

Characterizing the Accumulated Displacement of Geogrid under the Cyclic Pullout Loading Considering the Interaction with Soil



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Research Introduction

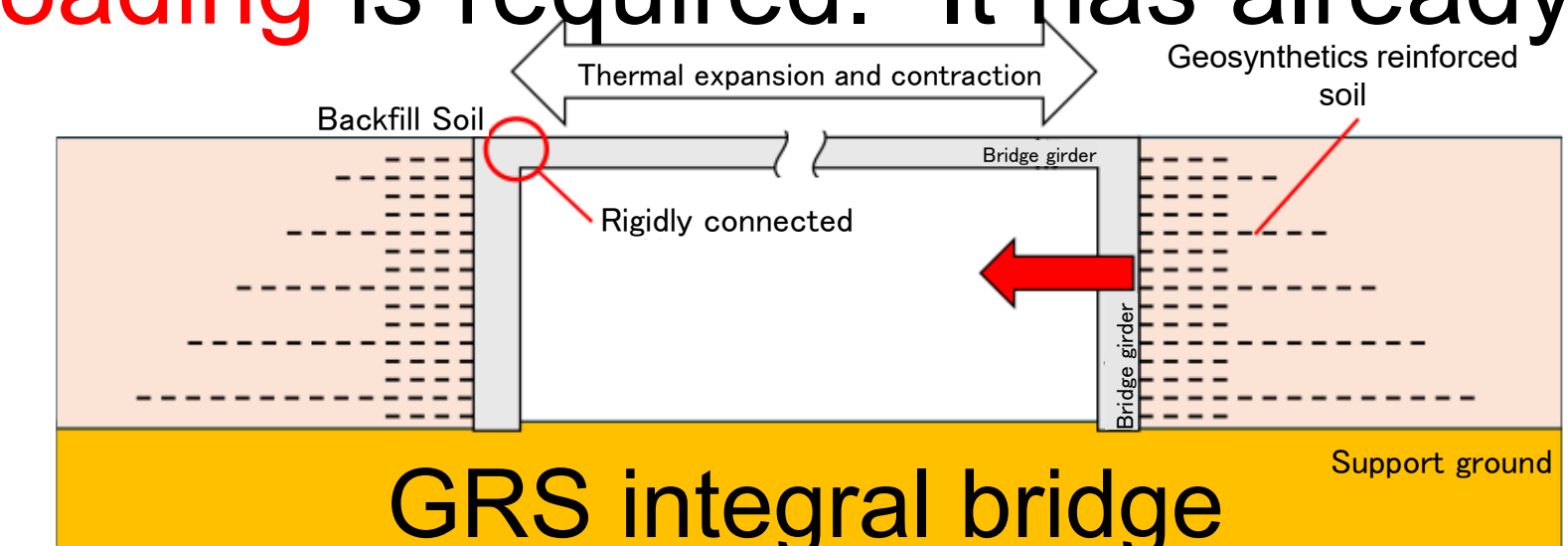
Geosynthetics Reinforced Soil (GRS), which is **widespread in railway structures** due to its high resistance to earthquake, has gradually spread its applicability. In 2016, the first **GRS integral bridge** was opened in Hokkaido Shinkansen. GRS integral bridge has advantages in structural and geotechnical engineering because its girder is rigidly connected to the RC wall and the backfill soil is reinforced by GRS. However, because the **thermal expansion and contraction of the girder** is directly transmitted to the backfill, the knowledge of the **behavior of the geogrid under the cyclic pullout loading** is required. It has already been known that the **pullout displacement accumulates under the cyclic loading, especially with low stiffness geogrid**, but the reason is still unclear.

In this research, **in-isolation test** and **pullout test** are conducted with 2 types of geogrid with different stiffness in order to investigate the characteristics of the accumulation.



