Structural design of Geumjeong gymnasium for 2002 Busan Asian games

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INTRODUCTION

Holding of 2002 Busan Asian Games gives the opportunity to build a lot of large-scaled stadia, and each of it is designed uniquely.   Geumjeong gymnasium is for the basketball games of 2002 Busan Asian Games and has a seating capacity of approximately 5,500.

The Goumjeong gymnasium is composed of a reinforced concrete core ring and a structural steel truss roof.   The core ring is again composed of inner wall, ring slab and outer wall. The roof of this gymnasium is composed of convex lens-like shaped steel trusses.   The simply supported steel truss has maximum moment at mid-span and thus the steel truss has convex lens-like shape in elevation.

In this paper, it is introduced the design of roof structure which is composed of steel truss has convex lens-like shape in elevation, and detail of triangular supports.

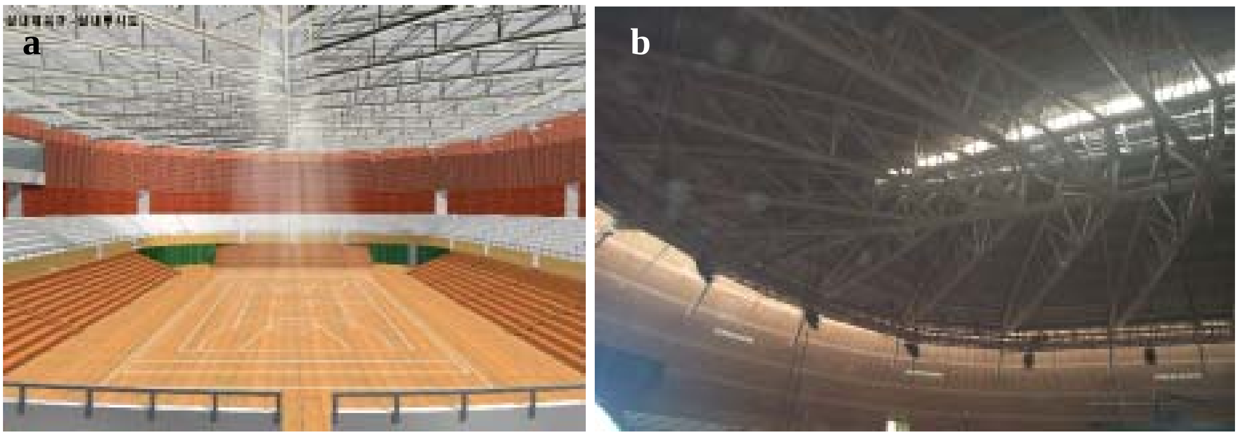


Fig. 1. a) Interior view - perspective, b) Interior view – construction

DESIGN LOAD FOR ROOF STRUCTURE

Initially, the roof structure is designed for load based on the latest Korean code (1996). At the design of the roof structure, the loads written bellow had been considered.

Dead Load

As the weight of connection and weld of the roof, the 10 percentage of the dead load is added to themselves secondary. And the supplemental loads include purlin, finish, light, speaker and so on.

Live Load and Snow Load

80 kgf/m^2 live load is applied in accordance with the latest Korean code (1996). As snow load is less than live load, snow load is replaced by live load in the load combination.

Uplift Wind Load

Wind load produces not only the lateral force but also the uplift force to the structure. The code requires a basic wind speed of 40m/sec for Busan. And consequently 160kgf/m^2 of wind load is used as uplift force.

Thermal Effect

Because it is resisted thermal effect by the whole roof, temperature change is checked on the structural analysis phase. Temperature loads are based on meteorological observation data. Analysis for temperature loads is divided into two parts. One is the construction phase, and the other is the construction completion phase. In the construction phase, because the steel member of the roof exposed to the direct rays of the sun, the value +30°C is applied. And in the construction completion phase, the value +20°C for a temperature rise and -15°C for a temperature down are used.

MATERIAL

Table 1. Welded sections

Thick(mm)	Sign	Yield strength(fy)
~ 40	SM490 B (KS D 3515)	3.3 tonf/cm^2

Table 2. Steel Member

Member	Sign	Yield strength(fy)
Rolled beam	SS400	2.4 tonf/cm^2
Steel tubes	SPS400 SPS490	2.4 tonf/cm^2 3.3 tonf/cm^2

ROOF STRUCTURE

24 radial trusses are connected to the main truss which is located at center of the roof and each truss has two top chords and one bottom chord.(fig 2-b) It is inverse triangular shape in section. The triangular shaped section does not occur global buckling of truss.

