Sustainable Solutions in Structural Engineering and Construction
Edited by Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A.

ISBN: 978-0-9960437-0-0

EXPERIMENTAL EVALUATION OF FLEXURAL CAPACITY OF FULL SCALE PRECAST CONCRETE SHEETPILE

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A flexural capacity test is presented of a long precast concrete sheetpile system, intended as a protection wall for a water storage canal bank in soft-ground conditions, for a nursing college in Penang, Malaysia. The precast concrete sheetpile with a length of 7 m and a maximum exposed corrugated-section height of 1.8 m, was designed at Ultimate Limit State (ULS) bending moment of 175 kNm. A total of 2 specimens of precast concrete sheetpiles were tested in the Heavy Structure Laboratory at School of Civil Engineering, Universiti Sains Malaysia. The test method specified in Malaysian Standard MS 1314 was adopted. The results showed that the capacity of Specimens 1 and 2 were respectively 1.49 and 1.48 times higher than the designed capacity at ULS. The test set-up, to reflect the practical behavior of precast concrete sheetpile, and the test procedures are also described.

Keywords: Precast concrete sheetpile system, Corrugated section, Flexural capacity, Soft ground, Water storage canal.

1 INTRODUCTION

Steel sheetpile wall has been widely used worldwide for slope protection purposes. Although steel sheetpile walls are structures with better performance as slope stabilizers, they are very expensive to build and maintain against corrosion. To address this problem, a new Precast Concrete Sheetpile System with a corrugated section was developed.

Over the years, there has been little research carried out on the different geometries of concrete sheetpiles. Yee (2006) carried out a full-scale flexural testing of 6m concrete corrugated sheetpiles. Two samples were restrained at the opening-up section and two samples were not. The results showed that the restrained samples had bending moments closer to the designed bending moment. Tan (2013) explored the behavior of high-strength thin C-section of concrete sheetpiles. On average, the tested samples had a bending moment that was 1.59 times the designed bending moment.

There are also research studies on reinforced concrete solid beams and hollow beams. Bhatt and Mousa (1996) tested concrete box beams under non-monotonic loading. Alnauimi and Bhatt (2004) used the direct design method to design eight reinforced concrete hollow beams subjected to a combined load of bending, shear, and torsion. Good agreement was found between the design and experimental failure loads. Skrinar (2002) carried out a uniaxial bending analysis of RC trapezoidal open sections.

Due to a linear change of the width of the cross section, the analysis procedures for trapezoidal cross sections essentially deviated from the analysis of rectangular cross sections.

In this paper, a precast concrete pile system with corrugated sections was used as a protection wall for a water storage canal in soft-ground conditions, in a project involving a nursing college in Penang, Malaysia. A 7m-length of precast concrete sheetpile was chosen based on the soil conditions from soil investigation results. It was designed at an Ultimate Limit State (ULS) bending moment of 175 kNm based on BS 8110: Part 1: 1997. To verify the design principles and real structural behavior of the corrugated section of the concrete sheet pile, a four-point flexural test was carried out at the Heavy Structure Laboratory of School of Civil Engineering, Universiti Sains Malaysia. Its main objectives were:

(i) to determine if the flexural capacity of the sheetpile satisfies the capacity at ultimate limit state according to geotechnical requirement in the design

(ii) to determine the maximum flexural capacity of the sheetpile

2 THE TEST SET-UP

MS 1314: Part 2: 2004 Precast Concrete Piles: Part 2: Method for Determination of Bending Strength of Precast Concrete Pile (Bend Test) (First Revision) was adopted. Figure 1 shows the dimension of the 7m precast RC sheet pile tested. The testing set-up is shown in Figure 2. As for the project requirement, the main bar was designed at the web of corrugated section. Hence, for testing purposes, the web of precast concrete sheetpile section was placed as the bottom beam. The distance between the supports and the loaded points used during the test were 4.0m and 1.0m, respectively. The distance between the supports is slightly less than the distance according to MS 1314 due to obstructions from the lifting hooks. The sheet pile was retrained laterally at four locations: two locations close to the loaded points, and another two close to the supports, as shown in Figure 2. Lateral restraints as shown in Figure 2 were attached for the purpose of simulating the ground conditions, where the two wing flanges of a sheet pile are prevented from displacing laterally. Figures 3 and 4 show scenes during the test. The lateral restraint used can be clearly seen in Figure 4.

Figure 1. Dimension details of Precast Concrete Sheetpile ST-Series.

