High-rise Mixed-use Building with RC and Hybrid Structure
— Ark Hills Sengokuyama Mori Tower —

鉄筋コンクリート構造とハイブリッド構造による超高層複合用途建物
— アークヒルズ仙石山森タワー —

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Keywords: high-rise building, hybrid RC/S structure, all precast construction method
DOI: 10.11474/JPCI.NR.2018.7

Synopsis
Ark Hills Sengokuyama Mori Tower, one of the tallest mixed-use buildings in Japan, was built in the Toranomonn-Roppongi area of Tokyo. The building (**Fig.1**), which has 47 stories and a floor area of 143,550m^2 as detailed in the structural data, is expected to be a core part of the international and cultural life of the area. Additionally, a large green space was built to protect the greenery and ecosystem of the area (**Fig.2**). The underground floors of the building are used for parking, the first and second floors for shops, floors 3–24 for residences, and floors 25–47 for offices.
The structural design is a hybrid structural system (RC/S system) of reinforced concrete (RC) column and steel (S) girder, with two types of damper system. For the construction, the left–right vertical (LRV) and left–right vertical–horizontal (LRV-H) installation methods—precast methods for high-rise residential buildings by the Obayashi Corporation—were used.

Fig.2 Protecting ecosystem of this area

Fig.1 Ark Hills Sengokuyama Mori Tower

Structural Data
Building Name: Ark Hills Sengokuyama Mori Tower
Owner: Mori Building Co., Ltd.
Contractor: Obayashi Corporation
Number of Stories: 47 above ground, 4 basement floors
Maximum Height: 206.69m
Total Floor Area: 143,550.04m^2
Construction Period: Oct. 2009 – Aug. 2012
Location: Toranomon, Tokyo, Japan

1. Outline of Structure
The standard floor area is 50.4m × 50.4m, the span length is 7.2m on the RC residential floors, and the long span length (max. 22m) is achieved by the RC/S system on the office floors. The floor framing plans of a residential floor and an office floor are shown in **Fig.3** and a framing elevation is shown in **Fig.4**; these figures also show the locations of the RC/S system and the two types of damper.

2. Structural Design
(1) Damper System
A feature of the structural design is the use of two types of passive damper. One is a brake damper, which is a stud-type friction damper with sliding brake linings, and the other is a wall-type viscous damper (**Figs.5**, **6**). These provide very high earthquake resistance while allowing the building to be highly habitable. The

