NTNU

Norwegian University of Science and Technology

GEOTHERMAL DHC

Towards Decarbonized Heating and Cooling!

Driven Geothermal Energy Pile: An Innovative Solution for Heating/Cooling

1. Introduction

Geothermal energy piles are deep foundations primarily used to support a building and can be used as ground heat exchangers for heating/cooling a building. There are three types of energy piles: (a) bored piles, (b) continuous flight auger (CFA) piles, (c) driven piles. Bored and CFA piles are cast in place piles and have been used as energy piles, while driven piles are precasted at a concrete factory and have been limitedly utilized as energy piles. Recently, we have developed an innovative solution that makes it easier for driven piles to be used as energy piles. There were challenges in the past with driven piles to place heat exchanging (HE) loops and maintain their continuity through the pile joint which is commonly used to connect pile segments. Driven piles are casted in a factory in lengths of 12 to 15 m segments as there are limitations with transportation of longer segments to a site. This study presents the development of novel and innovative driven energy pile joint which is ready to be used as a commercial product in the construction industry.

2. Driven energy pile (DEP) Joint

Steel Joints for normal piles have been modified to accommodate the heat exchanging (HE) loops by having side wall channels, which are covered by a shielding plate at the end. DEP joints come in two sizes of 270 mm (single loop) and 350 mm (double loops), as shown in Fig. 1.

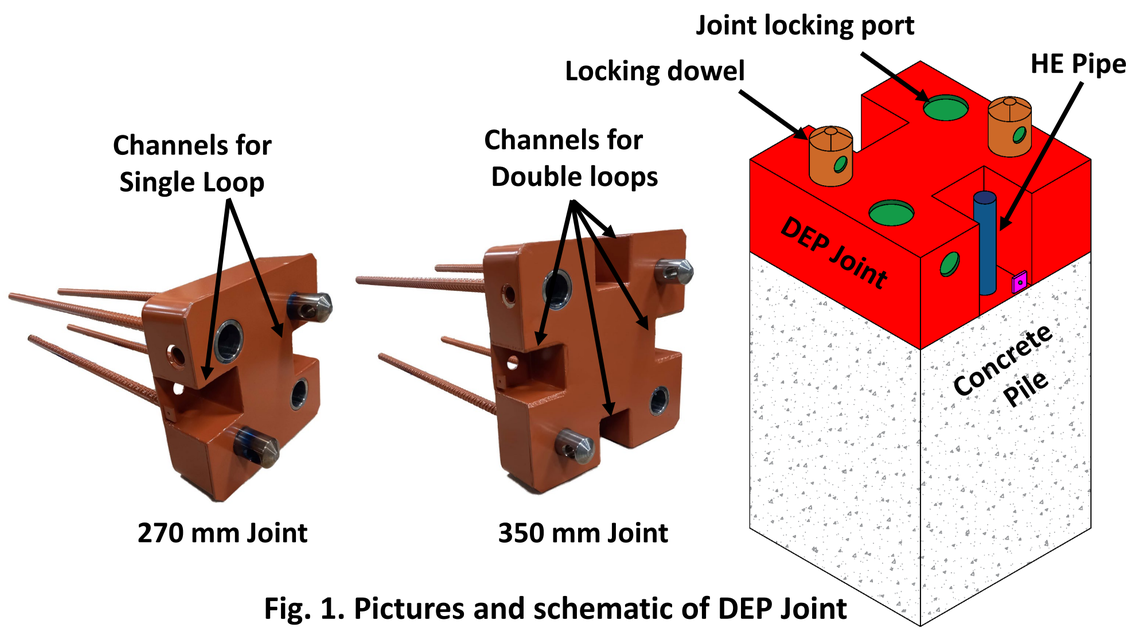

Fig. 1. Pictures and schematic of DEP Joint

3. Casting of Driven energy piles

HE loops are connected to the cage and are extended out of the pile segments through DEP Joints and finally embedded inside concrete as shown in Fig. 2. DEP Joints are held by casting guides in the middle.

