Institute of Geotechnics

GEOLAB Blind Prediction Contest

Report on Pile Calibration

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1 Introduction

In the context of GEOLAB project, a series of pile tests will be conducted at the geotechnical testing pit of the Institute of Geotechnics at the Technical University of Darmstadt. These experiments involve subjecting the steel pile to horizontal loading. The pile is equipped with a total of 16 strain gauges, distributed along its length, to capture the bending moments and strains during the experimental tests. To accurately analyse the experimental data the strain gauges should be properly calibrated. The calibration process of the strain gauges is carried out by performing three-point flexural test on the pile.

2 Model Test

The objective of the experiment was to calibrate strain gauges for accurate measurement of the strains in the pile to be used in upcoming pile tests with lateral loading. The pile used in the experiment was made up of steel sheet of grade 235 (the material properties are summarised in Table 1). The pile has a thickness of 5.25 mm and the inner diameter of 314.40 mm. The pile was supported by two supports located at 200 mm and 2700 mm from the left side of the pile (Figure 1). To properly understand the deformation behaviour of the pile, sixteen strain gauges were used at the top and bottom of the pile, as shown in Figure 2. A monotonic load of 90 kN (Figure 3) was applied at the centre of the pile. The loading rate was 0.5 kN/minute. The results are recorded in terms of strains at the top and bottom of the pile using strain gauges (DMS), as well as the deformation at the top of the pile using Linear Variable Differential Transformers (LVDT). It should be noted that deformation at the centre was measured with the hydraulic jack which is also represented as a LVDT 2 in Figure 2.

