Low-Rise Base-Isolated City Hall with Flat Slabs
- Amakusa City Hall -

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Synopsis

The primary concept of Amakusa City Hall is to be a “people-friendly and rational municipal building.” Besides ensuring earthquake resistance suitable for the city’s disaster prevention center, it was essential to create a universal space with exceptional functionality. To achieve this, the authors proposed a municipal building that is as wide and low as possible, avoiding the adjacent existing building while maximizing the floor space. In the building’s design, a seismically isolated structure was chosen to concentrate the lateral-force-resisting elements on the perimeter, with only slender reinforced concrete (RC) columns inside. Additionally, a flat slab structure was used to reduce the floor height, and a flat ceiling surface that aligns with the facilities plan was adopted, considering business continuity planning and the rational realization of an open space.

Structural Design

(1) Overall Structural System

The authors proposed a structural framework that lowers the wide floor while creating a usable space with good visibility. The earthquake-resistant walls are concentrated between the outer space on the building perimeter and the interior office space, and the interior is supported by slender RC columns that bear only long-term axial forces. The concrete strength is based on Fc30, and the interior columns on the first and second floors are precast concrete (PCa) columns with a strength of Fc60, and the member size is reduced to 400 mm × 400 mm. The floor beams on the second and third floors—including the perimeter beams—are flat slab and flat beam structures to reduce the clear height of the stories. In principle, the outer zone of the perimeter is a cantilevered structure to concentrate axial forces on the seismically isolated perimeter members (Fig. 4).

(2) Flat Slab Structure with Inverted Capitals

To reduce the height of the second and third stories, the building is a flat-slab flat-beam structure, and the column capitals on the second floor are inverted capitals that extend above the floor slab on the second floor (Fig. 5). The ceiling of the first story, which provides the open space for the public, is fully flat (Fig. 6). Consistent with the facility plan, the ceiling lighting wiring of the first story was embedded in the flat slab on the second floor, and the space on the second floor—created by the inverted capitals—was used as duct space for floor air-conditioning (Fig. 7). Business continuity after earthquakes was enhanced by making the first and second stories without ceiling space. The flat-slab structure also incorporates the following innovations.

(1) Flat beams for perimeter beams: Normally, flat slab structures have rigid beams at the perimeter to transmit stress to lateral-force-resisting elements such as earthquake-resistant walls, but in this building, the perimeter beams are flat beams (800 mm at the thickest part) with appropriate reinforcement to ensure stress transmission, thereby contributing to a low-rise building.

(2) Adoption of void slabs in the zone between columns on the second floor: Void slabs were used in the zone between columns on the second floor to reduce the weight of the building and to reduce the size of the columns on the first story and the load on the foundation. Spherical voids were used to minimize directional stress transmission, and buried lighting wiring was planned and the void placement was determined at the design stage.

Structural Data

Location: Amakusa, Kumamoto Prefecture, Japan
Owner: Amakusa City
Designer: Nikken Sekkei Ltd.
Contractor: Hazama Ando, Yoshinaga, and Nakamura (joint venture)
Site Area: 11,194.83 m2
Building Area: 3,741.26 m2
Gross Floor Area: 9,828.38 m2
Construction Period: Jun. 2017 – Apr. 2019
Number of Stories: 4 above ground
Structure: RC, prestressed concrete, PCa, and wood

(3) Wood Beams Made of Small-diameter Local Lumber

The roof is entirely made of wood (finish: insulated sandwich panels + sheet waterproofing; large beams: RC), except for the MEP (mechanical, electrical, and plumbing) areas. The wooden roof structure consists of laminated beams joined with structural screws as small beams, and there are two types: a flat truss-type roof beam and a five-story roof beam. The flat truss-type roof overlay beam used for the ceiling of the third-floor assembly hall spans 8.1 m and is made entirely of 4-m-long 105-square cypress lumber, which is a standard product for distribution(Fig. 8). The structural system consists of a single unit of layered beams made of lumber joined in two stages with structural screws, and this unit is trussed in the plane, cantilevered out from both ends of the span in the elevation, and a simple beam is placed on this cantilevered beam in the center. At first glance, the wooden beams appear to be delicately designed, but at the same time, they are able to support the roof. The structural performance of this wooden beam was confirmed by a detailed analytical model in which the structural screws were replaced by springs with equivalent axial and shear rigidity.

