CHAPTER VI

DISCUSSION

1 The Load-Settlement Curve

The load settlements of all piles are shown in Fig 23 to Fig 25. From the tests all piles fail suddenly after the ultimate load is reached. This indicates that all are friction piles. Therefore it can also be expressed that "For short piles in Bangkok clay, the failure of the pile is suddenly after the shaft friction is mobilized". The test is in agreement with Chirrupapa (1968) Taechathummarak (1970). The settlement at failure ranges from 4.40 mm to 5.30 mm. This settlement should be the settlement for mobilization of the skin friction. Chirruppa (1968) found that this settlement ranges from 0.325 in to 0.425 in (8.25 mm to 10.8 mm) for short cast-in-situ bored piles. Taechathummarak (1970) suggested that it varies from 0.09 to 0.13 in (2.3 mm to 3.3 mm) for short wooden pile of 6 in diameter and 6m long. Holmberg (1970) suggested after his extensive testing of short driven piles in stiff Bangkok clay that a top settlement of 5 mm was sufficient to bring pile failure.

Settlement at 0.5 and 0.75 failure load are summarized in table 2. At 0.5 failure load the settlement ranges from 0.75 to 0.85 mm. At 0.75 failure load it varies from 1.5 to 2.00 mm. Therefore it is very reasonable to recommend that working load of friction pile should be one-half of the ultimate load. In deciding the working load of pile the problem of settlement should be considered carefully.

The top and toe settlement of the pile are measured. It clearly shows that the elastic shortening is very small. At failure load the maximum stress occuring in the pile is only 29.2 ksc while the ultimate compressive stress of the concrete at 28 days is not less than 350 ksc.

2 The Plastic and Elastic Settlement of Piles

The plastic and elastic settlement at failure of all piles are summarized in table 3. When the load is small the settlement of the pile top is based on elastic settlement. When the load is higher and the ultimate load is near the plastic settlement increases rapidly. At the ultimate load the plastic settlement is dependent on the time that the load is maintained. Before the ultimate load is reached the plastic and elastic curve will intercept each other. The settlement at this interception of all piles ranges from 1.46 mm to 2.02 mm.

3 The Load-Ratio And Total, Plastic, Elastic Settlement

The load-ratio and total plastic, elastic settlement are shown in fig 35 to fig 40. This method of plotting is suggested by F.G. Butter and K. Morton (1970). It will be seen that there is a straight line relationship between the elastic settlement to the load ratio. This relation is true when the load ratio is less than 0.8

The relationship of the load-ratio to total and plastic settlement is nonelinear. At low values of load-ratio the plastic settlements are very small. There is a transition to a rapidly increasing plastic settlement with increasing the load ratio. This is due to "plastic yield" occuring. F.G. Butter and K Morton suggested that this transition is well defined and will be termed the "critical load ratio" and this load ratio is 0.7. From the test it is in good agreement with the typical value. The critical load ratio varies from 0.72 to 0.8. The plastic settlement ranges from 0.52 to 0.70 mm. Therefore it can be seen that for short piles this relationship between load-ratio to the plastic settlement gives a good guide to show the performance of piles under load.

4 The Quick Test

In finding only the load capacity of piles the quick test method should be performed. From the tests of all sections, the ultimate loads do not vary so much from the loads gotten from the ML test. The difference is less than 5%. It is obvious that the settlement recorded for a given applied load in the quick test will always be lower than the comparative settlement for the ML test. Therefore the settlements gotten from quick test give no meaning in predicting the true settlement of pile during its working life. Because in the test, the settlement is short-term settlement, no time is allowed for settlement and settlement due to consolidation.

5 The Load Capacity of Piles Related to Soil Properties

In this investigation, attempt has been tried to separate the shaft friction and the end fearing of piles by indirect method and Van Weele's concept. The results gotten do not ma sense because the stiffness of the pile is very high. From the curve in Fig 26 to Fig 28, they show that the top and toe is nearly equal. The idea of getting the load distribution of piles are impossible. Therefore the strain-rods can not be used for short piles in Bangkok clay because the ultimate load capacity is too small. The Van Weele method has also been tried to separate the shaft friction and end bearing of piles, but the straight portion of end load can not be obtained because when the ultimate loads are reached all piles fail suddenly. The plastic settlement is greater than the elastic shortening of the subgrade. Therefore the straight portion of curve after the mobilization of shaft friction cannot be obtained.

