In-situ Load Test of Press-in Steel Pipe Pile for Seismic Isolation Retrofit

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ABSTRACT

There are several projects with relatively small construction space to retrofit the old building in narrow spaces and areas with low overhead clearance. Pile construction for existing structures to strengthen the seismic resistance such as the seismic isolation retrofit is subjected to constraints on the construction site and process. Furthermore, noise and industrial waste need to be considered with regard to their effects on the surrounding environment. A construction of a seismic isolation retrofit for an old building was planned in Kagawa prefecture, Japan. The compressive load dominates because it is needed to support the dead load of existing building. In this project, a press-in steel pipe pile which supports the existing old building was applied. Appropriate estimation of the bearing capacity of the press-in steel pipe pile against the dead load was a major concern in the foundation design. Therefore, an in-situ compression load test was carried out to confirm the bearing capacity of press-in steel pipe pile. The paper describes the results of in-situ pile load test for foundations supporting an existing building, also presents the empirical design method for a press-in steel pipe pile.

Key words: *Seismic Isolation Retrofit, Building, Press-in Pile, Bearing Capacity, In-situ Load Test*

1. Outline of the project

1.1. Place

A construction of a seismic isolation retrofit for an old building was planned in Kagawa prefecture, Japan. The planned building is located in the center of Takamatsu city, Kagawa prefecture.

1.2. Background and objectives of the project

There are several projects with relatively small construction spaces to retrofit old buildings in narrow spaces and areas with low overhead clearance. Pile construction for existing structures to strengthen the seismic resistance such as the seismic isolation retrofit is subjected to constraints on the construction site and process. Furthermore, noise and industrial waste need to be considered with regard to their effects on the surrounding environment.

In this project, the seismic isolation retrofit will be carried out as the building is being used before the retrofit construction. Thus, the temporary pile supports the building after the excavation under the building. The schematic view of press-in process for the in-situ load test indicates in **Fig. 1**.

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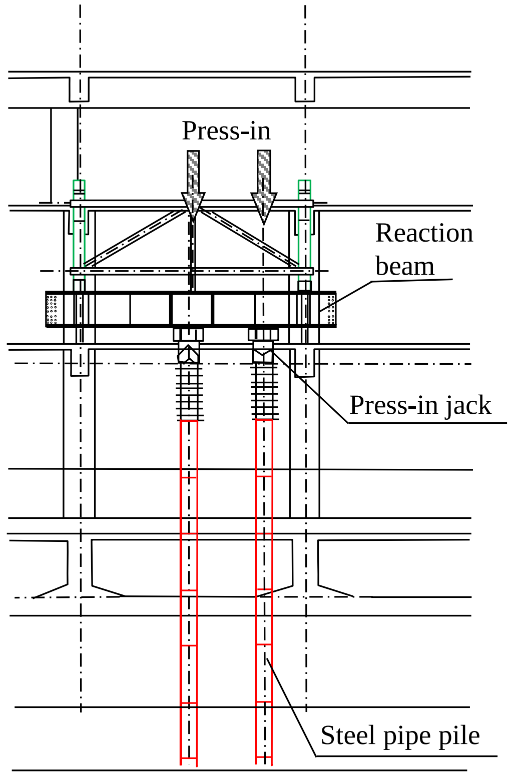