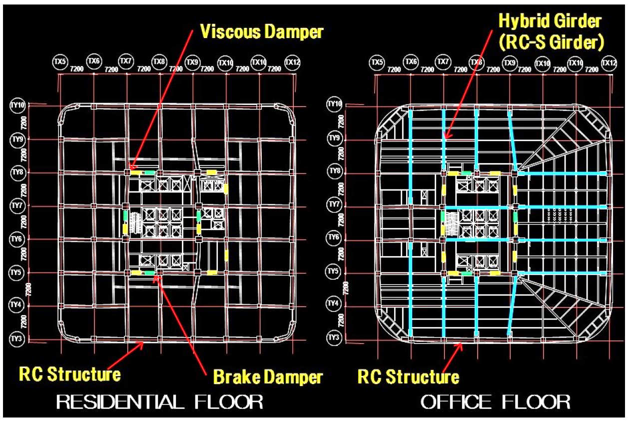


Fig.3 Floor framing plans

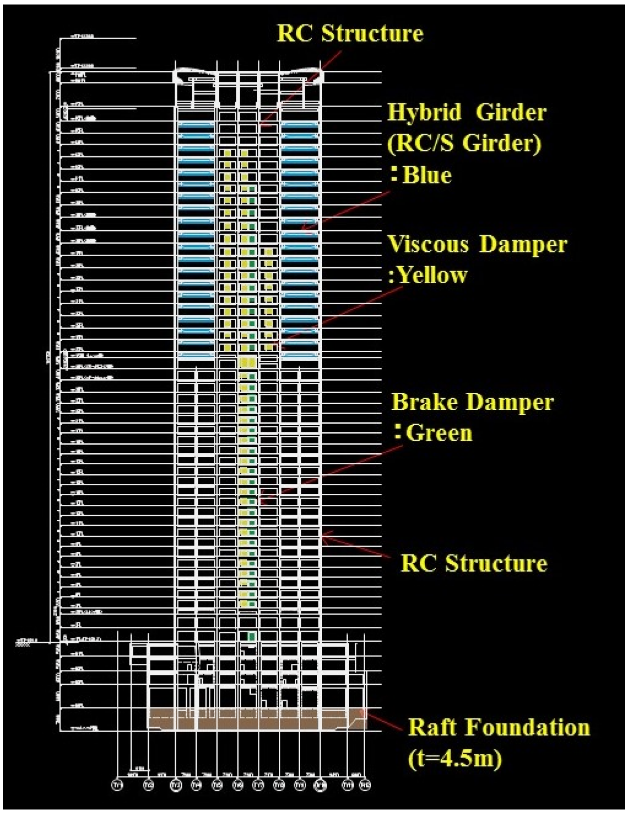
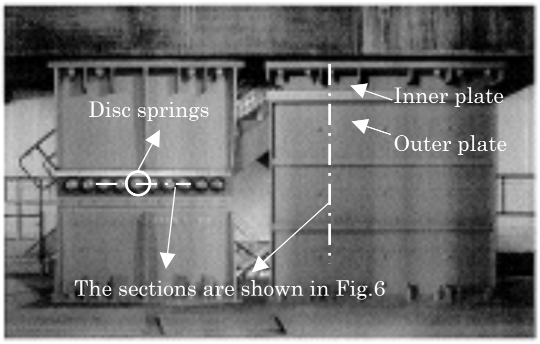
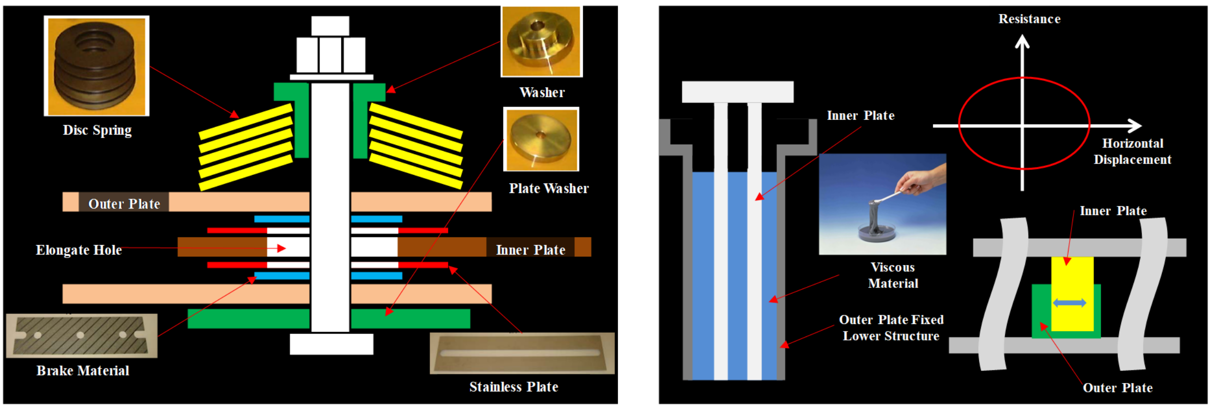


Fig.4 Framing elevation



Brake damper **Viscous damper**

Fig.5 Setting state of dampers



Brake damper **Viscous damper**

Fig.6 Detail of dampers

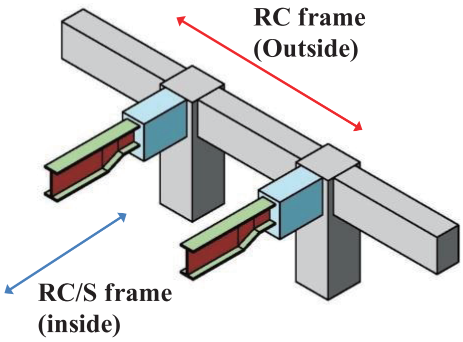


Fig.7 RC/S system

natural periods are 4.45s in the x-direction and 4.28s in the y-direction. Adopting these dampers decreases the responses to wind, medium-sized earthquake, and long-period ground motion. Even in a large earthquake, the ductility of each story remains under 1.0.

