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ANALYSIS OF DAMAGE PHENOMENON BY VIDEO IN VIBRATION TEST OF CEILING / CABLE TRAY USING LARGE SHAKING TABLE

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Abstract

Regarding the phenomenon of US-style suspended ceiling panel falling and the phenomenon of cable tray damage during the earthquake, we analyzed the process of collapse of non-structural members using images obtained from vibration experiments using a large shaking table.

These series of experiments were conducted as part of a joint research project between Tongji University and a laboratory in Japan at the International Joint Research Laboratory of Earthquake Engineering (ILEE) established by Tongji University. The leader is Prof. Kasai at Tokyo Tech. and co-leader is Prof. Huanjun JIANG at Tongji University.

One of the major objectives of the shaking table test for non-structural elements in this project is to extract damage patterns during earthquakes. In order to realize earthquake damage in the laboratory, it is desirable to increase the scale of a specimen as much as possible. Therefore, in principle, the design of the steel frame on which the test specimen is installed is performed on condition that a test specimen having a size of 12 m × 12 m can be installed.

An example of the damage pattern were confirmed in specimens with peripheral clearance and braces. The ceiling panel in the vicinity of the brace has dropped, and the ceiling panel in the middle part of the brace has not dropped. The suspension bolt breaks due to the low cycle fatigue failure phenomenon at the brace upper end joint, and the ceiling panel dropped in a chain from the grid formed by the T-bar. Both of these are consistent with the type of damage confirmed in actual earthquake damage.

As for the seismic reinforcement of the cable tray, three types of type-S, type-B and type-A were vibrated simultaneously. In the seismic reinforced type-A cable tray, there was a large displacement difference between the reinforcement part and the part of the weight only suspension, and the cable tray sub-girder fell off the main-girder. The reason why the sub-girder falls may be because the grid of the main-girder and sub-girder, which was originally rectangular, was converted into a parallelogram near the seismic reinforcement.

Keywords: US-style suspended ceiling; Cable tray; Damage Phenomenon by Video; Shaking table test

1. Introduction

Regarding the phenomenon of US-style suspended ceiling panel falling and the phenomenon of cable tray damage during the earthquake, we analyzed the process of collapse of non-structural members using images obtained from vibration experiments using a large shaking table.

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Testing was conducted by using two of the 4m x 6m bi-axial shaking table at Earthquake Engineering Hall of Tongji University in Shanghai, China (**Photo 1**).