Fig. 1 Schematic view of press-in process

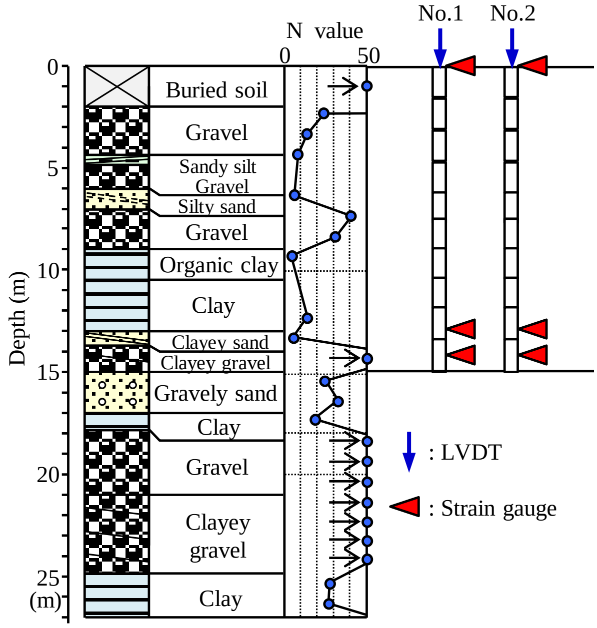


Fig. 2 Soil profile and test piles

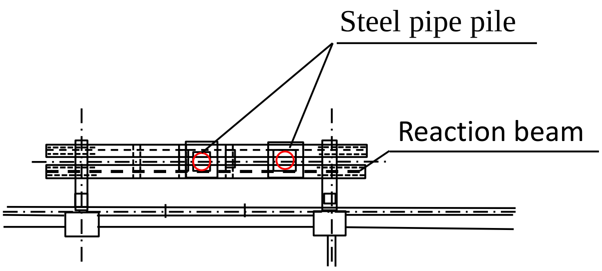


Fig. 3 Arrangement of test piles and reaction beam

2. Structural type and piling method

2.1. Site condition

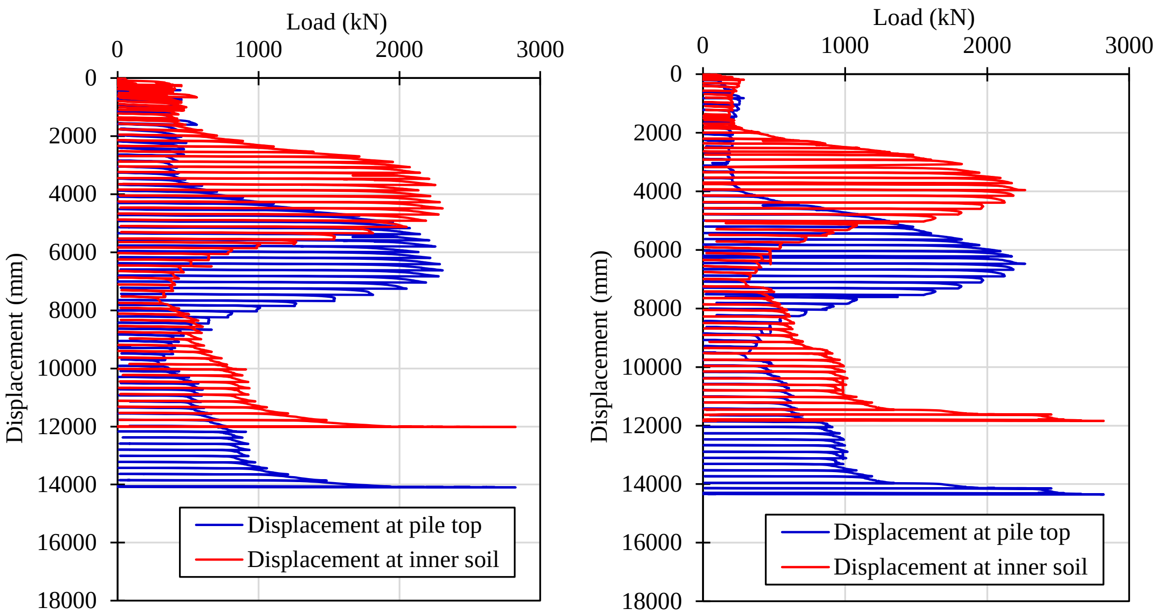
There are some buildings such as offices and apartment buildings near the planned building. The construction condition of seismic retrofit construction required consideration for the neighboring environment. Therefore, noise, vibration and industrial waste need to be considered with regard to the construction of pile construction.

2.2. Ground condition

Fig. 2 shows the soil profile and test pile. The test ground was composed of gravel and silty sand up to about GL −9.0m, of organic clay and clay from GL -9.0 to 12.0m, and of gravely sand and gravel below GL -12.0m. The bearing stratum was adopted to be N=50 from the results of ground investigation. The test piles were embedded in the bearing stratum of SPT N value of 50.

