43‘rd international symposium of CIB W062 on water supply and drainage for buildings
23-25 August, 2017 Haarlem, The Netherlands

Maintaining the Functionality of a Plumbing System

Kogakuin university

○ KEISUKE YAGASAKI
TOYOHIRO NISHIKAWA

Outline

1 Introduction

2 Damage inflicted to Building Equipment due to the 2016 Kumamoto Earthquake

3 Overview of Aseismic-Performance Evaluation of the Plumbing System

4 Result of Aseismic-Performance Evaluation of the Plumbing

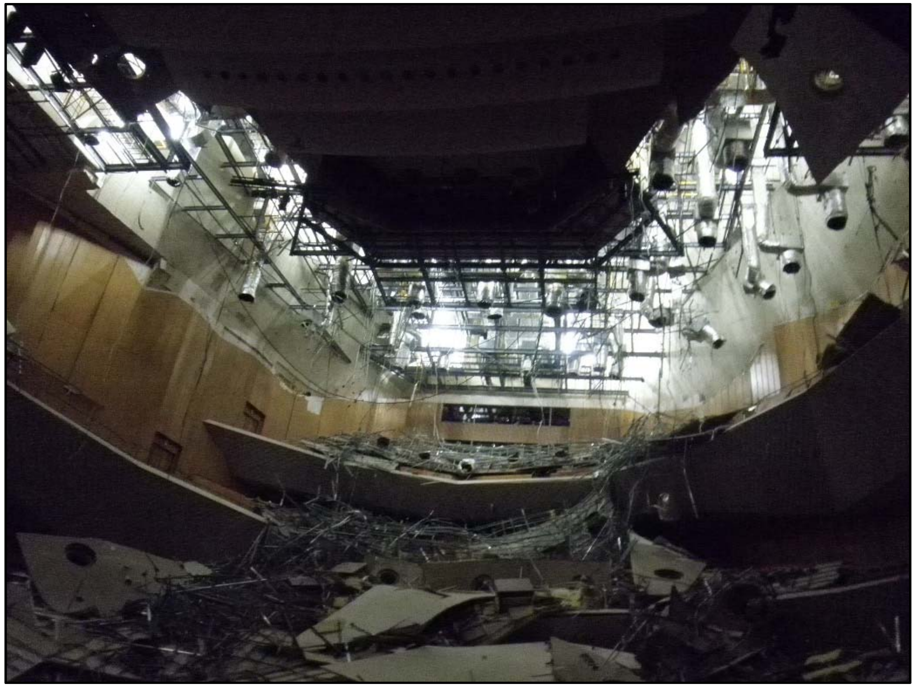
5 Seismic Risk of Plumbing System

6 Conclusions

1 Introduction

<Background>

The damage of building structures caused by the earthquake ground motion was insignificant. However, building equipment suffered great damage owing to the earthquake ground motion. It’s shows the low aseismic performance of the building equipment became apparent.

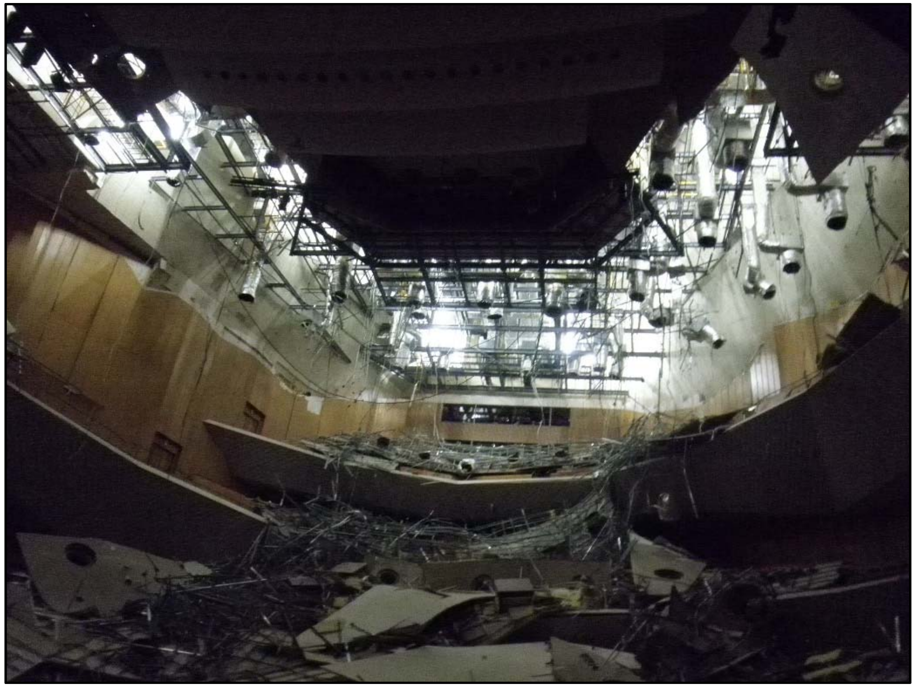


Reference : Japanese Association of Building Mechanical and Electrical Engineers.

1 Introduction

<Purpose>

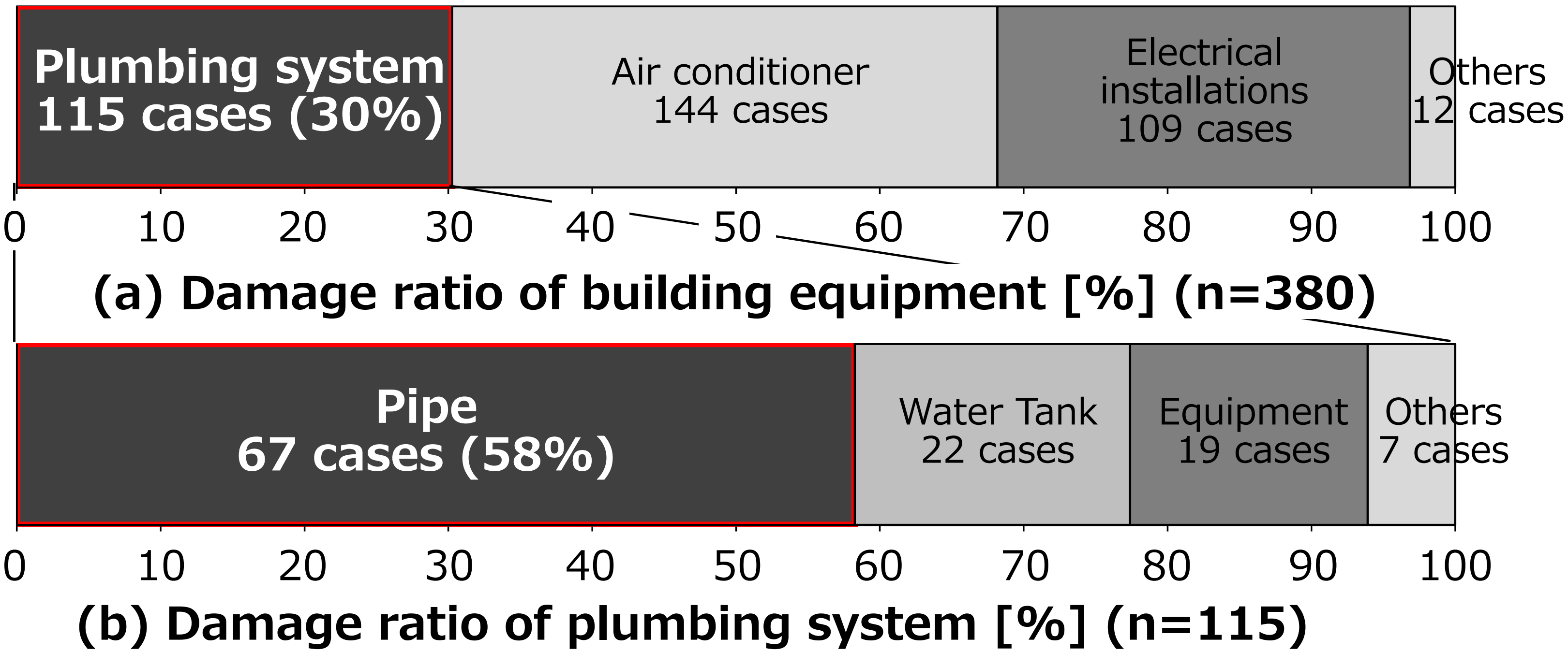
The purpose of this study is to evaluate the seismic risk of building equipment. Moreover, this study explored effective aseismic measures for the weak points of the plumbing system. Hence, a plumbing system model ware created at the Kogakuin University, Shinjuku campus for the purpose of this study.