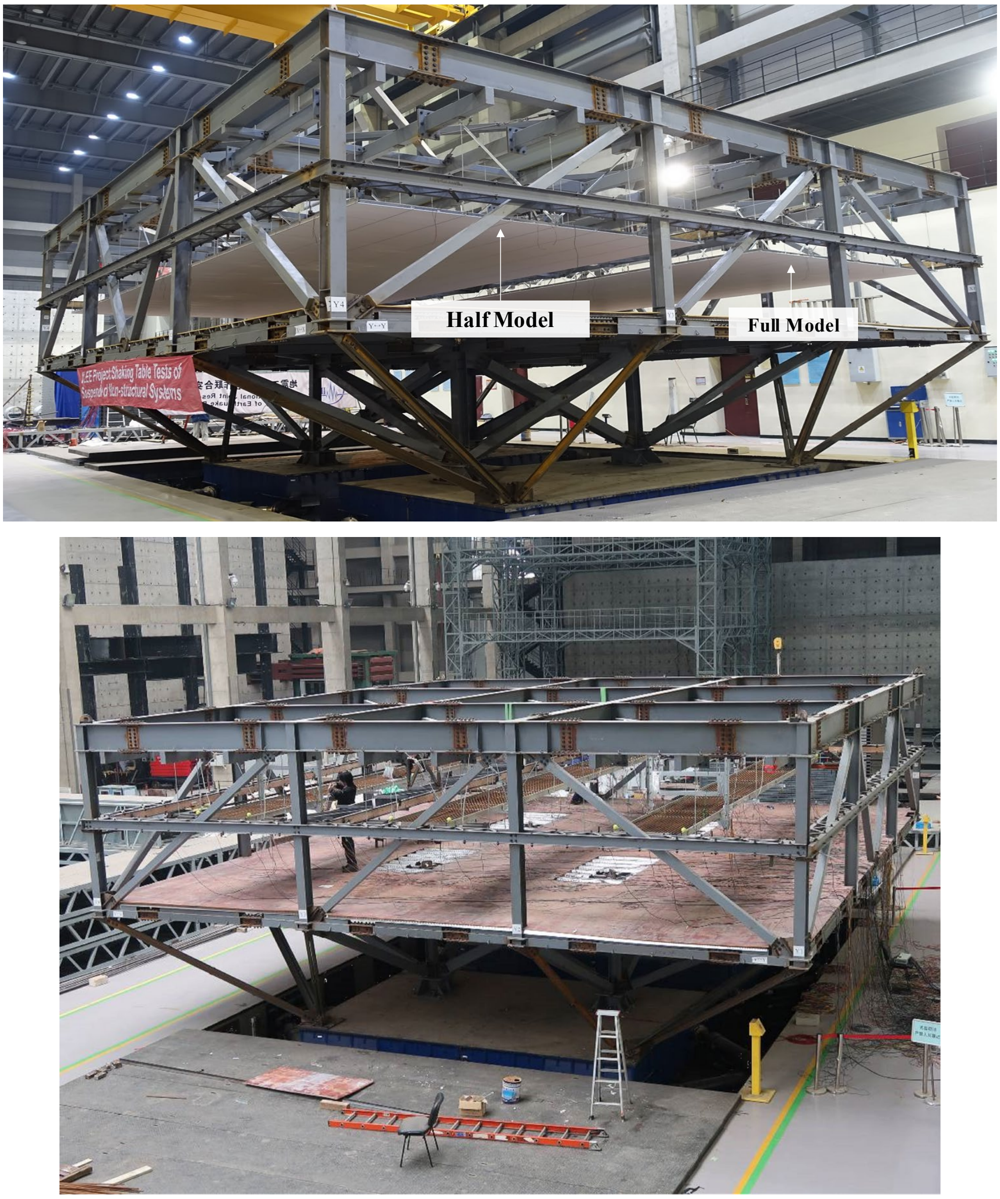


Photo 1 Overall view of the test specimen and supporting frame

2. Shaking Table Test for Ceiling System

2.1 Experiment outline

This experiment is designed to confirm the effect of brace arrangement on the seismic performance of the ceiling system, in particular, focus on the influence of eccentricity of the brace mounting position, and the evaluation of the ceiling-in-plane shear stiffness shown in the past studies. **Fig. 1** shows the frame supporting the ceiling specimen and the outline of the specimen.