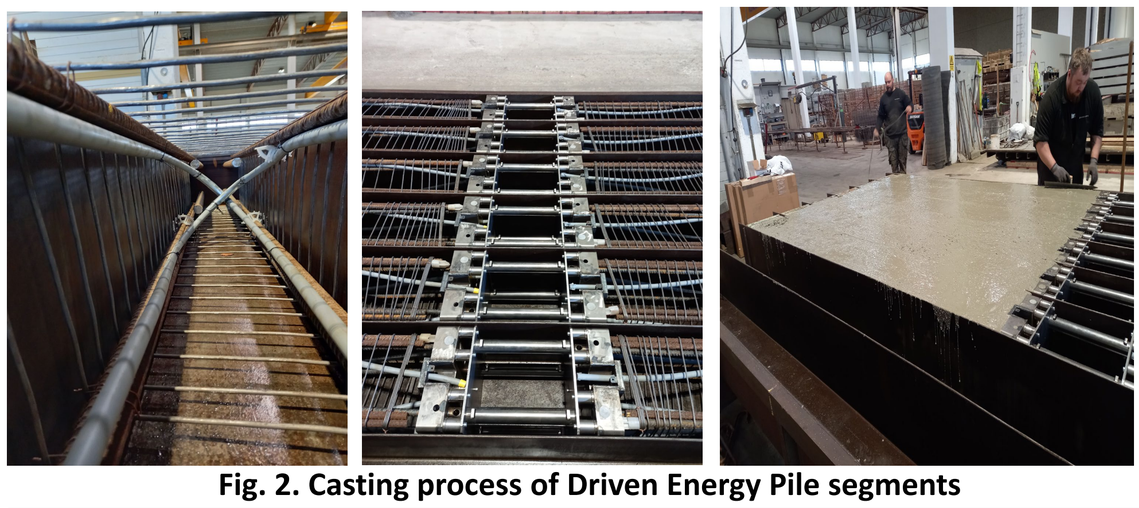

Fig. 2. Casting process of Driven Energy Pile segments

4. Impact test

Fig. 3 shows DEP Joint and HE pipes before & after connecting 2 segments. Pipes are connected using standard fittings, and joints are connected using steel pins.