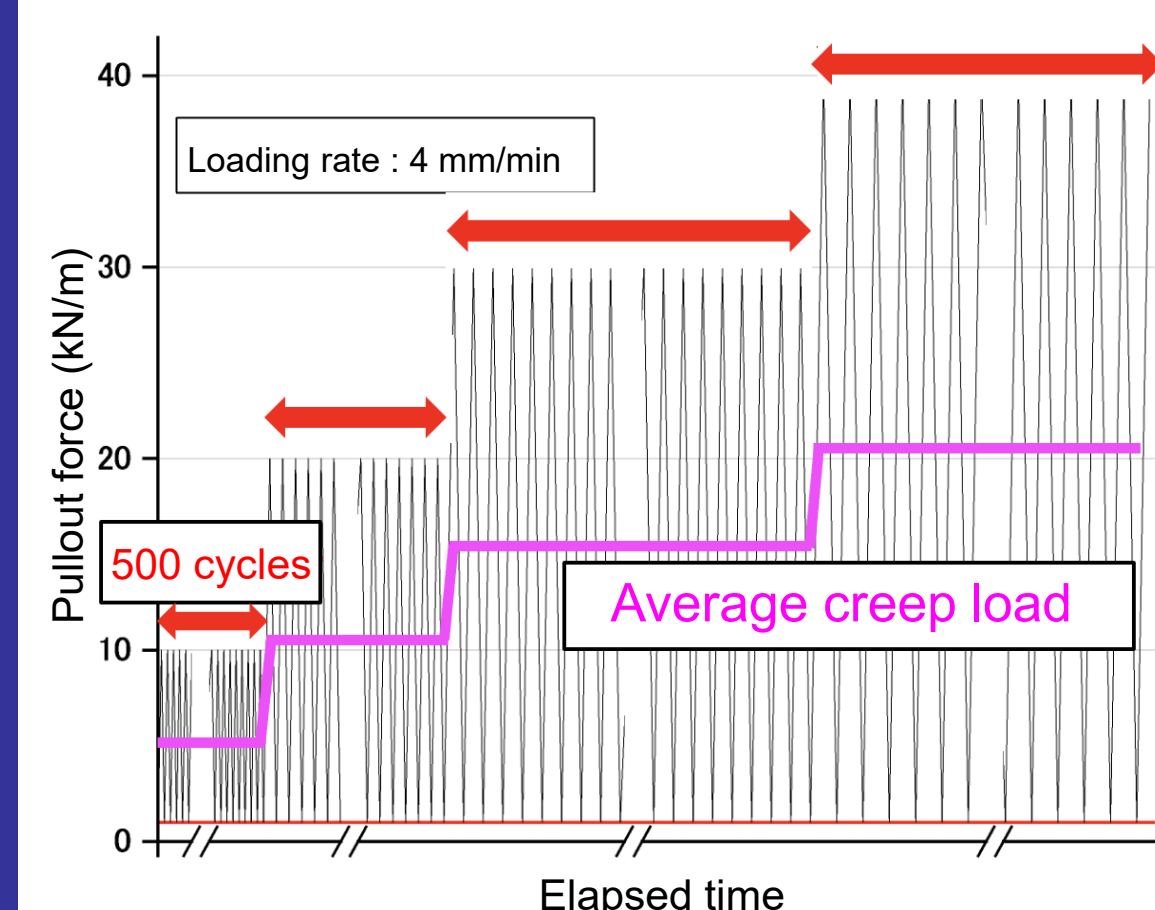
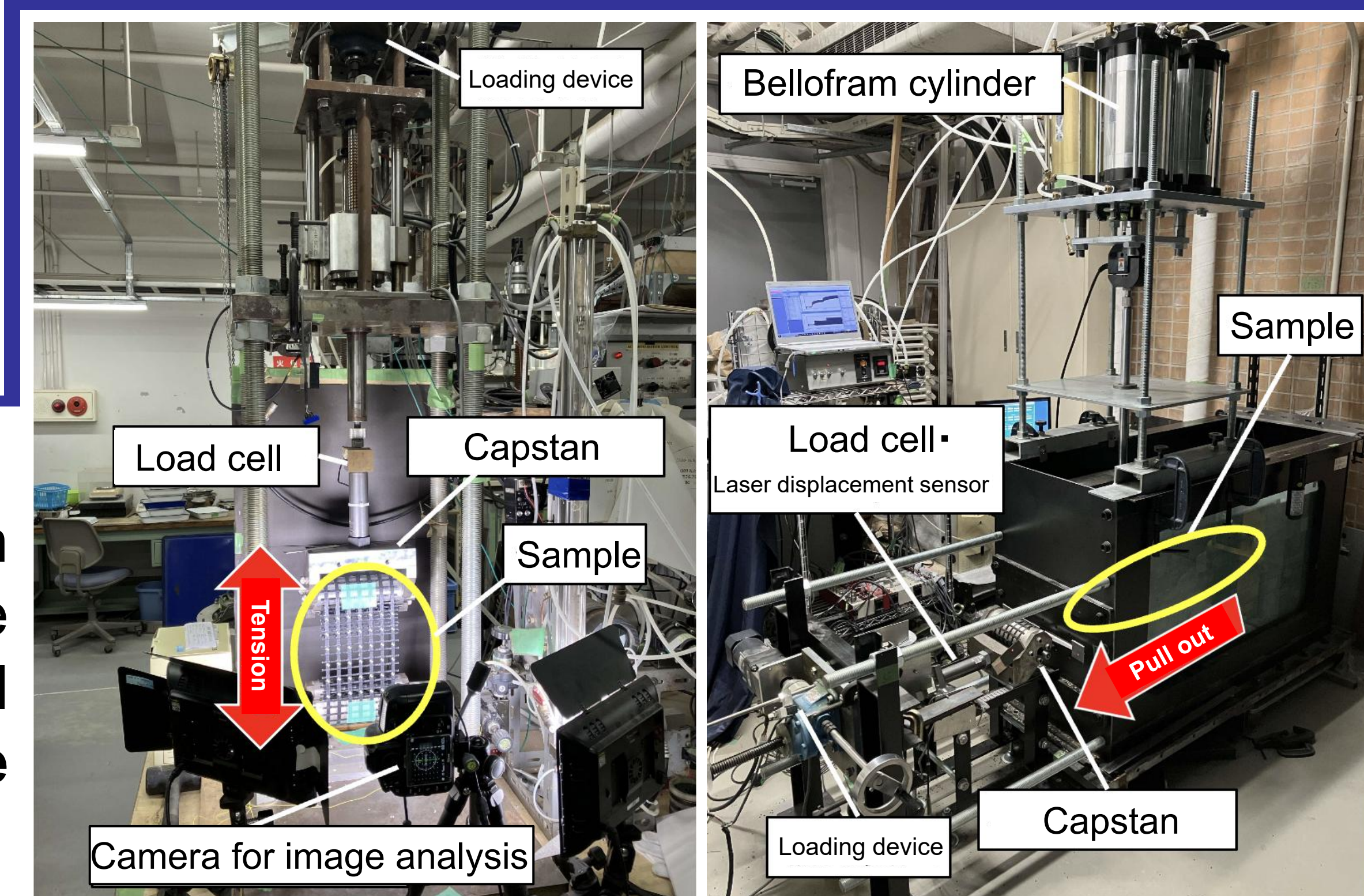
←GRS integral bridge adopted for the restoration of the bridge swept away by tsunami (Haipе-sawa, Iwate)