(2) Hybrid Structure

Fig.7 shows the hybrid RC/S system of RC columns and steel girders on the office floors, and **Fig.8** shows an end of a steel girder. A feature of this system is that the steel girders do not extend to beam–column joints but instead change gradually to RC girders at the girder ends. This is because of the precast construction method, which is explained below, and the penetration of the column's main bar. The girders were designed as RC at the column faces and to yield at the steel ends before at the column faces. To confirm the S-to-RC transmission of stress and the deformability of the hinge zones, structural experiments were performed[1][2].

3. Construction

The LRV method was used for the outside frame and the LRV-H method was used for the RC inside frame. A feature of these methods is the use of precast members that contain beam–column joints. By using these methods, the floors of stories 14–24 and 35 upward were constructed in three days[2].

Fig.8 End of steel girder

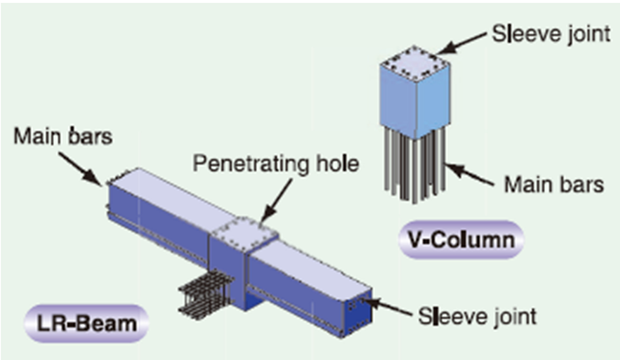
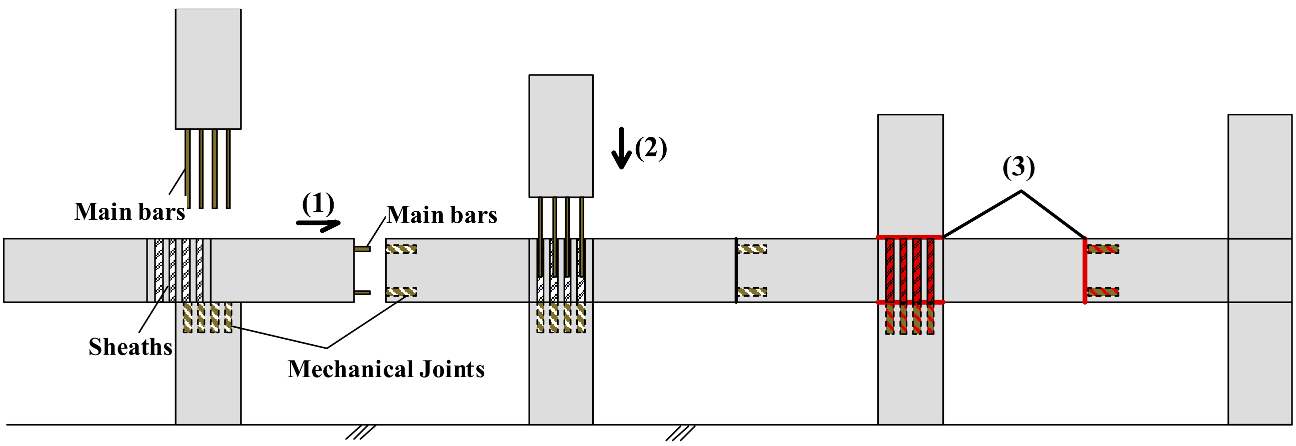