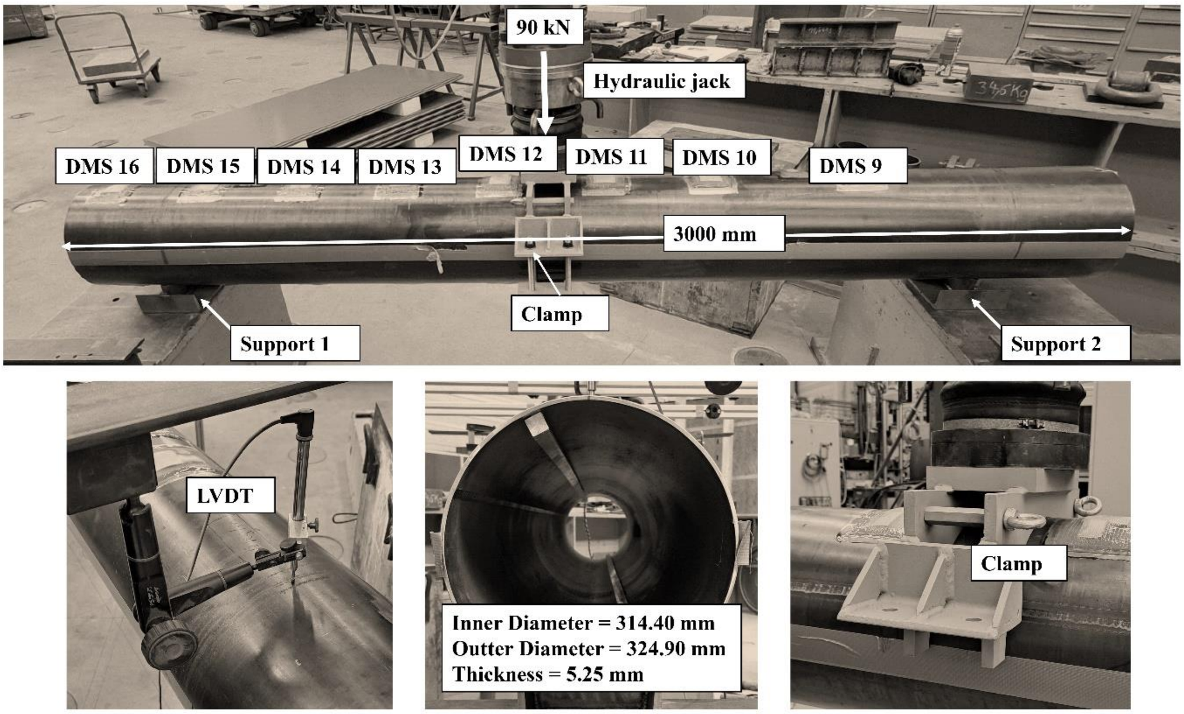

Figure 1. Experimental Setup

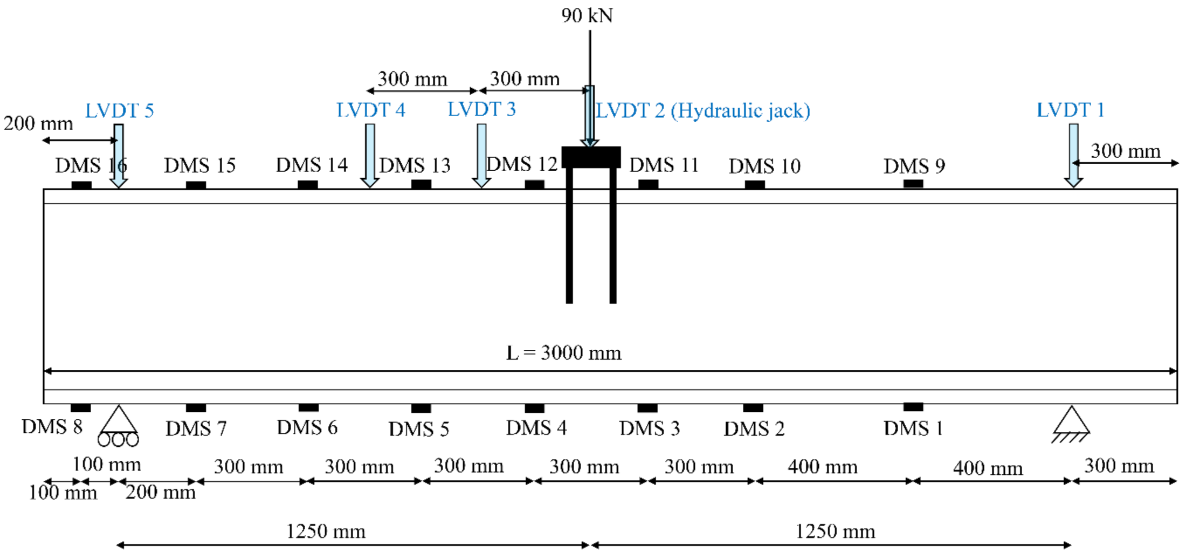

Figure 2. Schematic representation of the testing setup and instrumentation.