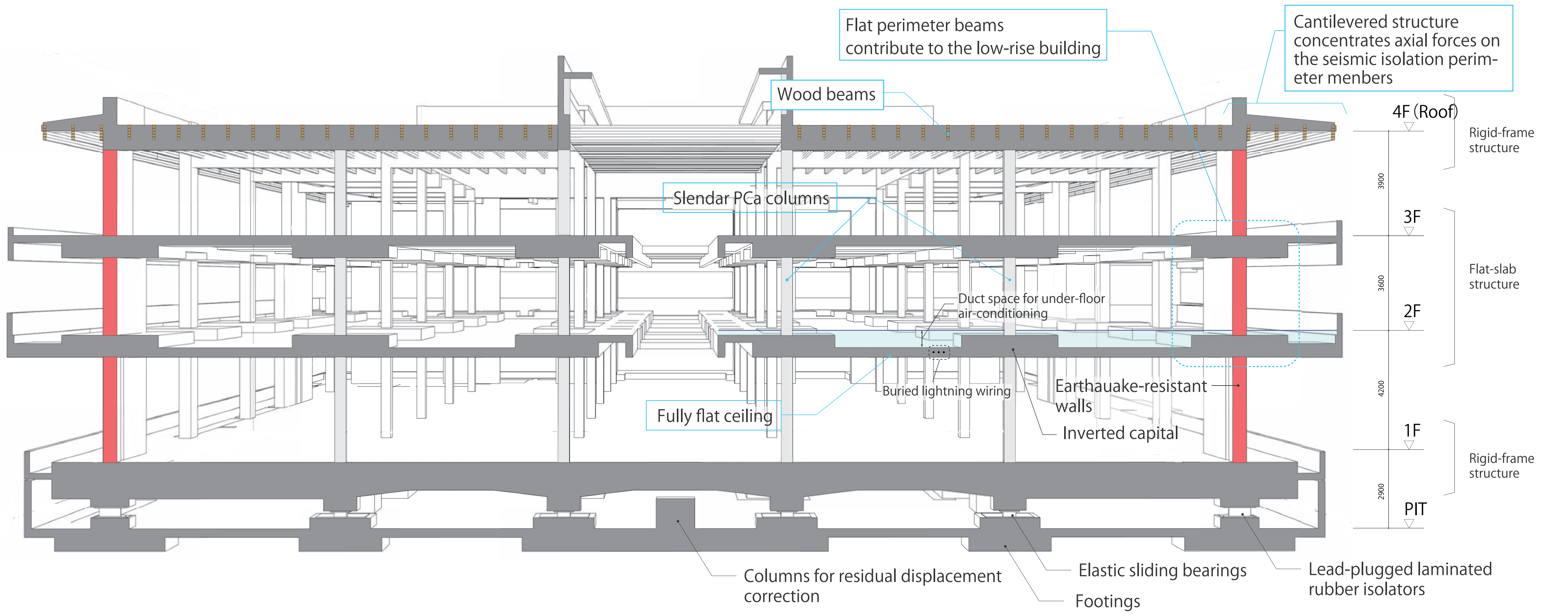
(1) Input Seismic Motion for Design, Reflecting Kumamoto Earthquake Findings