In-isolation test(left) and Pullout test(right)→



Testing Apparatus and Methodology

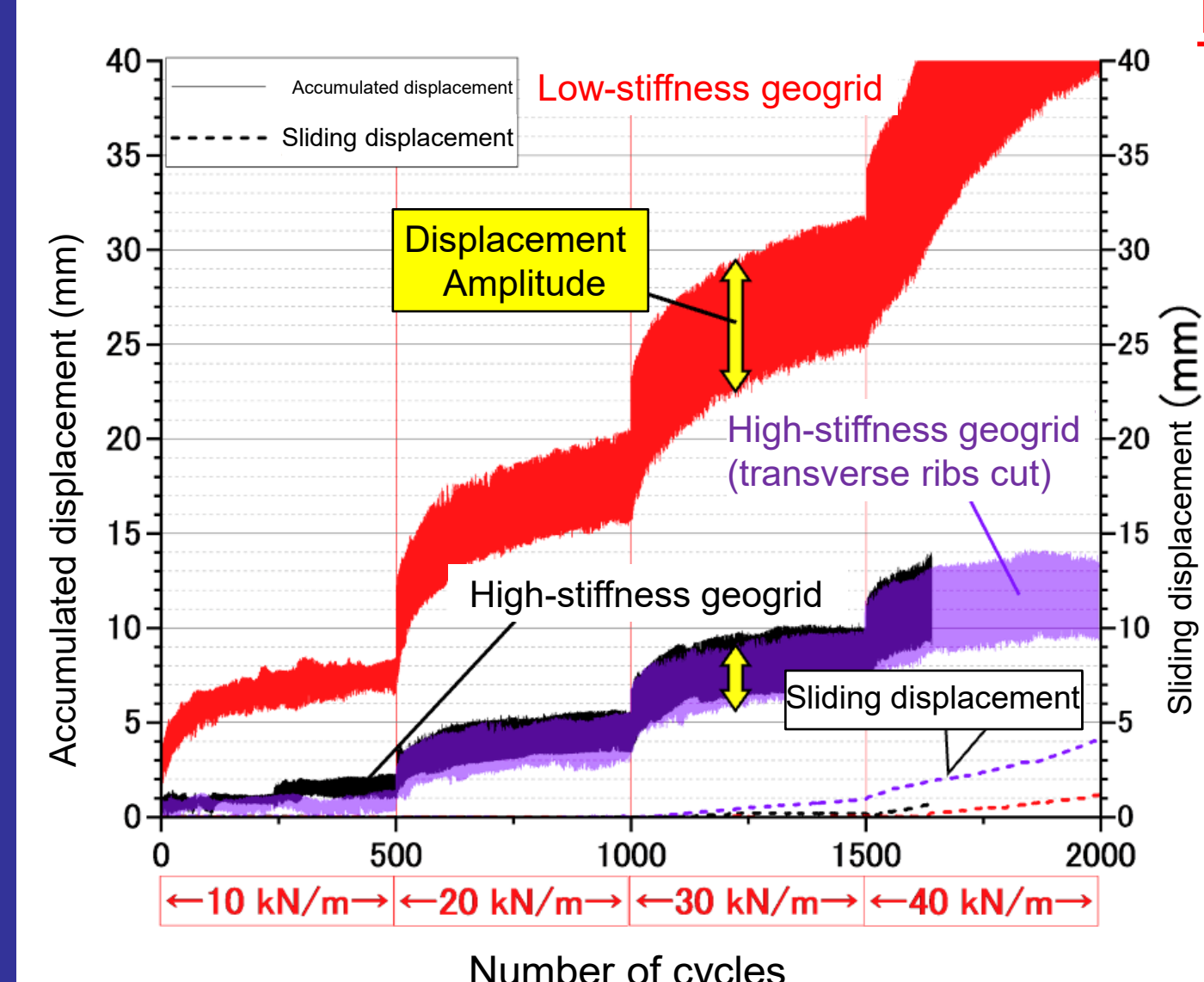
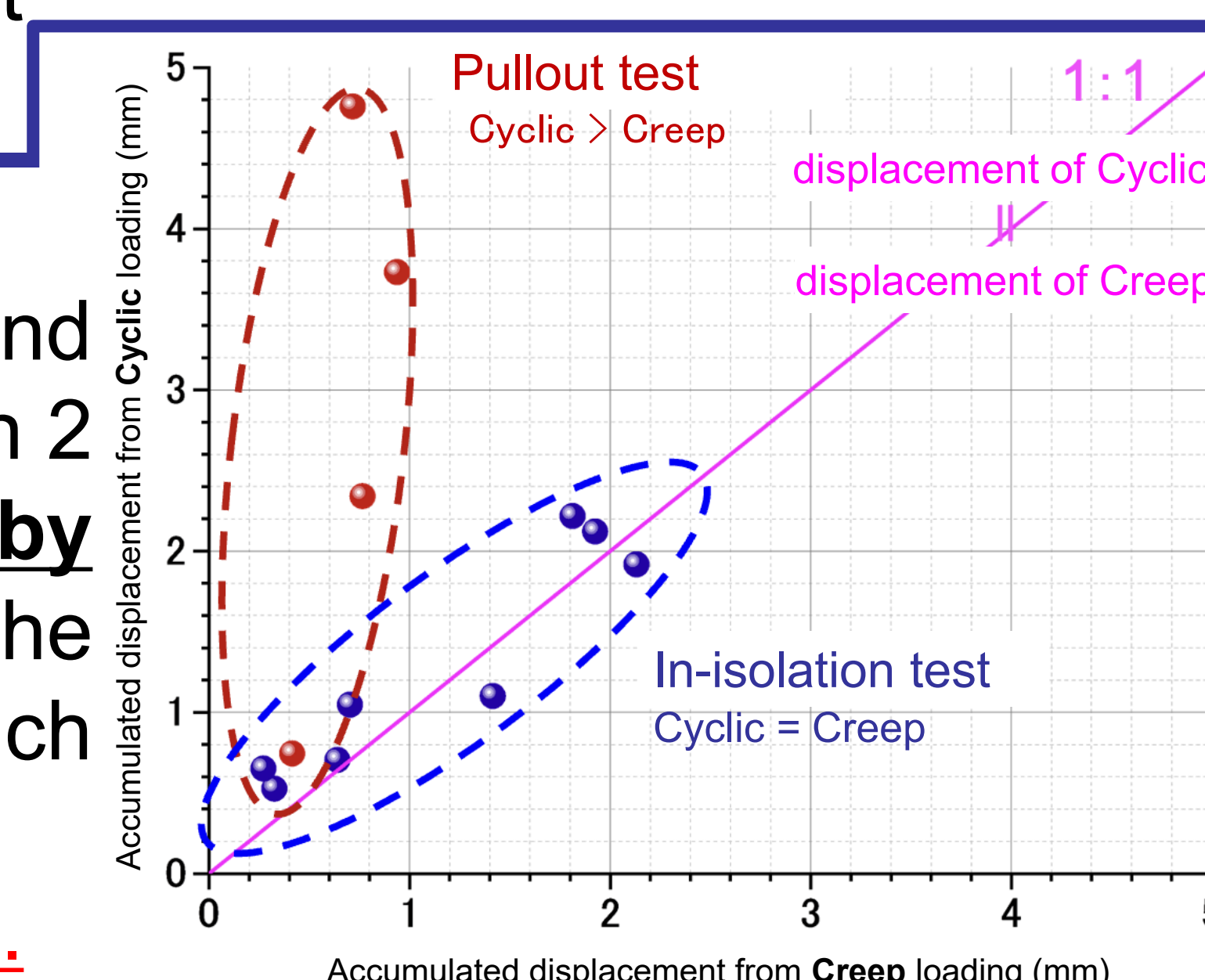
In in-isolation tests, tensile force is applied vertically to the geogrid sample in air, while measuring the strain with image analysis. In pullout tests, pullout force is applied to the sample installed in the model ground under constant vertical confining pressure (60 kPa). To evaluate the **horizontal distribution of the tensile force**, strain gauges are attached to the sample.