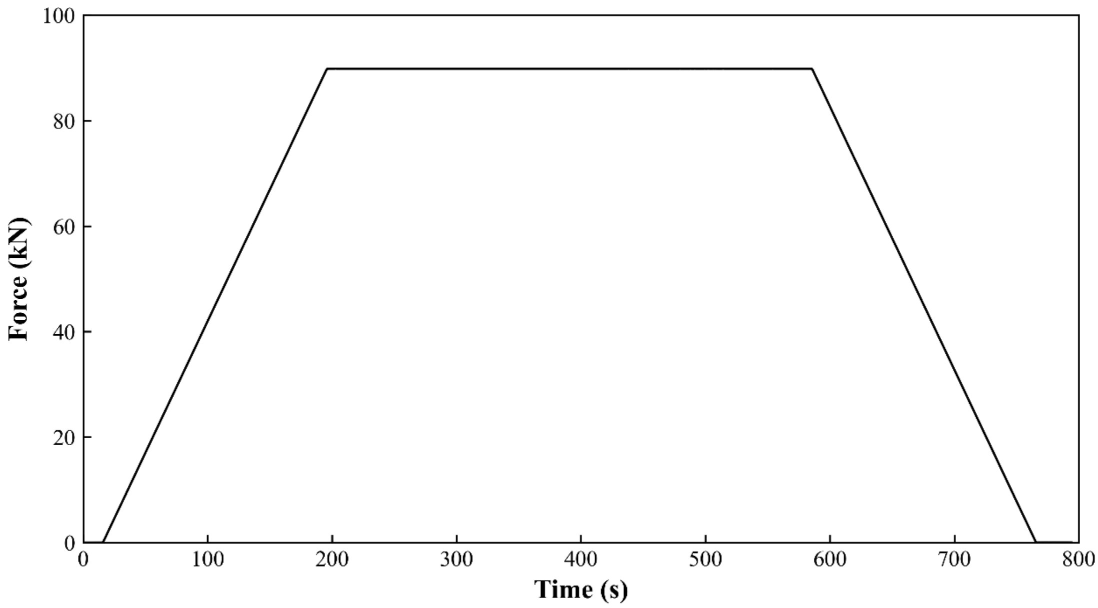

Figure 3. Loading applied at the top of the pile

Table 1: Standard material properties of Steel 235 according to Eurocode 3.

Material Property	**Value**
Density	78.5 kN/m^3
Modulus of elasticity	210000 MPa
Poisson's ratio	0.3
Surface contact (friction coefficient)	0.35

3 Abaqus Simulations

Finite element (FE) simulations were carried out using Abaqus software to provide an additional plausibility check on the measured strains and therefore the installed strain gauges. Figure 4 shows the developed three-dimensional FE model, including the location of loading, supports, clamp and boundary conditions. The pile was discretized using C3D20R elements, which are 20-noded quadratic brick elements with reduced integration. The clamp has a circular shape and was discretized using 15-noded C3D15 quadratic triangular prismatic elements (Figure 5). The material parameters were adopted from Eurocode 3 and are detailed in Table 1. It is worth noting that the experiment was conducted within the elastic range. As a result, the simulation was performed only up to the maximum loading (the simulation will stop once the loading reaches 90 kN). Figure 6 illustrates the specific points where strains and deformations were analysed in the finite element analysis.

To prevent the horizontal displacements of the pile, it was fixed (in the x and z directions) at the top center of the pile. It's noteworthy to mention that developing a satisfactory connection between the pile and the supports was numerically challenging. Therefore, it was decided to fix the pile in the vertical direction (y-direction) at the contact areas between the supports and the pile in the experiment.

