RISK IN ESTIMATION OF ULTIMATE LOADS OF ASH FILL BY MODEL TESTS

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SYNOPSIS - The paper presents the reliability of bearing capacity equations for calculating ultimate load with respect to Model Plate Load Test on ash fill at different depths. The advantage of conducting Model Tests is that the test parameters that influence the estimated value of ultimate load significantly can be controlled effectively. As there is serious problem of disposal of fly ash, this study is done on compacted ash fill with a view to use it in land filling and reclamation of low lying areas. For this, an experimental program has been conducted to study the difference in the measured ultimate load by Model Plate Load Tests (MPLT) and bearing capacity equation. The results indicate that the bearing capacity equation over-estimates the actual value of bearing capacity for D/B ratio < 0.5 and under-estimates the bearing capacity value for D/B ratio ≥ 1.0.

INTRODUCTION

For comparing the results by Model Plate Load Tests (MPLT) with bearing capacity equations for fly ash, a term called risk factor is defined. RISK FACTOR (F_r) is defined as ratio of ultimate load carrying capacity of footing by Model Tests to the ultimate load carrying capacity determined by bearing capacity equations for ash fills. MPLT were conducted under plane strain conditions in a specially fabricated tank of inner dimensions of 150mm x 600mm with a height of 600mm with 10mm thick mild steel plate.

For conducting the MPLT, a plate of width 100 mm is used as footing and effect of depth is studied by performing tests at D/B ratio equal to 0, 0.5 and 1.0 for strip footing. The results obtained from MPLT are compared with bearing capacity equations obtained by limit equilibrium methods on fly ash with help of statistical models (Normal Probability Distribution).

LITERATURE REVIEW ON PLATE LOAD TEST FOR FLY ASH

The ultimate load when deformations are large is related to the strength of soil and load deformation behaviour is related to soil stiffness. A case study on typical ASTM class F Ontario ash was reported by Toth et.al., (1988). During the compaction of fly ash landfill, it was observed that the densities being achieved in the field were below 95 percent of standard Proctor density. On the basis of behaviour of the fly ash during model plate load tests, 90 percent of standard Proctor density was selected as the target density for the fly ash and land fill (Crag and Chan, 1988).

Results of investigations conducted by Toth, et al, (1988) are given in Table 1. They contain some apparent contradictions. Test no.1 and 2 conducted on same degree of compaction (93.4%) and same plate size (600mm diameter) show different settlement at stress level of 100 kPa (2.61 and 3.59 mm). In the opinion of the author, the difference may probably be due to variation in ash type deposited or moisture conditions at test location.

Table 1 : Results of plate load test on compacted Ontario ash (Toth et.al, 1988)

Test No.	Plate dia in mm	Maximum Pressure Applied, kPa	Maximum Settlement mm	Settlement in mm at 100 KPa
1	600	157	4.1	2.61
2	600	192	6.9	3.59
3	600	225	3.2	1.42
4	300	225	1.0	0.44
5	600	278	4.0	1.44
6	300	1246	7.3	0.58
7	300	1246	4.0	0.32

EXPERIMENTAL PROGRAMME

Model Plate Load Tests (MPLT) were conducted in a specially fabricated tank of dimensions 600 mm x 150 mm x 600 mm under plane strain conditions. Fly ash collected from the discharge point in the ash pond at Ropar Thermal Power Station was used. It was placed in five layers in the tank, each layer conducting 5 kg of fly ash. Each layer was compacted statically under a pressure of 400 kPa. By this method, a compacted dry density of 1.022 g/cc was achieved which is equivalent to 90 percent of maximum density determined by the standard Proctor test (IS 2720 Part 7).

The MPLT was then conducted using a 100 mm size plate. While the test at D/B = 0 was conducted by placing the plate on the compacted fill, the tests at deeper levels were conducted after carefully removing the fly ash to the desired depth. The outer limits of the zone of fly ash to be removed were marked by inserting two sharp edge sheets to the required depth on either side spaced 100 mm apart. After removing the fly ash, the model footing was carefully inserted.

The test load was applied in increments of 40 kPa with help of a hydraulic jack. The deflections were measured using two dial gauges and the load was recorded using a calibrated proving ring. The load was maintained till the settlement became negligible (upto 1 hr). Thereafter, the load was increased in increments till the failure occurs. Twelve tests were conducted at each depth ratio (D/B = 0, 0.5, 1.0).

Properties of Fly Ash Used for Study

Grain Size Analysis
D_{10} (mm) = 0.018
D_{50} (mm) = 0.100

Specific Gravity
Specific Gravity G_s = 1.98

Compaction Characteristics
OMC (%) = 40
Maximum Dry Density (kN/m^3) = 10.22

Shear Strength (Direct Shear Test under Dry Condition)
Degree of Compaction = 90%
Cohesion intercept, c = 0
Angle of internal friction, ϕ = 43.5°

The c and ϕ values given above are the mean of 12 direct shear tests.

Permeability
k = 5.43×10^{-4} cm/sec.

RESULTS AND DISCUSSIONS

The load settlement curve was plotted and the ultimate bearing capacity was taken as the point at which the tangents drawn from the initial portion of the curve and from the final portion of curve intersect. Typical results from one test are presented on Fig.1.

