Seismic Isolation Retrofit of a Building with Large Cylindrical Columns — Yamanashi Press and Broadcasting Center —

円筒形大断面柱を持つ建物の免震改修工事 — 山梨文化会館 —




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Synopsis
The Yamanashi Press and Broadcasting Center (**Fig. 1**), located in Kofu City, Yamanashi Prefecture, is a masterpiece of architect Kenzo Tange, completed 50 years ago, it was made retrofitting for seismic isolation to continue its use for another 50 years. This building is an office building that continues to operate 24 hours a day, 365 days a year as a TV and radio studio and press center. A structural feature of this building is that 16 large cylindrical columns with a diameter of 5 m are installed as cantilever columns from the foundation. The supported load of a single cylindrical column is as high as 25,000 kN, and it was difficult work to cut each column and install four or five seismic isolation devices and dampers.

Fig. 1 Yamanashi Press and Broadcasting Center

Structural Data
[Building before Retrofit]
Structure: steel reinforced concrete
Number of Stories: 8 above ground, 2 basement floors
Maximum Height: 58.3 m
Building Area: 3,091 m^2
Total Floor Area: 21,883 m^2
Former Designer: Kenzo Tange & Urtec
Former Contractor: Sumitomo Mitsui Construction
Completion: 1966
[Retrofit Work]
Structure: seismic isolation at B2 floor level
Main Isolation Device & Damper
: CLB (Crossed linear bearing)
: SnRB (Tin plugged rubber bearing)
: NRB (Natural rubber bearing)
Designers: Architectural; Tange Associates
Structural; Orimoto Structural Engineers
Mechanical & Electrical; K.S.S.K.
Contractor: Sumitomo Mitsui Construction
Construction Period: Jun. 2015 – Dec. 2016

1. Outline of the Structure
The plan of the second basement floor is shown in **Fig. 2**. This building is supported by 16 cylindrical columns with a diameter of 5 m and a wall thickness of 50 cm[1]. The maximum span of the frame is 17.3 m.

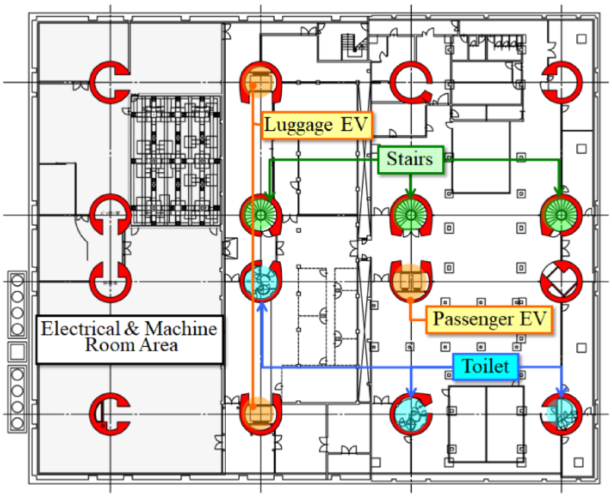

Fig. 2 B2 floor plan

The inside spaces of the cylindrical columns are used for stairs, elevators, and electrical equipment rooms. The framing elevation and moment diagram are shown in **Fig. 3**. However, the cylindrical columns rise from the foundation beams on the second basement floor and are connected by girders on each floor, and the bending stiffness of the cylindrical columns is extremely high. Therefore, they can be regarded as cantilever columns against horizontal forces[1].

2. Structural Design

In the retrofitting plan, seismic isolation was planned by cutting the bottom of the cylindrical columns connected at the second basement floor, installing seismic isolation devices, and cutting the perimeter slabs of the ground floor as shown in **Fig. 4**. The range of movement as a seismic isolated structure is 400 mm.

(1) Arrangement of Seismic Isolation Devices

Fig. 5 shows the layout of the seismic isolation devices installed at the bottom of the cylindrical columns[2]. There, compressive and tensile forces are generated in the seismic isolation devices because of the large bending moments. In particular, four CLB (Crossed linear bearing) devices with large tensile resistance are arranged at both sides of the building (lines 1 and 4) where the vertical loads are small, and NRB (Natural rubber bearing) and SnRB (Tin plugged rubber bearing) are arranged at other cylindrical column positions (**Fig. 6**). At the corners of the building, SnRB as a damper is additionally arranged in the center of cylindrical columns. In addition, 60 sliding bearings are placed at the supporting studs of floor B2 and the joints between the ground floor slabs and the perimeter basement walls.