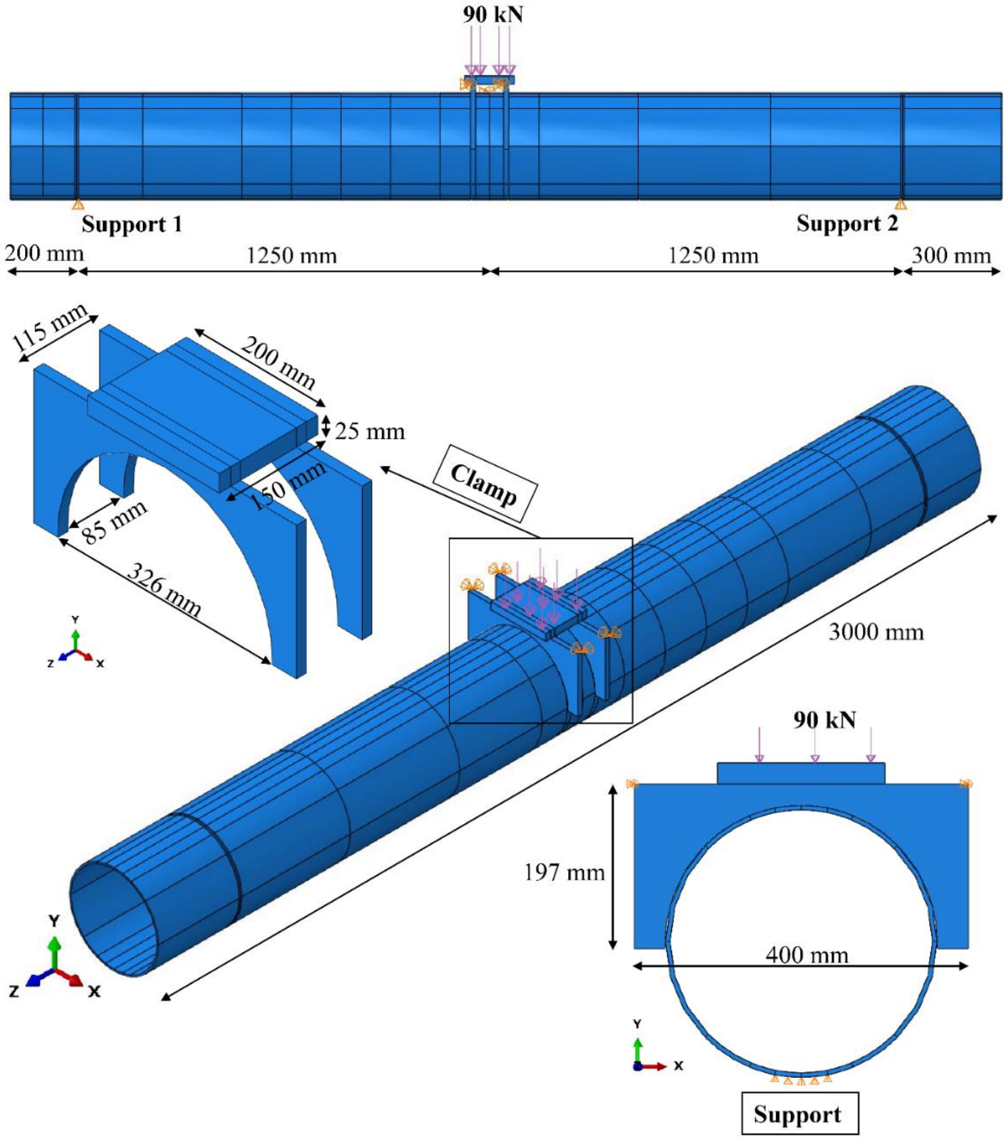

Figure 4. Three-dimensioned numerical model of pile and clamp.

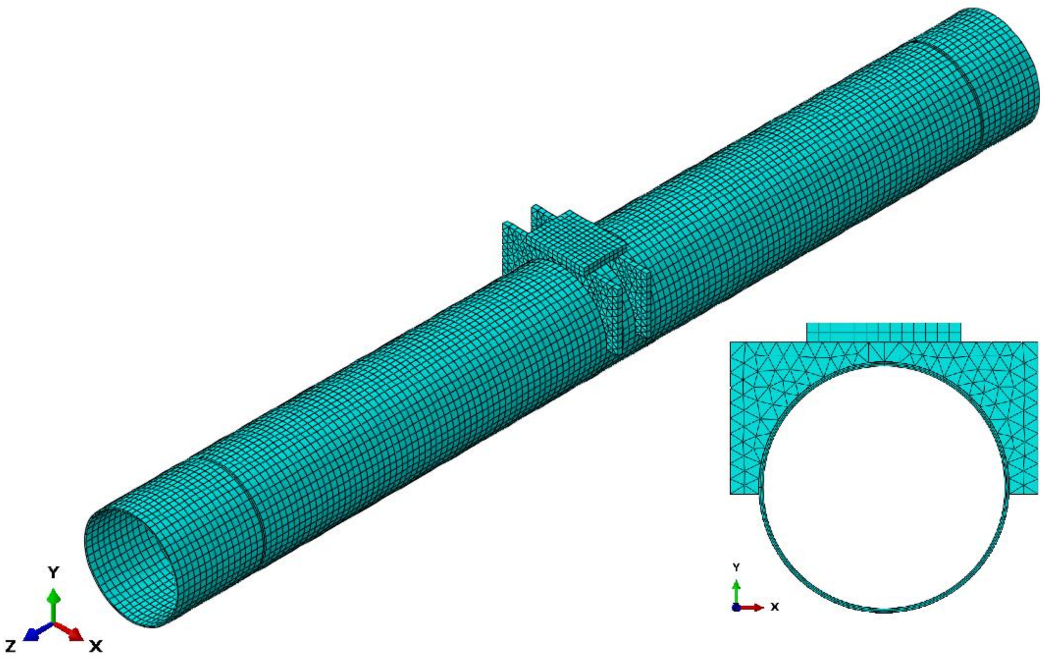

Figure 5. Finite element mesh of the numerical model.