In order that the skin friction and the end bearing can be separated, the Nc factor is assumed to be 9 in calculation the end bearing. By substrating the end load from the total load the shaft load in obtained. The unit skin frictions of all piles are summarized in table 6. They range from 1.21 to 1.42 ton/m^2 (vane shear) and 1.24 to 1.46 ton/m^2 (U/C). The unit skin friction of driven pile is greater than cast-in-situ bored pile. Chirruppa (1968) found that the unit skin friction varies from 0.65 to 1.29 ton/m^2. These differences should be due to the differences methods of embedding the piles. For bored piles the unit skin friction is less than the driven piles, because the lateral pressure is dropped during the process of performing bored piles.

The adhesion factors of all piles are summarized in table 6. Based on the vane shear test the adhesion factors vary from 0.48 to 0.57. Comparing the results with Tomlinson's curve the lower curve should be used. When compared with Holmberg's investigation the results are lower. Based on U/C test the results lie on the intermediate limit of Tomlinson's curve and are lower than Holmberg's curve.

6 The Square Shape And The Double Half Moon Shape

The purpose of this comparison is to confirm that in calculating the shaft resistance of precast concrete pile in soft clay the minimum perimeter should be used. The maximum perimeter is the perimeter around the boundary of the pile and the minimum perimeter is the shortest distance joining to enclose the cross section of the pile. Although the perimeter of the double half moon shape is greater than the square shape, its ultimate bearing capacity seems to be less than the square. When the minimum perimeter of the double half moon shape is used for caculation, the unit skin friction is still smaller. From the test, the unit skin friction of the square shape is 1.42 ton/m^2 (vane shear) 1.46 ton/m^2 (U/C) while the average unit skin friction of the double-half moon shape is only 1.21 ton/m^2 (vane shear) and 1.24 ton/m^2 (U/C) which is only 85% of the unit skin friction of the square shape. If the straight sides of the double half moon shape is considered to have the same unit skin friction as the square shape, the half moon sides of the double-half moon shape give the unit skin friction only 0.96 ton/m^2. This can be explained that the soil does not fail along the half moon boundary but it will fail along the path that the summation of cohesion and adhesion is minimum. Because of the irregular boundary on the half moon sides, the stress in the soil is not uniform resulting in the development of the low value of the unit skin friction. In this comparison the boudary of the pile is very important in influencing the shaft friction. From the load settlement curve, at the same top load the settlement of the double half moon is greater. The settlement at failure load of the square shape and the double-half moon shape is 5.30 mm and 4.80 mm respectively. The load capacity per volume of the double half moon is greater, therefore the concrete used in manufacturing the double half moon shape to carry equal load is smaller.

7 <u>The Circular Shape and The Octagonal Shape</u>

The stiffness property is compared. The boundary of both are almost the same. From the test the unit skin friction of the circular is 1.41 ton/m^2 (vane shear), 1.46 ton/m^2 (U/C) and the octagon is 1.30 ton/m^2 (vane shear), 1.35 ton/m^2 (U/C). The difference is 8%. From the load-settlement curves they conicide at low value of load, the curve seperates at the load 14 ton. The settlement of octagonal shape is greater. This should be due to the fact that the length of the circular shape is greater than the octagon 0.50 m. From this experiment it reveals that the short hollow and solid pile will carry almost the same ultimate load if it's structural capacity is enough.

8 <u>The Equilateral Triangular Shape and The Y Shape</u>

The cross section area of both are almost equal. The actual perimeter of the Y shape is greater than the equlateral triangular shape (114 cm to 105 cm) but the ultimate loads of both are equal. This should be due to the fact that the more corner of the Y shape destroys the unit skin friction. The boundary of Y shape is smoother than the double half moon and the radues of curvature of the Y shape is greater so it destroys smaller unit skin friction. From the load settlement curves of the triangular and the Y shape they coincide because their axial stiffnesses are equal.