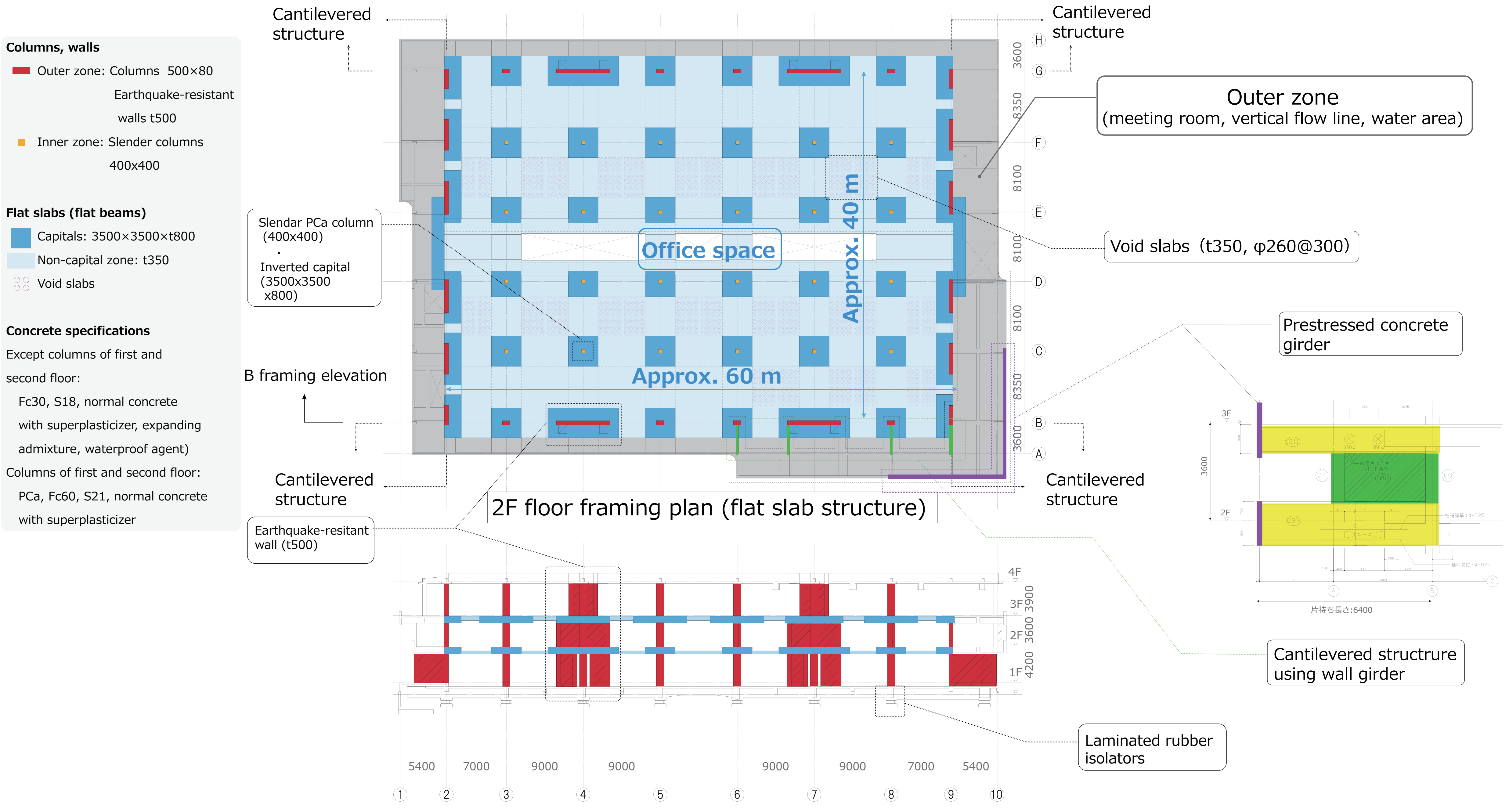
The 2016 Kumamoto Earthquake occurred during the design of this building. The authors created an input seismic motion based on the findings from the main shock of the Kumamoto Earthquake and compared it with that of an anticipated Nankai Trough earthquake, which the authors had originally planned to adopt. After confirming that the input seismic motion of the Kumamoto Earthquake had a greater impact on the building, the authors decided to use it as part of the input seismic motions for the design, and confirmed that the building is a seismically isolated structure with high earthquake resistance performance that more closely suits the regional characteristics of the site.

(2) Base-isolated Structure

Base isolation was adopted for the structure. In addition to natural rubber isolators and lead-plugged laminated rubber isolators, sliding bearings (low-friction type) were used for seismic isolation (Fig. 9). By placing as many sliding bearings as possible, a high-performance seismic isolation structure with an effective fundamental period of about 4 s was achieved despite of the low-rise structure.

As a result, the maximum floor response acceleration of the office floors (1-3F) during extremely rare seismic motion could be suppressed to about 120 cm/s2 (Fig. 10).





B framing elevation

4. Conclusion

A new city hall was constructed in Amakusa City. A seismically isolated structure was adopted to reduce lateral loads while ensuring sufficient seismic resistance and considering the way that the city hall would be used in Amakusa and the surrounding environment. The shear walls are concentrated around the perimeter of the building, and the interior is composed of slender PCa columns and flat slabs, eliminating fixed elements such as cores and creating a flexible and homogeneous office space.

In particular, the large 40 m × 60 m interior space on the first floor, which is used mainly by the public, was designed with flat slab capitals at the tops of the columns as inverted capitals that protrude above the slab, which is consistent with the facility plan that also uses the space created under the second floor as facility space. The ceiling on the first story is a fully flat representation of the building frame, creating an easy-to-use space with good visibility and a non-flamboyant appearance.

Amakusa City Hall won the award of the Japan Concrete Institute (2021) and the 22nd Prize of the Japan Society of Seismic Isolation (2021).