Fig.9 Precast pieces for LRV method

(1) LRV Method

Fig.9 and **10** show the LRV method, which involves an LR-beam and a V-column. The LR-beam, which contains a beam–column joint with penetrating sheaths for the column's main bars, is assembled horizontally and jointed to the next LR-beam (**Fig.10** (1)). The V-column is then assembled vertically (**Fig.10** (2)), and all the main bars and joints of the piece are grouted (**Fig.10** (3)). The sleeve joints are used for the main bars at the end of precasting. **Fig.11** shows pictures of the LRV method being used at the construction site.

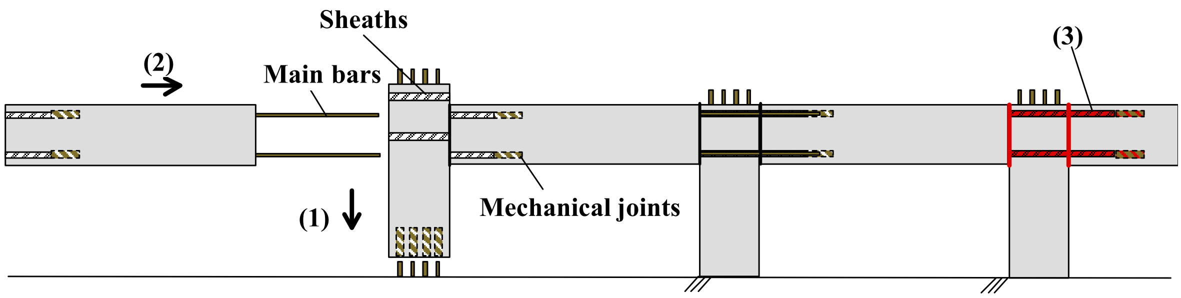


(1) LR-beam is slid horizontally (2) V-column is brought down (3) Joints and sheaths are grouted

Fig.10 Assembly process of LRV method

LR-beam V-column

Fig.11 Pictures of assembling the precast pieces



(1) Column piece is put on the slab (2) Beam piece is slid horizontally (3) Joints and sheaths are grouted

Fig.12 Assembly process of LRV-H method

(2) LRV-H Method

Fig.12 shows the LRV-H method, which differs from the LRV method as follows. The beam–column joint is contained with the column piece, and the penetrating sheaths for the beam's main bars are set in the beam–column joint.

4. Conclusion

The features of Ark Hills Sengokuyama Mori Tower are as follows.

(1) The large green space on the site is comfortable for residents, workers, and visitors and facilitates biodiversity.

(2) This mixed-use tower was constructed with precast concrete members and long-span steel girders, and it is equipped with vibration control devices to guard against earthquakes.

(3) Using precast concrete techniques, we can build an office building that comprises mainly RC members as quickly as we can a steel structure.

This building won the Award of the Japan Concrete Institute in 2014.

References

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概　要

虎ノ門六本木地区に「緑の生活都心」をコンセプトに，居住機能と商業・業務機能等が高次に複合した国際性・文化性の豊かな良好で魅力ある街づくりを目指した超高層複合用途建物として「アークヒルズ仙石山森タワー」が2012 年8 月に竣工した。本建物は低層部が集合住宅，高層部が事務所であり，それぞれの用途に応じて低層部が RC 構造，高層部が柱 RC 梁 S 混合構造を採用している。

構造設計では，2 種類の制震装置を用いることにより，風に対する揺れおよび中小地震から大地震動に対する揺れを低減するとともに，長周期地震動に対する対策も施されている。高層部で大空間を構成する混合構造においては，梁端部で S 造と RC 造が切り替わり，S 造部分が降伏する梁としている。

施工面では，大林組が開発した LRV 工法によるプレキャスト化施工を採用し，現場打ち部分がほとんど無い高速施工により，鉄骨造と同程度の工期を達成している。