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著者(和文)	Chengrui LUO, 佐藤大樹, 笠井和彦, 佐分利和宏, 前田達彦, 増田寛之, OSABEL DAVE M
Authors(English)	Chengrui Luo, Daiki Sato, Kazuhiko Kasai, Kazuhiro Saburi, Tatsuhiko Maeda, Hiroyuki Masuda, Dave M Osabel
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## ギャップブレースを取り付けた鉄骨架構の力学的挙動の検討 その 6 有限要素モデルのシミュレーション

鉄骨架構 耐震設計 変形制御機構  
有限要素モデル 曲げモーメント分布

正会員	Luo Chengrui* <sup>1</sup>	同	佐藤大樹* <sup>2</sup>
同	笠井和彦* <sup>3</sup>	同	佐分利和宏* <sup>4</sup>
同	前田達彦* <sup>4</sup>	同	増田寛之* <sup>4</sup>
同	OSABEL Dave M.* <sup>5</sup>		

### 1. Introduction

In response to the need for mitigating displacement of frame structures during major seismic events, a novel seismic device called "Gap Brace" has emerged from collaborative efforts between the Tokyo Institute of Technology (Sato Lab and Kasai Lab) and Takenaka Corporation. The concept design and mechanism of the Gap Brace was first proposed in 2020<sup>1)</sup>, and in the same year, reduced-scale test specimens were designed and manufactured for static cyclic load experiment<sup>2)-4)</sup>. The experiment confirmed that the Gap Brace can enhance the interlayer lateral stiffness only under large force<sup>2)-4)</sup>.

While experiment provides real-world behavior of the Gap Brace, the interpretation of results hinges significantly on the instrumentation deployed, such as the number of sensors (e.g., strain gauges) employed. Conversely, a rigorously validated finite element (FE) model can provide a more information. Hence, this paper carries out three-dimensional finite element analysis of the Gap Brace using ABAQUS (ver 2021). Serving as preliminary study, this paper validates the finite element modeling by scrutinizing the displacement limitation effect and moment distribution characteristics of the Gap Brace.

### 2. The finite element model

To faithfully replicate the reduced-scale experiment, the finite element model in ABAQUS has been meticulously constructed, encompassing the following key aspects:

- **Component Modeling:** all components utilized in the experiment are accurately simulated, such as the upper beam, Gap Brace, and so on. Figure 1 illustrates that Gap refers to the boundary distance between the beam hedge and brace head, as the value of 7.5 mm.
- **Material Properties:** Utilization of materials is outlined in Table 1, with constitutive relationships derived from material testing. Additionally, the FE model adopts isotropic hardening assumptions for the plastic stage.
- **Load Application:** The FE model comply with the load protocol consistent with the experiment, as illustrated in

Figure 2. Positive load denotes compression on the left plate, while negative load denotes compression on the right plate.

- **Boundary condition:** Consistent with experimental conditions, reference points are established at the hinge joints. Coupling reference points to the lower surface of basement ensures equivalence of unnecessary modeling entities. Under this configuration, translation in all directions and rotation around the X and Y axes are constrained for the reference points, while rotation around the Z-axis remains free.

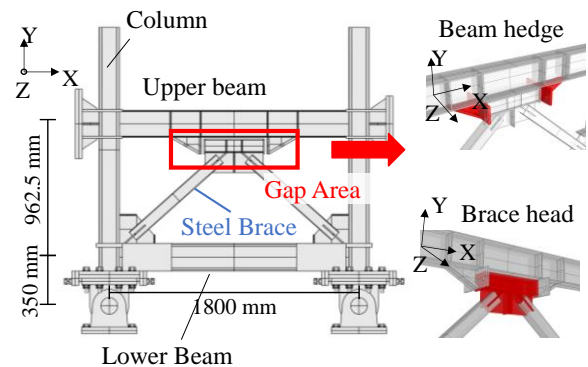
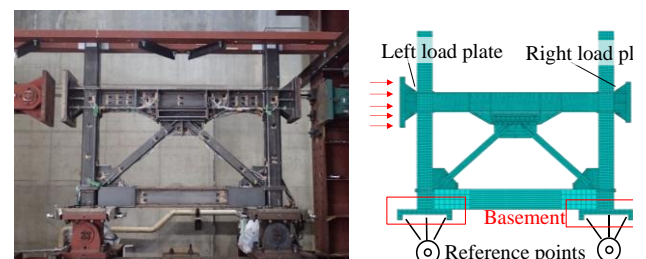


Figure 1 The design drawing of Gap Brace



(a) Experiment photo (b) FE model  
Figure 2 front view of the Gap Brace

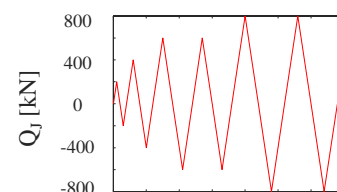


Figure 3 Load protocol

Study on mechanical behavior of steel frame with gap brace system, Part 6: Finite element model simulation