interior view of assembly hall using wood beams

Fig.8 Wood roof

Fig.5 Flat slab with inverted capital

Fig. 6 Interior view of first-floor ceiling without ceiling material

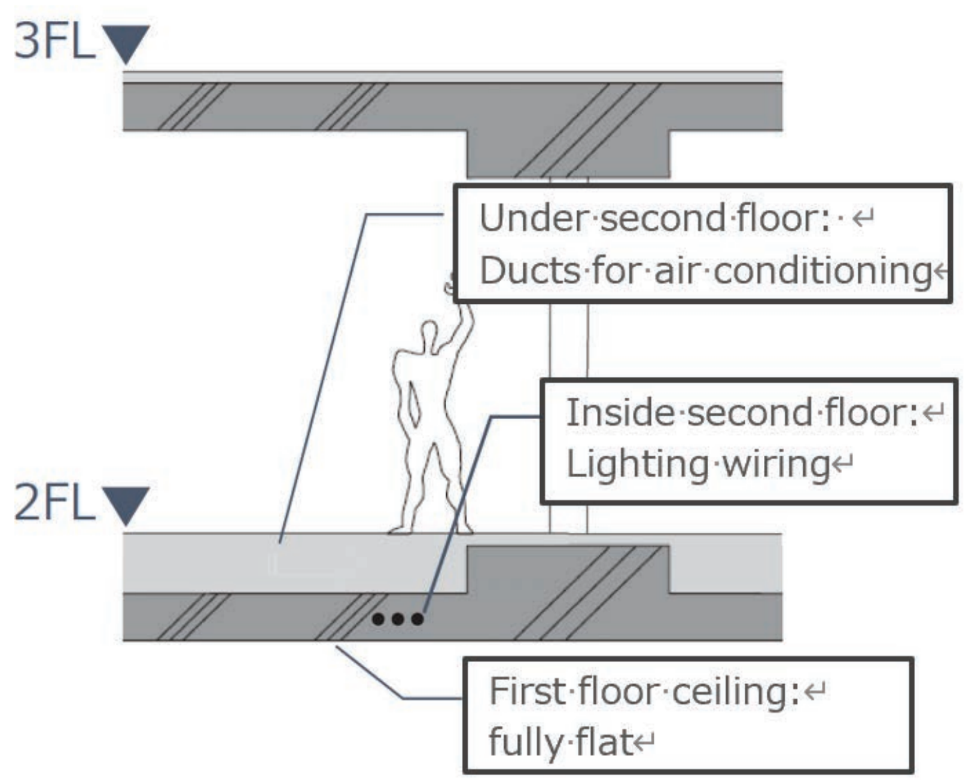
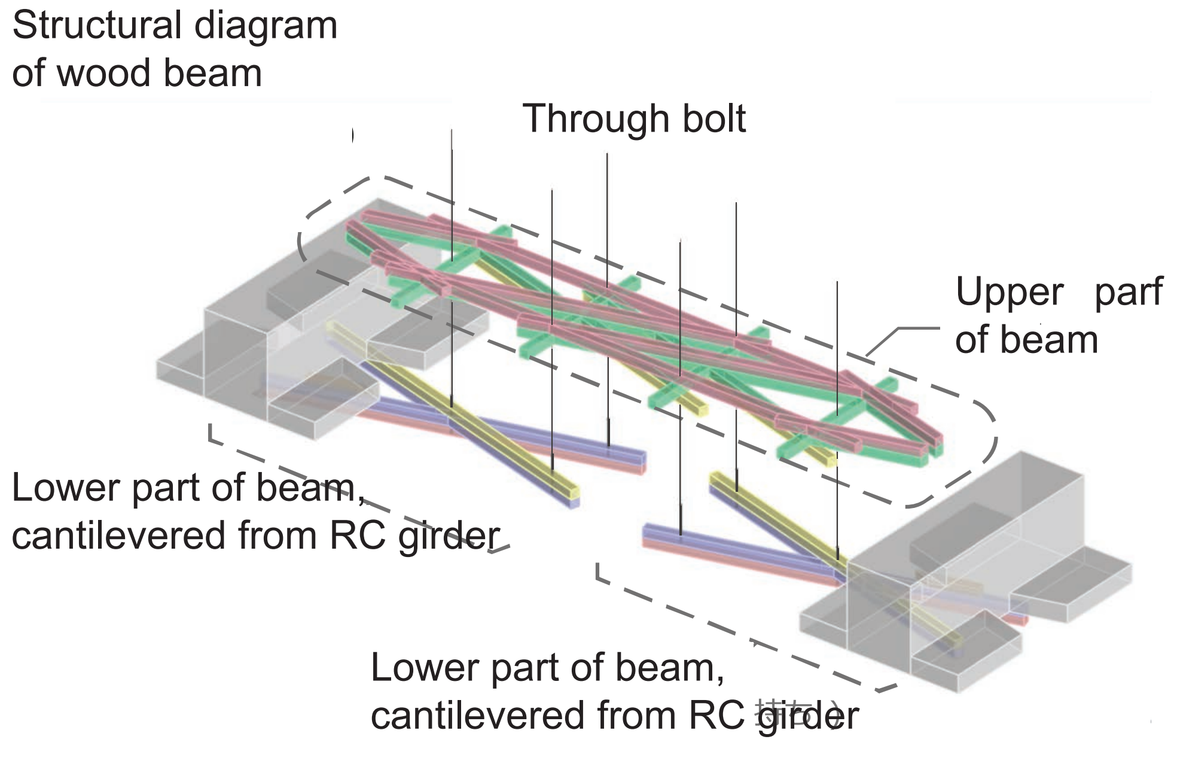


Fig. 7 Flat slab system consistend M&E system



Wood beams structural system