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Structural Design for Concert Hall in IFEZ Arts Center

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Abstract

The concert hall of big scaled building for Arts Center, is located on IFEZ (Inchon Free Economic Zone) G2-1 Block. It comprises of 7 floors and 2 basements.

This paper represents the structural design of the building and the methods being issued which protect from floor vibration and noise effects. Another issue item is to make large span hall and cantilever. At first time, we proposed to use the super-column supported roof trusses. But these super-columns had some problems of architectural module, economics and constructability.

It is lied large span trusses at roof and 7th floor, and the roof truss has a large cantilever about 40m. Trusses are supported by core walls and SRC columns. For reduce the displacement of truss, we proposed the rigid joint of the connection of truss at edge core walls. It is occurred a big member force at this joint, and then we proposed the embedded plate in the core wall.

It is experienced the structural design of concert hall as music hall, because the structural designer engaged floor vibration and also acoustic parts.

Keywords: Concert Hall, large span truss, hanging column, acoustic joint, floor vibration

1. Introduction

The multi-culture complexes, allowing people to experience various cultural contents, have recently increased in number. The planning is working on procedure in IFEZ(Inchon free economic zone), for construction of Arts Center – concert hall, opera house, museum, music school and so on.

The concert hall is located on G2-1 Block with a large area of 260m by 246m of Arts Center. It is built on an area of 80m by 78m and has 7 floors and 2 basements with the gross area of 37,000m^2, and includes inner performance hall accommodating 1800 audiences, spacious multi-functional hall.

In this kind of building, architectural requirements usually affect structural systems because of its purpose. For this reason, from the first stage of design, various kinds of structural systems have been considered on account of architectural needs through discussion with architectural designer. As the design development occurs, structural systems have been changed and structural systems have been considered according to architectural plans.

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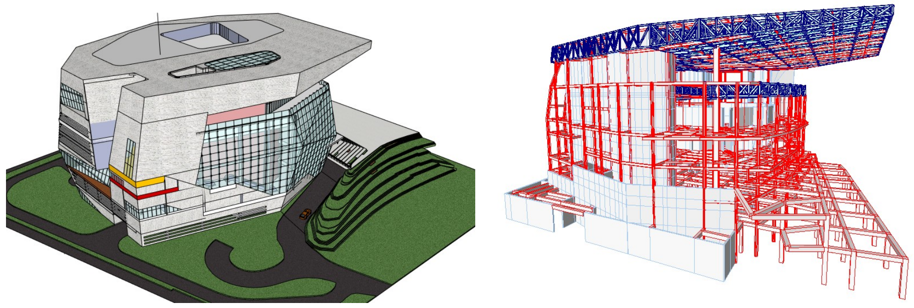