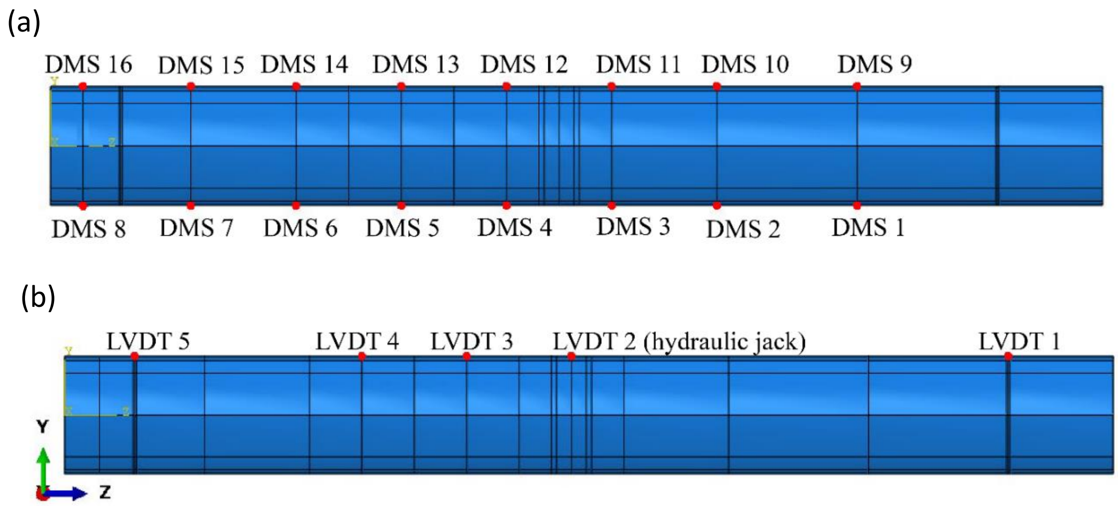

Figure 6. Location of (a) Strain gauges DMS1-DMS16 and (b) LVDT1-LVDT5.

4 Results

Figure 7 shows the contour of the displacement magnitude *u* at the end of the monotonic loading. To accurately visualise the deformation of the pile, the results were scaled up by a factor of 5. During the Finite Element Analysis (FEA) and experiment, it was noted that the cross-section of the pile deformed elliptically. This could be because both the experiment and FEA were conducted within the elastic region. No permanent deformation of the pile was observed, instead the upper part of the pile settled linearly in the y-direction, which is also shown in Figure 8.