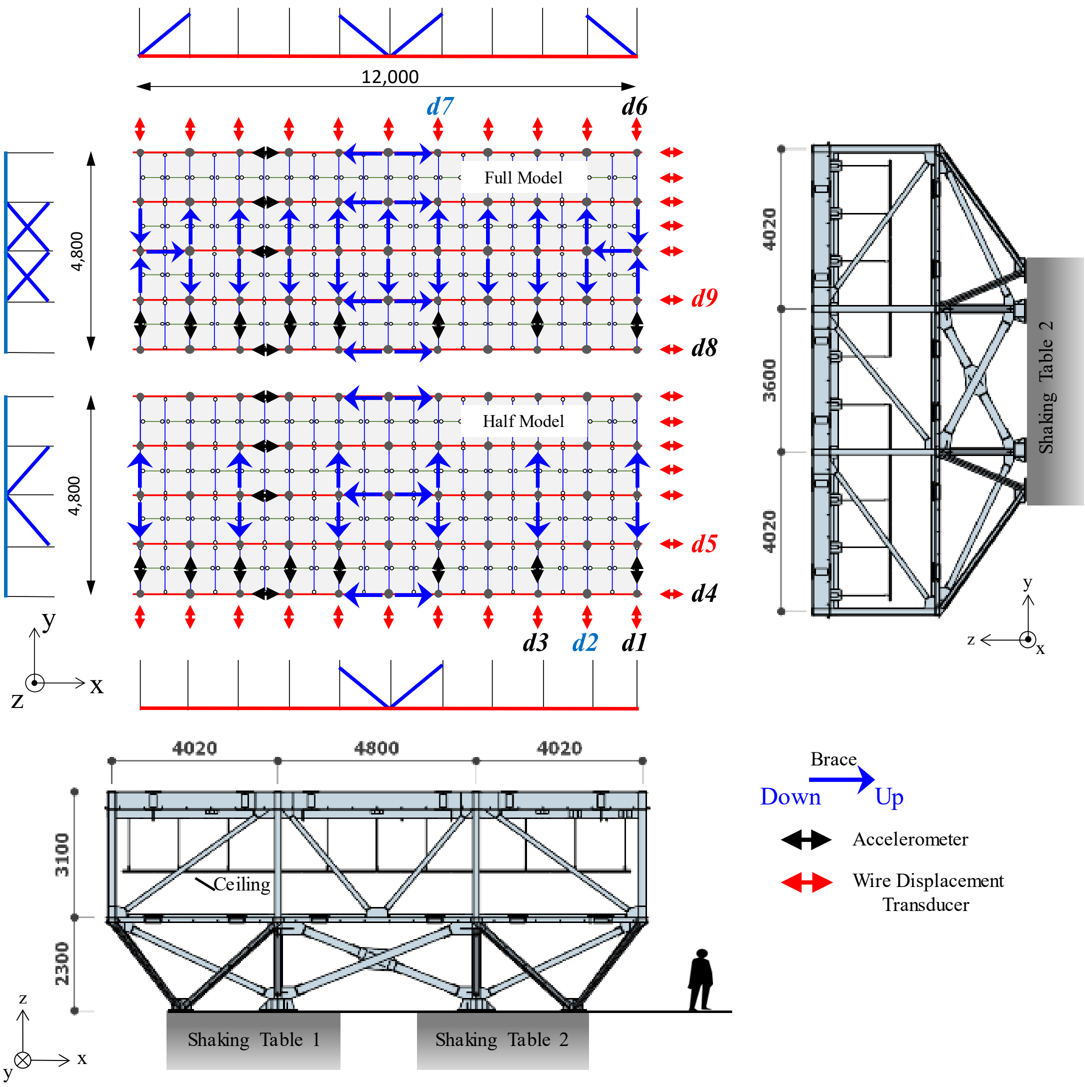


Fig. 1 Shaking Table Test for Ceiling System

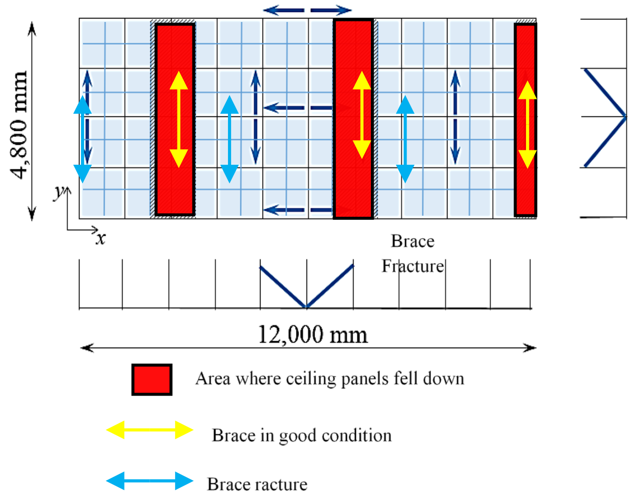
2.2 Damage pattern when vibrated in X direction

Damage pattern confirmed in the ceiling experiment is shown in Photo.2 and Fig.2. These were confirmed in specimens with peripheral clearance and braces. Fig. 2 illustrates the area where the ceiling panel has fallen. From this figure, it is observed that the ceiling panel in the vicinity of the brace has dropped, and the ceiling panel in the middle part of the brace has not dropped. Photo.2 (b) is an example in which the suspension bolt breaks due to the low cycle fatigue failure phenomenon at the brace upper end joint, and Photo.3 is the case where the ceiling panel dropped in a chain from the grid formed by the T-bar. It is an example. Both of these are consistent with the type of damage confirmed in actual earthquake damage.

(a) (b)

(b) (d)