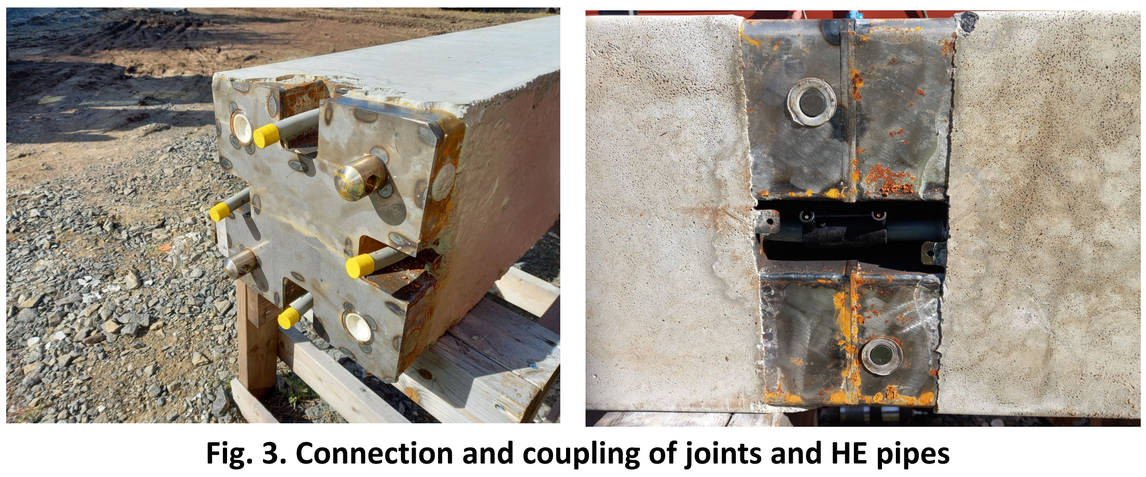

Fig. 3. Connection and coupling of joints and HE pipes

In order to test the robustness of steel DEP joints, 3 piles should be tested for impact and bending, according to the BS EN 12794 standard. The first part of these structural integrity tests includes applying 1000 impacts which impose a minimum stress of 28 MPa. Fig. 4 shows the Impact test setup with Pile Driving Analyser (PDA) measurements. During the impact tests, the concrete pile segments and joint should remain undamaged and later the same pile segments are testing for bending.

Fig. 4. Impact test with PDA measurements

5. Hydraulic Pressure tests

After the impact tests, the HE loops were pressurized to make sure that they remained leak-proof during and after the harsh impact load tests. The pressurizing was done according to the ASTM F2164–21. During the hydraulic pressure tests, the pipes were pressurized with water up to 100 psi (689 kPa) for 90 minutes and no leakage or pressure drop was observed in none of the piles. The hydraulic pressure test setup is shown in Fig. 5.

Fig. 5. Hydraulic pressure test

6. Bending Tests

The piles that were tested for impact and hydraulic pressure, were then cut into a length which provides slenderness ratio of 11 recommended by BS EN 12794 standard. Then the piles were tested for measuring the bending capacity by applying two point loads as shown in Fig. 6. The bending tests show that the joints remained undeformed and the ultimate capacity of the joints was larger than the capacity of the concrete pile segments as expected and also required by standard. It can be observed that the concrete failed around the joint but the joint was not affected.

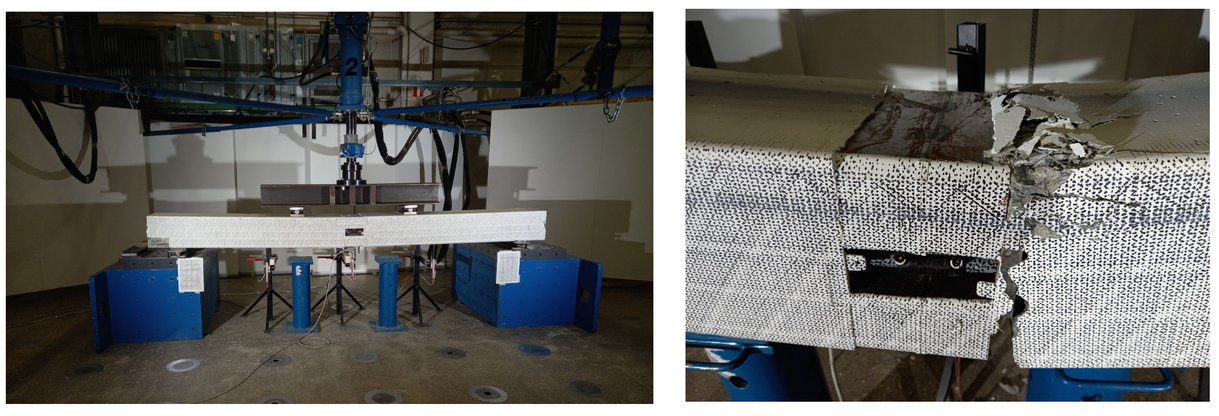

Fig. 6. Bending test

7. Conclusions

This study presents a novel and innovative steel joint designed to connect driven geothermal energy pile segments. The joint allows single and double heat exchanging (HE) loops to pass through the precast concrete pile segments. The major conclusions of the present study are:

1. The pile segments connected by DEP Joints passed the impact tests successfully when subjected to 1000 blows.
2. The pipes remained intact and leak-proof during the harsh impact test loads. This was tested by applying a pressure of 100 psi to the HE pipes.
3. The bending tests show that the joints are robust and have enough bending capacity to connect precast concrete pile segments. The joints remained undamaged after the bending test.

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