(2) Structural Design of Foundation with CLB

Figs. 7 and **8** show plan and cross-sectional views of the foundation on which the CLB is installed. Because the reaction force of the CLB device is large, prestressing steel rods (hereinafter referred to as PC-bars) are arranged in an X shape in order to rigidly

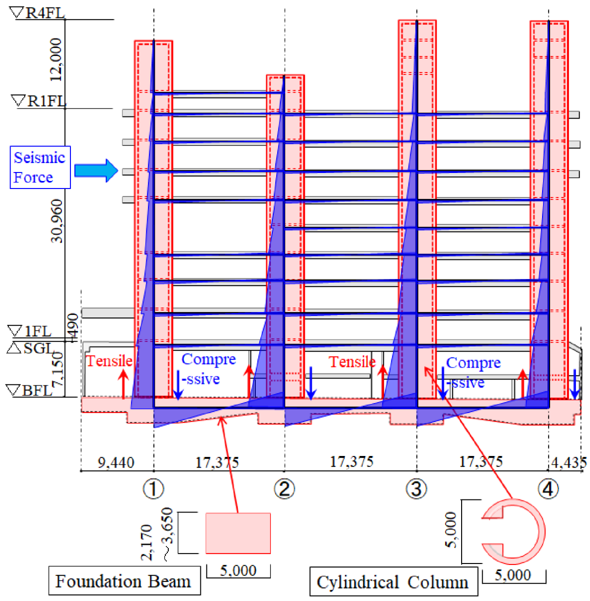

Fig. 3 Framing elevation and moment diagram

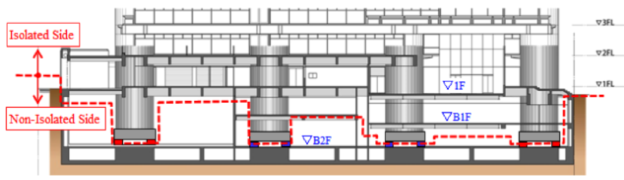

Fig. 4 Seismic isolation position

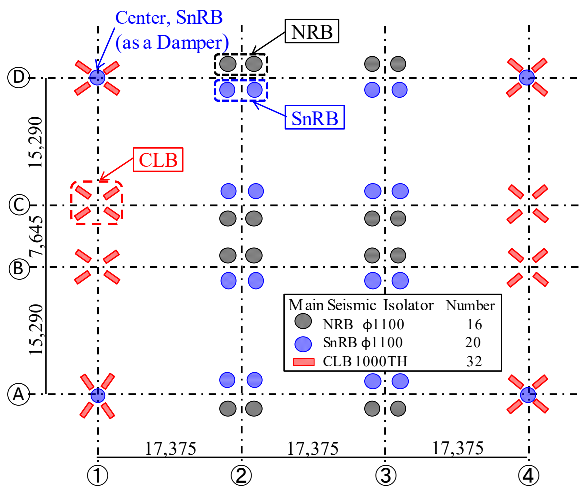

Fig. 5 Arrangement of seismic isolation devices

CLB SnRB

Fig. 6 CLB and SnRB

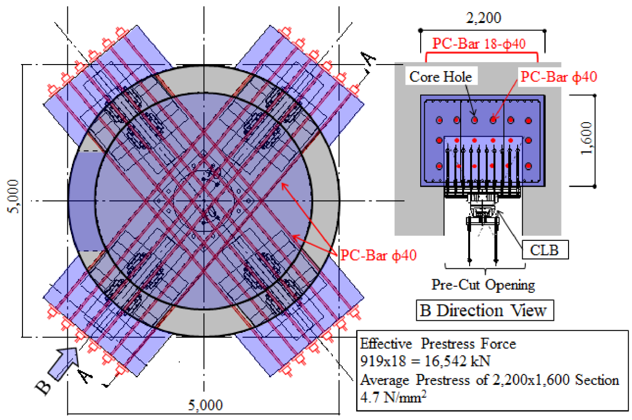

Fig. 7 Plan view of upper foundation with CLB

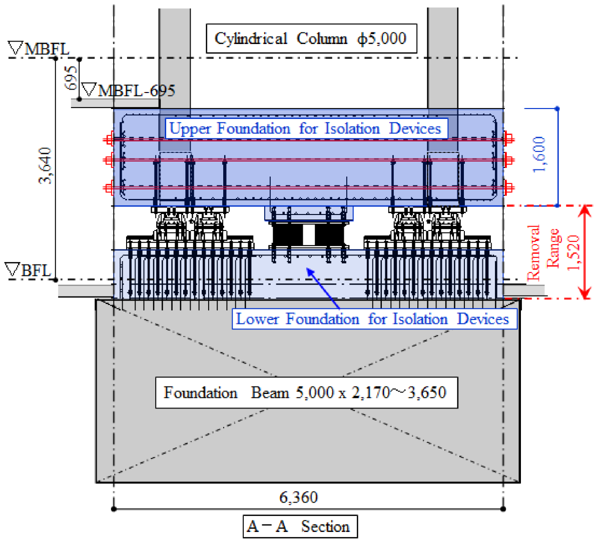

Fig. 8 Cross-sectional view of foundation with CLB

connect the foundation and the cylindrical column by applying prestress force in two directions. The number of PC-bars arranged in one direction is 18 (∅40 mm), and the effective compressive force is 16,542 kN in total. This prestress force minimizes the range of demolition and suppresses the occurrence of shear cracks, making it possible to minimize the foundation.

Fig. 9 shows the shear stress and principal stress contours at pre-loading for jack-down including prestress forces[1]. Although the shear stress exceeds the allowable value (1.49 N/mm^2), diagonal tension is suppressed by prestress force. **Fig. 10** shows the principal stress contours at the design load including seismic load, and it can be confirmed that joint surface is in a fully compressed state with respect to the design load.