Reference : Japanese Association of Building Mechanical and Electrical Engineers.

2 Damage inflicted to Building Equipment due to the 2016 Kumamoto Earthquake (Fig. 1)

The plumbing systems sustained the second greatest damage because of the 2016 Kumamoto earthquake, second only to air conditioners. The total damage percentage of the piping system to the plumbing system is approximately 58%. In the plumbing systems, the pipes sustained most of the damage, highlighting the fragility of the water-supply system



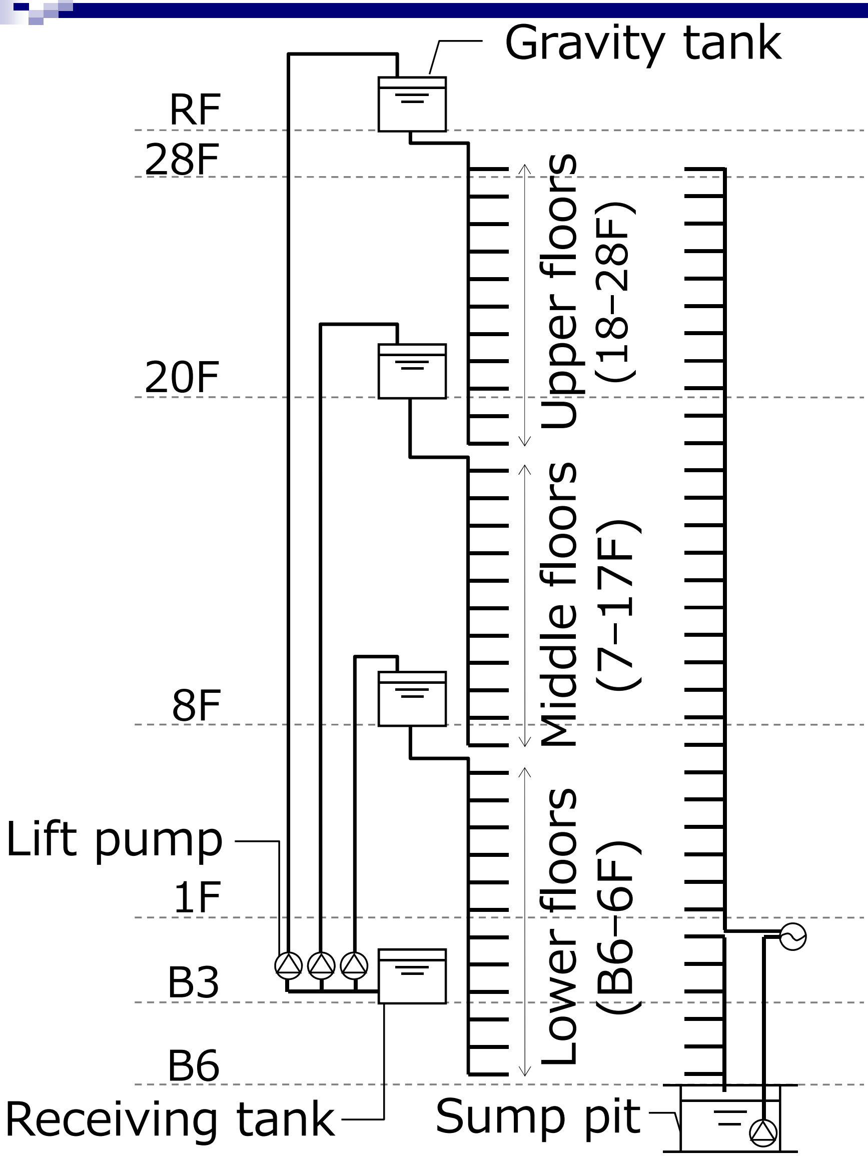
(a) Damage ratio of building equipment [%] (n=380)

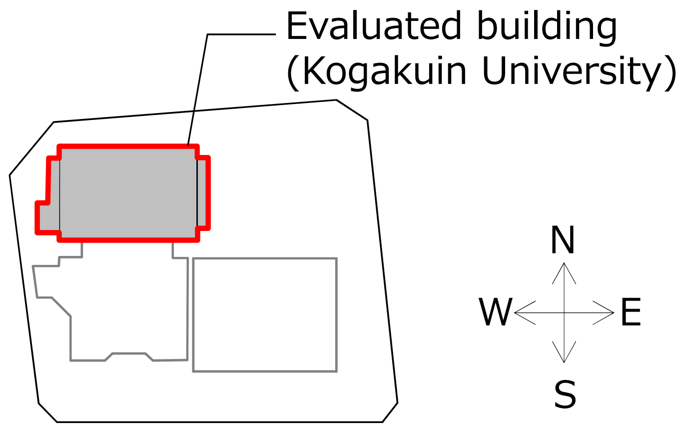
(b) Damage ratio of plumbing system [%] (n=115)

Reference : The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan. Report on the 2016 Kumamoto earthquake disaster. Available at:
<http://www.shasej.org/base.html?topics/1612/kumamoto_report/kumamoto_report.html> (accessed 2017-07-03)

