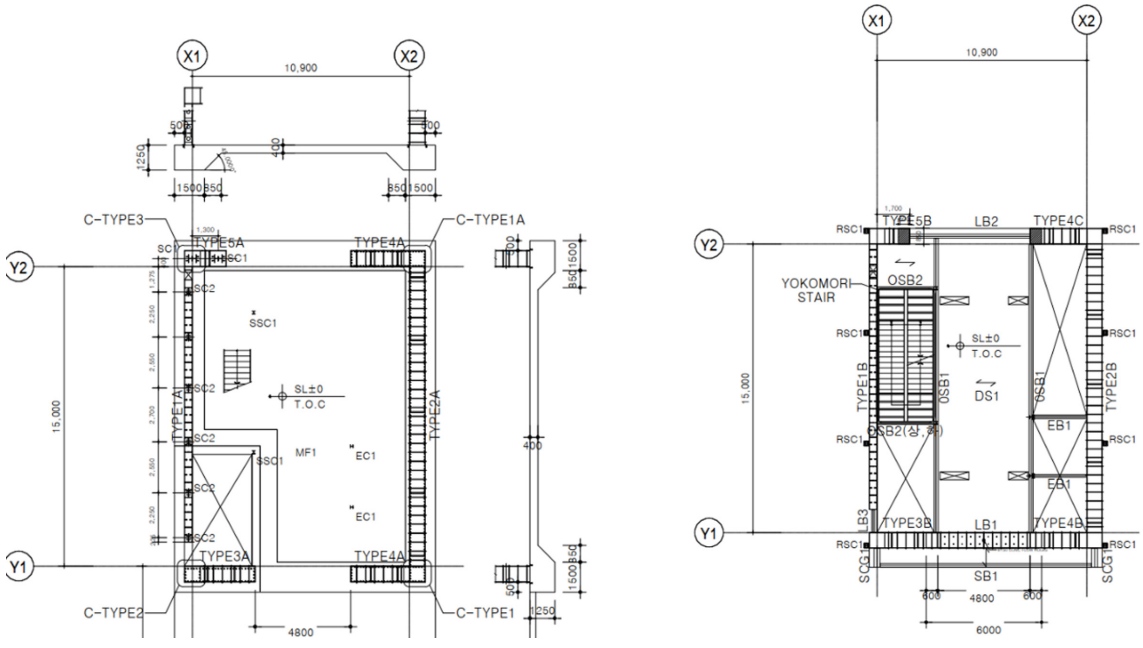


Figure 11. Structural Plans for Mock-up.

walls, products from the Off-Site Construction (OSC) business, which are currently under research, were actively applied. The applied OSC products that were trial-tested included a Prefabricated Plumbing (PFP) shaft, an elevator cage, steel stairs, and a modular OSC bathroom.