Both in-isolation and pullout test are conducted with the same loading pattern. In **cyclic loading tests**, the loading level increased step by step every 500 cycles. In **creep loading tests**, to compare the results with those of cyclic cases, the average force in cyclic tests was applied for the same time duration as the cyclic tests. Cyclic-pullout tests were performed with **high-stiffness geogrid (transvers ribs cut)**, whose 3 transvers ribs are cut per 4 ribs, and **low-stiffness geogrid (Nylon)**. In-isolation and creep cases are carried out with high and low stiffness geogrid.

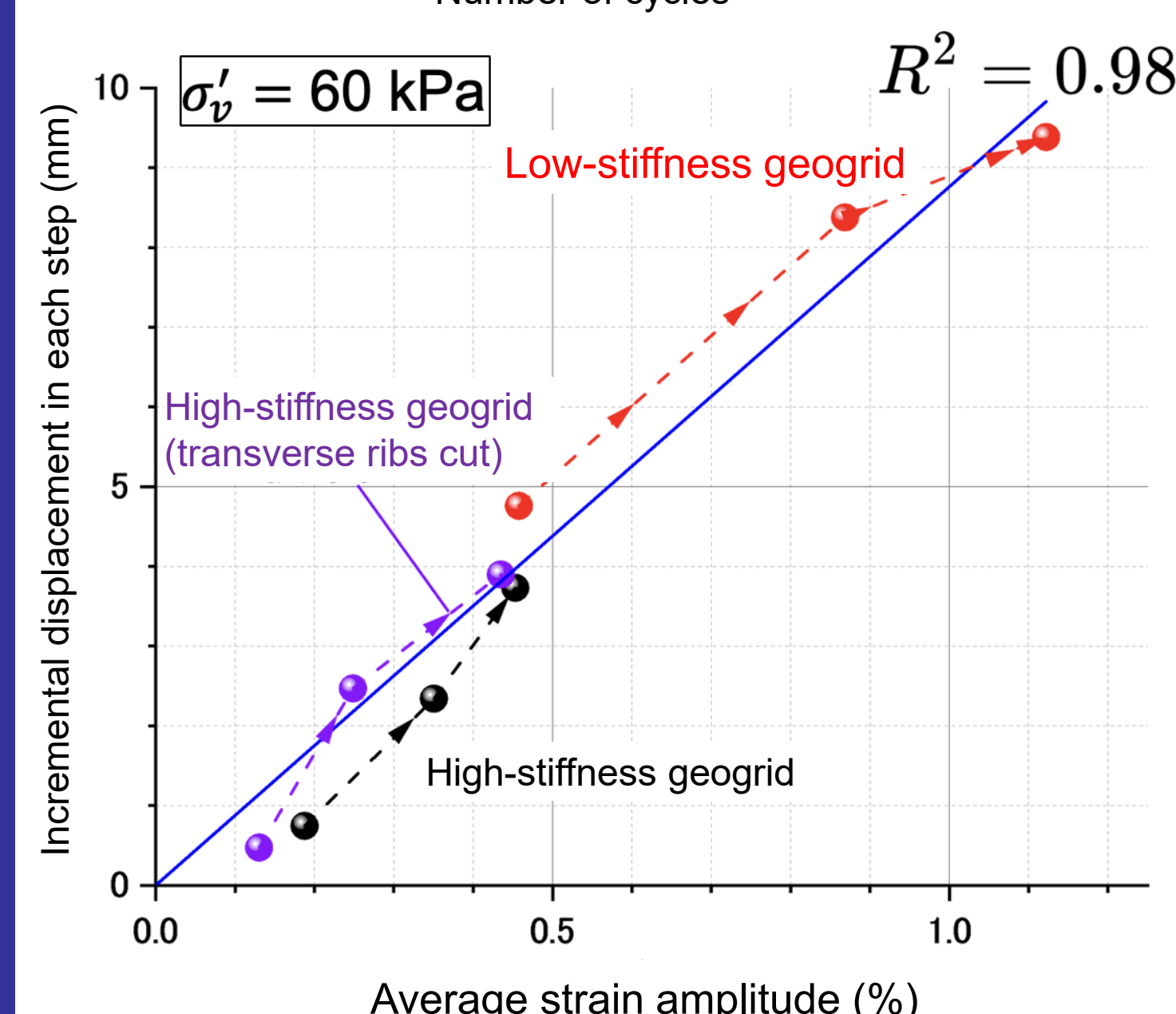
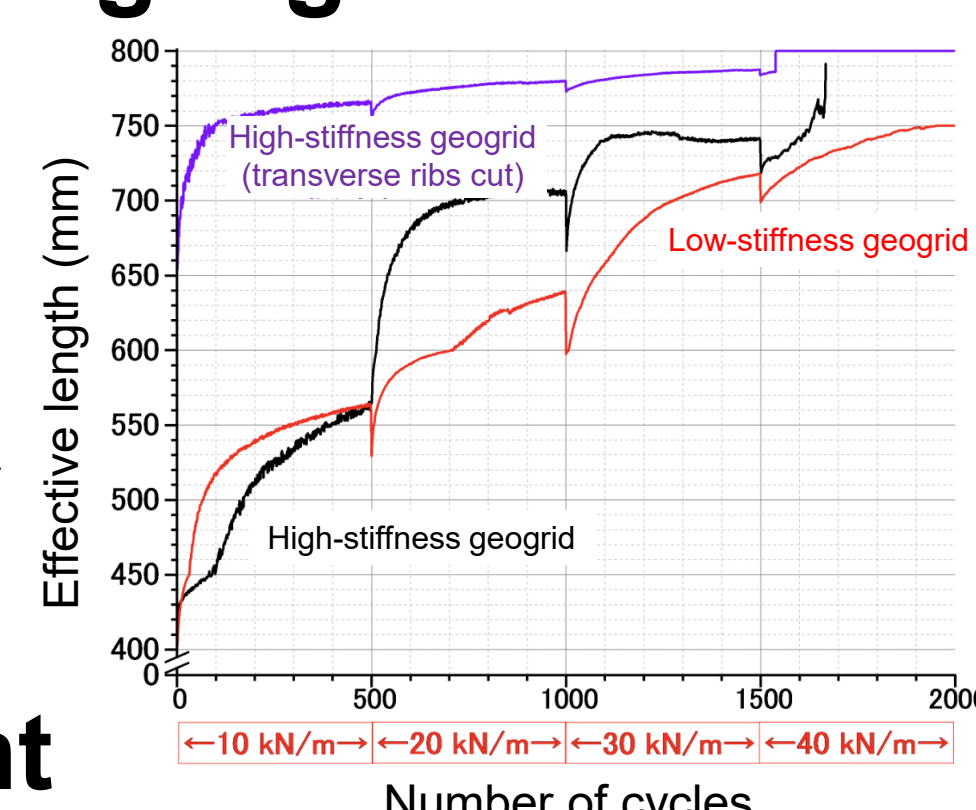
Results and Conclusion