3 TESTING PROCEDURES

The load *P* shown in Figure 2 was applied using a 1500kN hydraulic cylinder. The load applied was measured using a 1000kN load cell. Central vertical deflection at mid-span of the tested RC sheet pile specimen was measured using LVDT. Apart from the central LVDT, lateral displacements of two other locations were also measured using two sets of LVDT: one close to the loaded point, and the other one close to the support. A data-logger was used to record all the measurements of load and displacement. A total of two specimens (Specimen 1 and 2) were tested.

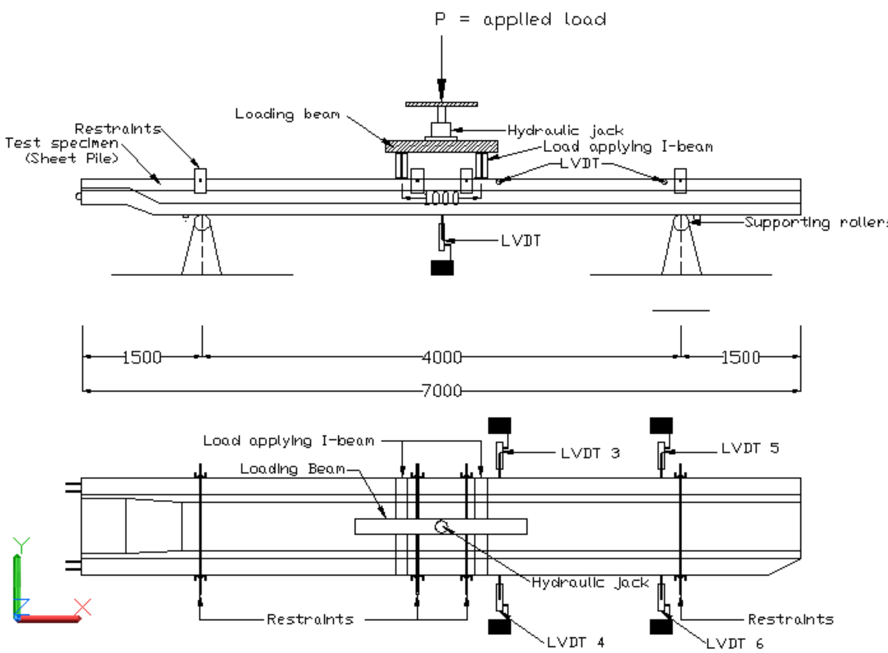

Figure 2. Schematic diagram of testing set up for precast concrete sheet pile.

Figure 3. Overall test set up.

Each test specimen was subjected to two loading phases. The first loading phase consisted of few cycles of 0 to 10 kN loading, for the purpose of situating the test specimen in the test set-up, and removing any initial unevenness present prior to

Figure 4. The set of lateral restraint during testing.

actual testing. In the second loading phase, the specimen was subjected to loading up to a level of 34kN, corresponding to the ULS according to geotechnical analysis requirements. The load level was sustained for observation of cracks. The test specimen was then loaded up to 133kN, corresponding to loads at serviceability limit state (SLS) for the test specimen. This load level was again sustained for observations of cracks and crack patterns. Then the specimen was further loaded up to 221kN corresponding to the load at the ULS of the test specimen. This load level was sustained in order to observe any structural distress in the precast concrete sheet pile. After the loading to ULS, loading was continued until failure of the specimen was observed. The specimen was considered to have achieved failure load when further application of hydraulic cylinder resulted in a decrease of load recorded. During the whole loading process, deflections were recorded in real time using data-logger. Figure 5 summarizes the loading sequence used during the test.

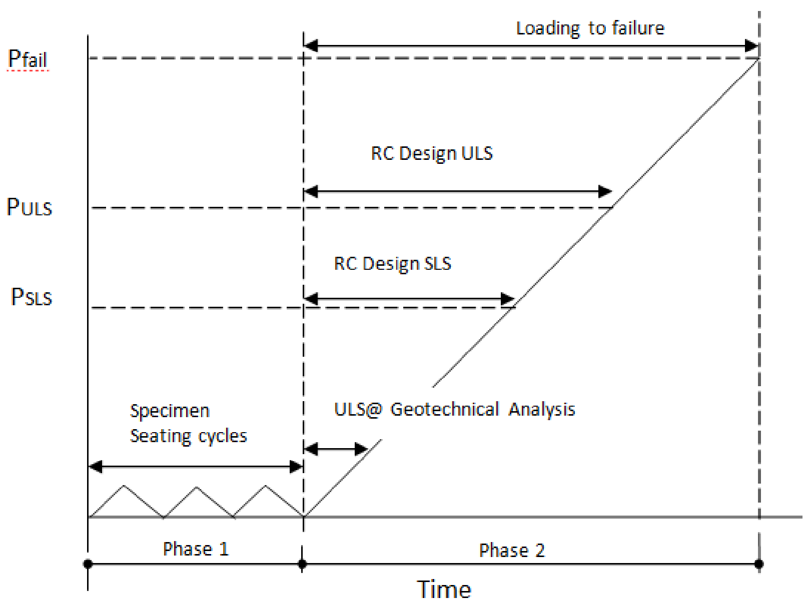

Figure 5. Loading sequence.