Various connection methods were applied, including

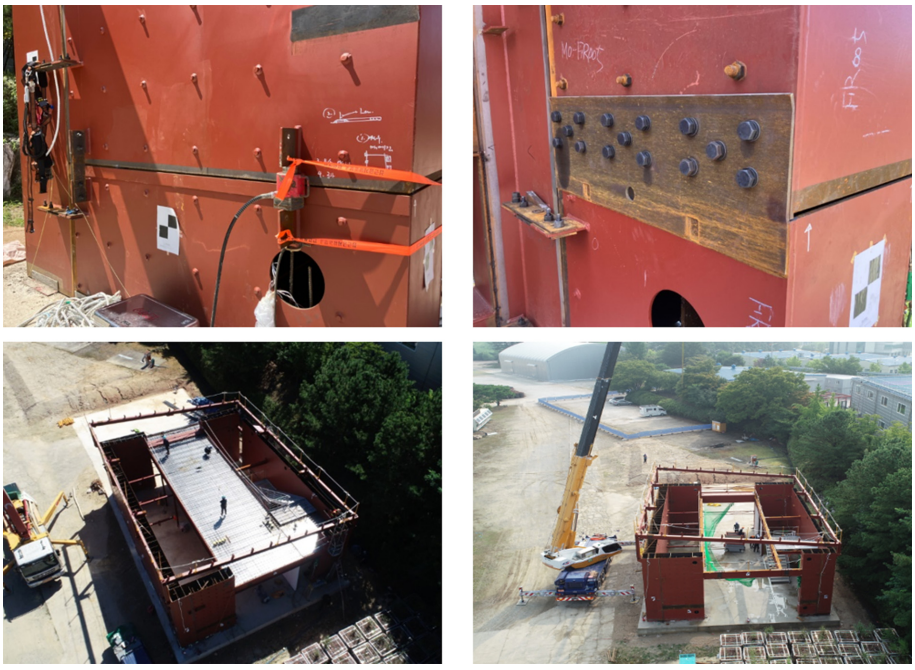


Figure 12. Mock-up Construction Progress.

Table 4. Comparison of RC Core and Speed Core

Model			1st Mode	2nd Mode	3rd Mode
Flat-type (35F)	RC CORE	Natural Period (sec)	3.96 (UY)	3.79 (UX)	2.40 (RZ)
		Mass Participation Ratio	35.12%	34.86%	63.71%
	SPEEDCORE	Natural Period (sec)	3.69 (UX)	3.56 (UY)	2.35 (RZ)
		Mass Participation Ratio	38.39%	31.93%	60.73%
Tower-type (59F)	RC CORE	Natural Period (sec)	6.24 (UX)	5.21 (UY)	2.35 (RZ)
		Mass Participation Ratio	54.93%	55.67%	76.91%
	SPEEDCORE	Natural Period (sec)	5.90 (UX)	4.93 (UY)	2.30 (RZ)
		Mass Participation Ratio	52.73%	53.81%	77.38%

Model		X-Direction		Y-Direction		Remark
		Maximum Displacement	H/500	Maximum Displacement	H/500	
Flat-type (35F)	RC CORE	74.6 mm	H/1,618	225.0 mm	H/536	O.K
	SPEEDCORE	62.3 mm	H/1,937	193.2 mm	H/625	O.K
Tower-type (59F)	RC CORE	248.4 mm	H/831	164.4 mm	H/1,256	O.K
	SPEEDCORE	212.5 mm	H/972	144.0 mm	H/1,434	O.K

manual Complete Joint Penetration (CJP) welding, manual Partial Joint Penetration (PJP) welding, automatic CJP welding, automatic PJP welding, standard bolted connections, and bolted connections using aluminum arc-welded splice plates.

5. Conclusions

5.1. Unit Member Case Study

The structural performance of SPEEDCORE walls, both in-plane and out-of-plane, was verified by varying the aspect ratio. The width-to-height ratio was varied to 1:1, 2:1, and 1:2. Compared to conventional reinforced concrete walls, the lateral stiffness based on displacement increased by similar amounts of 130%, 132%, and 135%, respectively. The out-of-plane stiffness increased by 272%, 270%, and 272%. It was confirmed that the increase in out-of-plane stiffness was significantly greater than that of the in-plane stiffness.

5.2. Structure-Level Case Study

When analyzing a standardized, square-plan building at 20, 40, and 60 stories, the lateral stiffness, based on lateral displacement, increased by an average of 156%,

129%, and 114% in the x and y directions, respectively. This confirmed that the effectiveness slightly decreases as the building height increases. In high-rise buildings, the primary benefit of applying SPEEDCORE is the reduction of the construction period; the enhancement of structural performance should be considered a secondary objective.

5.3. Residential Pilot Project

The effectiveness of SPEEDCORE walls was investigated for a 35-story (120m) Flat-Type and a 59-story (206.5m) tower-type residential building, based on the standards for the Seoul region. For the Flat-Type building, the period decreased from 3.96 seconds to 3.69 seconds, and the structural performance, based on wind drift, improved to 117%. For the tower-type building, the period decreased from 6.24 seconds to 5.9 seconds, and the structural performance, based on wind drift, similarly improved to 117%.

5.4. Performance-Based Fire Design

The primary factors considered in the standard are the wall height (length), the axial load ratio, and the thickness, and it was found that the fire-resistance time increases as the thickness increases. This was incorporated into a program for calculation, and it was confirmed that the fire-resistance time of the alternatively designed member is approximately 5 hours.