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E-Isolation—Design of Japan's First Full-Scale Seismic Isolation Testing Facility.

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ABSTRACT

In Japan, the seismic isolations and damping materials used are diversifying and increasing in size due to the application to various civil engineering and building structures. However, the mechanical properties of these members have not been sufficiently experimentally verified. Many engineers understood that dynamic tests using full-scale members were necessary to verify and understand the dynamic characteristics of seismic isolation bearing members under vertical loads. Since there was no "testing facility", verification by experiment was difficult. However, in 2023, Japan's first "full-scale seismic isolation testing facility" was completed and started operation. In this paper, we would like to describe the mechanism and features of this testing facility called as E-isolation.

1. INTRODUCTION

The "full-scale seismic isolation testing facility" designed this time is the first testing facility in Japan that can excite the high-speed and large deformation that occurs during an actual earthquake while applying a vertical load of up to 36,000kN. And this testing facility was built adjacent to the full-scale three-dimensional seismic destruction test facility "E-Defense" in Miki City, Hyogo Prefecture. The building's large shaking table and full-fledged seismic isolation testing machine are installed in one place, and it is expected to become a base for seismic structure research around the world.

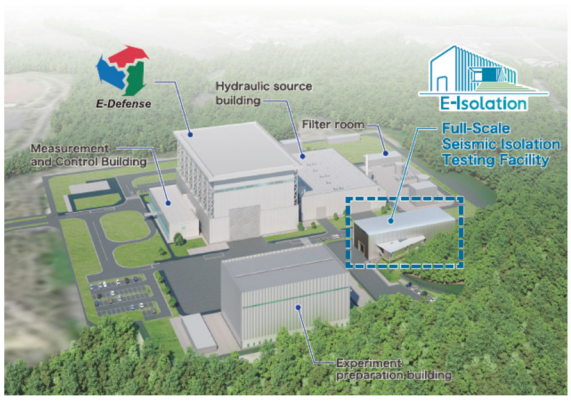

Fig. 1 Facility Appearance

Fig. 2 Facility Interior

2. DEVICE OVERVIEW

E-Isolation's full-scale testing machine has a vertical load capacity of 36,000 kN(static), 30,000 kN(dynamic), stroke limit of 250mm and velocity capacity of 70 mm/sec. In the horizontal direction, dynamic single directional loading capacity is 6,500 kN(static), 5,100 kN(dynamic) with ±1,300 mm stroke limit and the max velocity is 800 mm/sec.

The specimen is placed in a sandwich between 24 vertical dynamic jacks placed side by side on the bottom plate against the vertical direction and the center of the upper reaction beam span, as shown in the Fig 3.

Compressive axial forces are applied to this specimen. The reaction beams and bottom plate are held in compression by a total of 48 unbonded PC steel strands inserted into the sidewalls of the concrete dock and subjected to a constant prestressing force of 50,000kN. On the other hand, horizontal loads are applied dynamically by means of horizontal dynamic jacks to the upper moving plate, which is placed on bearings arranged on the lower moving plate in the Fig 3. The reaction beam is supported horizontally by V-shaped reaction measurement links and rotational constraint reaction force measurement links, and is elastically fixed to the dock RC frame in the horizontal plane via "12 units of natural rubber laminated rubber with no holes".

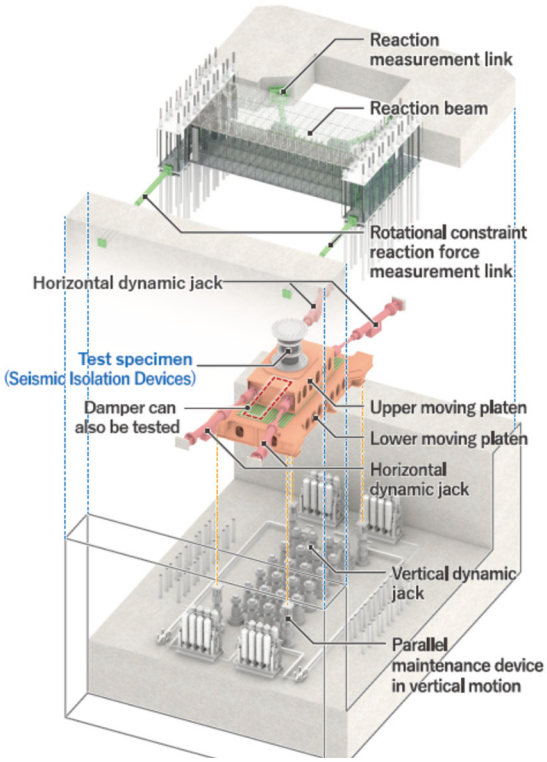

Fig 3 Overview of Measuring Equipment

3. DEVICE CONCEPT

The new E-Isolation full-scale testing machine, as shown in Fig 4, consists of 12 natural rubber laminated bearings mounted on a rigid RC bearing wall, with the test specimen mounted on the center underside of the wall. 4 reaction force measurement links are horizontally connected between the reaction beam and the rigid RC reaction wall. Majority of the horizontal reaction force is measured in real-time through these force-measurement links, and since the reaction beam moves minimally, almost no inertia force is generated. Furthermore, by supporting the reaction beam with elastomeric bearings, less than 1% horizontal force is transmitted through the support layer. To keep the bearings under compression, pre-tensioned PC strands are provided, while the horizontal stiffness with their P-Δ effects can also accurately be captured because their tension forces are unchanged.