3 Overview of Aseismic-Performance Evaluation of the Plumbing System

3.1 Overview of the Evaluated Building (Fig. 2)

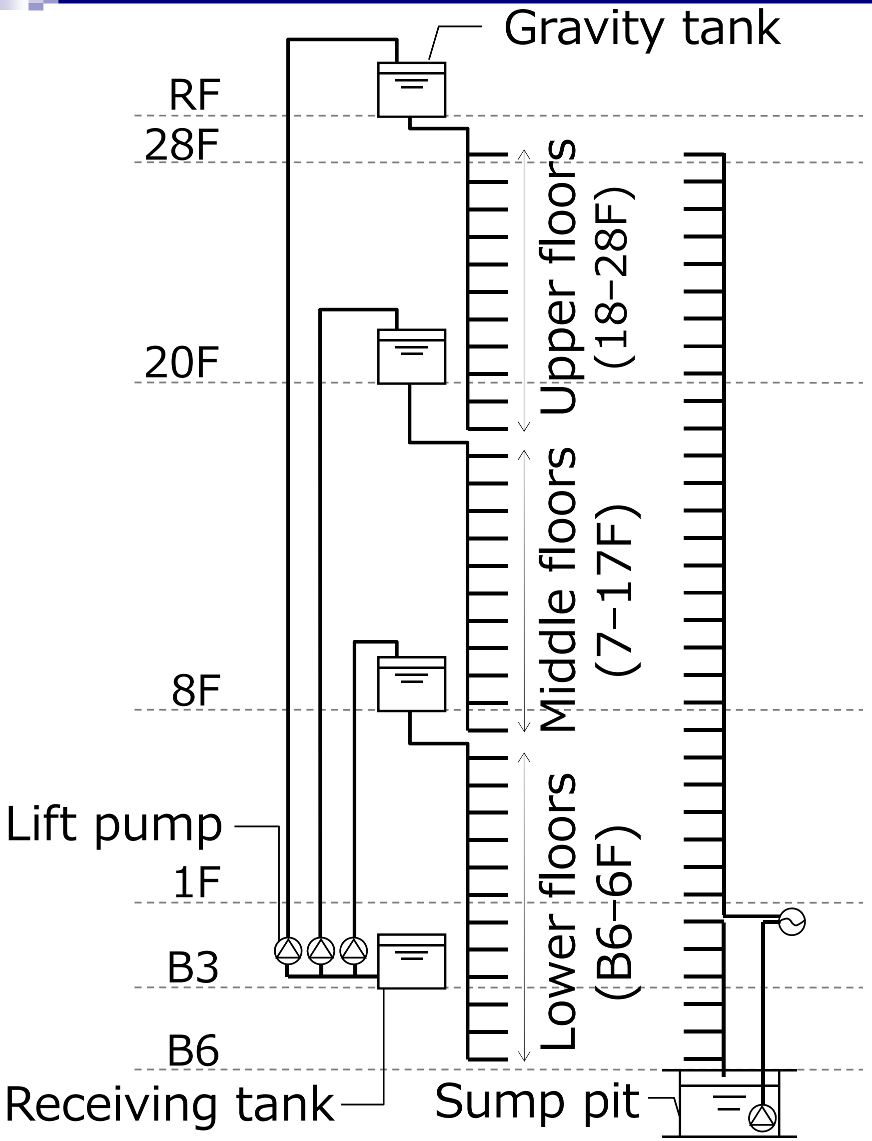


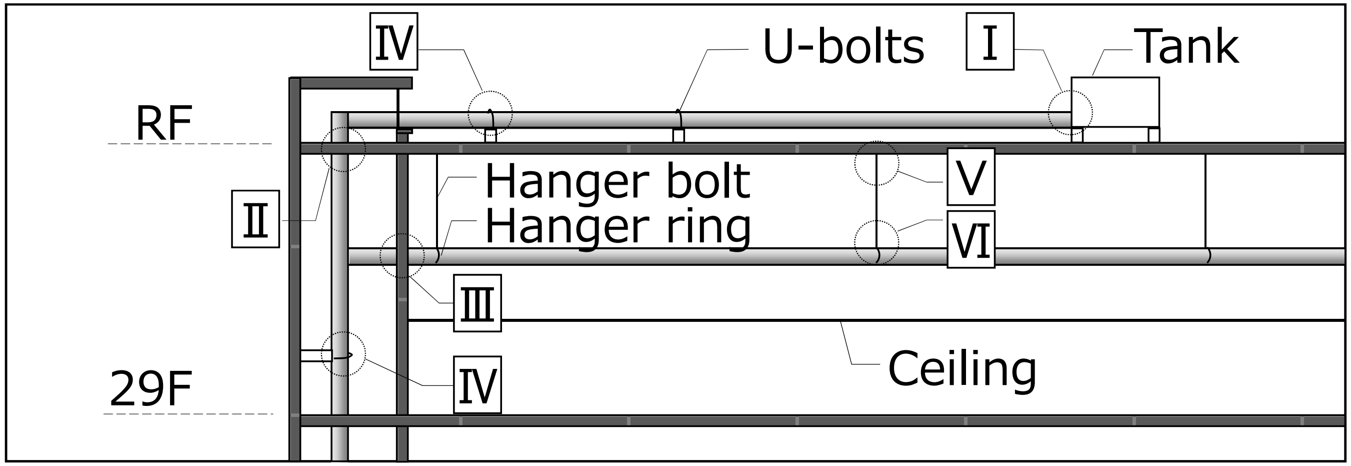


The evaluated building is a high-rise building with 29 floors above the ground and 6 floors below. The water supply system used was the gravity tank system. The water was supplied to the receiver tank installed in the 6th basement to pump water up to the three gravity tanks installed on the 8th and 20th floors and the roof floor. The evaluated building was supplied with potable and non-potable water to the upper (18–28F), middle (7–17F), and lower floors (B6–6F).

3 Overview of Aseismic-Performance Evaluation of the Plumbing System

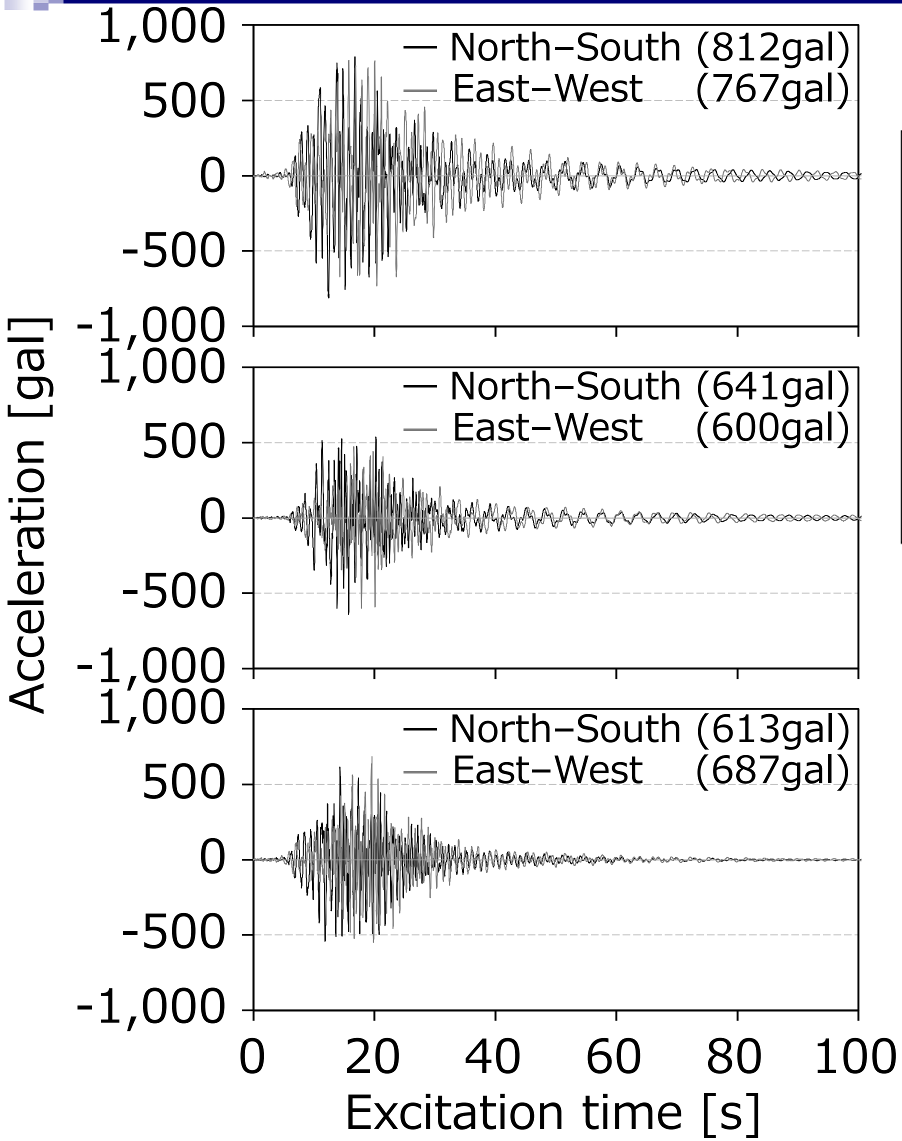
3.2 Model development of Plumbing System and Details of Input Seismic Wave

