CHAPTER V

EXPERIMENTAL INVESTIGATION

5.1 Description of Models

Eight one-third geometric scale model pile caps as shown in Fig. 5.1 were constructed. All linear dimensions of the model have been scaled down from the corresponding dimensions of the proposed prototype. The models consisted of 4 triangular three-pile caps, and 4 square four-pile caps were constructed and supported on a pile spacing of 35 cm. from center to center of piles. The model reinforcement has been proportioned by stress scale factor with full anchorage beyond the supporting piles.

The depth, steel ratio, and column size are similar for all the models. However, the pattern of reinforcement arrangements were varied in all the models as shown in Fig. 3.11-3.12 . The properties of each test model are summarized in Table 4 .

5.2 Materials and Fabrication

Similar type of concrete was used to simulate the concrete in the prototype pile cap construction. The following mix was employed for the testing program on model of pile caps.

Water-Cement Ratio ; 0.65-0.70

Cement:Coarse Aggregate:Fine Aggregate ; 1:2:4 by volume

Coarse Aggregate ; crushed gravel with the maximum size of aggregate is $\frac{3}{4}$"

Fine Aggregate ; river sand

Cement ; portland cement Type III (rapid hardening)

The concrete compressive strength was determined from a group of control cylinders for model of the same mix. These cylinders were capped with graphite capping compound. The cylinders were tested on the same testing days as each of the pile caps. The mechanical properties of the concrete are listed in Table 3 . The typical stress-strain curves of the concrete are shown in Fig. 6.2 .

The reinforcement conforming to ASTM designation: A-615-68, Grade 50, plain bar, was used as flexural reinforcement in all specimens. These steel reinforcement were fully anchoraged beyond the supporting piles. Measured yield stress of reinforcing bars are listed in Table 2 . Fig. 6.1 shows representative stress-strain curves for steel used in all specimens.

Based on the technique for casting a model of pile cap plywood forms with removable sides and bottom were employed. The side forms were constructed of 10 mm. plywood and $1\frac{1}{2}$"x3" hard wood locked in place with wedges. The bottom side was punched for number of holes to locate the position of the supporting piles, with a clearance of 5 mm. for removing the form.

Prior to casting, surfaces of the form to be in contact with the mix were oiled. The reinforcement was laid on the supporting piles and adjusted to obtain the average effective depth within 25 cm.. The concrete was placed into the form continually with vibration till the form was full. For each specimen, control cylinders were casted from the same mix to determine the mechanical properties of the casting concrete.

Approximately 2 days after fabrication the side forms were removed and the specimen was cured with wet cloth in room temperature about 5 days, then the bottom side was pushed out. Control cylinders were cured in the same manner. Each specimen with control cylinders were tested in the same day within 10 days after fabrication. Fig. 5.2-5.3 show the set-up for casting three-pile cap and four-pile cap.

5.3 Instrumentation

Load; The load was applied from a hydraulic jack by AMSLER UNIVERSAL MACHINE Type 500 D74 and transmitted to the load head through the supports of specimen upward. Upper loading head was fixed and a steel column was inserted between the fixed head and top surface of specimen to transmit the load as a column load. The general view of the instrumentation are shown in Fig. 5.6 .

Strain; A manual multi-channel strain indicator and a 24-channel switching and balancing box were used to monitor strain gage read out. Electrical strain gages of 30 mm. were used for the steel and concrete in all specimen, For each specimen the longitudinal strains in the steel were measured at the middle, and on the concrete surface were measured at midway between the two adjacent piles. Each electrical strain gage was put into attachment following the manufacturer instructions.

Vertical Deflection; To record vertical deflection of the specimen, dial gages were placed on top surface of the cap at locations on the center of supporting piles as shown in Fig. 5.6 . The dial gages used were read to the nearest 0.01 millimeter.

5.4 Testing Procedures

Before positioning the specimen, the concrete surface in contact with the upper loading head was sand blasted and some homosote pads were placed between the supporting piles and the lower loading head to ensure the uniform distribution of column load and reactions. The load was applied to each specimen by the loading head in increments of 2 tons up to failure. At each load increment data was taken on dial gages, electrical strain gages on the reinforcing steel and concrete surface. Cracking in the bottom surface were observed by a mirror.