Displacement accumulation was observed in both cyclic and creep loading tests. The right-hand figure shows the comparison between them. The accumulated displacement was almost equal in 2 loading patterns, hence it can be said that **the accumulated displacement in air is caused by the creep effect from the average tensile force of cyclic load**. On the other hand, in the soil, the accumulated displacement was much larger with cyclic loading than with creep loading, which suggests that **the displacement accumulation in the soil mainly comes from the interaction between the geogrid and the soil (not only from the creep effect)**.



The left graph shows the accumulated displacement and tail sliding displacement. From the comparison in the same loading level, **low-stiffness geogrid has shown large accumulation**. In the case with less transvers ribs, while accumulated displacement has not changed a lot, the whole part of geogrid was more likely to slide. Also, **displacement amplitude**, the difference of displacement between loaded and unloaded state, was **larger with low-stiffness geogrid**.

During the cyclic loading, the depth of pullout force transmission also changes. According to the right graph, the **effective length** (the length of the geogrid up to which a tensile force equivalent to 5% of the pullout force reaches, starting from the loading point.) during the cyclic loading is **largely affected by the stiffness and shape of the geogrid**.



Average strain amplitude, which is defined as the **ratio of the displacement amplitude to the effective length**, means **how much the geogrid expands and contracts in the area resisting the pullout force**. Left-side figure shows the relationship between the average strain amplitude and the accumulated displacement in each loading step.

From the results, it is implied that **the characteristic of the displacement accumulation is linearly related with the average strain amplitude regardless of its stiffness and shape**. Therefore, for the practical design, it is important to **adopt stiffer geogrid** in order to **reduce the average strain amplitude** and suppress the displacement accumulation under cyclic loading.

Further study on **the mechanism of the displacement accumulation** is needed.