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Technical Note

Behaviour of a Conical Shell Foundation in Sand

S.K.A. Zaidi*, Mazhar Ali*, Tabassum Naqvi†, S.M. Muzhir‡ and Aslam Qadeer‡

Introduction

Annular, circular and raft footings are commonly used for Water Towers, TV Towers, Cement Silos, Smoke Stacks, Microwave Transmission Towers, Cooling Towers etc. All the forces, which a structure is to withstand, are ultimately transferred to the soil through its foundation. Since the shell structures derive their strength from "Form" rather than "Mass", a shell footing only few centimetre thick can provide the same rigidity as a much thicker raft, and hence shell foundation has now emerged as an economical and feasible alternative for circular and annular footings. Due to large reduction in bending in the shell foundation, considerable saving in the volume of concrete and steel is achieved, though the shell foundation in the present forms is a new comer in the family of structural foundations (Kurian, 1982).

Experimental Details

Model Details

Three aluminium conical shells with semi-vertex angle 30°, 45° and 50° having base diameter, 155mm top section diameter 20mm and wall thickness 1.0mm have been tested individually. The 17mm wide bottom ring beam was provided throughout the periphery. 6mm diameter hole was provided at the top of cone to fill the core soil in the shell body and also to accommodate a ball so that the model can be centered with the proving ring and load applied centrically.

* Lecturer, University Polytechnic, Aligarh Muslim University, Aligarh.

† Sr. Lecturer, Department of Civil Engineering, Z.H. College of Engrg. and Tech., Aligarh Muslim University, Aligarh.

‡ Professor, Department of Civil Engineering, Z.H. College of Engrg. and Tech., Aligarh Muslim University, Aligarh.

Experimental Box

A tank 2.0m × 1.0m × 1.0m internal dimension was used for accommodating the bed of sand. The bottom and three sides of the tank were made of 6 mm thick steel plate and the remaining longer vertical side had glass sheet mounted on M-S channel and angle iron in the form of horizontal and vertical stiffeners by which the whole load of tank is transferred. The size of the model shell was so selected to keep the rupture zones 2.5D from centre of shell footing in horizontal direction and 3D from the base of shell footing vertically to avoid the effect of boundaries of the tank.

Maintaining the Density

The density of sand was maintained by the rainfall technique (Walker and Whitkar, 1967). The density of sand in the raining technique depends upon the intensity of rain and the height of fall. The raining equipment designed and fabricated, consists of a container (2.50m × 0.3m × 0.15m) made of mild steel plates, having 300 micron sieve at its bottom. The container was mounted on trolley which could move on a track laid at a suitable height above the tank. The trolley was brought near one end of the tank and the container was filled with air-dried clean sand. The height of the trolley was raised gradually to maintain the height of fall approximately constant. The sand was deposited in the tank by method of raining the layers of 100mm. The core was also filled by sand falling from the same height to obtain equal density in and out of the conical shell.

Mounting and Protecting the Strain Gauges

The models were first cleaned using emery paper, then degreased with carbon tetrachloride using cotton wool. Strain gauges (type SA-10) were mounted at selected locations using durofix adhesive. The gauges were kept pressed on to the specimen for about twenty four hours for hardening. The leads were then soldered to these gauges for connecting with the strain recording bridge.

All those gauges were from the same lot resistance 121.0 + 0.2 ohms, gauge factor 2.06 + 2% and gauge length 10mm for both active and dummy (temperature compensatory) gauges.

Channel Strain Gauge Set

A schematic circuit diagram of wheatstone bridge was used with a spot galvanometer and a multiway apex unit. The apex unit available had 32

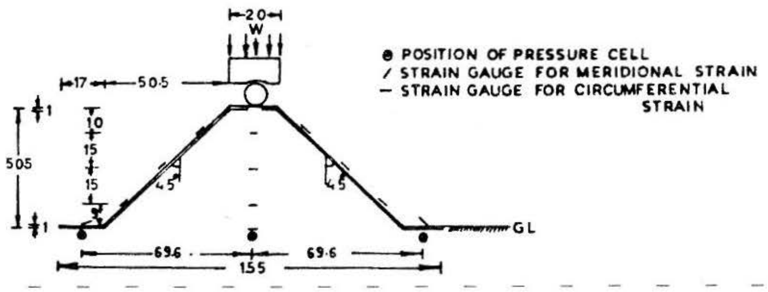

FIGURE 1 : Location of Pressure Cells, Strain Gauges of a Conical Shell (Semi-Vertex Angle 45°)

channels which can be brought into service separately by using three 12 point selector switches.