Photo 2 Progress of ceiling damage when vibrated in the X direction



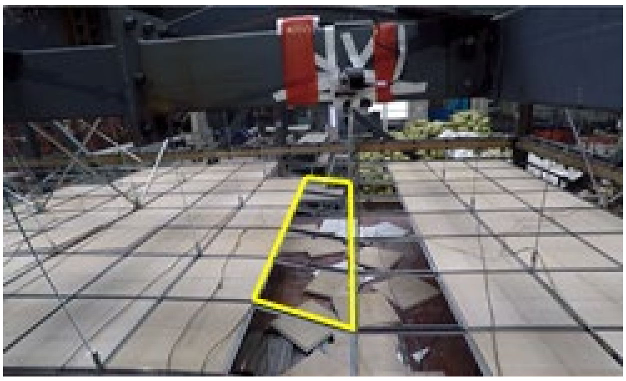
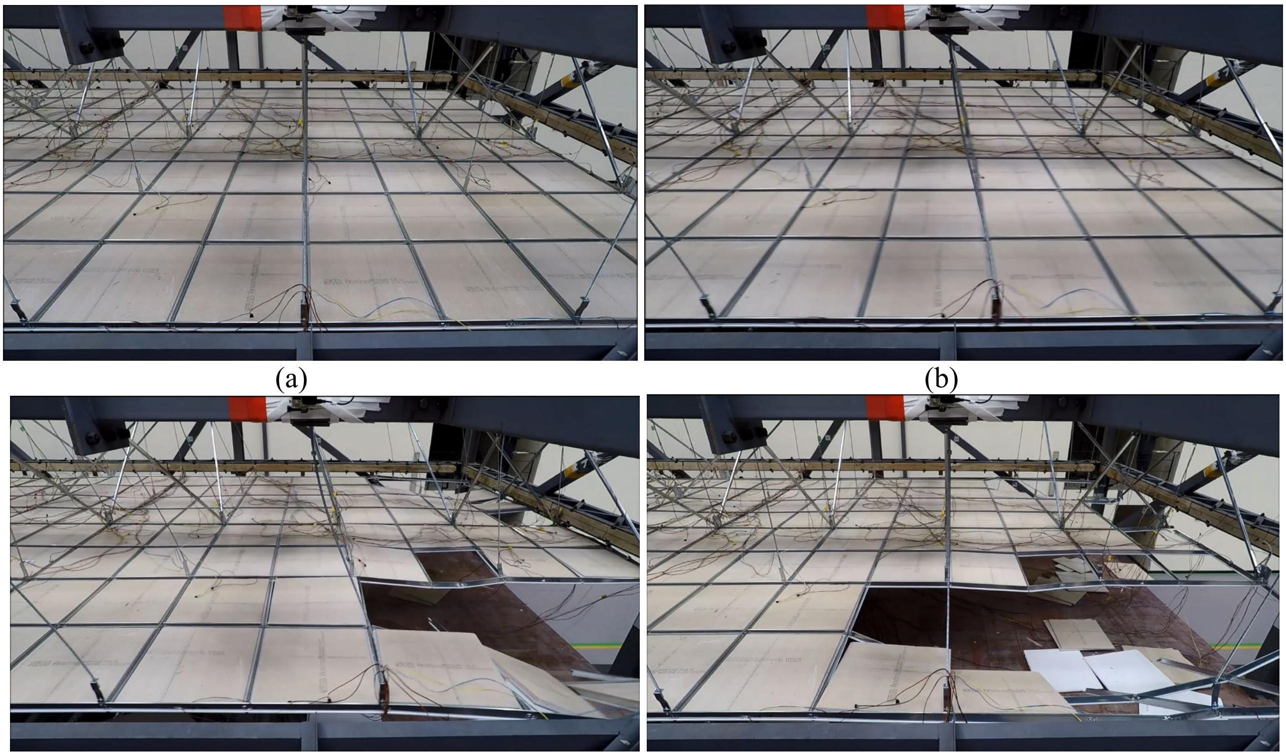


Photo.3 Damage of the ceiling

Fig.2 Damage pattern confirmed in the ceiling experiment

2.3 Damage pattern when vibrated in Y direction

Photo 4 shows the motion when vibrating in the Y direction. When vibrated in the Y direction, the panel did not drop until the ceiling hit the wall, but when the ceiling hit the wall, the frame of the ceiling bent and the panel dropped. Photo 5 shows the ceiling experiment taken with the drone.



(a) (b)

(b) (d)