2.3. Structural type

The test steel pipe pile had a diameter of 0.4m in axial part. The pile base sat on the gravel layer below 15.0m depth. However, the ground surface is located at GL -1.0m because the load tests were carried out at the basement floor of existing building. Thus, the actual pile length is 14.0m. The reaction beam system was employed to apply loads on the test pile by using the existing building structure. The test pile consisted of 1.5m length steel pipe pile which was connected 15.0m length. The welded joints were applied to the steel pipe pile joints when the upper pile was connected to the lower pile. Because the piles constructed with this method were assumed to be for construction in narrow spaces, the steel pipes were joined by short pieces into lengths of 1.5 m. In order to make such short joints, there should be a welded part with a pitch of 1.5m. The piles were used to be fabricated from JIS standard STK400 steel pipe to ensure a low cost and certain level of quality.



(a) Test pile: No. 1 (b) Test pile: No. 2

Fig. 4 Relationships between load and displacement in press-in process

2.4. Piling method

The standard press-in steel pile method was applied to the construction of test pile because it was assumed that the pile would be constructed under the basement of existing building. The existing building is used to the reaction when the press-in of pile is carried out. Because there is possibility to break the soil plug inside steel pipe pile, the water jet technology is not applied to the construction of test piles.

3. Press-in piling

3.1. Layout

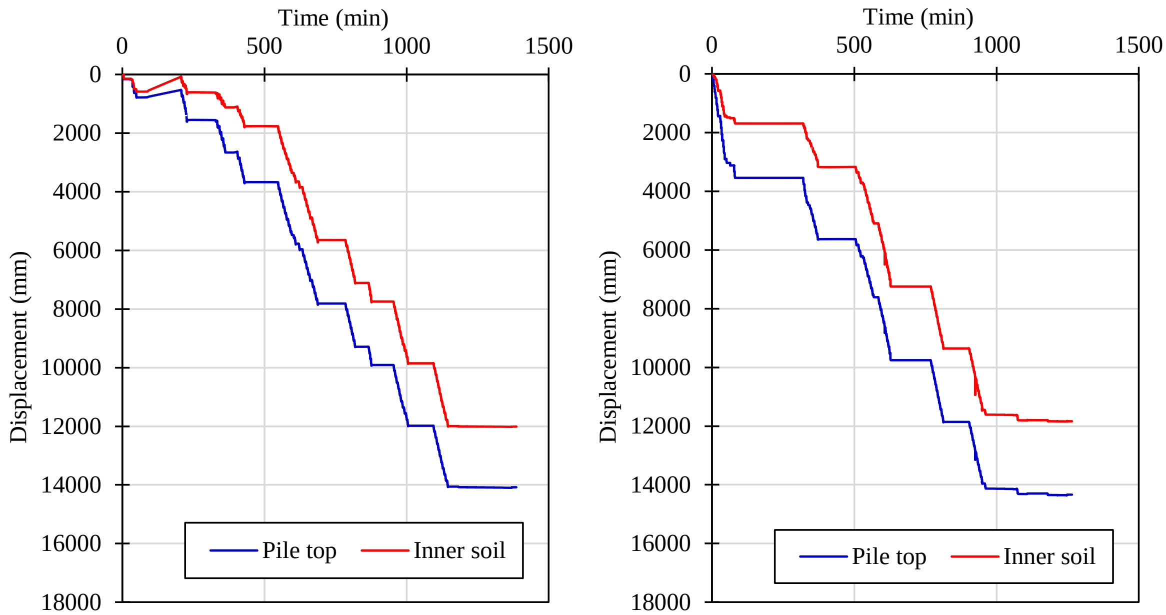
Fig. 3 shows the arrangement of the test and reaction piles. The influence range for the each test piles conformed to the Japanese Geotechnical Society standard (2001). Specifically, each test piles were separated by 3 times the pile diameter.

3.2. Piling data

The relationships between the load and the displacement in press-in process are shown in **Fig. 4**. According to **Fig. 4**, the both piles are inserted into the gravel soil layer which is located at depth below GL-14.0m. Moreover, the press-in load increases when the test piles reach the depth of GL -7.0m. This is due to the stiff gravel soil which is located at the GL-6.0~8.0m. The difference of displacement between the pile top and the inner soil means the plugging effect in the steel pipe pile. Thus, it is said that the inner part of steel pipe pile was partially plugged during the installation process.