The roof of Geumjeong gymnasium is 4,570 m^2 in area and composed of convex lens-like shaped steel trusses. The simply supported steel truss has maximum moment at mid-span and thus the steel truss has convex lens-like shape in elevation.(fig 2-a)

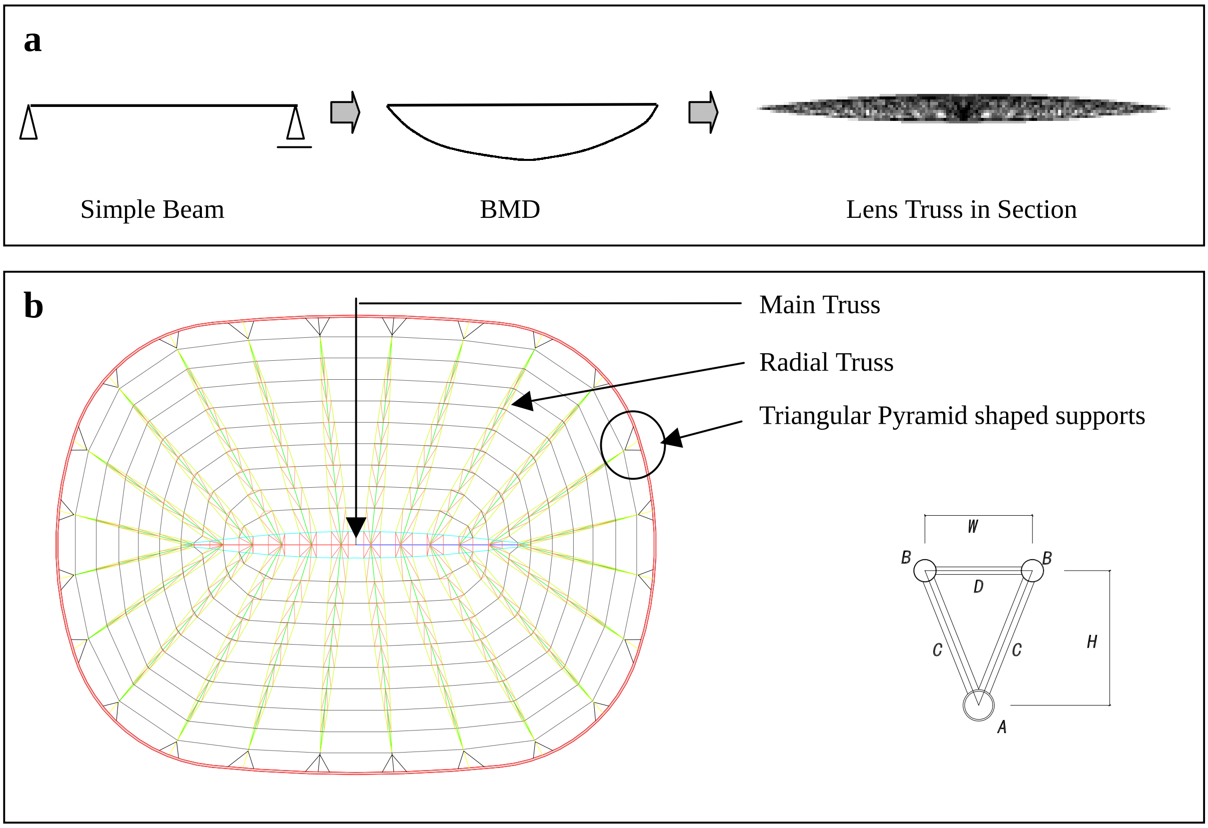


Fig. 2. a) Structural roof system concept, b) roof plan and section shape

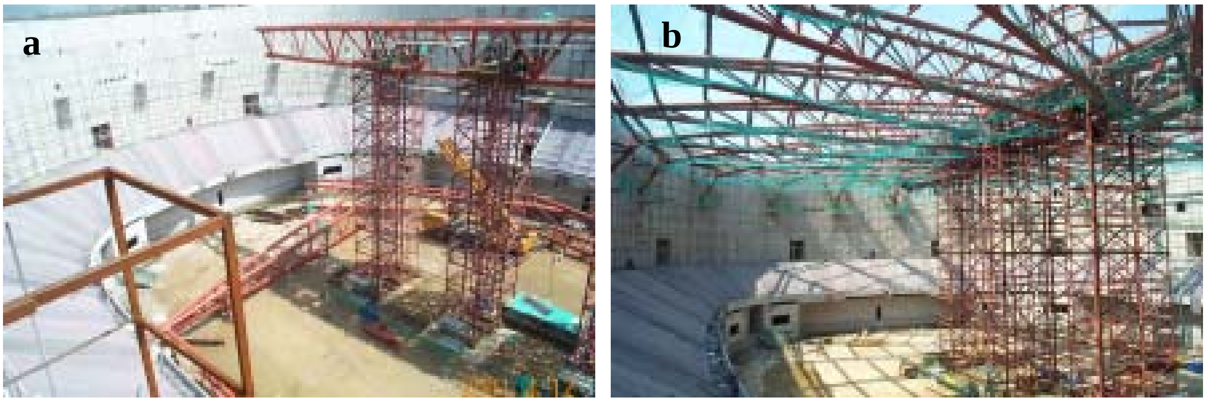


Fig. 3. a) Main truss erection, b)Radial truss erection

Structural Analysis and Design

Optimized structural design is a major goal for on any structural engineers. On this project, it was a much greater concern than usual. All of the structural elements of the roof (trusses, triangular supports and purlins) are exposed to view. They are intended to serve as architectural elements in addition to their structural purpose. Therefore it was necessary to design the structure to resist the loads satisfactorily so that the steel tonnage would be as low as possible.

In order to analyze and design the roof structure 3-D finite element analysis program was used. Because this gymnasium has irregular shape, it is very difficult to ascertain the coordinates of the structure. Thus, it is used the input of the nodal coordinates in FEM modeling from the 3-D CAD program. In this way, not only the consumed time during input of the nodal coordinates of the structural model is reduced but also the geometrical difference between the real structure and the structural model is minimized.(fig. 4-a)

Most of FEM models are simulated to reflect the accurate configurations of each part of the structure ; A large-scaled model is analyzed to check the general behavior of the entire structure, and a string of small detailed model is analyzed to