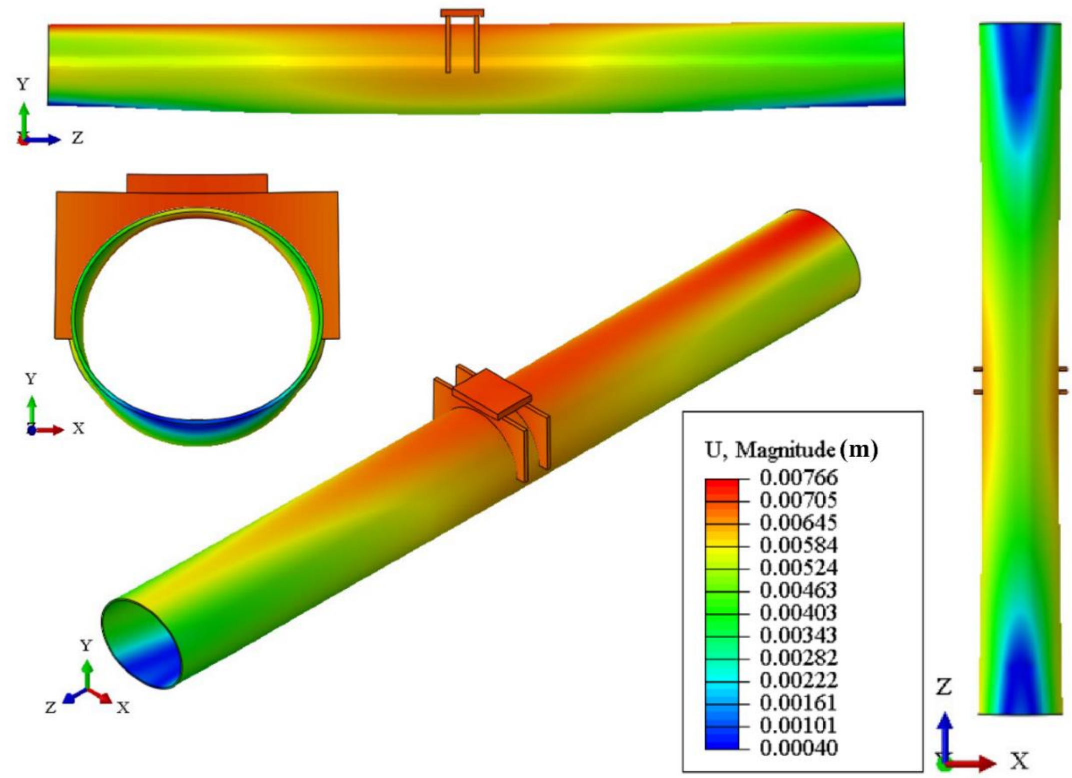

Figure 7. Displacement contour field (scaled up by factor of 5).

The deformation at the centre of the pile did not match the experimental results precisely, as shown in Figure 8. It should be noted that the deformation at the centre of the pile was measured by the hydraulic jack, whereas LVDTs were used at other locations. Thus, the disparity could be attributed to the difference in measurement accuracy between the hydraulic jack and LVDTs employed in the experiment.

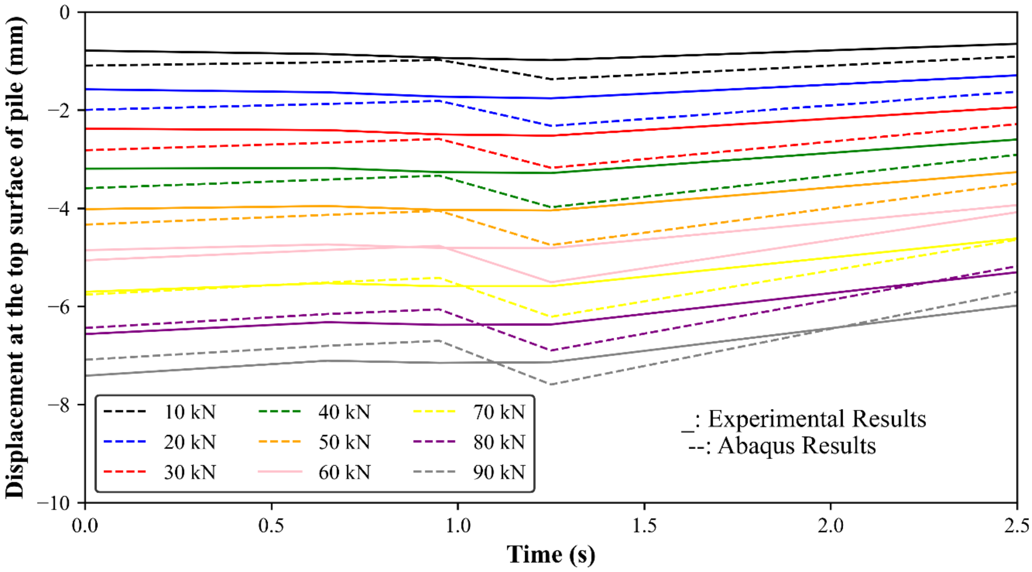

Figure 8. Deformation along the pile axis

Figure 9 shows the comparision of simulation results with the experimental results at various locations (as shown in Figure 6) . It was observed that the results obtained from the finite element analysis show good agreement with the experimental results for both strains and deformations.

