THE DUTCH CONE TEST: STUDY OF THE SHAPE OF THE ELECTRICAL CONE

L'ESSAI DE PENETRATION HOLLANDAIS: ETUDE PAR RAPPORT A LA FORME DU CONE ELECTRIQUE

ИСПЫТАНИЯ ГОЛЛАНДСКИМ КОНУСОМ С ИСПОЛЬЗОВАНИЕМ ЭЛЕКТРИЧЕСКОГО ТОКА

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SYNOPSIS. In consequence of the replacement of the discontinuous mechanical Dutch sounding method by the more precise and more rapid method with an electrical cone, Delft Soil Mechanics Laboratory has carried out an extensive program of tests with regard to the shape of the electrical cone. Based upon the results of these tests the decision was taken to apply an electrical sounding cone which has a narrowed part just above the cone-shaped point of 36 mm diameter. This cone has the advantage that the results of the penetration tests are fully comparable with the results of the discontinuous mechanical soundings. Besides it has the additional advantage that more detailed information is obtained of the composition and the strength of the various soil layers.

INTRODUCTION

The static penetration test or the so-called Dutch Cone Test, is widely applied in the Netherlands since about 1934 when it was introduced by Keverling Buisman.

In principal the method consists of the measurement of the force on a cone-shaped point of 10 sq. cms and a top angle of 60° during its penetration into the soil. Normally these measurements are taken at depth intervals of 20 cms. Before the introduction of the electrical sounding method the force on the cone has to be measured above ground-level by means of a string of rods inside the so-called sounding tubes.

In general the mechanical sounding method is performed in a discontinuous way. First the system of the cone together with the sounding tubes is pressed down to the required depth. Next the cone is displaced downwards separately with a speed of approximately 1.5 cm/s by means of the inner rods, over a traject of about 7 cms.
The cone-resistance and the local friction are measured in this short period. Because the sounding tubes are at rest at this moment only small frictional forces are developed along the shaft of these tubes. This means that the data obtained with discontinuous mechanical soundings are not influenced by such forces and only depend on the properties of the soil on the depth where the measurements are taken.
About 20 years ago the Delft Soil Mechanics Laboratory carried out tests with electrical sounding cones of various diameter (Geuze, E.C.W.A., 1953).
A few years later the electrical sounding method was introduced for routine investigations too. The electrical sounding cone at that time had a constant diameter of 36 mm. The force on the point is measured by electrical strain gauges on a thin steel cylinder inside this instrument. This measuring cylinder is fixed to the sounding tube. So it is not possible to move the cone shaped point separately from the string of sounding tubes. As a result of this measurements can only be obtained when the system of sounding tubes and cone is moving downwards continuously. The sounding graphs are automatically plotted on an electronic recorder.

As a result of this continuous downward movement frictional forces are exerted along the part of the shaft of the sounding tubes in contact with the soil.
Due to these forces an increase of the level of the effective stresses in the soil in the vicinity of the sounding cone is evoked. The magnitude of this increase depends on the soil condition. It is substantial in the case of soundings in sandy soils. Consequently much higher cone-resistances were obtained with an electrical cone of constant diameter in such cases in comparison with the results of the discontinuous mechanical method.
From a theoretical analysis, based upon an integration along a pile shaft of Mindlin's equation for the stress distribution evoked by a concentrated vertical force in the interior of an electric semi-space, follows an increase of approximately 15%. (Tejchman, A., 1969).
However, practical experience has shown differences ranging from 20-100%.

As mentioned before it may be expected that the magnitude of the deviation depends upon the soil condition. It is also obvious that the length over diameter ratio of the system of cone plus sounding tubes is another important factor of influence.
In consequence of both effects the results of soundings with an electrical sounding cone of constant diameter cannot be applied directly for bearing capacity computations for piles of which

the length over diameter ratio differs considerably from that of the sounding system. For an important part the experience of the sounding method is based upon the comparison of loading tests on piles with the results of mechanical soundings. Moreover, it is important that respective properties of the concerned soil layer can be derived from sounding results without the application of uncertain adjustment coefficients. In consequence of these problems the Delft Soil Mechanics Laboratory decided to perform a research program on this matter. The main object of this program was to find out whether it is possible to reduce the effect of the shaft friction on the cone-resistance by reducing the diameter of a part of the shaft of the electrical sounding cone.