3. Construction of Foundation with CLB

Fig. 11 shows the construction procedure of the foundation with CLB installed[1]. (1) As preparatory work, the authors installed a displacement meter to measure the vertical displacement during construction and mark the pre-cut opening position of the cylindrical column. (2) The pre-cut opening for installing the CLB was made with a wire saw, then (3) the PC-bars and reinforcement of the upper foundation were arranged, the upper base plate of the CLB was installed, and then concrete was casted in place. (4) The CLB was installed by hanging it from the upper base plate, the reinforcement of the lower foundation was arranged, and concrete was placed. (5) The concrete strength was confirmed and the PC-bars were prestressed. Next, a jack was inserted between the upper and lower foundations, and a pre-load equivalent to the vertical load of the cylindrical column was applied. (6) After that, the remaining parts of the cylindrical column were cut with a wire saw and jacked down. (7) To temporarily fix the seismically isolated cylindrical columns, upper and lower foundations were connected with steel plates to restrain the movement during construction. These plates were removed all at once after the seismic isolation work for all the cylindrical columns was completed. Finally, a fireproof coating was applied to the seismic isolation devices and PC-bar anchor plates.

When cutting a cylindrical column with a wire saw, it was cut into small pieces such that one piece was 20 kN or less. **Fig. 12** shows the situation of pulling