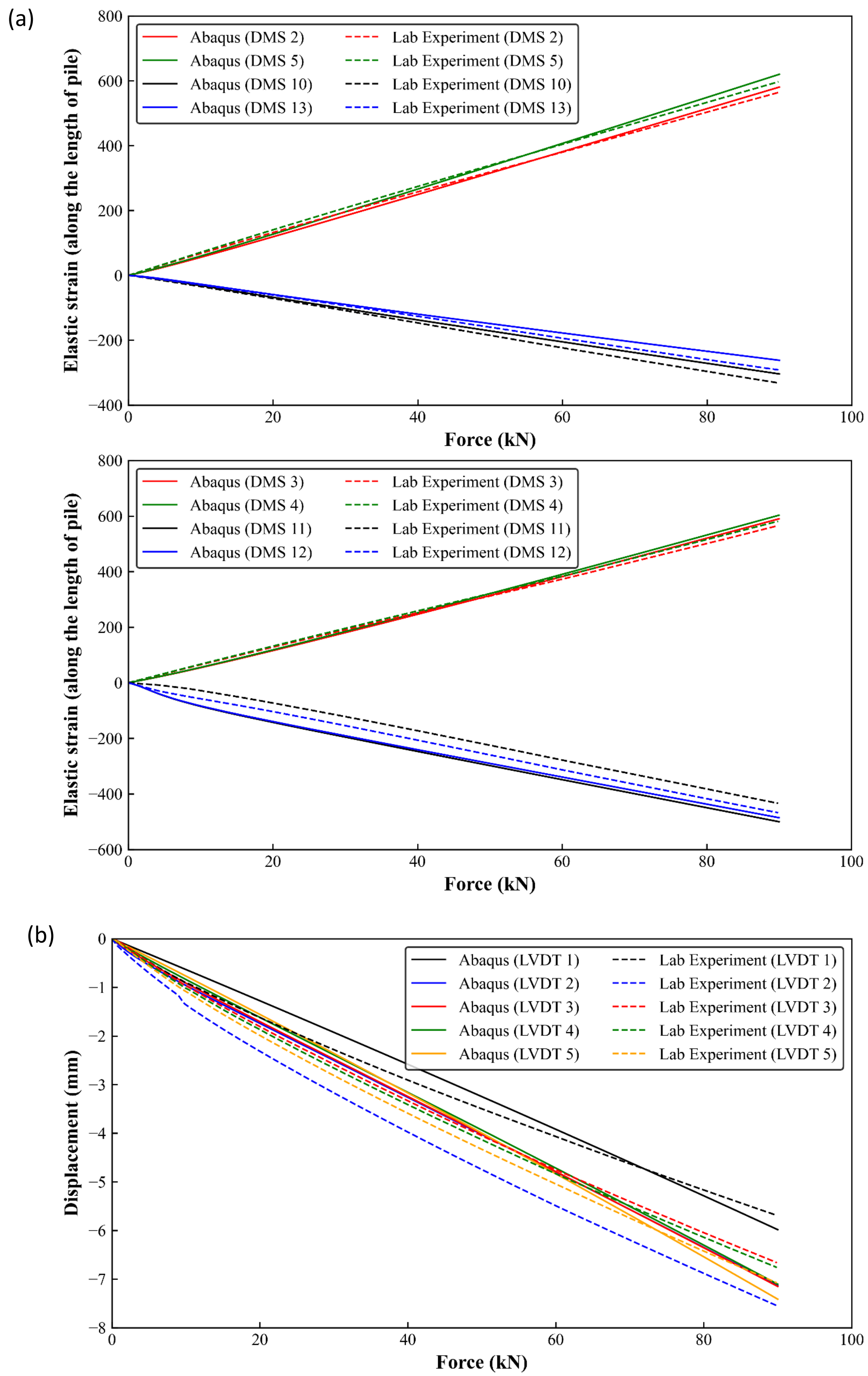

Figure 9. Comaprision of simulation results with the experimental results, development of (a) strains and (b) displacement vs. force

5 Conclusion

The results obtained by finite element analysis were in good agreement with the experimental data, except for a small discrepancy in the centre, possibly due to differences in measurement accuracy (human error, modulus of elasticity, tolerance of LVDTs and hydraulic jack, weld in the pile and contact between support and pile) between the experimental setup and the numerical model.

6 References

Eurocode 3: Table of design material properties for structural steel. URL: https://eurocodeapplied.com/design/en1993/steel-design-properties (accesed on 05/08/2023)