Loading Arrangement

The loads on the shell model were applied by means of screw jack and calibrated proving ring of 250kg capacity. Loads were applied in small increments and the next increment was applied when the settlement became constant (Fig. 4).

Measurement of settlement

Two sensitive dial gauges of least count (0.01mm) were placed directly at the edge beam on diametrically opposite sides. The dial gauge were mounted through magnetic bases with the help of M-S channel at the top of the tank. An average settlement was obtained from the settlement recorded by the two dial gauges for each increment of load applied.

Measurement of pressure in the soil mass

Three free earth pressure cells were embedded at 20mm depth from the base of shell footing during filling of the tank (Fig. 1). The earth pressure at these locations was measured using the pressure cells and the recording devices (switching and balancing unit and universal indicator).

Measurement of strain

Sixteen number of strain gauges were used for each model in which eight were placed for hoop strain and remaining eight for meridional strain.

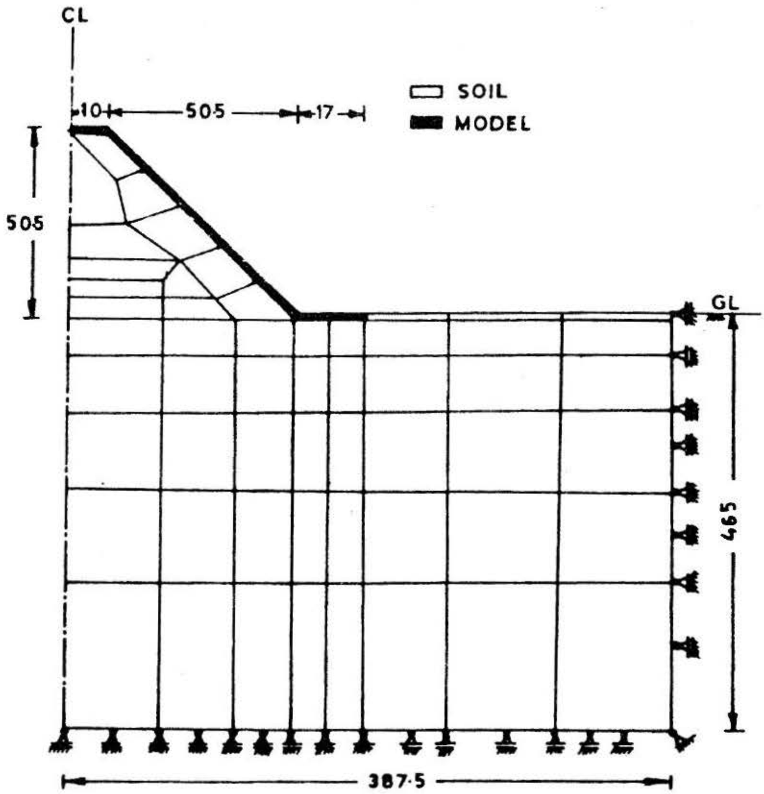

FIGURE 2 : Discretised Mesh with Boundary Condition for 45° Semi-Vertex Angle Conical Shell Footing

Soil used

In this study medium uniform river sand was used.

Properties of sand

Uniformity coefficient, C_u	=	1.54
Coefficient of curvature, C_c	=	12.01
Effective size, D_{10}	=	0.120 mm
Specific gravity	=	2.63
Dry density	=	1.61
Angle of internal friction	=	37°
Cohesion, c	=	0
Void ratio	=	0.63