(a) Overview (b) Structural modeling

Figure 1: Shape of concert hall

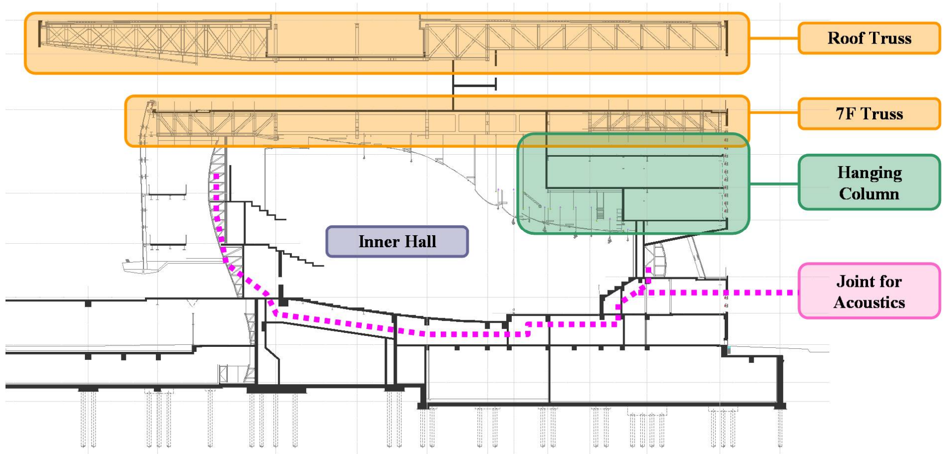


Figure 2: Section view of concert hall

This building is composed of steel structure and RC structure. RC beam and girder system for basement and steel beam and girder system for over ground floor are used. SRC columns help stress flow from floor steel frame to columns being optimized. For lateral force resisting system, building frame system with RC shear walls is used.

Inner hall is important in respect to architectural design as well as acoustic planning. Thus, RC structure favorable to acoustic plan is applied making cantilever at a part of structure and auditorium. Also, to prevent auditorium from floor vibration and noise outside, hall and outer foyer are isolated using acoustic joint. Similarly, in order to prevent auditorium from vibration of upper part of hall, long-span truss structures are designed. In this context, hanging structure to upper long-span truss is adopted for the slab and panels making inner hall roof shapes. It shuts out of floor vibration flowing into inner hall. In addition to separating inner hall from outside foyer using acoustic joint, at bottom floor of auditorium, floating floor system is applied using anti-vibration pad. As a result, it would meet the acoustic planning requirements that allow for protect inner space of concert hall from outside noise and vibration.

At 7th floor and roof, long-span trusses up to 52m are designed with non-column space. Moreover, about 30m cantilever is formed at roof.

In this paper, structural plan to apply truss structure and acoustic plan of inner hall will be presented.

2. Truss system

2.1. Design process

In this building, trusses are located at 7th floor and roof and consist of long-spans and a long cantilever. Each truss makes a non-column space up to 52m and a 30m cantilever roof.

At the first stage, using super columns to support roof trusses was suggested. However, it was hard to adopt super columns because it would cause many problems in respect to architectural design, economical efficiency, constructional workability, and etc. So, SRC steel column in core wall is used to support trusses. Furthermore, to relieve truss deflection caused by long-span, rigid joint for the end of truss is designed.

Truss members of this project are designed using domestic products as much as possible. Also, same basic materials are used for the end details of trusses.

Thickness (mm)	Sign	Yield strength (F_y)	Ultimate strength (F_u)
~ 40	SM490	325 N/mm^2	490 N/mm^2
40 over ~ 100		295 N/mm^2	