RESULTS OF THE COMPARATIVE TESTS

In order to establish the required length and diameter of the narrowed part of the shafts of the sounding cone comparative field tests were carried out with different types of sounding cones nrs. 1 to 8 included.

Type nr. 1: Mechanical cone without friction sleeve (see also fig. 5, type IA).
Type nr. 2: Mechanical cone with friction sleeve (see also fig. 5, type IB).
Type nr. 3: Electrical cone of constant diameter (see also fig. 5, type VI).
Type nr. 4: Electrical cone with a reduced diameter of 28 mm over a length of 100 mm directly behind the cone followed by a part with a diameter of 22 mm over a length of 160 mm.
Type nr. 5: Electrical cone, reduced diameter of 28 mm over a length of 100 mm, followed by a narrowed part of 22 mm diameter over a length of 200 mm.
Type nr. 6: Electrical cone, reduced diameter of 28 mm over a length of 100 mm, followed by a part of 25 mm diameter over a length of 350 mm.
Type nr. 7: Electrical cone, reduced diameter of 28 mm over a length of 100 mm followed by a part with a diameter of 27 mm over a length of 570 mm.
Type nr. 8: Electrical cone of which the shaft is narrowed to 31 mm over a length of 1000 mm.

The length over diameter ratio of the narrowed part of these electrical cones followed from buckling conditions under a load of 5 metric tons.
The comparitive investigation comprised 288 soundings spread over 18 groups. In every group 2 soundings were executed with each of the 8 sounding cones. The situation of the soundings in the groups was established with the aid of random permutations of 8 numbers. In one direction the distance between the sounding amounted 1.50 m; in the other direction 2.40 m.
The results of the soundings with the electrical cones 3 to 8 included were compared with the results of the soundings with the mechanical cone nr. 1. This was done by means of a statistical analysis.
The computed lineair regression lines are plotted in figure 1.
In order to reduce the effect of local inhomogeneities in the soil on the regression analysis the cone resistance diagram of the soundings was converted into pile toe resistance diagram. This was done according to the calculation method developed at Delft Soil Mechanics Laboratory (Begemann, H.K.S.Ph, 1963). In figure 2 the regression lines for this pile toe resistance are given.

Obviously the regression lines obtained from the cone resistance do not differ significantly from those derived from the pile toe resistance values. From the results of figure 2 the relation between the length of the narrowed part of the cone and the pile point resistance for the respective soundings is derived. The results are shown in figure 2.