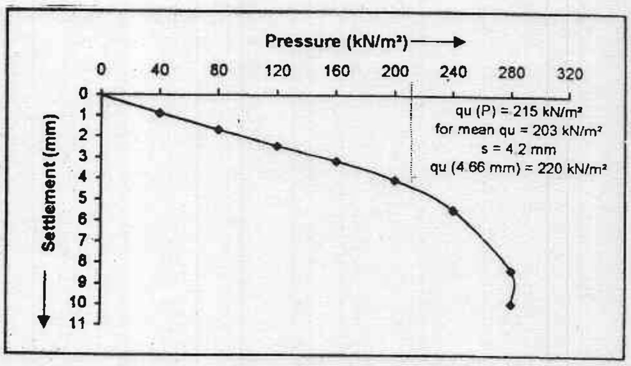

Fig.1 : Typical Results of Model Plate Load Test on Fly ash at D/B = 0

(1) The mean value of ultimate bearing capacity from 12 MPLT for strip footing of width 100mm at D/B = 0 is 203 kN/m^2 with 9.15 standard deviation.

The results of MPLT have been compared with bearing capacity equation for fly ash as modified by Trivedi. A, (1999).

$$q_u = c\,N_c S_c d_c i_c + \gamma D_f S_q d_q i_q + \tfrac{1}{2} B\gamma N_\gamma S_\gamma d_\gamma i_\gamma$$

where N_c, N_q and N_γ are bearing capacity factors. The bearing capacity factors have been modified by Trivedi based on experimental studies on flyash and analysis based on limit equilibrium condition as follows :

$$N_\gamma = e^{(0.11\phi+1)} \qquad if\ \phi < 40°$$

$$N_\gamma = e^{(0.22\phi-3.3)} \qquad if\ \phi \geq 40°$$

Depth factors are also modified by Trivedi, A, for fly ash.

$$d_q = d_\gamma = 1 + 0.2\ D/B \tan(\pi/4 + \phi/2)$$

The ultimate load from the above bearing capacity equation is 270.05 kN/m^2. On comparing the results of mean of 12 MPLT with the bearing capacity equation, it is found that equation overestimates the value of ultimate load at D/B = 0 by about 25 percent. Thus, the risk factor works out as 0.75.

(2) At D/B = 0.5 the mean value of ultimate bearing capacity of 12 MPLT is 388.9 kN/m^2 with 21.07 standard deviation, while the ultimate load from bearing capacity equations is 399.40 kN/m^2. Thus, at D/B = 0.5 the results of MPLT approximately matches with bearing capacity equation for ash fill, i.e. the risk factor is 1.

(3) At D/B = 1.0 the mean value of ultimate bearing capacity from 12 MPLT is 678 KN/m^2 with standard deviation of 27.25, while the ultimate load from bearing capacity equation is 553.92 KN/m^2, i.e., bearing capacity equation underestimates the ultimate load with respect to MPLT at higher depths. The risk factor in this case works out as 1.22.

(4) At all depths, the results of MPLT follow the Normal Probability Distribution. The results of all 12 tests lie between μ-2σ to μ+2σ where μ is the mean and σ is the standard deviation of bearing capacity at each depth ratio.

Normal Probability Distribution is

$$f(x) = N(X,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \left\{ e^{\frac{1\,(x-\mu)^2}{2\sigma^2}} \right\}$$

for $-\infty < x < \infty$ (Winer, B.J. (1971).)

where the mean, μ and the standard deviation, σ, are two parameters whose values determine f (x).

Typical curve of normal probability distribution at D/B = 0 is presented on Fig.2

CONCLUSIONS

For the evaluation of ash as a structural fill, the analysis of ultimate loads and settlements is done with help of Model Plate Load Test (MPLT). The results have been compared with the modified bearing capacity equation (limit equilibrium method) for ash fill at different D/B ratios.

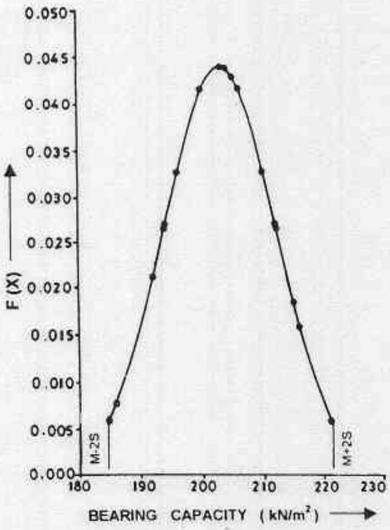

Fig.2 : Variation of Bearing Capacity with Normal Distribution at D/B = 0

- For surface footings, bearing capacity equations overestimates the value of ultimate load by about 25% (i.e. risk factor = 0.75).
- At D/B = 0.5 the results of MPLT approximately matches with bearing capacity equation for ash fill, i.e., risk factor is 1.
- At D/B = 1.0, the bearing capacity equation underestimates the ultimate load with respect to MPLT (i.e. risk factor > 1.0).

The authors believe that this under-estimation at higher D/B ratio may be due to following reasons :

(i) The bearing capacity equation under estimates the effect of surcharge, and

(ii) The intermediate principal stress (σ_2) which acts as a restoring force is not taken into account in bearing capacity equation at higher depths.

Based on this study, the authors recommend that the results from bearing capacity equation can be used safely except for footings with D/B ratio < 0.5.

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