4 TEST RESULTS

The test results for the 7m precast RC sheetpile (Specimens 1 and 2) are shown in Table 1. The load-deflection curves for mid-span points recorded during the test are shown in Figure 6. The bending moment was calculated using simple equilibrium analysis.

At the first load level where the load was at ULS geotechnical requirement, there were no cracks observed. As the load level increased to a maximum load of 330kN, the maximum crack width measured was 1.30mm (Specimen 2). From the measured result for deflection, the maximum value was 65.9mm.

Table 1. Test results for 7m precast concrete sheetpile.

Load Level	Load (kN)		Bending Moment (kNm)		Crack Width (mm)		Deflection (mm)	
	Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
1	34	34	35.14	35.14	No Crack	No Crack	0.7	1.1
2	133	133	109.4	109.4	0.05	0.05	9.4	9.7
3	221	221	175	175	0.1	0.1	17.1	17.9
4	334.6	332.2	260.59	258.79	1.05	1.3	46.1	65.9

Note:
Load Level 1 - ULS Geotechnical Requirement
Load Level 2 - SLS of RC sheetpile
Load Level 3 - ULS of RC sheetpile
Load Level 4 - Maximum Load

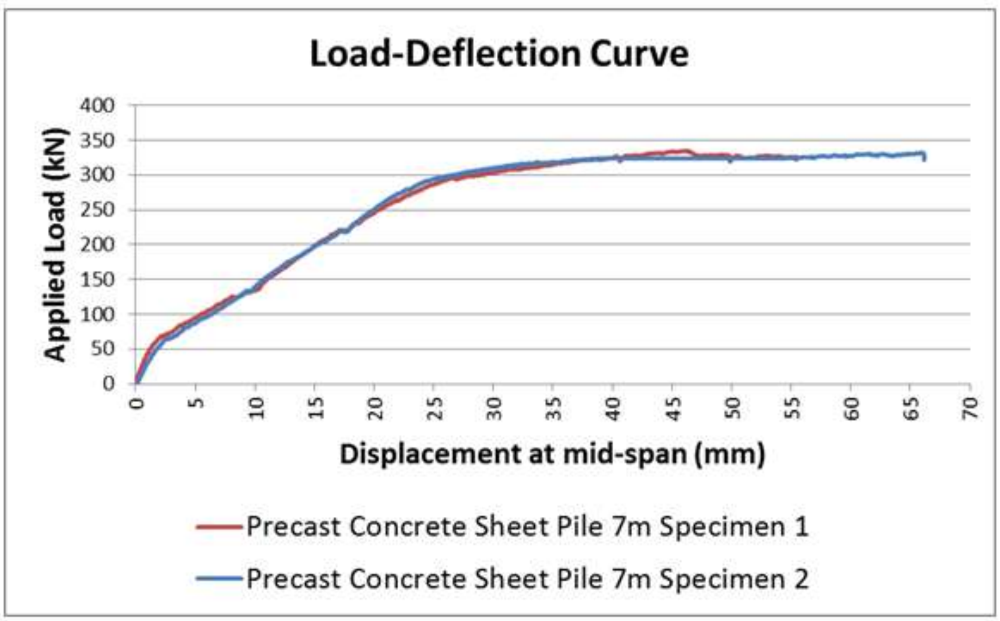

Figure 6. Load-deflection curve precast 7m RC sheetpile (Specimen 1 and 2).

Figure 7(a) and 7(b) show views of the tested specimen at maximum load level for Specimen 1 and 2, respectively.

(a)

(b)

Figure 7. View of tested specimen at maximum load; (a) Specimen 1, (b) Specimen 2.

5 CONCLUDING REMARKS

Precast concrete sheetpile was designed at a bending moment of 175kNm at ULS. Two specimens were tested using a four-point flexural test. The results indicated that the ULS bending moment capacity of 35.14kNm according to geotechnical requirement is achieved for both Specimens 1 and 2. In addition, the maximum bending moment capacity determined was 260.59kNm and 258.79kNm for Specimen 1 and 2, respectively. The capacity is 1.49 and 1.48 times higher than the estimated capacity at ULS of 175kNm.

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