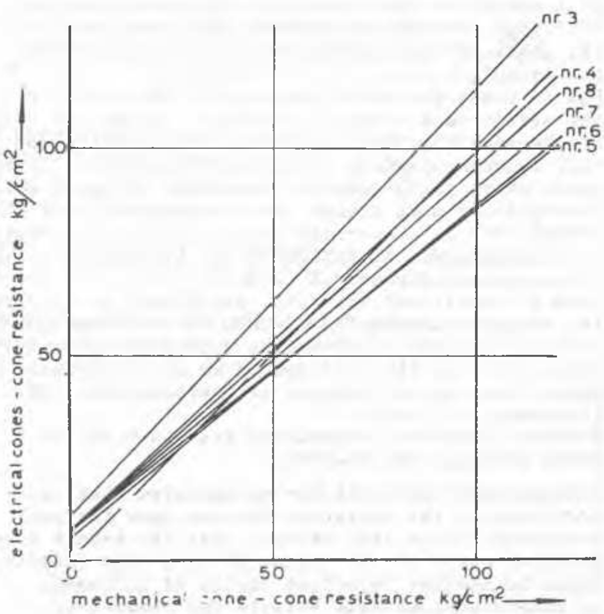

FIG. 1. REGRESSION LINES FOR THE DIFFERENT SOUNDING CONES

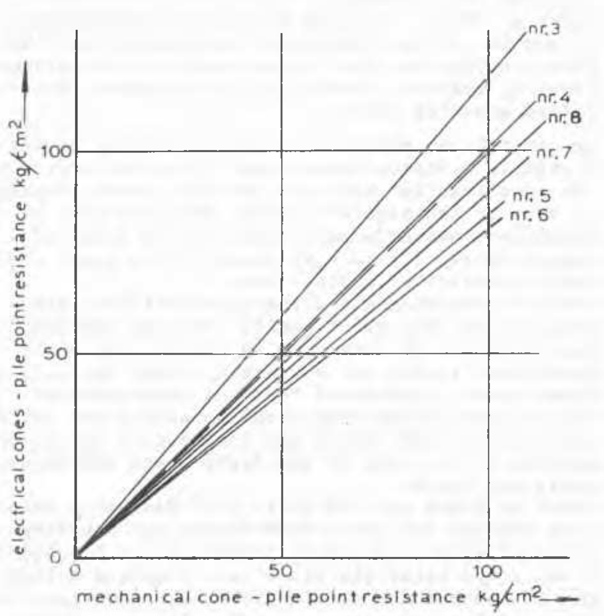

FIG. 2. REGRESSION LINES FOR COMPUTED PILE TOE RESISTANCE

The ordinate in this graph gives the tangent $\frac{IJ}{X}$ of the different regression lines of figure 2.

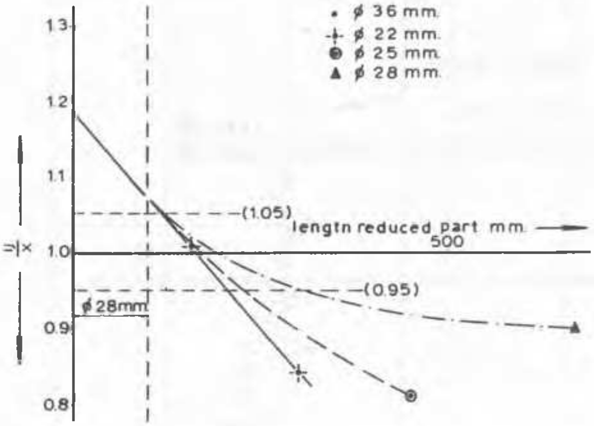

FIG. 3. RELATION BETWEEN THE DIMENSIONS OF THE NARROWED PART AND THE RESULTS OF THE ELECTRICAL SOUNDINGS

The relation given by the line IJ:X=1.0 of figure 4 indicates the possibilities for the choice of the required dimensions of the narrowed part of the shaft of the electrical cone.

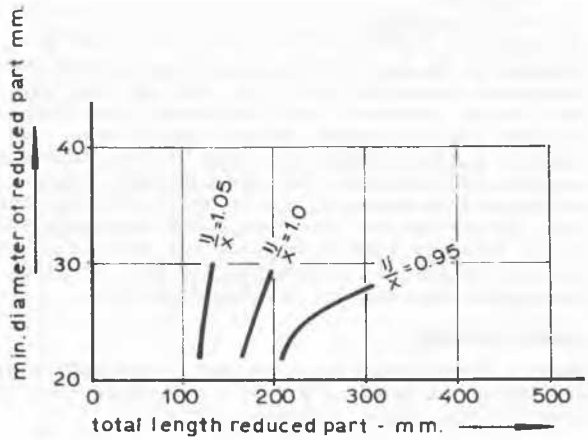

FIG. 4. RELATION BETWEEN LENGTH AND DIAMETER OF THE NARROWED PART OF THE SHAFT OF THE ELECTRICAL CONE FOR DIFFERENT VALUES OF THE TANGENT IJ:X

It is obvious from the results shown in figures 1 and 2, that the data obtained at this site with an electrical cone of a constant diameter of 36 mm are on the average about 20% higher than the readings of the mechanical soundings. This coincides fairly well with the values derived from a theoretical analysis.
As mentioned before higher deviations were observed at other locations.
In consequence of the results of these comparative tests the Delft Soil Mechanics Laboratory concluded to the application of an electrical sounding cone of which a part of the shaft directly behind the cone shaped point has a reduced diameter. The dimensions of this part have to be chosen according to the line IJ:X=1.0 from figure 4. Because of strength requirements of the electrical cone which has to withstand forces up to 7 metric tons