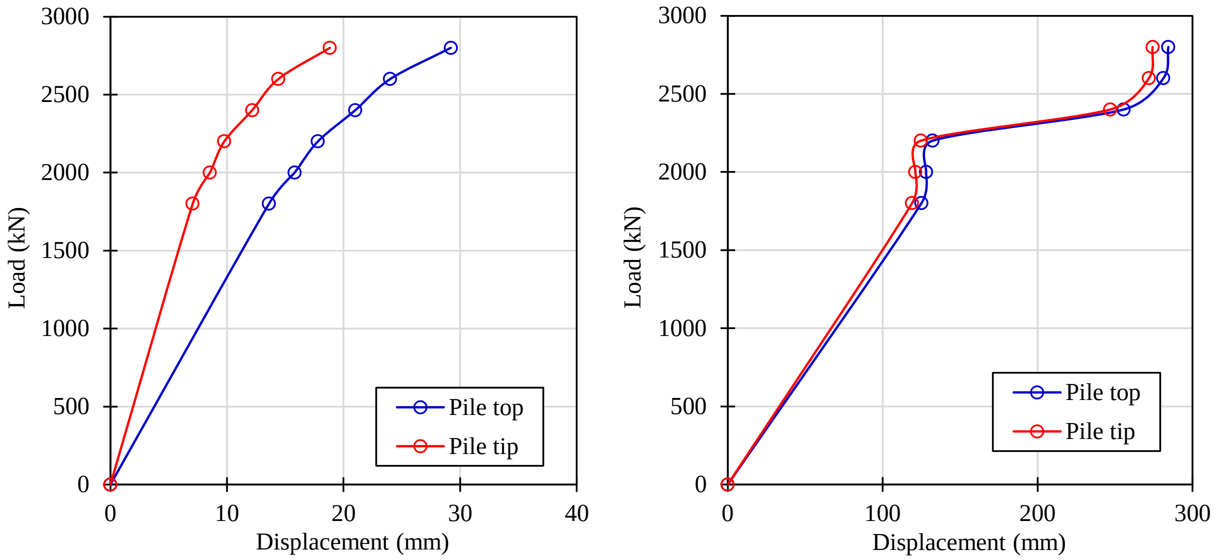
The data obtained by the press-in process which indicates the relations between displacement and time are shown in **Fig. 5**. These data provides the creep displacement in the press-in process. From **Fig. 5**, the displacement slightly increases in the initial press-in process such as the depth of GL-2.0m when the press-in load holds. However, it is found that the creep displacement does not occur as the press-in process proceeds.

The static load tests were carried out after the press-in of steel pipe pile until the gravel soil layer which is predetermined depth of GL -15.0m. The static load tests were carried out based on the standards of the Japanese Geotechnical Society ("Methods for vertical load test of piles") (2001). A stepwise multi-cycle loading system was employed with a new load holding period of 30min, hysteretic load holding duration of 2min, and zero load holding duration of 2min. The measured parameters were the pile top load, displacement at pile top, and strain of the steel pipe. The pile tip displacement was calculated by the displacement at pile top and strain of steel pipe.