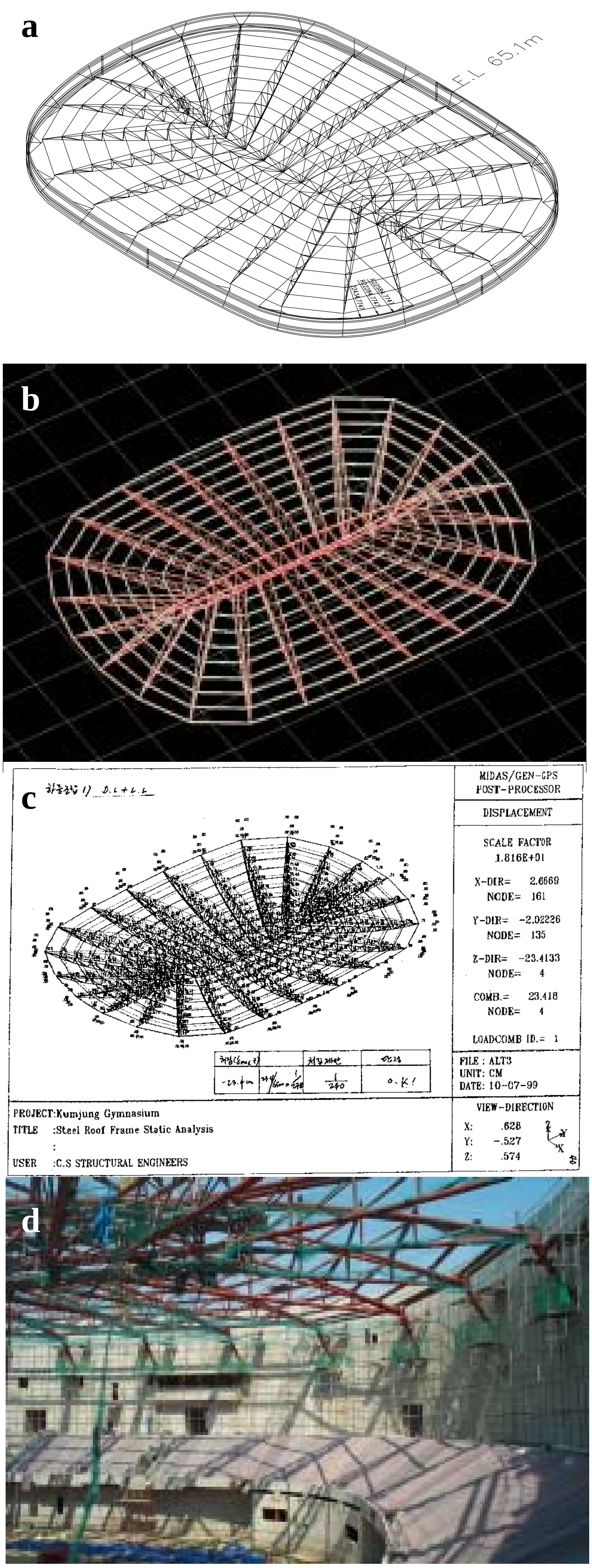


Fig. 4. a) 3-D drawing by CAD, b) FEM analysis model, c) Displacement check, d) Roof construction

confirm safety of the structurally suspicious parts of the structure

The design procedure for the roof was broken into three phases : Schematic Design, Optimized Design, and Final Design. First, the Schematic Design phase was to determine the structural system that would perform most efficiently. Many different structural schemes were explored and many modifications were made to the original conceptual design to save weight.

Once the final structural scheme had been determined, the Optimized Design phase was begun.

And the Final Design phase had two objectives. First, the roof need to be analyzed for the unbalanced loading condition. Second, the member sizes needed to be finalized with consideration to architectural and constructability requirements.

After the entire structure had been analyzed for all load conditions, Midas-GEN, 3D FEM analysis program, performed a code check on all members. Each member that did not satisfy the code check was replaced with a satisfactory member and the structure was reanalyzed. To ensure complete structural integrity, this process was repeated until all members passed the code check.