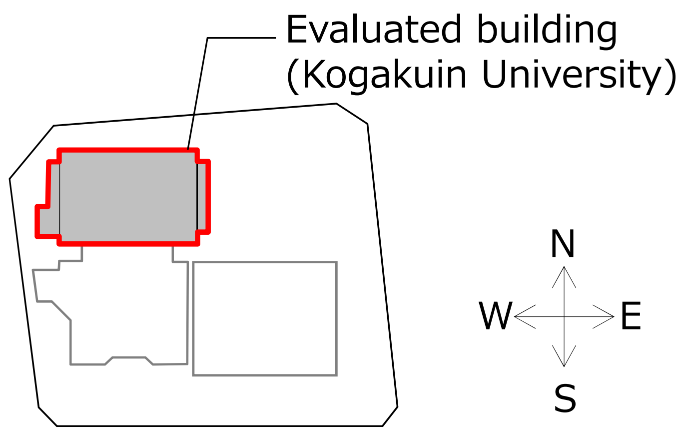




	Each element	Boundary conditions	
		Case A	**Case B**
Ⅰ	Tank･pump - piping	Rigid joint	
Ⅱ	upper and lower floor slabs - piping	Rigid joint	
Ⅲ	piping - smoke control zone compartments penetration	Rigid joint	
Ⅳ	Fixed point of piping（U-bolts)	Pin moveable joint	Pin joint
Ⅴ	The slab of upper floor and hanger bolts	Rigid joint	
Ⅵ	Hanger ring	Pin joint	

3.2 Model development of Plumbing System and Details of Input Seismic Wave

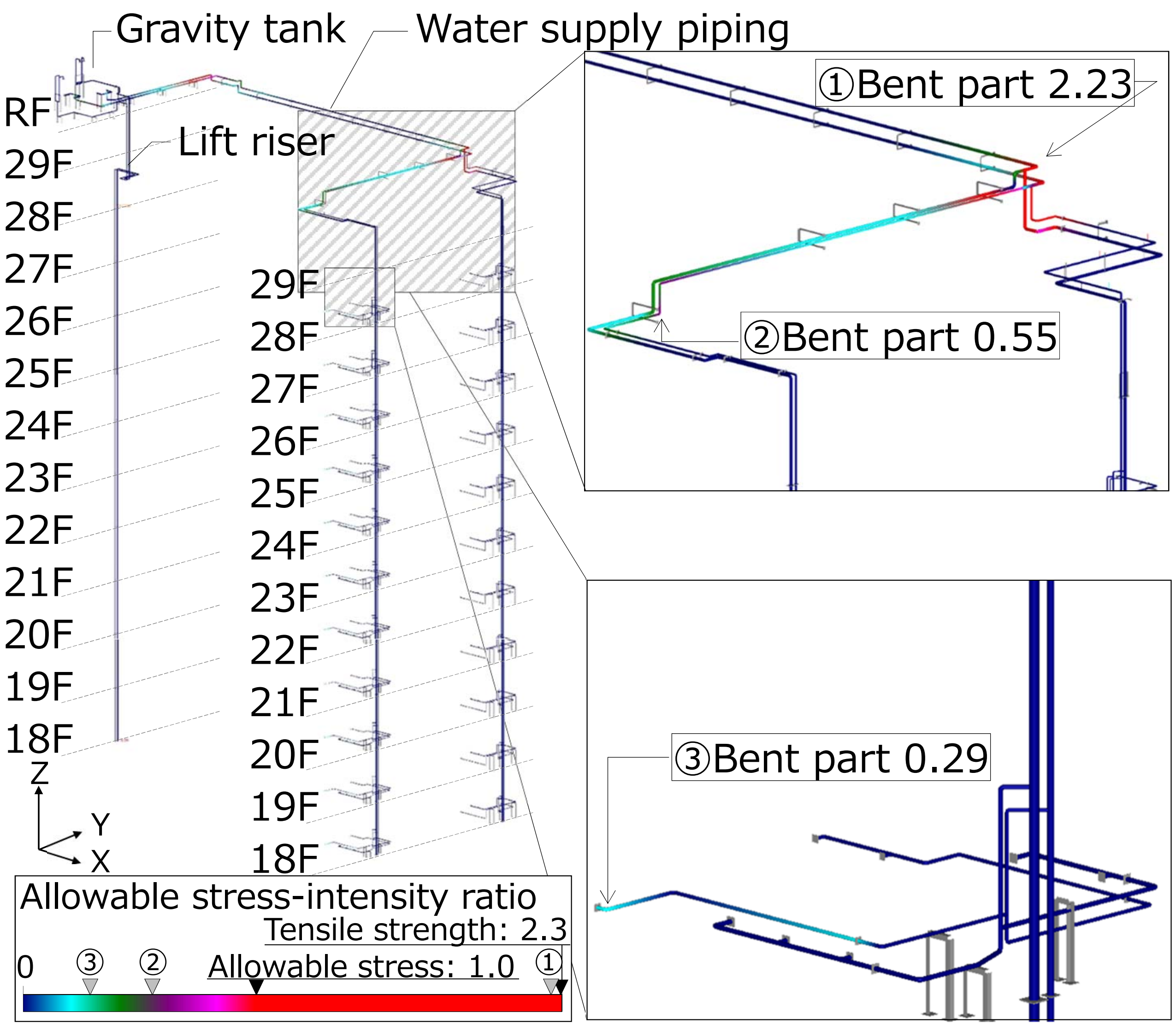


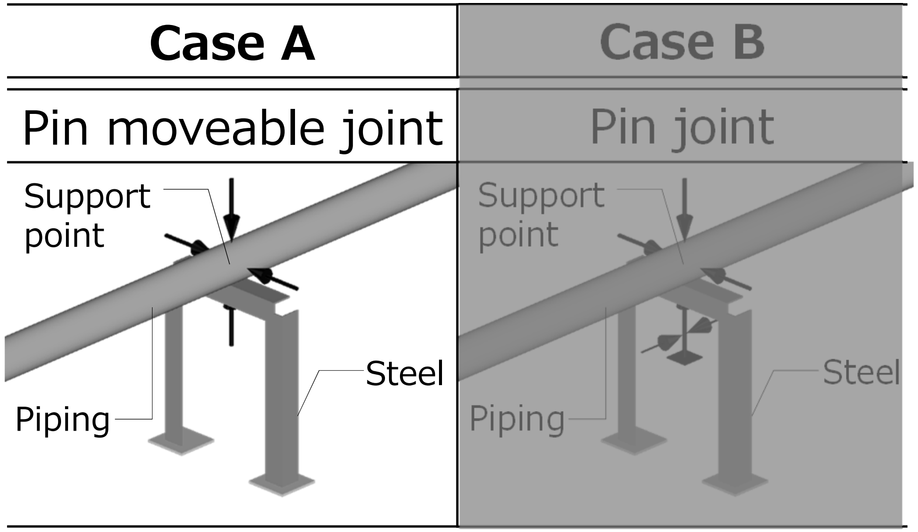


The input wave was a random wave expected in the Kogakuin University for the Tokyo inland earthquake. The maximum acceleration of the Tokyo inland earthquake, which is bigger than that of a typical observed wave, is used to structure the high-rise building design.