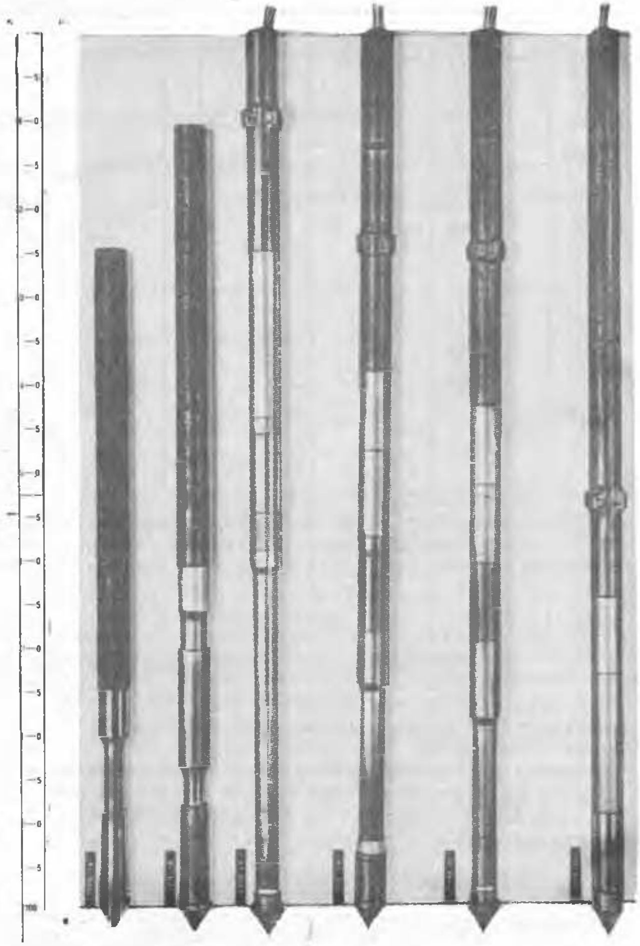

FIG. 5. CONES APPLIED FOR THE ADDITIONAL TESTS

the largest possible diameter of the narrowed part is prefered. In order to come to a definite choice additional tests were carried out on a site where the soil conditions are rather homogeneous. On the photograph of figure 5 the sounding cones used for these test are shown.

The dimension of the narrowed part of the shaft of the electrical cones meet the relation given in figure 4 for a tangent IJ:X=1.0.
Some of the results of these tests are shown in figure 6.

As expected the results of the continuous, electrical soundings with a cone having a narrowed part of 28 mm diameter and 200 mm length are in good agreement with the results of the discontinuous mechanical soundings.
The deviation of the results of the electrical cone of constant diameter (type VI) averaged about 30% in this case.
The effect of this deviation on the calculated pile point resistance can be considerable greater and amounts in this case about 80%.
Also included in this additional investigation was an electrical sounding cone of which the narrowed part of the shaft is situated behind the friction sleeve (see: type IV of figure 5). As shown in figure 6 the cone resistance results obtained with