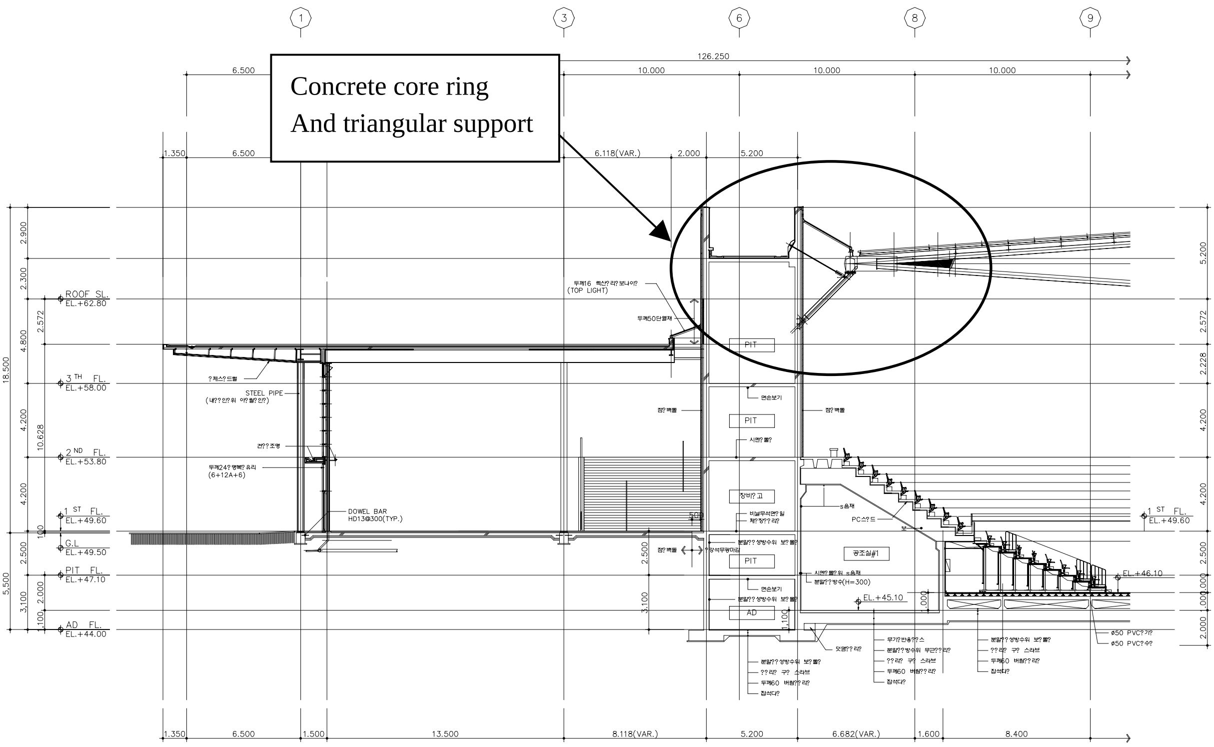


Fig. 5. Section of whole structure

a

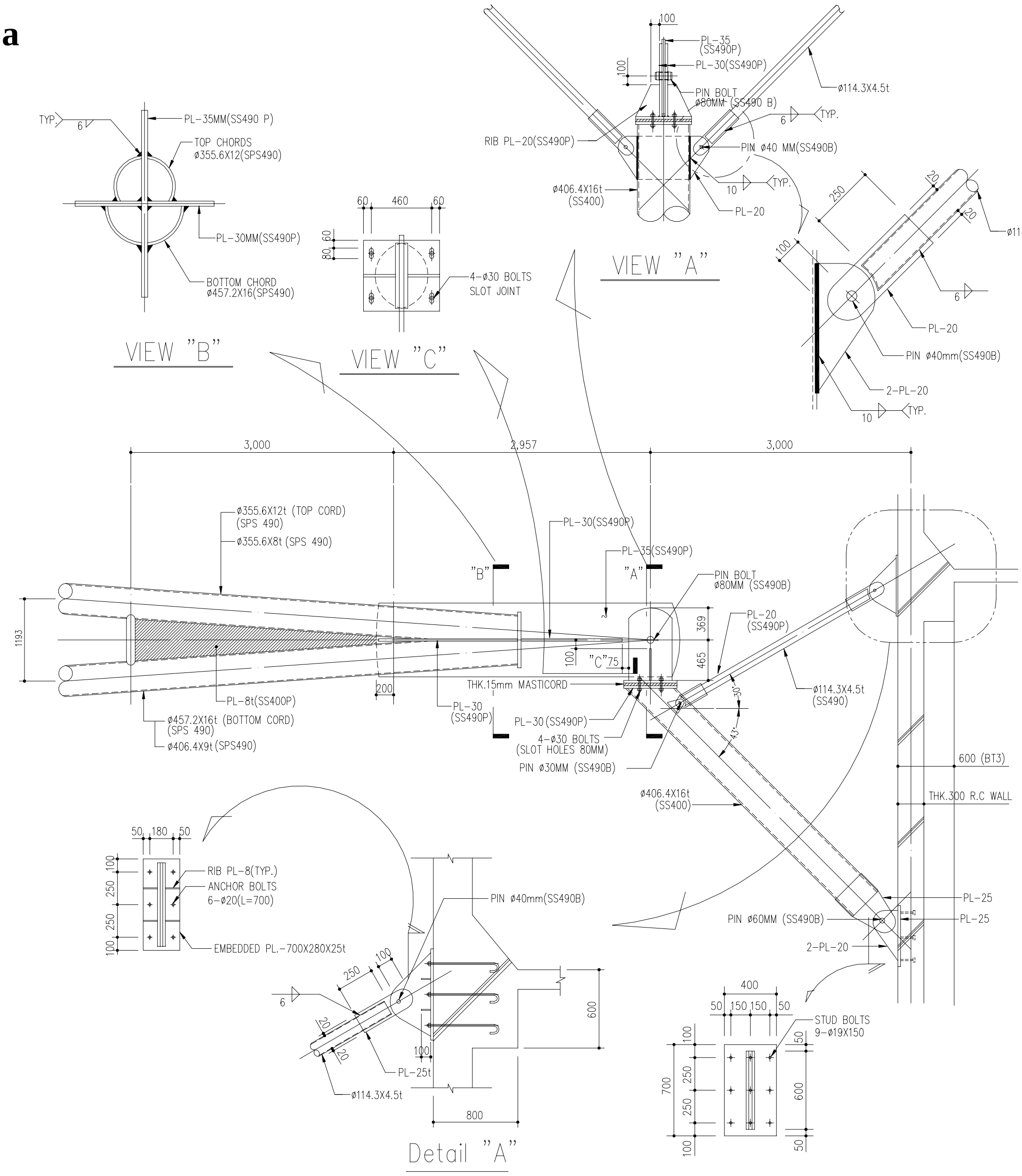
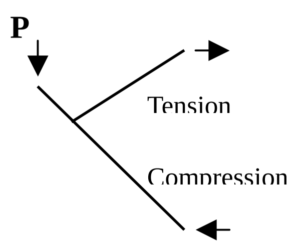


Fig. 6. a) Detail of triangular support, b) Triangular support system

b



Supports

The roof radial truss spread out the force of the whole roof to 24 supports, which has a slot joint permitting lateral displacements due to gravity loads and thermal effect. It resembles a triangular pyramid in elevation. It has two top chords resist tension force and one bottom chord resist compression force. The triangular Support was designed by using another FEM model resisted main roof reactions. It was performed a code check on all member by 3D FEM analysis program. And connection design was performed by detail model analysis.