Table 1: Welded sections

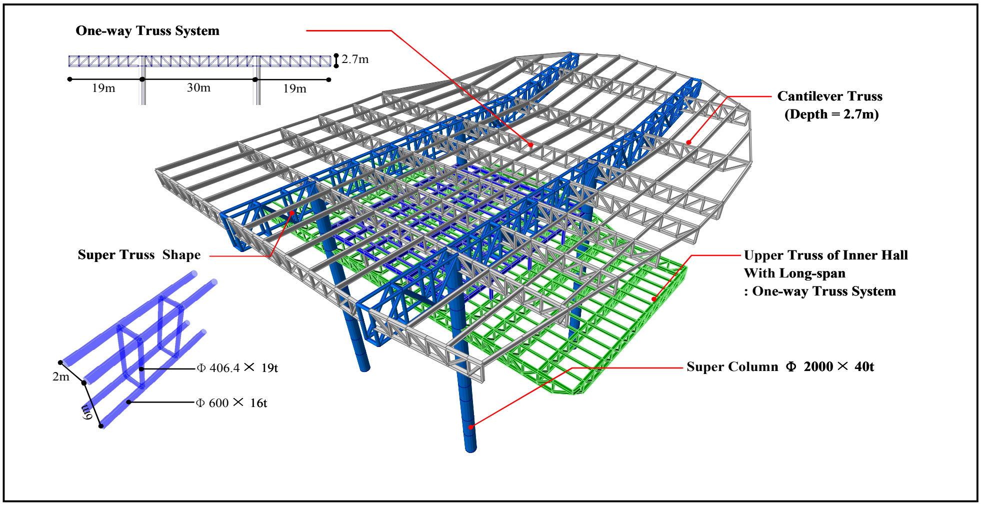
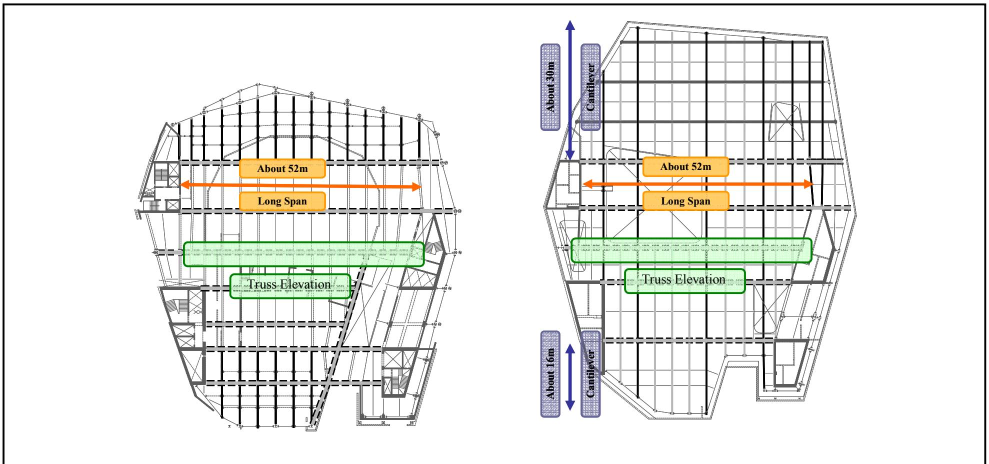


Figure 3: Design of the first stage (proposal)

2.2. System determination for trusses

7th floor, as multi-functional hall, is located over inner hall. In order to prevent inner hall from noise and floor vibration caused at multi-functional hall, 7th floor is separated from inner hall. And its slab is composed of 3100mm depth long-span trusses up to 52m span. Truss is used at roof on top of 7th floor. Program of multi-functional hall at 7th floor is expected to be modified. To accommodate this flexibility, the truss is installed at roof so that it could make changeable non-column space.



(a) 7th floor (b) Roof floor

Figure 4: Framing plans

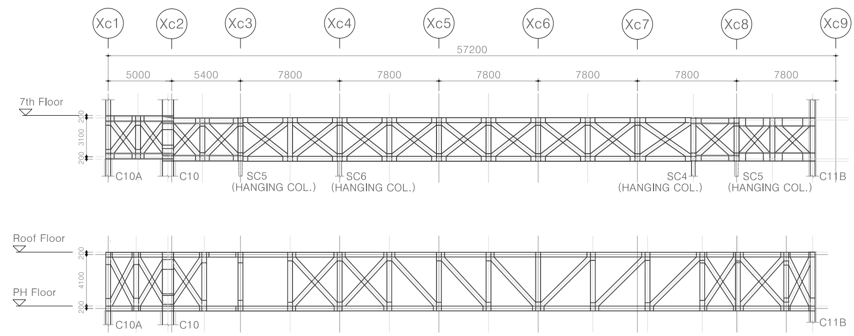
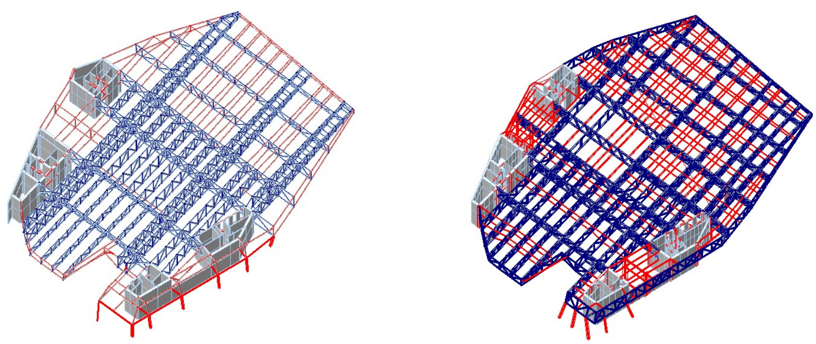