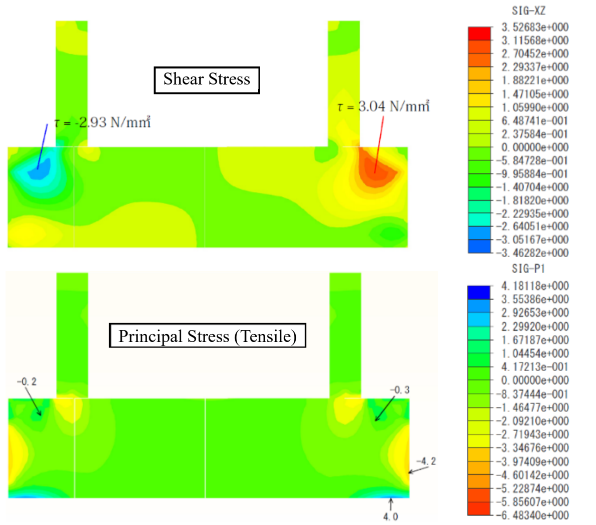

Fig. 9 Shear and principal stress (tensile) at pre-loading

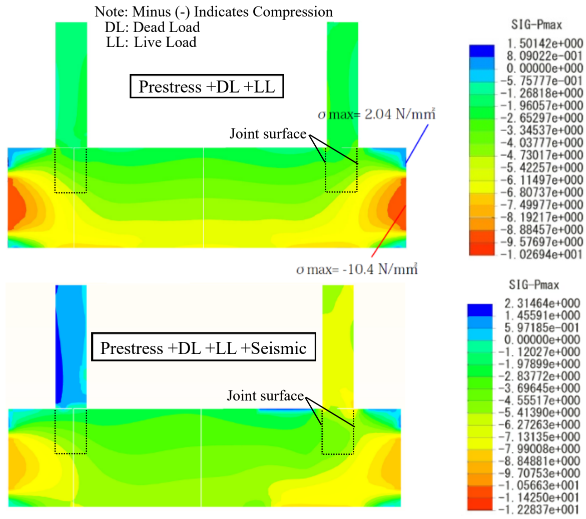

Fig. 10 Principal stress at design load

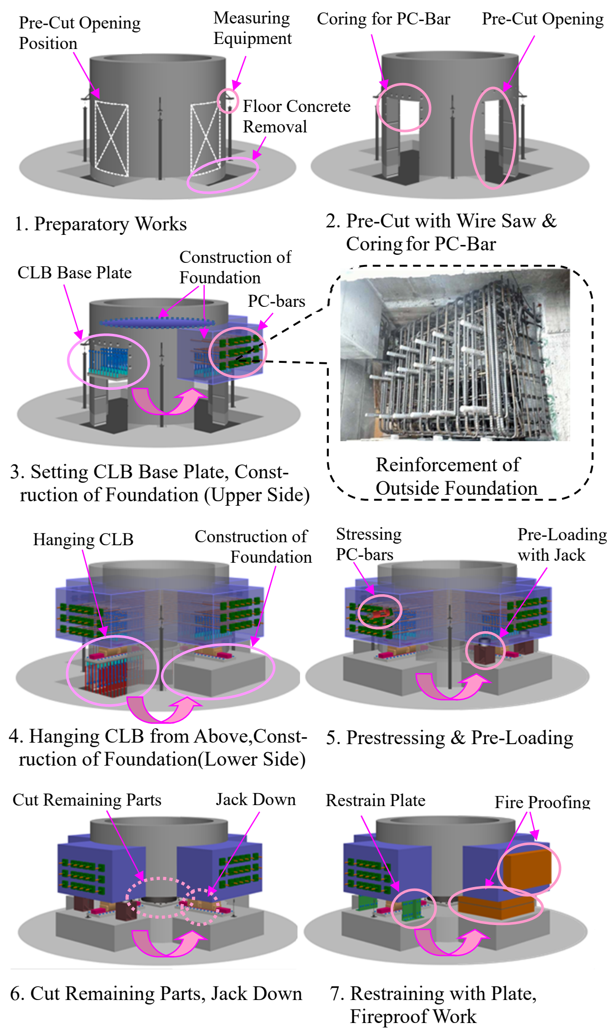

Fig. 11 Construction procedure for foundation with CLB

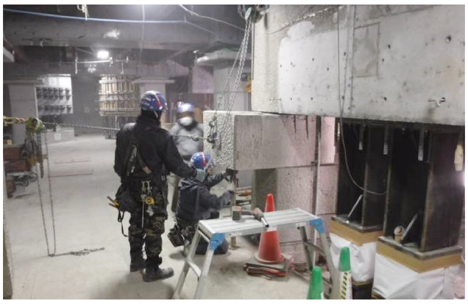

Fig. 12 Pulling out a cut piece

Fig. 13 CLB installed in pre-cut opening

out a piece of a cut cylindrical column. Because the total weight of one CLB was 39 kN, it was divided into upper and lower parts, set in the pre-cut opening, jacked up, and hung from the upper base plate. The state of the CLB installed in the pre-cut opening is shown in **Fig. 13**.

4. Conclusion

Although the seismic isolation retrofit of this building with large cylindrical columns was technically difficult in terms of both design and construction, it was completed in 19 months as originally planned. This work was carried out with the aim of continuing to use this building, which is a masterpiece of architect Kenzo Tange, for another 50 years, adapting its use and shape to modern needs while preserving the characteristic identity of modern architecture. In recognition of these points, this work, including past renovations, received the Docomomo Rehabilitation Award (Metamorphosed functions category) from Docomomo International in 2021.

References

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概　要

建築家丹下健三の代表作である山梨文化会館は，竣工後50年を経て今後新たに50年間使い続けるために免震改修工事が行われた。365日24時間稼働を続けるプレスセンターという用途と，直径 5 メートルの円筒形柱による片持ち構造という特殊性を考慮して，建物を使い続けながら地下 2 階位置で円筒形柱を切断し，各円筒形柱脚部に 4 または 5 基の免震装置とダンパーを配置する免震化計画が立案された。

円筒形柱の支持力は最大25,000kN に達するが，免震装置に大きな引張力が作用する位置には交差型直動転がり支承（CLB）が採用された。CLB が取付く免震基礎のコンパクト化と解体工事の最小化を目的として，免震基礎にプレストレスを導入して円筒形柱に圧着させる計画とした。工期19ヵ月を経て，建物外観を全く変えることなく改修工事が終了した。過去の改修を含む本改修工事が，モダン建築の特徴的なアイデンティティを守りながら，用途や形を現代のニーズに適合させた点が評価され，2021年 Docomomo Rehabilitation Award を受賞した。