(a) Test pile: No. 1 (b) Test pile: No. 2

Fig. 5 Relationships between displacement and time in press-in process



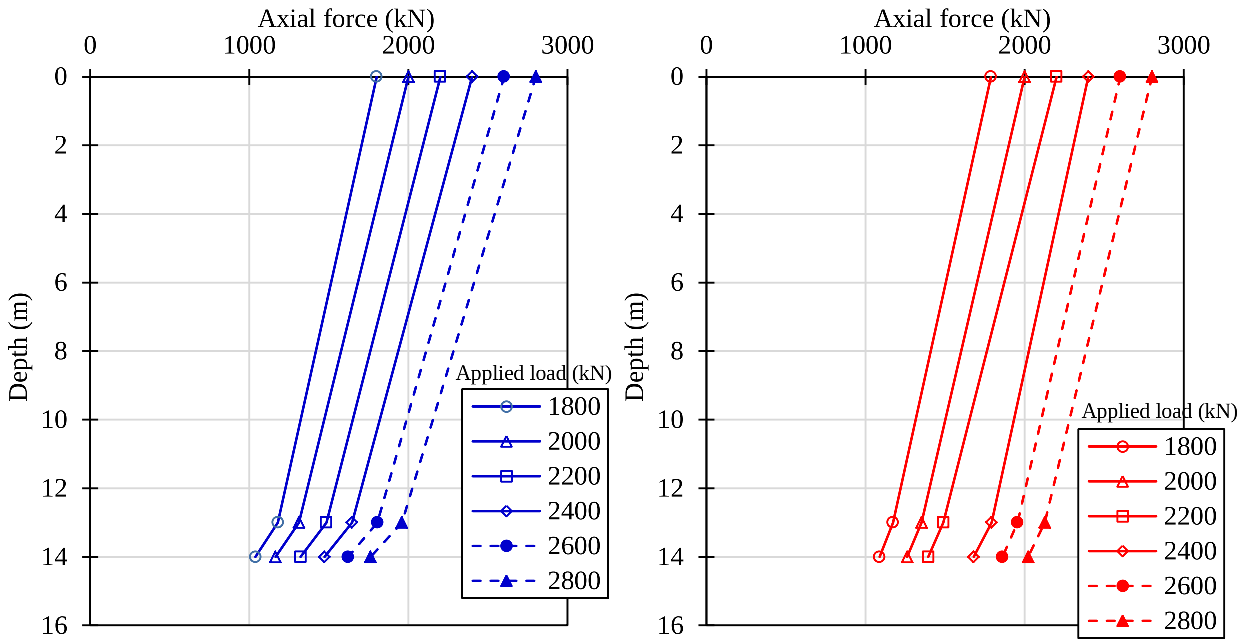
(a) Test pile: No. 1 (b) Test pile: No. 2

Fig. 6 Relationships between load and displacement in load tests process

Fig. 6 indicates the relationships between load and displacement at pile top and pile tip. The displacement at pile tip is the calculated value although the displacement at pile top is the measured value. The load and stiffness increase as the displacement increases. This trend is noticeable in test pile No.1. In test pile No. 2, the large displacement occurs in the load test. This is believed to be due to the influence of inhomogeneity for the gravelly sand layer which is located below GL -15.0m to -17.0m.

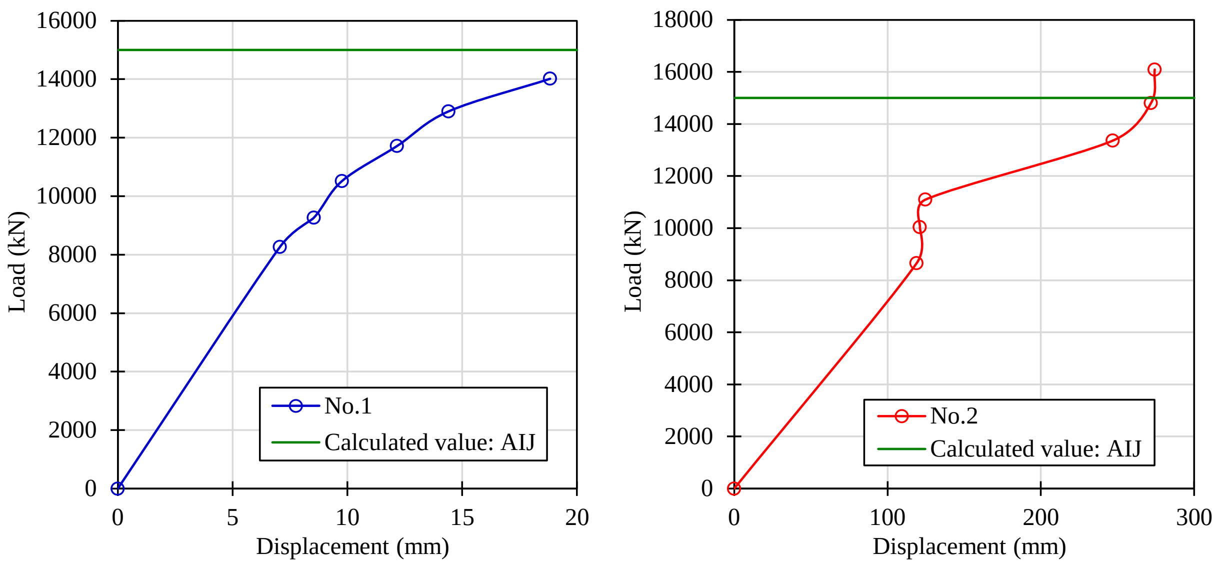
Axial force distribution in load tests process is presented in **Fig. 7**. The axial force was calculated by considering only the steel pipe; the strain of the steel pipe obtained from the test was multiplied with the Young's modulus and cross-sectional area of the steel pipe. For the both test piles, the axial force reaching the pile tip increased with the applied load. Furthermore, the difference of axial force from pile top to pile tip shows the large value. It is said that the shaft resistance increases as the applied load increases. Thus, the shaft resistance contributes to the pile resistance although these piles except to calculate only the pile tip resistance in the practical engineering because the shaft resistance is small between the pile and the soil.