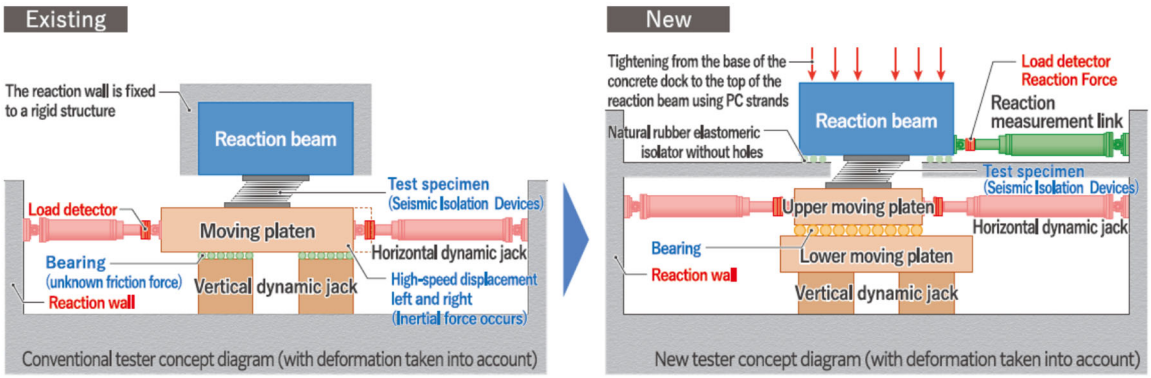

Fig 4. Comparison between the conventional system and the proposed measurement system

The parallelogram hysteresis loop shown in green is the load history from the horizontal dynamic jack, and the black loop with almost no hysteresis is measured with four load measurement links. Until now, in the measurements conducted in Japan, the results of horizontal jacking have been corrected and judged based on the frictional force of the bearings and the results of experiments using reduced-size test specimens. With E-Isolation, we can observe the behavior of full-scale seismic isolation members and check their performance in real time without modifying them.

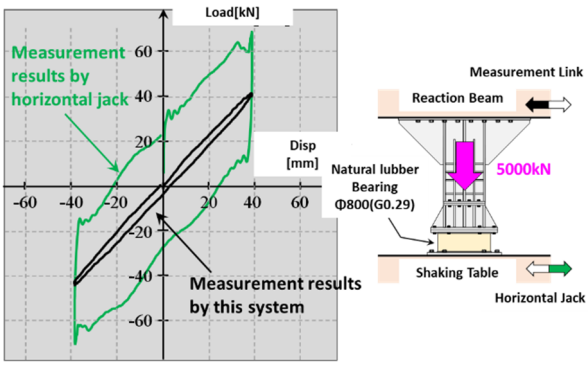

Fig 5 Verification test results using laminated rubber

4. REACTION STEEL BEAM AND RC WALL

The RC reaction wall has been designed to withstand future extension to 50,000 kN vertical loading capacity with a two-dimensional horizontal exciting plan. The reaction beam has 11 m clear span, the thickness of the reaction walls is 3.50 m, and the foundation thickness is 4.5 m. Prestressing is implemented in the foundation and walls, for preventing cracks in these concrete walls.To allow the expected horizontal movement of the reaction beam, PC strands have been placed in sheath tubes with 190.7 mm diameter. The 11.52 m tall sheath tubes are precisely installed into the RC reaction walls within 1/650 error margin, using template frameworks.

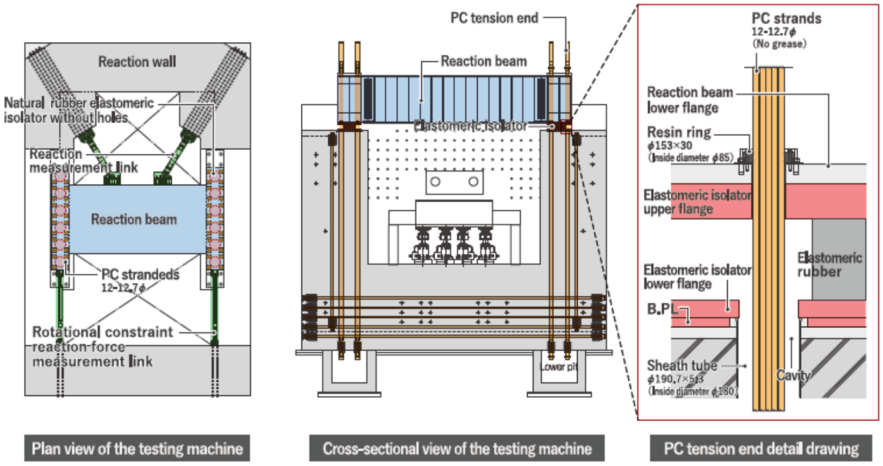

Fig 6 Plan and cross section of the full-scale seismic isolation tester

Fig 7 Pictures of PC Strand during construction and after completion

5. CONCLUSION

Unlike existing facilities in the world, E-Isolation is a high-performance experimental facility that can obtain experimental results in real time. By using this facility, it has become possible to conduct various new experiments, such as hybrid simulations that connect experimental results and analysis in virtual space in real time.

REFERENCES

Yoshikazu Takahashi et al (2023), “E-Isolation--High-performance Dynamic Testing Installation for Seismic Isolation Bearings and Damping Devices” International Journal of High-Rise Buildings March 2023, vol12, No1, 1-13