Figure 5: Truss elevations for 7th floor and roof floor

Roof truss is composed of two 4100mm height trusses over penthouse roof and roof. It makes not only long-span up to 52m but also 30m projected cantilever which makes roof. Cantilever trusses are made at right angles to long-span trusses. Roof truss is composed of light-weight materials, excluding a portion of roof. Thus, brace is installed to make diaphragm for unified behavior of roof truss.

At the first stage, truss in which 2-row were connected by box shape was designed. But truss shape had to be modified because roof garden and corridors between each room were changed and it would cause clashes with architectural design. After adjusting the design several times, truss arrangement has been confirmed satisfying standards of deflection for wind load as well as architectural needs. Compared to previous design, gross material quantity becomes reduced.



(a) Previous design (b) Final design

Figure 6: Alteration of roof truss design

	Member size	Material	Total weight	Ratio
Previous design	Φ 609.6 x 22t Φ 406.4 x 16t	STK490 (F_y = 330 N/mm^2)	15,117 kN	100 %
Final design	H-400x400x13x21 H-414x405x18x28	SM490 (F_y = 330 N/mm^2)	11,810 kN	78 %

Table 2: Quantity comparison between previous and final design

For designing a projected cantilever at roof, not only gravity loads but also uplift and downward wind load should be considered. As a result of examination through computing structures, deflection would be more crucial than stress. On that account, frame is designed for deflection to cover serviceability. Deflection of cantilever roof by wind load would be under the limit l/150 presented AISC, after arranging projected main trusses and adjusting strength by selecting members.

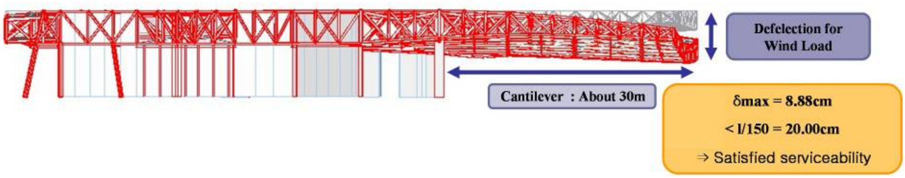
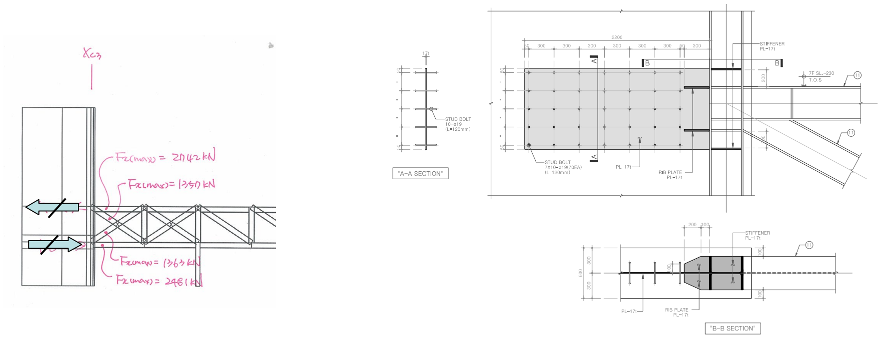


Figure 7: Deflection of cantilever roof

2.3. Details

Long-span trusses for each floor would be settled at steel column of SRC columns in RC core wall. So as to reduce deflection, top chords and bottom chords are connected with steel column by rigid joints. As a result, top and bottom chords would cause lateral forces which