9 The Group of Geometric Shapes of Piles

In this group, the square, equilateral triangular, circular, octagonal shapes are considered. The boundary of this group is smooth. The minimum and the maximum perimeters are equal. From the load test the unit skin friction is almost equal. The maximum settlement ranges between 4.40 mm to 5.50 mm It can be concluded that if the pile has geometric cross section, smooth boundary, and its minimum and maximum perimeters are equal, the unit skin friction in soft Bangkok clay is equal.

10 The Group of Irrequar Shapes of Piles

There are only two shapes, the double half moon and Y shape. These two shapes have been manufactured on the idea that the pile will fail along its boundary perimeter. Therefore the irreqular shape can be arranged by increasing the perimeter but decreasing the cross-section. From the test, this idea is warry the more ultimate load than the geometric group of pile of the same equal minimum perimeter (comparison with the square and the equilateral triangular shape). Therefore it should be noted that in soft clay the boundary of the pile is very important in influencing the shaft friction.

11 The Perimeter Effect

Four piles of approximately the same perimeter but varying in shapes are investigated. Three of them are geometric piles, equilateral triangular (3X35 cm), circular (3.14 X 35 cm) and octagonal (3.31 X 35 cm) respectively and the south one is irregular (3.24 X 35 cm, minimum perimeter). All the geometric shapes develop the almost equal unit skin friction therefore the perimeter does not affect the skin friction of geometric shapes because their boundaries are all smooth. For the Y shape its boundary can be assumed smooth. The gap is filled by the movement of the soil. This condition occurs only in soft clay. So in stiff clay this gap should be carefully considered. From the test, if the minimum perimeter is used in calculation, the unit skin friction of the Y shape is approxinately equal to the geometric shapes.

12 The Economical Section

The main point of this investigation is to find the economical section of pile which should be as follows :-

1. The process of manufactering should be easy (the square and the equilateral triangular shape are the best)
2. The boundary of the pile must be smooth (For geometric shape is recommended)
3. The shape of the pile should offer high skin friction while the cross section is minimum (For solid geometric piles the equilateral

triangular shape is the best)

4. The load-capacity per cross section should offer a high value

5. For friction piles (length is less than 10 m) the pile should be hollow but the structural capacity of the pile is enough to carry the ultimate load

In determining the shapes other properties should also be considered such as the handling stress, the resistance of pile to the effect of driving, finally the load capacity. In analysing the cost of a pile, contemplation should be made on the cost of manufacture, transportation, driving etc. In some shapes of pile such as hollow piles, they offer high unit skin friction while the cross sections are minimum. The problem of manufacture should be considered because the cost of workmenship in this production is high although the cost of the concrete at the hollow section is saved

13 The Specific Perimeter of Piles

All the piles used in this research are very stiff. The ultimate load ranges between 15 - 22 ton which is almost equal to the load capacity of five wooden piles of ϕ 6" - 6 m. In comparison the wooden piles are much cheaper. In this research, however, the stiff piles are used in order to campare only the shapes effect.

The specific perimeter is defined as "The perimeter per unit area of pile". The higher the specific perimeter the lower the cost. According to the subsoil of Bangkok clay the top layer is soft to very soft, an increase in the specific perimeter of the same shape does not cause the buckling problem of short piles during driving.

14 Special Collected Data

The purpose of the procedure of test is to separate the end load and shaft load by cycling loading. The test does not carry to failure because of the uplift of anchored pile. From the test, the maximum test load is 150 ton, the load-settlement curve of circular pile at 150 ton seems to show that the ultimate load is nearly reached. The load-settlement curve of the square and I shape show no sight of failure. The top settlement at 150 ton of square I and circular shape is 7.8 9.7 and 18.7 mm. The settlement of the circular is greatest because its cross section is minimum. From the load-elastic settlement curve it shows that the elastic settlement is 11 mm. Conclusions which can be drawn from this investigation are :-

1. The calculation of the shaft load must be made on the minimum perimeter both for long piles and short piles

2. The cross section of long pile is the main factor to predict the settlement of pile top although the performance of the pile can be considered on the load-plastic settlement

3. Although minimum perimeter of the double half moon and I shape is used on calculation at the shaft load some reduction factor must be multiplied to the minimum perimeter because the ulimate load of the solid square is greater