4 Result of Aseismic-Performance Evaluation of the Plumbing

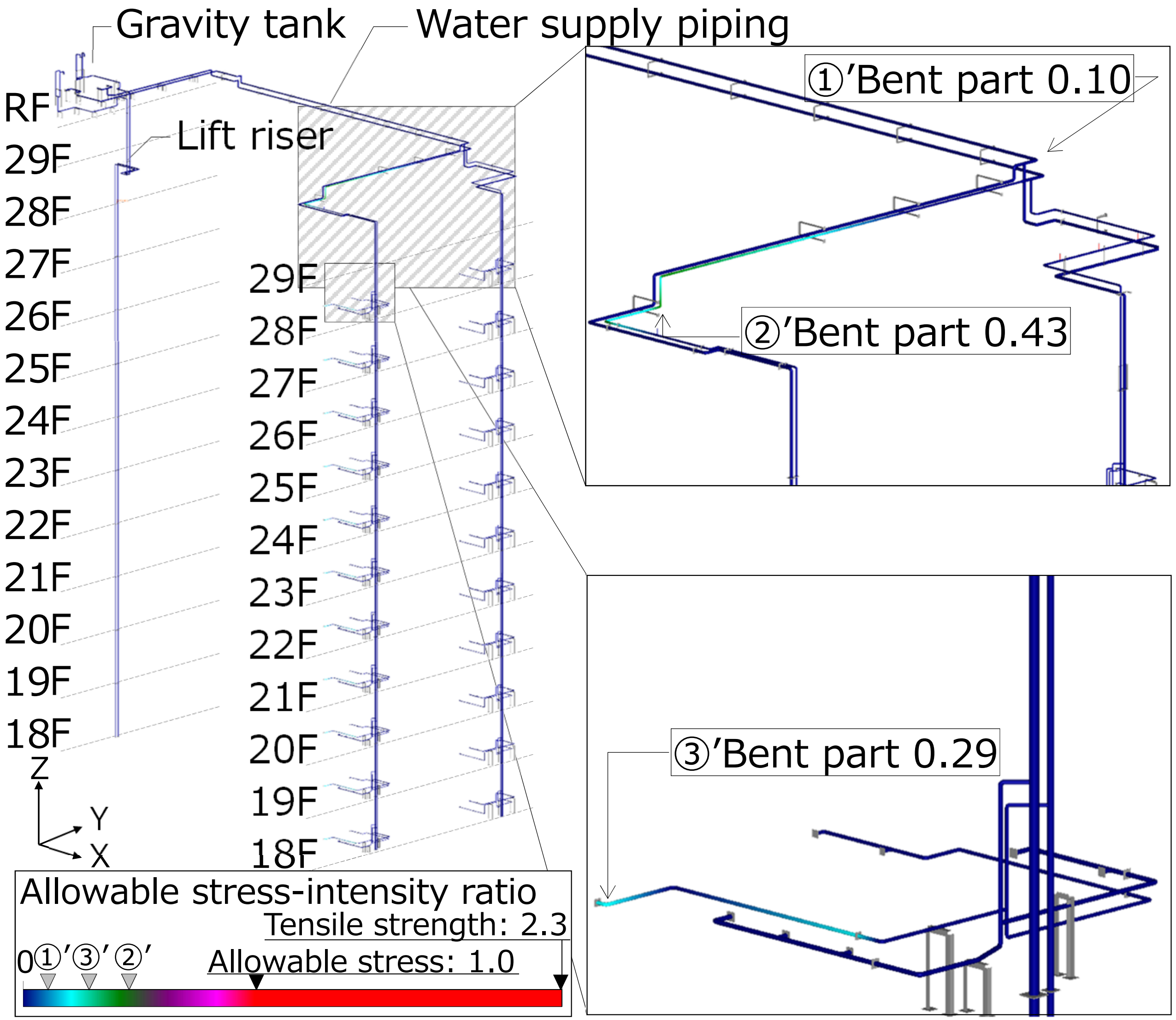
4.1 Results of Water Supply Piping system (Fig. 3)

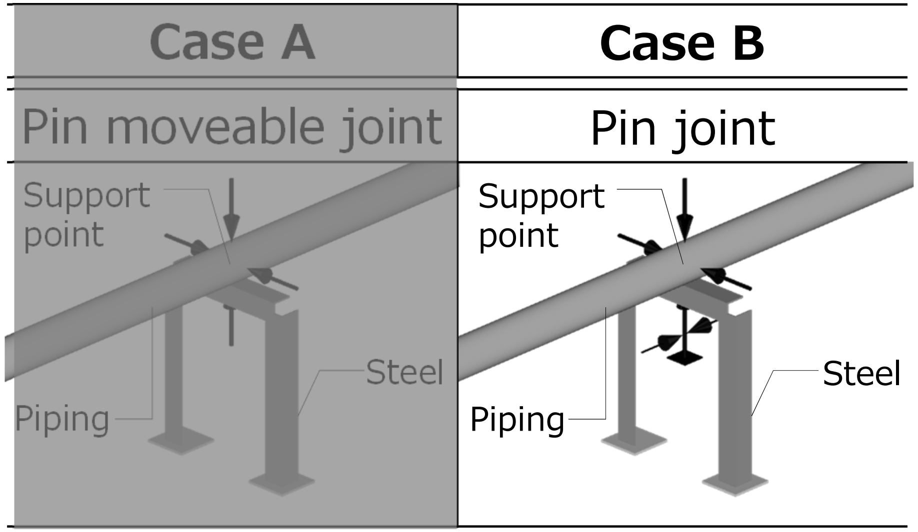




A maximum allowable stress-intensity ratio of 2.23 was obtained for the bent part of the roof floor (①). The maximum allowable stress-intensity ratio was obtained for the horizontal pipe, which is connected from the gravity tank installed on the west side to the pipe shaft on the east side in the evaluated building.