The strains were recorded up to the load causing the yielding or damage of the strain gages. Deflections were measured up to the failure of each specimen.

5.5 Behaviour of Testing Specimens

During testing the load was applied incrementally so that the behaviour of the cracks could be studied with objective to determine the limit of elastic and ultimate of the specimens. Independent of the quality of the concrete and type of reinforcement, the behaviour of specimens under loading were observed in each particular test.

5.5.1 Three-Pile Cap Test Results

The average vertical deflection measured at centroid of pile caps increased linearly in the initial stages of loading. The linear vertical deflection at support no.3 increased at higher rate than those of the support no.1 and no.2. The corresponding numbers of faces and supports are shown in Fig. 5.1 .

P3-1 ; No significant cracking was observed by visual inspection until load 46 tons at which time some cracks were formed on the bottom face at the centroid of the cap and rapidly extended to the bottom edge of face 3. The maximum deflection at this stage was 0.42 mm.. Continued loading more cracks were observed on the bottom edges of face 2 and face 1 at the load stages 52 tons and 54 tons respectively. About the load 58 tons, the cracks continued extending vertically to the middle level of each face and slight widening of existing cracks were observed. Up to the load 74 tons, the major cracks almost reached the top surface of the cap, a sudden diagonal cracks are formed from the middle of the top edges on face 2 and face 3 and sloped downward at an angle about 45 degrees. After continued loading the deflection are increased rapidly until the ultimate capacity was reached at the load 76.8 tons and a diagonal crack was produced on face 1. The load was still applied until it started to drop and wider opening of the existing cracks on the bottom face and diagonal cracks on the top edges of face 2 and face 3 were observed. These diagonal cracks proceeded the failure which was accompanied by spalling of the concrete on face 2 in the region of the anchorage. The maximum deflection at ultimate condition was 0.88 mm.. Fig. 5.7 shows the model P3-1 after test.

<u>P3-2</u> ; The first crack was observed at the load stage 50 tons on the bottom edges of face 2 and face 3 about the same time and extended rapidly to the middle level of both faces. On face 1, the first crack was appeared at the load 54 tons and the maximum deflection measured at cracking load was 0.50 mm.. Continued loading the crack on face 2 extended faster than the other faces and slight widening of existing cracks was observed. At the load 64 tons, the crack on face 2 progressed to the top surface while those on face 1 and face 3 terminated at about 5 cm. below the top surface. When the load was continued up to about 70 tons, a short crack increased on face 1 and the crack on face 3 almost reached the top surface, a sudden diagonal cracks were formed on face 2 and face 3 approximately at the middle of the top edge and sloped downward to the supporting pile no.3 at an angle about 45 degrees. At ultimate load, 76.3 tons, wider opening of the diagonal cracks were observed and the load strated to drop. The maximum deflection was 1.17 mm.. Fig. 5.8 shows the model P3-2 after test.

<u>P3-3</u> ; At the load stage 40 tons, first cracks were formed on the bottom edges of face 1 and face 3 with the maximum deflection 0.52 mm.. These cracks increased to the middle level of both faces at the load 48 tons. The first crack on face 2 was observed at the load of 49 tons and propagated to the middle level at the load of 54 tons. After continued loading the major cracks on each face increased and the opening of cracks were wider. When the load was increased to 66 tons the cracks on face 2 and face 3 reached the top surface approximately at the middle. At 68 tons the crack on

face 1 was terminated about 6 cm. below the top edge with a diagonal crack strated from the middle level and sloped downward to the supporting pile. At this stage the crack on the top surface extended from face 2 had reached the loading point. The ultimate load was observed at 69.2 tons with the maximum deflection at 1.27 mm.. Fig. 5.9 shows the model P3-3 after test.