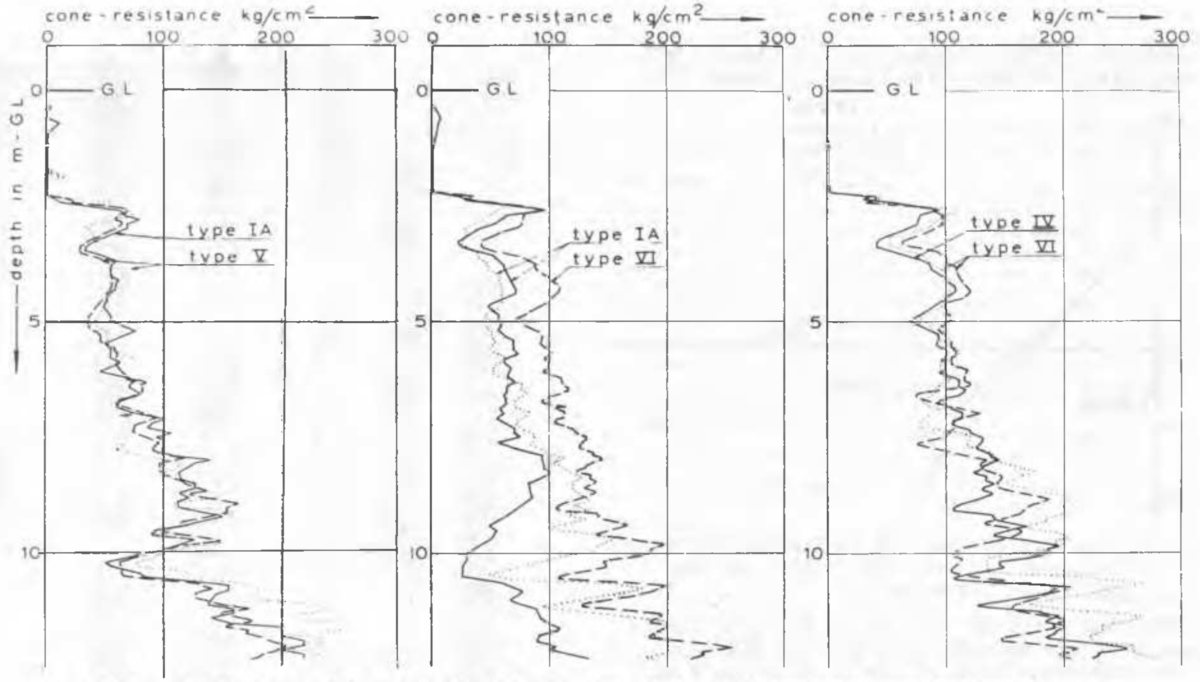

FIG. 6. COMPARISON OF THE RESULTS OF THE SOUNDINGS OBTAINED FROM THE ADDITIONAL TESTS

this type differ only slightly from the sounding results with the electrical cone of constant diameter (type VI).
Evidently narrowings placed at a distance of more than 10 cm above the point of the cone does not give sufficient relief to the increased soil pressures around the cone.

CONCLUDING REMARKS

According to the results of the described comparative investigation the Delft Soil Mechanics Laboratory has decided to apply an electrical cone with a narrowed part of 28 mm diameter and 200 mm length placed directly behind the cone-point. The results of soundings with this instrument are fully comparable with the results of the discontinuous,

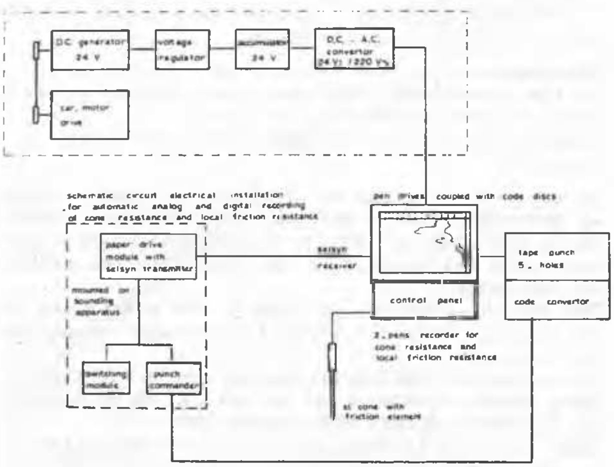

FIG. 7. SCHEME OF THE RECORDING EQUIPMENT IN THE SOUNDING TRUCKS OF THE DELFT SOIL MECHANICS LABORATORY

mechanical soundings.
The friction sleeve of 150 sq.cms is placed at a distance of 30 cms from the cone-point. From the results of soundings with this cone in sand layers a rather constant cone resistance over local friction ratio of about 100 was established. In figure 7 a broad scheme is shown of the facilities in the sounding trucks for the automatic registration of the cone-resistance and local friction data. The results of the tape punch apparatus can be fed directly into a computer for automatic computation of the toe resistance and skin friction for foundation piles of various diameter.

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The soil mechanical interpretation of the results was carried out in close co-operation with Mr. A.W. Koppejan.

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