4 Result of Aseismic-Performance Evaluation of the Plumbing
4.1 Results of Water Supply Piping system (Fig. 4)

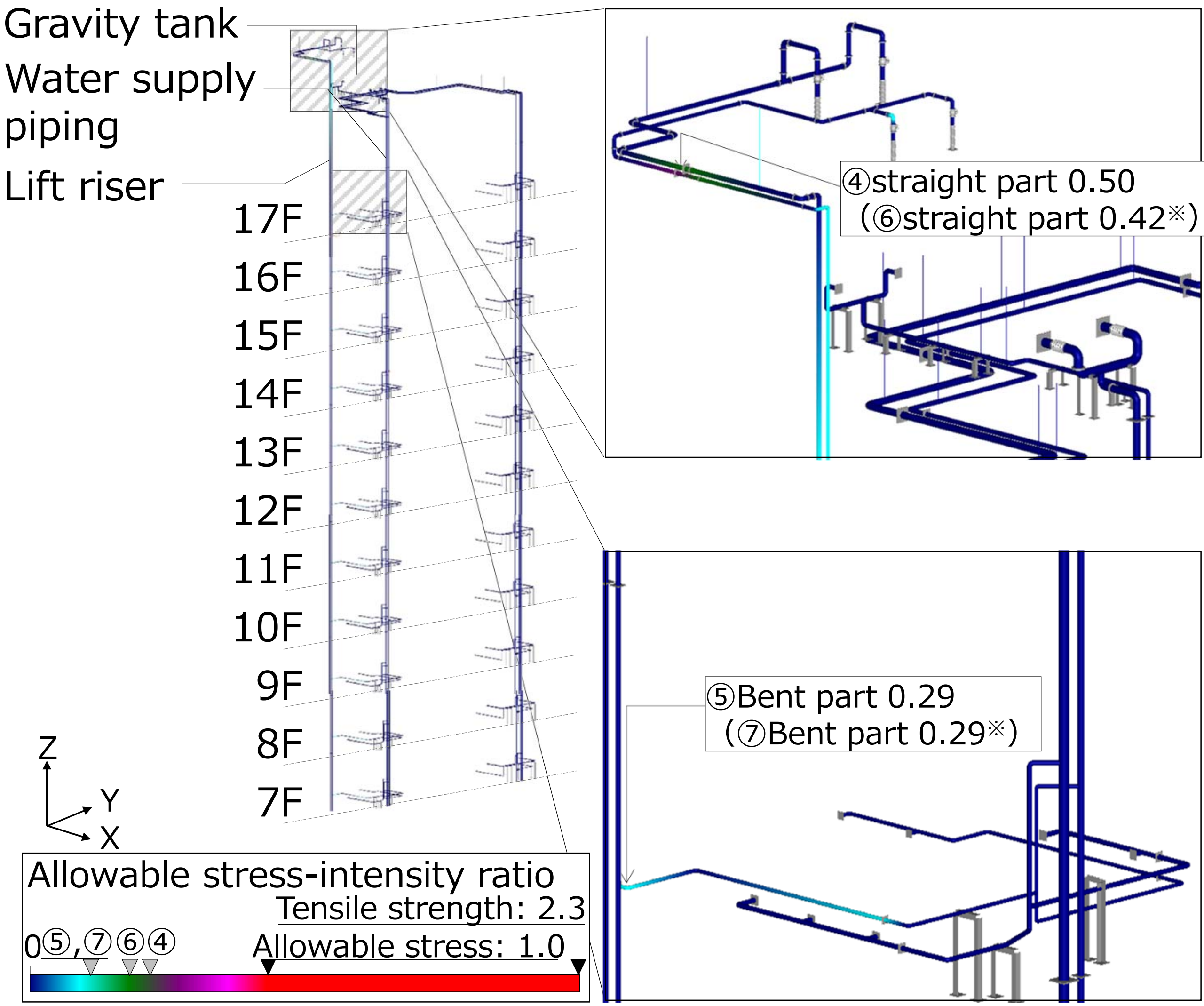


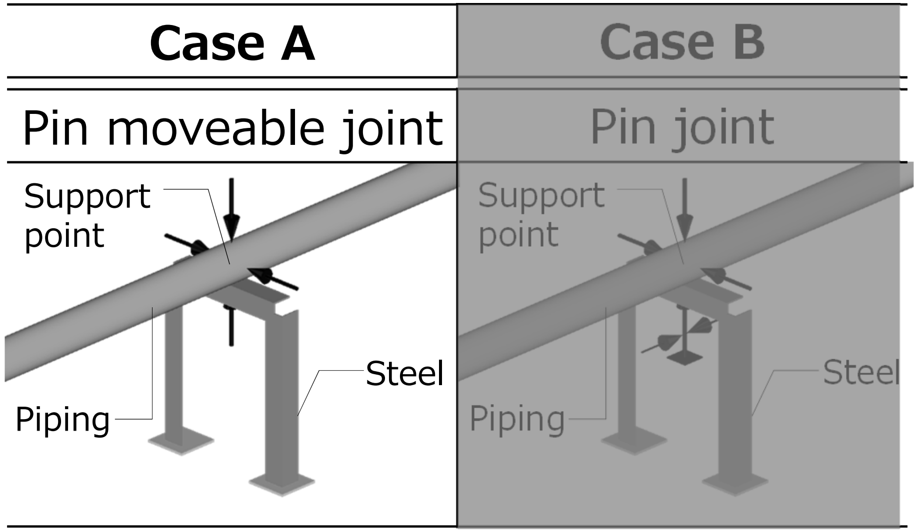


A maximum allowable stress-intensity ratio of 0.43 was observed for the bent part of the roof floor (②'). The parts of occurrence of the maximum allowable stress-intensity ratio calculated based on cases A and B are different because the displacement in the axial direction of the pipe is fixed.