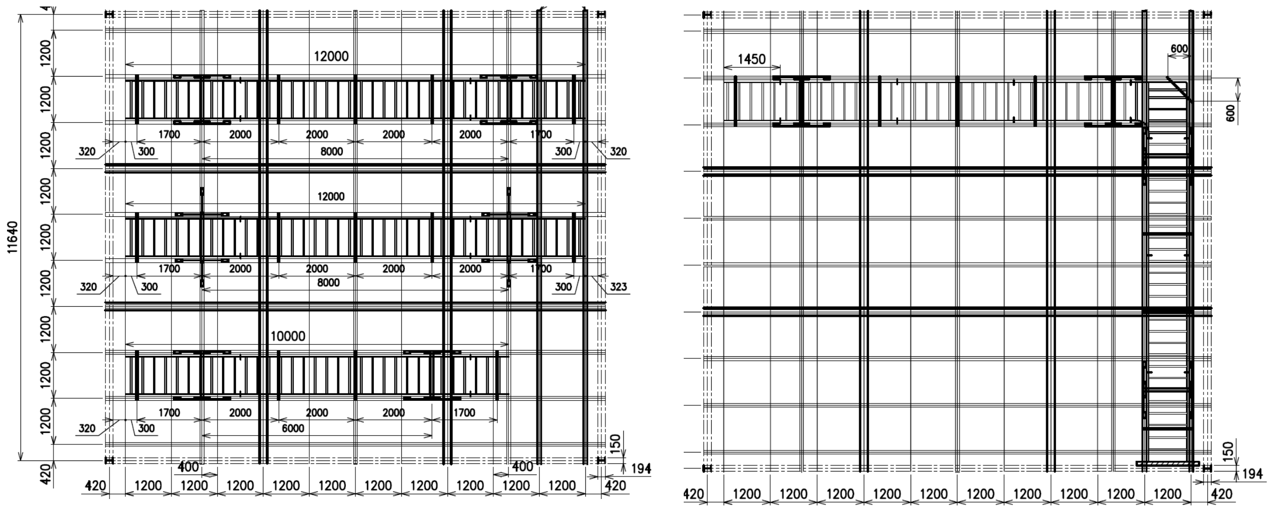
Photo 4 Progress of ceiling damage when vibrated in the Ydirection

Photo 5 Ceiling experiments taken with a drone

3. Shaking Table Test for Cable Tray

3.1 Experiment outline

The cable tray system tests were carried out twice, Test 1 and Test 2 as shown in Fig.2(a) and (b). As for the Test 1, three long cable tray systems which have different seismic elements Type B, Type A and Type SA were tested and the distribution of each seismic elements was set to minimum amount required in Japanese design guideline. In each types have same braces in cable tray direction but different seismic element in perpendicular direction.



