Structural Design of a High-rise Building above a Motorway

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Summary

TORANOMON HILLS is the main building of a large-scale re-development project located in the center of Tokyo. This high-rise building has a height of 247m and 52 floors above ground, 5 floors below ground, and 61m x 85m in plan. It is used as hotel, residential facilities, offices, shops and conference facilities.The remarkable feature of this high-rise building is that the motorway runs through the basements of the building, which makes it stand just above the motorway.This condition is an important factor of the building design. The plan shape is designed to fit along the curve of the motorway.

Special columns at the corners are required to avoid placing columns in the motorway. This special column is a single inclined column in the lower floors that branches into two columns in the mid-floors to suit the column location in the upper floors. The cast steel joint is used for the branching point of each special column to securely transfer the stress.

Keywords: High-rise buildings, Response-control Devices, Structure-switching Truss, Road Culvert Structure and Underground, Damping devices

Fig. 1 Appearance photo

1. Introduction

TORANOMON HILLS-Shimbashi/Toranomon Re-development Project, Zone III" is a large-scale urban re-development project proposed for the Toranomon area of Tokyo. A notable feature of this project is that the planned Loop Road No. 2 will cross east to west through the development site and under a completed super high-rise building with a height of 247 m.(Refer to Figs. 1,2) Most of the re-development zone is occupied by the super high-rise building and the underground section where a tunnel for the Loop Road No. 2 passes.

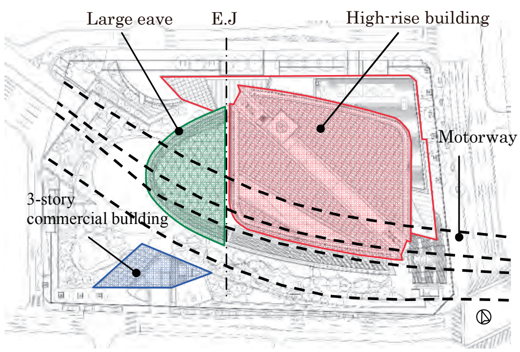

Fig. 2 Floor Framing of Standard Floors

2. Outline of building and structure

The aboveground section of the super high-rise building is mainly a rigid steel frame structure (using concrete-filled steel tube columns) with response control devices attached, and the commercial building and large eave are also steel frame structures. The underground section is a mixed structure composed of steel, steel-reinforced concrete, and reinforced concrete framings. The podium structure (artificial ground) on the Loop Road tunnel consists of 1 m-thick precast slabs. The inverted construction method was adopted for the foundation construction in order to reduce the construction term. Cast-in-place piles were used to form a piled raft foundation in which the piles and spread foundation bear loads respectively according to their rigidity.

3. Response-control Structure

A response-control structure was selected for the super structure, with 85m × 61m in plan, and the response-control devices are positioned in different sections of the center core. (Fig.3) A mega-frame, that covers from the 1st story to the 51st story, is created in order to effectively suppress bending deformation of the entire building. (Fig.4) A combination of three kinds of response-control devices is used: oil dampers (516), buckling-restraint braces (448) and friction dampers (620). A response-control mechanism can successfully secure high seismic resistance by reducing the inter-story drift angle during an earthquake to 1.5-more times less than common high-rise buildings.

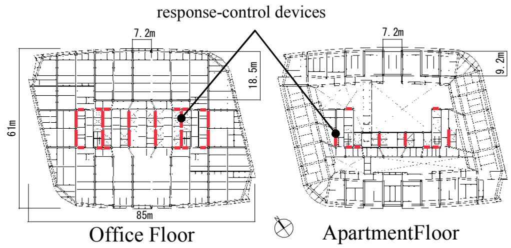

Fig. 3 Arrangement of Various Structures

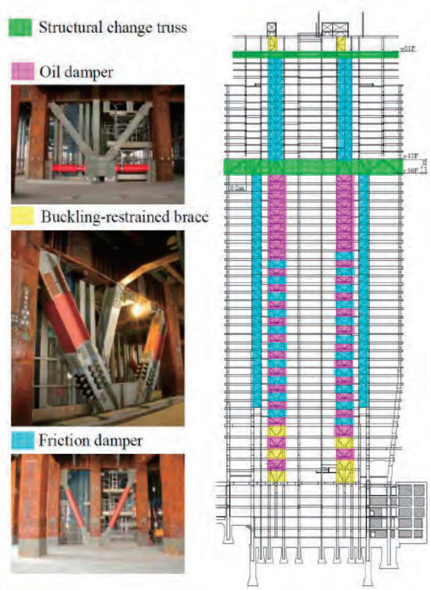

Fig. 4 Arrangement of Response-control Devices and Structure-switching Truss

4. Tilted Column-crossed Section

The tilted column system is adopted for the northwest, southeast and southwest corners of the building for the following reasons: columns can not be positioned above the area covering the Loop Road No. 2; and the building corners must be finished with sharply acute angles for aesthetic purposes. This is done from the 8th to the 13th floors, two tilted columns on each upper floor intersect and combine to form a single column on the floor below. Cast steel connections are adopted where the columns intersect so that the stress carried by the two upper columns can be securely transferred to the single column below. (Fig. 5)

Fig 5 Cast steel connection

5. Structure-changeing Truss

The building is arranged in a doughnut shape without changing the outer building design at the top of the 36th floor. (Fig. 6) To be able to do this columns located at 9m from the outer column are used (see Fig 4), and these are supported by the structure switching floor trusses of 7.7m height at level 36. These space trusses are disposed over the entire area of the floor in two directions.

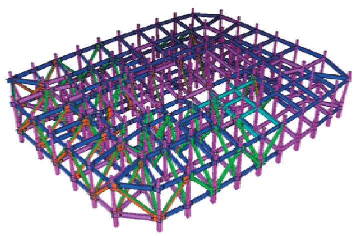

Fig. 6 Structural Frame for 36floor

6. Conclusions

The Toranomon Hills is a high-rise building for multiple use and with a distinctive shape that has restrictions of a driveway passing trhough its basement . This makes it a special structure to design. Furthermore, our objective to create a building where civil engineering and architecture are integrated is fully achieved. With the cooperation of all persons concerned the opening of this building was held this year in June with no incident. We are looking forward to contributing to the enlivenment of Tokyo through this building as a new symbol.