4 Result of Aseismic-Performance Evaluation of the Plumbing

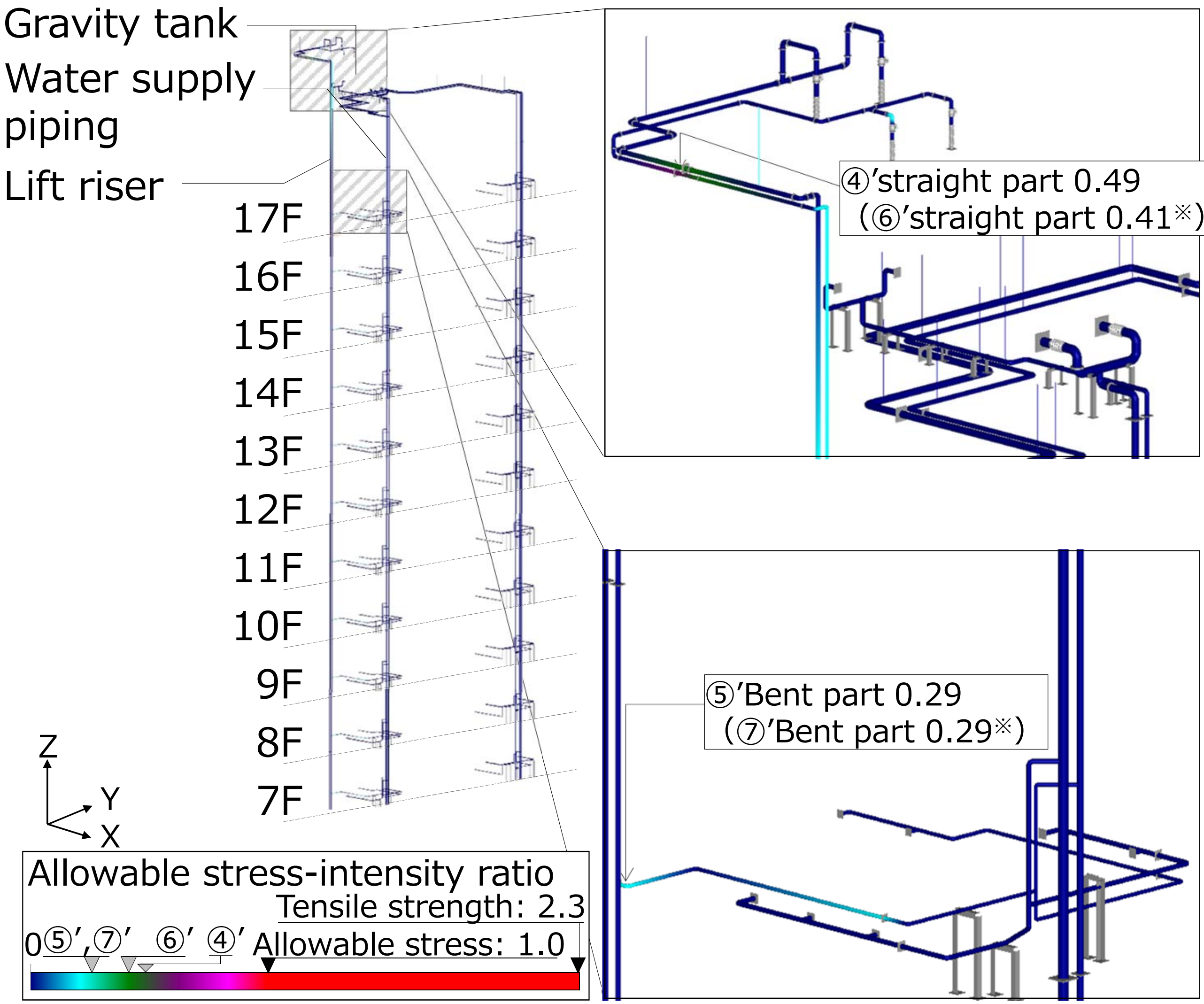
4.1 Results of Water Supply Piping system (Fig. 5)

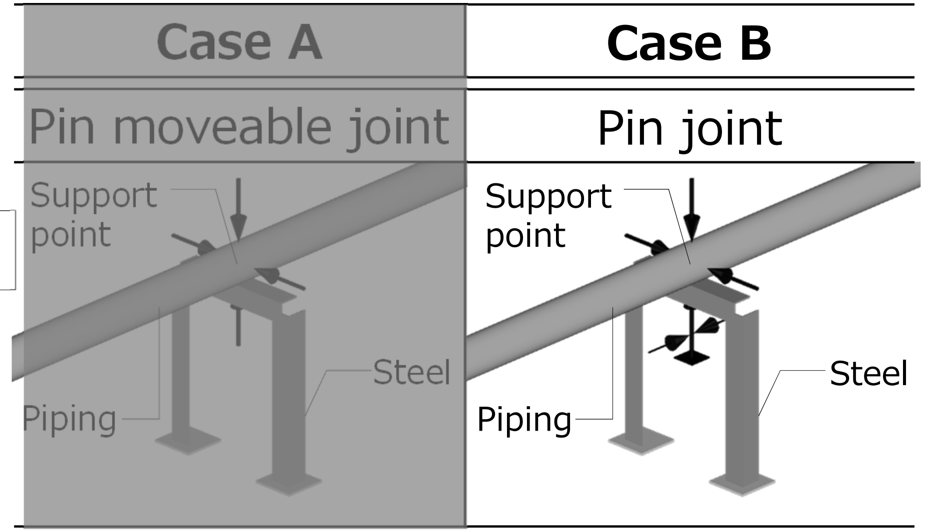




With regard to the middle floors, a maximum allowable stress-intensity ratio of 0.50 was observed for the straight pipe part located on the 20th floor (④). With regard to the lower floors, a maximum allowable stress-intensity ratio of 0.42 was observed for the straight pipe part located on the 8th floor (⑥).

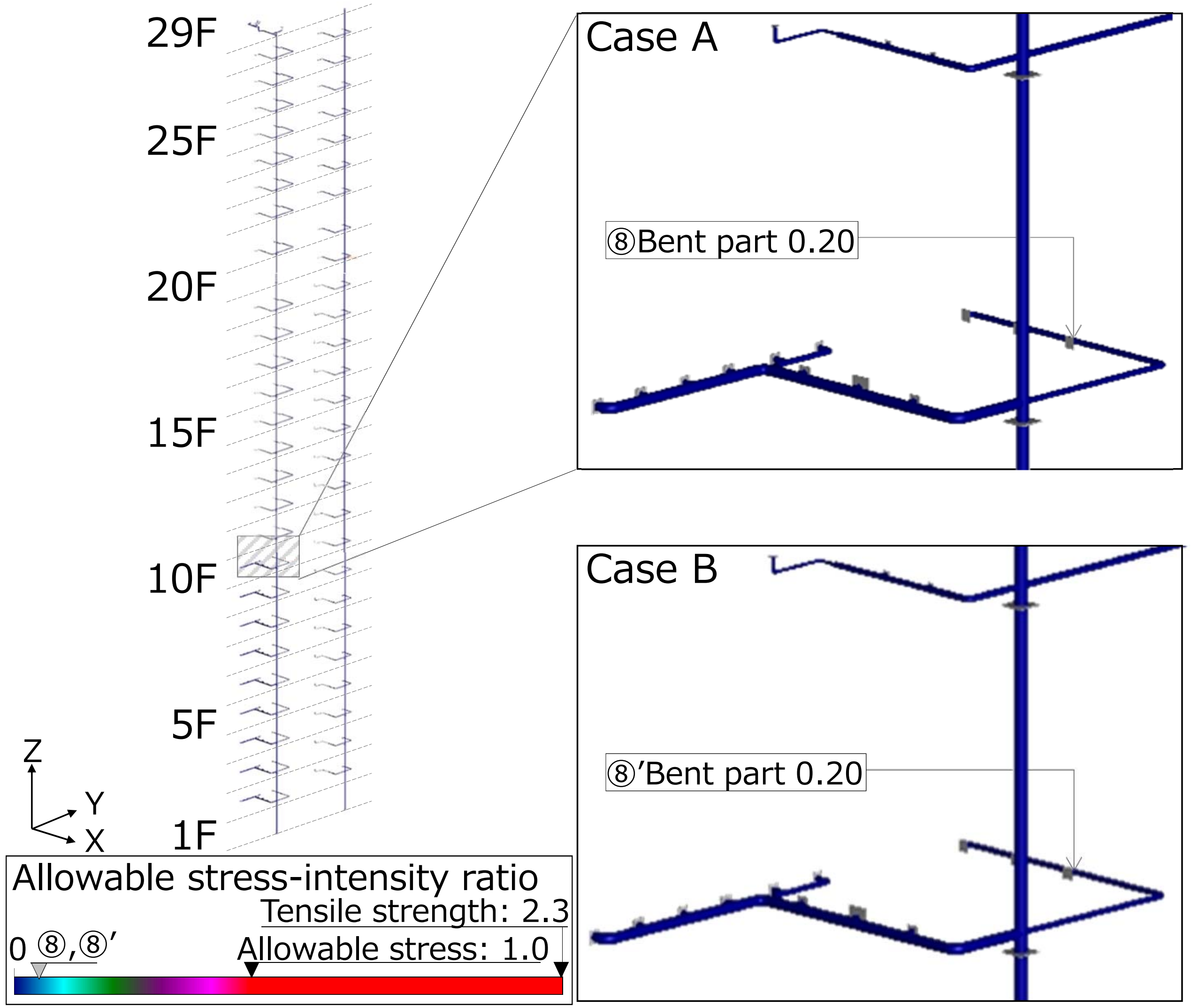
4 Result of Aseismic-Performance Evaluation of the Plumbing
4.1 Results of Water Supply Piping system (Fig. 6)