P3-4 ; The first crack was observed at the centriod of the cap on the bottom face and progressed suddenly to the middle level of face 2 at the load 45 tons. The maximum deflection at cracking load was 0.51 mm.. As the load increased to 50 tons, the development of cracking appeared on the bottom edges of face 1 and face 2. Continued loading produced the progressing crack on face 2 and wider openings were observed at bottom edges. At load of 64 tons, major cracks on face 2 had extended to the top edge. Beyond this stage short extended cracks were observed on face 1 and face 3 and progressed to the top edges at the load of 86 tons. With a small additional load applied, a sudden diagonal cracks was formed on face 3 and the ultimate load was then reached at 86.5 tons. The maximum deflection at ultimate load was 1.38 mm.. The model P3-4 after test was shown in Fig. 5.10 .

5.5.2 Four-Pile Cap Test Results

P4-1 ; The first crack was observed by visual inspection at the load stage 44 tons which strated from the bottom face near the supporting pile no.3 and progressed rapidly to the middle level of the face 3. The maximum deflection at this stage was 0.75 mm.. As the load increased, more cracks were formed on the bottom and extended to face 2 and face 4 at the load of 60 tons. The crack appeared on the bottom edge of face 1 at the load 64 tons. After cracks were foemed on every face, the existing cracks progressed to the middle level and the crack openings were wider in the continued loading up to the load about 70 tons. At the load 75 tons, the major cracks on face 2 terminated about 4 cm. below the top edge and a new crack was formed at the middle level which rapidly progressed to the top surface. On face 1, the crack terminated at 5 cm. below the top edge at the load 78 tons with some new diagonal cracks formed on the bottom edge. Up to the load of 80 tons and 82 tons the existing cracks were extended to the top surface on face 3 and face 4 respectively, and followed by some new tensile splitting cracks extended diagonally from the loading point to the position above piles on the top surface. At the ultimate load of 76.8 tons, the cracks on the top surface were wider spreaded and progressed to the supporting piles. The horizontal cracks were observed on face 1 and face 4. The maximum deflection at ultimate load was 1.66 mm.. Fig. 5.11 shows the model P4-1 after test.

P4-2 ; At the load 38 tons the cracks were formed on the bottom face at the centroid of the cap and extended diagonally to the inner faces of the supporting piles. Continued loading more cracks appeared on each face at the load of 44 tons. The maximum deflection at cracking load was 0.22 mm.. At the load 45 tons the major cracks on face 3 progressed to the top edge with a new diagonal crack strated from the bottom edge near the support and extended parallel to the former crack. In the similar manner, a new diagonal crack was formed on the face 2 at the load 50 tons. Continued loading to the load 66 tons, the crack on face 1 reached the top edge and produced some diagonal cracks on the bottom edge. Up to the ultimate load, the new diagonal crack on face 2, face 3, and face 4 were extended to the top edges and proceeded the failure at the load 82.1 tons. Some horizontal cracks were observed on face 2 and face 4 near the bottom edges. The maximum deflection at this stage was 1.34 mm.. The model P4-2 after test is shown in Fig. 5.12 .

P4-3 ; The first was observed by visual inspection on the bottom edge of face 3 at the load 40 tons and extended rapidly to the middle level. The following load stages represent the first cracking loads on each, 60 tons on face 1, 62 tons on face 2, and 64 tons on face 4. The maximum deflection at this stage was 0.54 mm.. At the load of 74 tons major cracks on face 1 and face 3 had reached the top edges and extended to the loading point. A new diagonal crack was formed on face 2 at the load 88 tons which started from the bottom edge at supporting pile no.3 sloped downward at an angle 45 degrees. The ultimate condition was reached at the load 89.1 tons with the maximum deflection at 1.85 mm.. Fig. 5.13 shows the model P4-3 after test.

P4-4 ; At the load stage 50 tons, the first crack was observed on the bottom face and extended to the face 3. The maximum deflection at this stage was 0.40 mm.. Continued loading the cracks progressed from the bottom face to the bottom edges of the face 3, face 1, and face 4 at the load stages 54 tons, 58 tons, and 64 tons respectively, then rapidly extended to the middle level of each faces.

The msjor cracks were vertically progressed as the load increased and reached the top surface at the load about 80 tons. At the ultimate load, 83.1 tons, the cracks on the top surface progressed to the loading point. The maximum deflection at this stage was 1.03 mm.