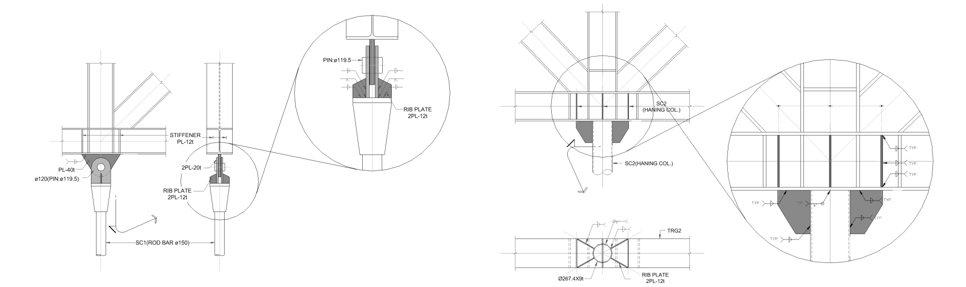


(a) Concept (b) Detail of the end connection

Figure 8: Details of the truss end connection

have different directions and they would make great shear force at core wall. In order to optimize shear force flow, plates are installed from each truss joint to rear side into core wall, and their joints are connected by stud bolts. Stud bolts could activate shear force flow toward core wall, resisting against tension and compressive force caused at top and bottom chords with their shear strength.

In order to prevent inner hall from noise and floor vibration, hanging column system, hung to 7th floor trusses, is used for a portion of slabs between top of inner hall and trusses at 7th floor so that the slabs are separated from inner hall.



(a) Rod bar type column (b) Circular column

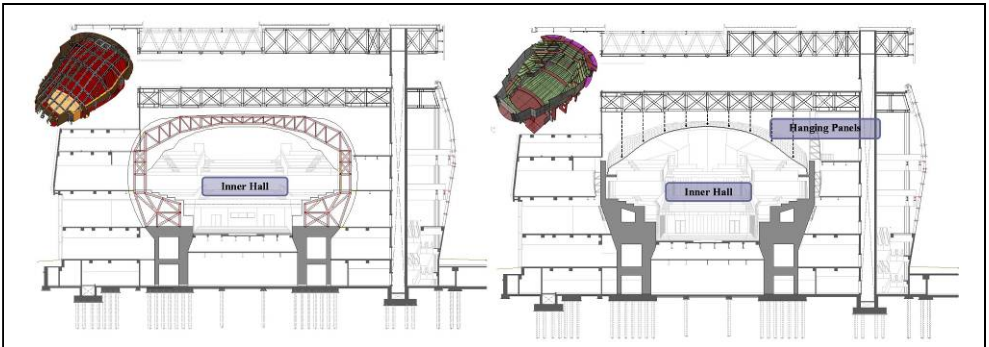
Figure 9: Hanging column details

3. System for acoustics of inner hall

3.1. Design process

Inner hall is from 2nd floor. On 2nd floor stage and audience seats are located on the whole floor, and on 3rd and 5th floor audience seats are located with projected shape.

At the beginning, steel truss was designed for inner hall shape. To lower part of 2nd floor audience seats start, RC columns were used. From 2nd floor, steel supported both egg-



(a) Previous design (b) Final design

Figure 10: Design for inner hall

shaped light-weight panel making inner hall roof and auditorium shape, making it easy to design flexible space freely.

Though, it becomes difficult to design egg-shaped structure in steel truss as the structural plan is changed to RC structure in order to optimize acoustic performance capacity. For that reason, RC supports slabs up to 5th floor which has top audience seats, by separating auditorium floor from final materials of the roof. Upper panels are hung to 7th floor trusses and they make the roof shape.

3.2. Isolated system

In order to ensure acoustic performance, in addition to that steel structural system is changed from steel to RC structure, inner auditorium is prevented from vibration caused at outside of inner hall.