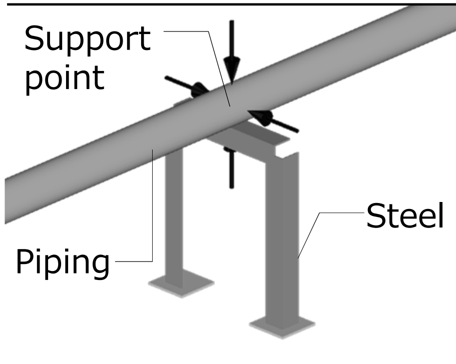


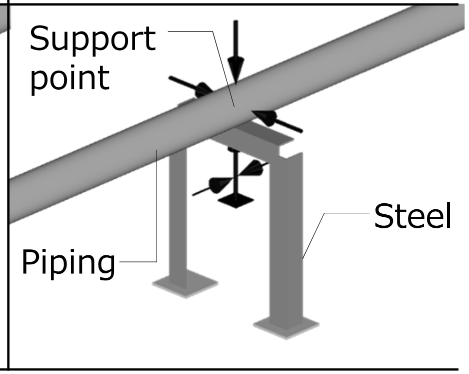
With regard to the middle floors, a maximum allowable stress-intensity ratio of 0.49 was observed for the straight pipe part located on the 20th floor (④′). With regard to the lower floors, a maximum allowable stress-intensity ratio of 0.41 was observed for taight pipe part located on the 8th floor (⑥′).

4 Result of Aseismic-Performance Evaluation of the Plumbing
4.2 Result of Drain Piping (Fig.7)



Case A	Case B
Pin moveable joint	Pin joint

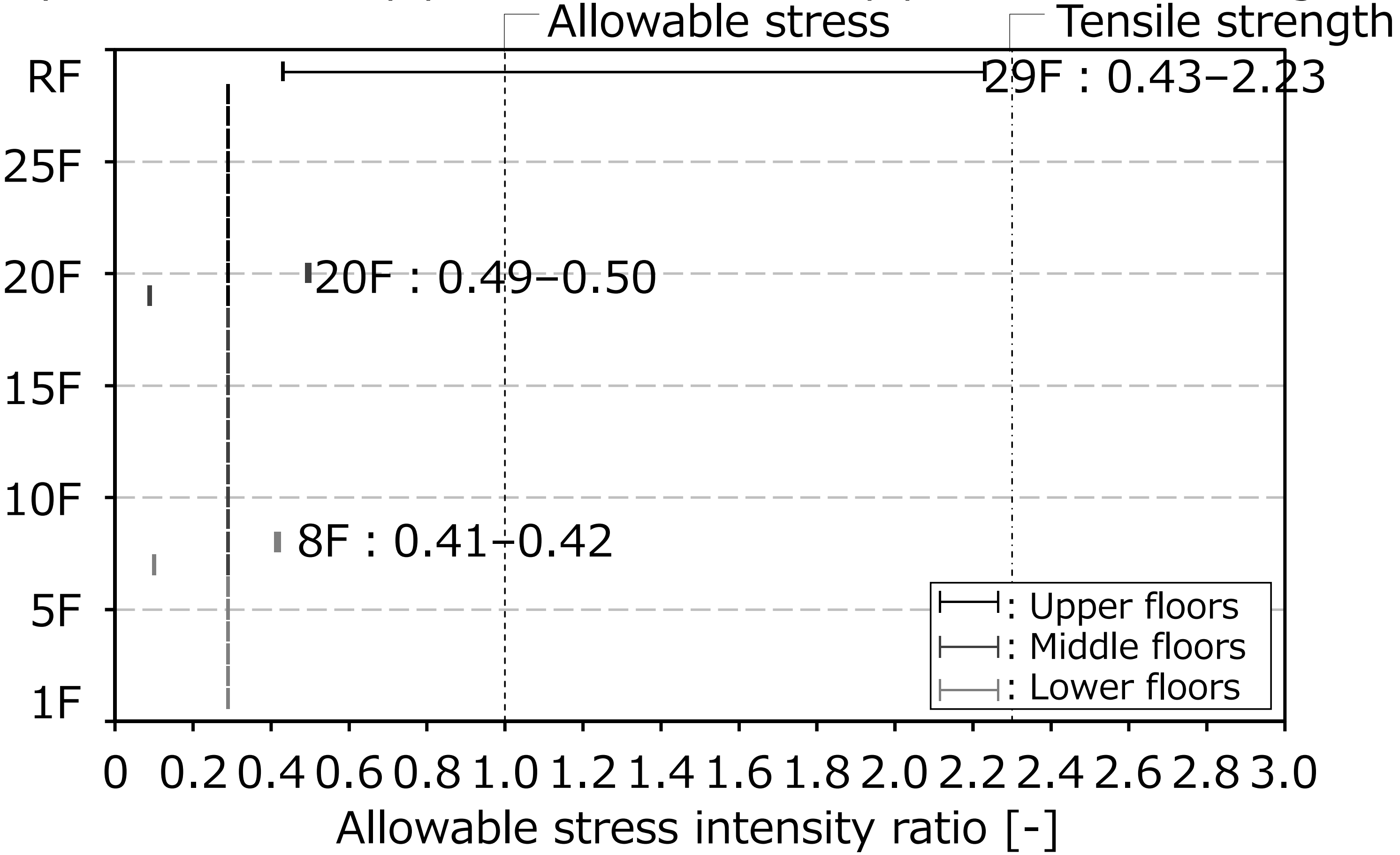




The maximum allowable stress-intensity ratio was 0.20 based on both cases A and B, which was obtained for the horizontal piping of the plumbing fixtures connected to the pipe shaft.

5 Seismic Risk of Plumbing System (Fig. 8)

The maximum allowable stress-intensity ratios are higher at the roof floor and the 20th and 8th floors in the range of 0.43–2.23, 0.49–0.50, and 0.41–0.42, respectively. However, the pipe connected from the pipe shaft to the plumbing fixtures has a lower allowable stress-intensity ratio than the pipe connected to the pipe shaft from the gravity tank.



6 Conclusion

This study was conducted to evaluate the aseismic performance of the plumbing system of the Kogakuin University, Shinjuku campus building using numerical analysis.

The maximum allowable stress-intensity ratio of the plumbing system varied in the range of 0.43–2.23 for the bent part of the horizontal water supply piping located on the upper floors. Moreover, the pipe connected from the pipe shaft to the plumbing fixtures has a lower allowable stress-intensity ratio than the pipe connected to the pipe shaft from the gravity tank. This is because the pipe connecting the pipe shaft from the gravity tank has a large support interval of the horizontal pipe.