Fig. 8 shows the relationships between the bearing capacity and the displacement at pile tip. The bearing capacity was calculated by dividing the axial force reaching the pile tip as shown in **Fig. 8** by the area of the steel pipe. If the reference displacement at pile tip is 10% of the steel pipe diameter (i.e., the reference displacement is maximum displacement when the displacement does not reach the reference displacement), the test pile of No. 1 showed the large bearing capacity of 14000kN/m^2, and the test pile of No. 2 showed the small bearing capacity of 3000kN/m^2. This means that the bearing capacity of test pile No. 2 is affected by the weak soil layer which is located below the bearing stratum.



(a) Test pile: No. 1 (b) Test pile: No. 2

Fig. 7 Axial force distribution in load tests process



(a) Test pile: No. 1 (b) Test pile: No. 2

Fig. 8 Relationships between bearing capacity and displacement at pile tip in load tests process

However, the maximum bearing capacity in the test pile of No. 2 exhibits 15000kN/m^2. The evaluation formula of end bearing capacity as shown in Eq. (1) for the driving pile is proposed by the Architecture Institute Japan.

$$q_p = 300\overline{N} \qquad (1)$$

Where, q_p: End bearing capacity for sandy soil (kN/m^2) and $\overline{N}$: Average SPT N value near pile tip

A comparison of **Fig. 8(a)** with the value calculated by the evaluation formula for end bearing capacity shows that the tested piles tend to show the almost same value in the pile tip displacement of 0.1D or the maximum bearing capacity. Thus, it may be concluded that the bearing capacity at pile tip is evaluated by the calculated formula for the driven pile proposed by Recommendation for Design of Building Foundations (2001).

3.3. Productivity

This paper describes the load test to evaluate the bearing capacity for the press-in construction method. Thus, two press-in piles were constructed in the site to carry out the load tests. Two days (i.e. 16 hours = 8 hours/day x 2 days) were spent to construct one press-in pile. It can be said that the press-in speed is almost 1.0m/hours.

3.4. Encountered difficulties

The press-in load shows the large value as shown in **Fig. 4** when the steel pipe pile reaches the middle section of gravel soil layer in the press-in process. It is needed to use the water jet technology to insert the steel pipe pile. However, there is a possibility to disturb the soil plug when the water jet method is used. Therefore, in this project, the water jet method is not applied to construct the pile.

4. Concluding remarks

Pile construction for existing structures to strengthen the seismic resistance such as the seismic isolation retrofit is subjected to constraints on the construction site and process. The construction of a seismic isolation retrofit for an old building was planned in Kagawa prefecture, Japan. The compressive load dominates because it was needed to support the dead load of existing building. In this project, a press-in steel pipe pile which supports the existing old building was applied. In this study, the in-situ compression load test were carried out to confirm the bearing capacity of press-in steel pipe pile. The following findings were obtained from this study.

1) The construction of test piles was completed by using only the basic press-in method. Thus, the water jet method was not applied in this study.

2) The press-in load increased as the steel pipe pile was inserted at the deeper depth. And the soil plugging effect was confirmed in the press-in process.

3) The creep displacement did not occur in the press-in process.

4) From the results of load tests after the press-in process, the bearing capacity almost showed the same value compared to the calculated value which was obtained by the evaluation formula for the driven pile.

5. Acknowledgements

We appreciate the member of work office in this project when the load tests were carried out.

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