(a) Test1 (b) Test2

Fig.2 Cable tray layout

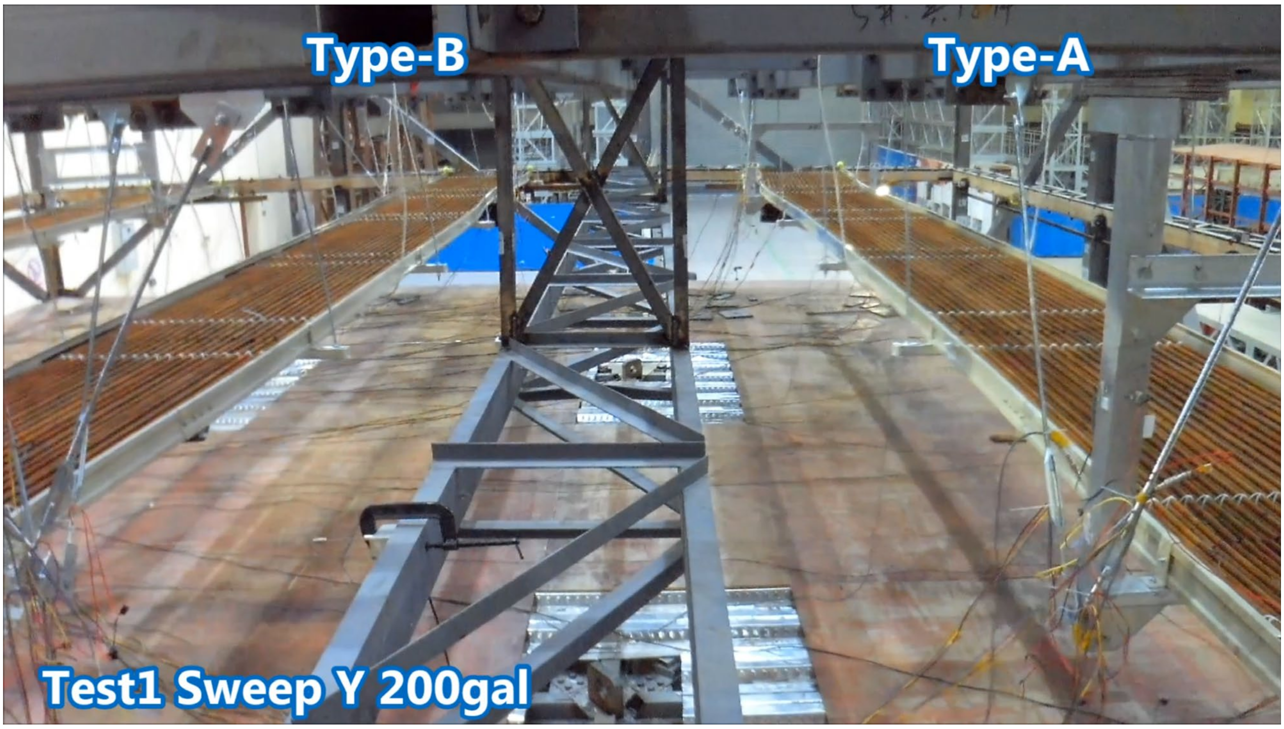


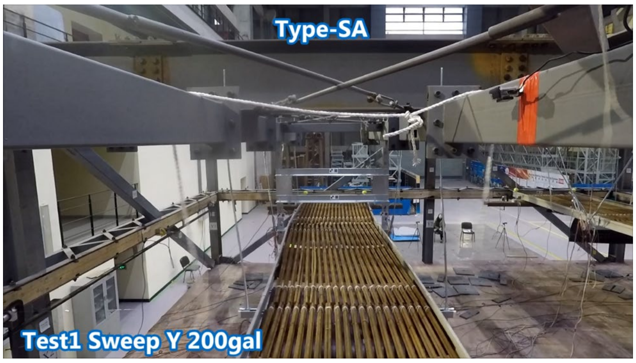
Photo 6 Ceiling experiments Test1

3.2 Damage pattern in Test1

Type-SA had higher amplitudes at higher frequencies, but did not damage the cable tray. Type A increased in amplitude at low frequencies, and the originally rectangular main and sub-girder grids were converted to parallelograms near the seismic reinforcement, causing the sub-girder to drop. Type B increased in amplitude at low frequencies like Type A, but the sub- girder did not drop.

Photo 10 shows the experiment of the cable tray Test1 taken with a drone. The difference in vibration characteristics between Type-SA, Type-A, and Type-B can be seen from the recorded video.

(a) Before vibration



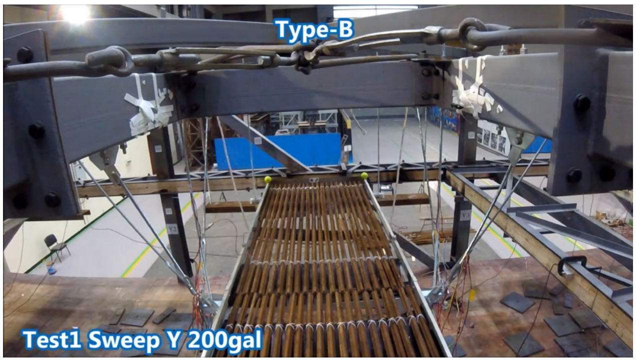
(b) Maximum amplitude

Photo 7 Cable Tray Type-SA

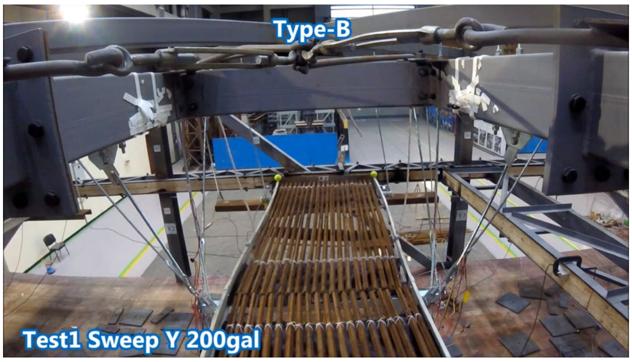
(a) Before vibration

(b) Maximum amplitude

Photo 8 Cable Tray Type-A



(a) Before vibration



(b) Maximum amplitude

Photo 9 Cable Tray Type-B

Photo 10 Cable Tray Test1 experiments taken with a drone

3.3 Damage pattern in Test2

Photo 11 shows the experiment of the cable tray Test2 taken with a drone. The displacement of the cable tray was large during the class A seismic support, but no damage occurred in the bending area.

Photo 11 Cable Tray Test2 experiments taken with a drone

4. Conclusion

In this paper, to understand the mechanical properties of the U.S. grid-type system ceiling, we conducted a shaking table test using large-scale test specimens, and clarified the steady state characteristics and the process leading to drop damage by video.

In addition, videos of full-scale cable rack shaking table tests were taken to clarify the vibration characteristics of each type of seismic support.

5. References

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