Audience seats are located on 2nd, 3rd, and 5th floor. Anti-vibration mount is installed at 2nd floor slab, and on top of that, floor is installed, so called floating floor. At 3rd and 5th floor, using acoustic joint which enables inner hall auditorium to be separated from exterior foyer, auditorium would be prevented from outside vibration.

3.3. Column shape of inner hall

It is not easy to slove structural problems because acoustic joint is used for RC system at inner hall auditorium stated above. Also, RC beam and girder system are hard to be applied

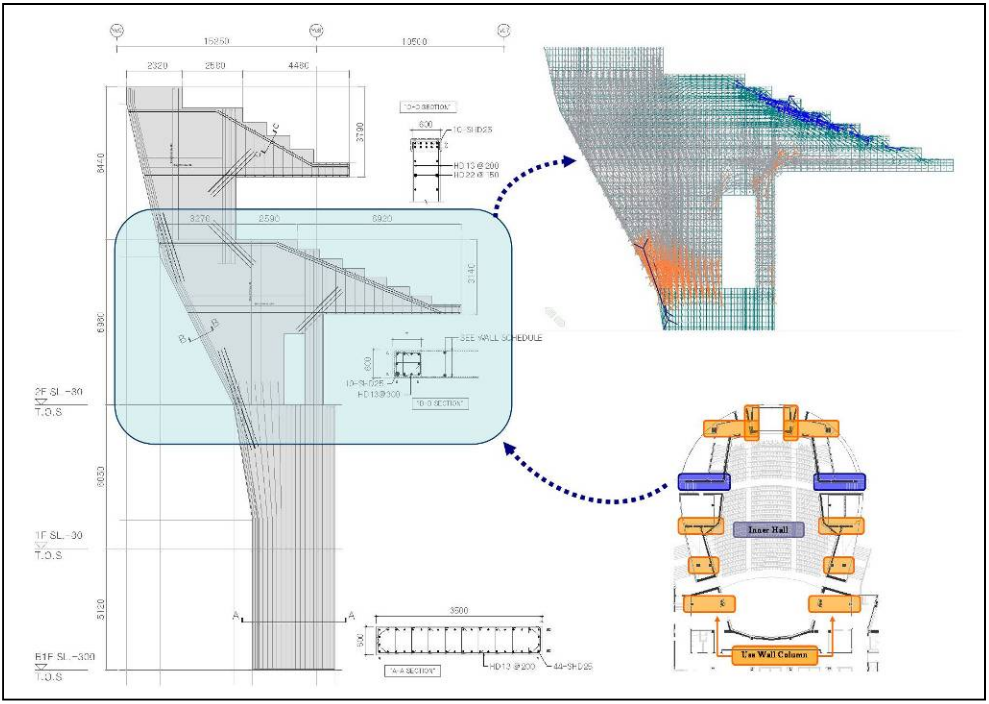


Figure 11: Detail analysis for inner hall column

because, in terms of architectural design, 3rd and 5th floor of auditoruim have not only projected cantilevers but big level difference between each area. Therefore, projected shape at auditoruim would be embodied using large RC columns which are like wall. Moreover, columns are connected by beams so the level difference of auditorium would be reduced. Stress flow along column's shape is examined through detail modeling. According to the result, steel bars are arranged to optimize stress flow.

4. Conclusion

As stated above, in this project, many favorable structural systems have been studied to meet the architectural and acoustic planning requirements. And unique structural systems, not being used in general, are used.

Likewise, there are some cases that architectural needs would affect structural plan as a matter of special functions. In this case, if structural engineers and architectural designers cooperate actively and grasp each other's needs, it is possible to proceed the project on behalf of each other. Accordingly, from the first stage, structural engineers should be out of the old simple role of merely computing structures, give advices, and suggest various alternatives in order to actualize architectural design.

We envisage that the concert hall of IFEZ Arts Center, as the precedent for these types of structures, will offer a foundation for multi-culture complex.

Acknowledgement

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