Structural Design of Steel Structure Made by Balanced Frames and of Transparency-conscious Pedestrian Bridge

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Summary

Of the buildings of the Grand Front Osaka, a huge complex development in front of JR Osaka station, this paper presents structural design of its symbolic, eye-stop steel structure having curved surfaces, and also the structural design of transparency-conscious, pedestrian bridge.

Keywords: steel structure; pedestrian bridge; three-dimensionally curved surface; inclined columns; balance; flat bar; transparency;

1. Introduction

Our entry is two buildings with structural characteristics that are featured prominently in their external appearances and which are part of a building complex having a total floor area of 570,000 m^2.

Umekita Ship is an impressive building with an exterior having three-dimensionally curved surfaces. Although the exterior has a complicated shape, the three-dimensionally curved surface is rationally formed by a combination of simple frames. Each frame is formed of inclined columns of small-diameter flat bars, with the frames at varying angles of inclination and distributed to provide an overall balance.

The connecting deck is a pedestrian bridge connecting the South Building and North Building high rises with a 46m span over a road. It is formed of tie rods combined with small-cross-section materials and fine details, and was designed to suppress the feeling of volume of the structural members and give an impression of transparency.

Fig. 1: View of building north side

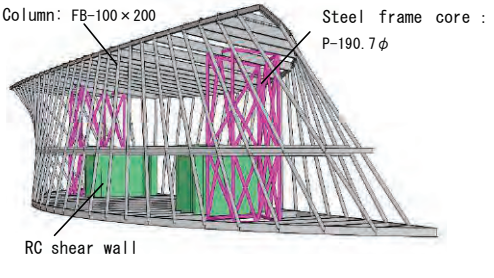

Fig. 2: Frame model diagram

2. Umekita Ship

2.1 Structural plan

In creating the structural plan for this building with a three-dimensional curved surface facade, a proposal with the following 2 points at its core was created to achieve a simple architecture that is as rational as possible:

- Priority was placed on securing stability for long-period loads, and a building shape in which the thrusts generated in each structural member during long-period loading would be balanced by the entire building was selected.
- The external facade that forms three-dimensional curved surfaces would be created by a series of simple inclined frames.

By arranging 27 single-span frames composed of inclined columns at 2 m intervals instead of using three-dimensional frame shapes that match the complicated shape of the design, we achieved the design using a combination of structurally simple frames. (Figure 1) Although making the columns of each frame inclined creates unstable frames in which thrusts are generated during long-period loading, these thrusts are cancelled out and stable frames created through the use of a "balanced frame" frame plan in which the entire structure is integrated via the floor. (Figure 2) These 27 frames are also the outer frames which create the external appearance of the building. (Photo 1)

2.2 Detailed design

In order to reduce the visible face width of the frame columns installed at 2 m intervals, at the start of design we considered using welded 4-sided boxes, but in order to reduce the amount of welding and further reduce the visible face width, we employed flat bars (100 mm × 200 mm). Flat bars (100 mm × 300 mm) having the same width were also employed for the beam ends that express the external appearance as outer frames.

Fig. 3: Bird's eye view

3. Pedestrian bridge

With the considerations of increasing transparency as well as securing sufficient height to allow the passage of large trucks on the roadway underneath, planning was performed with the following two points as the core:

- The visible face dimensions of the elements would be reduced by constructing the framework with a combination of small-cross-section elements.
- No horizontal braces would be installed in the central part of the roof surface.

Next, this framework which is located on both sides of the pedestrian bridge is formed by two members each for upper chord members and lower chord members. Compared to plans that have single members for the top and bottom chords, splitting them into two members each has the following merits:

- A framework plan in which the diagonal members and studs do not intersect becomes possible and enables the number of joints to be reduced.
- By connecting the two upper chord members that become compression members with a plate increases horizontal rigidity and enables a framework plan without horizontal braces in the central area of the roof surface.

Fig. 4: East elevation

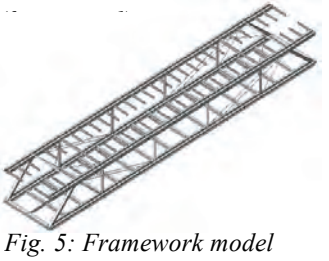

Fig. 5: Framework model drawing

4. Conclusion

Umekita Ship may be a small structure but it has a sophisticated geometric shape that leaves a strong lasting impression on visitors to Grand Front Osaka and serves as the landmark of Umekita Plaza, and together with the airy connecting deck has established itself in the minds of Osaka citizens.