Chengrui LUO, Daiki SATO, Kazuhiko KASAI,  
Kazuhiro SABURI, Tatsuhiko MAEDA,  
Hiroyuki MASUDA, Dave M. OSABEL

Table 1 Material used in experiment

Material	Thickness(mm)	Components
SS400	6 and 9	Upper beam
SN490	9 and 16	Gap brace, lower beam and other components
STKR490	12	Columns
STKR400	3.2	Brace B60 specimen

### 3 Result comparison

Figure 4 present comparative analysis between the FE model and experimental data across different load cycles. In these figures, the left subfigures illustrate the relationship between system shear force and interlayer deformation ( $Q_s-R$ ), wherein the system shear force represents the cumulative shear force acting on columns and braces. Meanwhile, the right subfigures depict the distribution of moments throughout the entire model from FE model and the section moments calculated from experiment data.

It is evident that both the relationship  $Q_s-R$  and moment distribution are effectively simulated during all load cycles. However, two noteworthy deviations are observed: 1) After 400 kN cycle, the experiment section moment of lower beam is larger than FE model; 2) after 400 kN cycle, the experiment section moment of left column's lower section significant diverges than FE model. These discrepancies may stem from inconsistencies in boundary condition settings or variations in bending moment calculation methodologies, warranting further investigation.

### 4. Conclusion

This paper employs ABAQUS software to simulate a reduced-scale static cyclic loading experiment of the Gap Brace, encompassing test specimens, material properties, boundary conditions, and cyclic loads. The result shows that, the finite element model can well simulate the experiment, which is confirmed by the result comparison of relationship  $Q_s-R$  and moment distribution of the Gap Brace.

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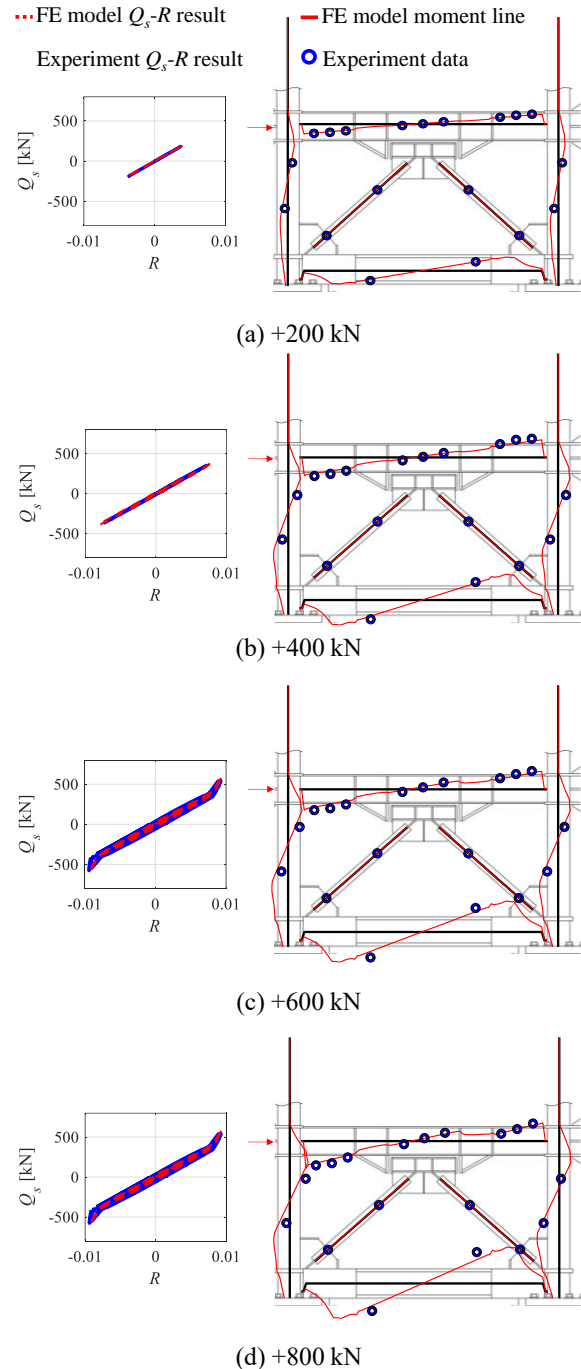


Figure 4 Comparison between experiment and FE model

- \*1 東京工業大学 環境社会理工学院 大学院生
- \*2 東京工業大学 准教授 博士 (工学)
- \*3 東京工業大学 名誉教授
- \*4 株式会社 竹中工務店
- \*5 東京工業大学 博士研究員

- \*1 Graduate Student, Tokyo Institute of Technology
- \*2 Associate Prof, Tokyo Institute of Technology, Dr. Eng.
- \*3 Honorary Prof., Tokyo Institute of Technology, Ph.D.
- \*4 Takenaka corporation
- \*5 Post PhD researcher, Tokyo Institute of Technology, Ph.D.