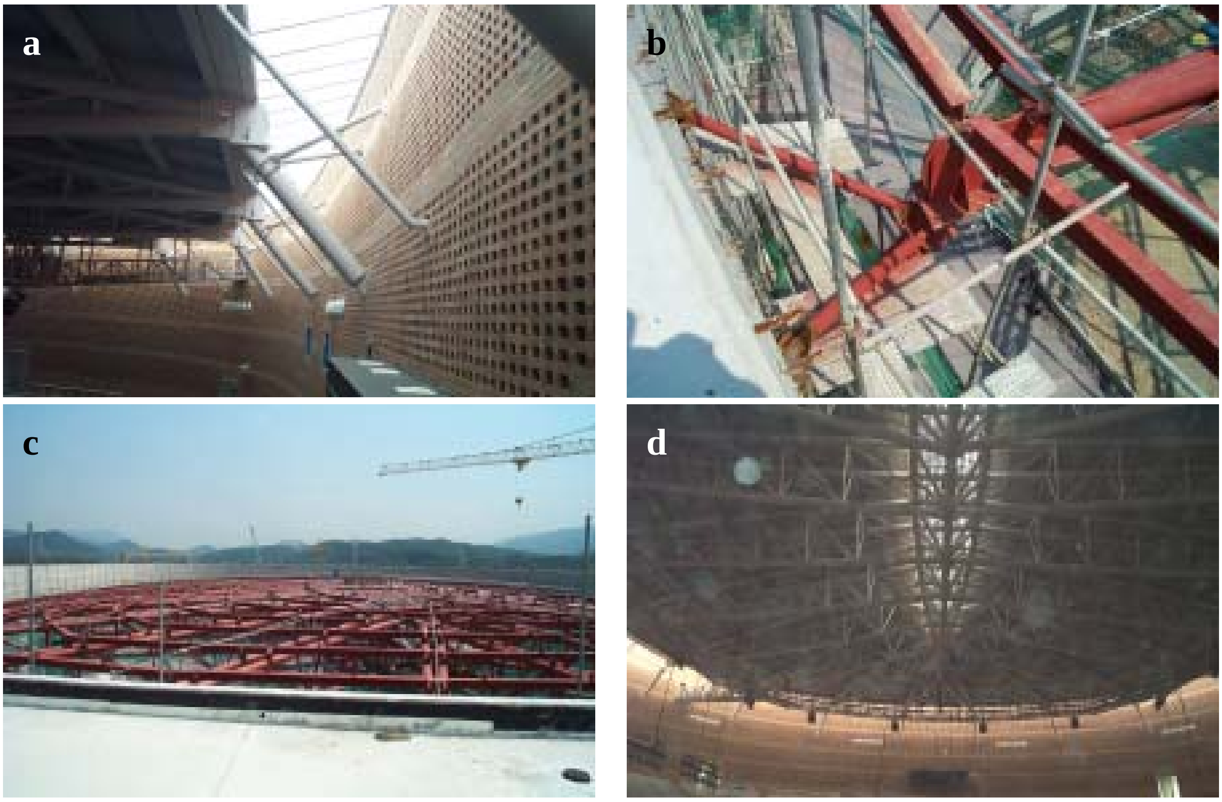


Fig. 7. a),b) triangular support - construction, c) exterior view, d) interior view of roof

CONCLUSION

The roof structure utilizes a unique structural system. That is rigid steel truss supported by triangular pyramid supports based on simple beam concepts. Using steel tubes and having the top light and side light, the roof has slender-legged external appearance.

For the entire roof structure the total steel tonnage, including all trusses, connections, purlins, supports was 440 metric tons. This gives an average steel weight of 0.096 tons/m^2. This cost-effective structural system, which meets budgetary and architectural requirements, was only possible though rigorous structural analysis and design.

REFERENCES

1. Korean Institute of Architects (1996), Minimum Design Loads for Building, Ministry of Constructions and Transportation, Seoul, Korea
2. Korean Institute of Architects (1996), Design Guide for Steel Tubes, Korean Institute of Architects, Seoul, Korea