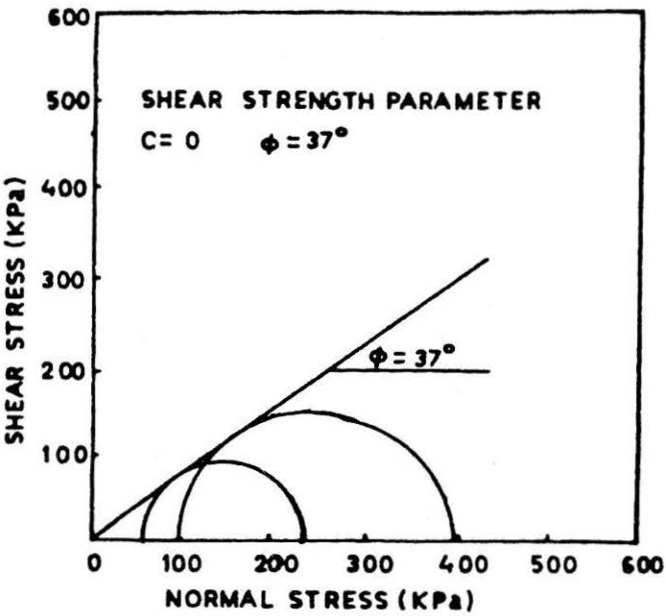

FIGURE 3 : Mohr Circle Diagram

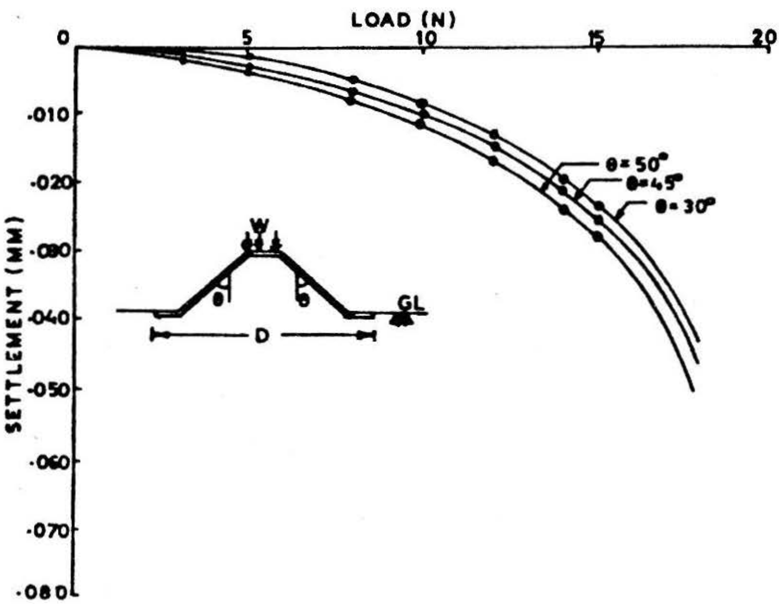

FIGURE 4 : Load – Settlement Curve (Experimental)

Poisson ratio of soil, μ_s	=	0.35
Young's Modulus of soil, E_s	=	80 MPa
Poisson ratio of Aluminium, μ_A	=	0.31
Young's Modulus of Aluminium, E_A	=	7000 MPa

The soil used was poorly graded sand (SP), the angle of shearing resistance was obtained from drained shear test for confining pressures from 50kPa to 100kPa (Fig. 3).

Analysis by Finite Element Method

Conical shell footing has been analysed for three different semi-vertex angles (30°, 45° and 50°), Young's modulus of soil (E_s) of 80 MPa and Poisson's ratio 0.35. The soil mass has been discretized into 92 elements giving 312 nodes. Eight noded isoparametric quadrilateral element has been employed in this analysis. The behaviour of soil has been assumed to be linear (Fig. 2).

Results and Discussion

(1) Out of the three cases of conical shell foundation having semi-vertex angle of 30°, 45° and 50°, the settlement was minimum in case of cone with semi-vertex angle of 30° (Fig.s 4 and 6), thereby giving larger bearing capacity as a result of which for the same base area, the load carrying capacity for this case will be maximum.

(2) The earlier study and also IS-9456:1980 recommendation assume uniform contact pressure. However, the Finite Element Analysis carried out in the present study, has revealed non-uniform contact pressure distribution giving maximum at junction of conical shell with the edge beam (Fig. 5).

(3) The vertical soil pressure measured experimentally at the axis of cone below the edge beam, came out to be approximately same which is in agreement with the theoretical results, where this variation is about 20% at specific location, that is axis of cone and the junction of cone with the ring beam.

(4) The meridional and circumferential moments computed are negligible which are in conformity with the property of shells.

(5) The pressure at the centre of cone base was more than that below the edge beam.

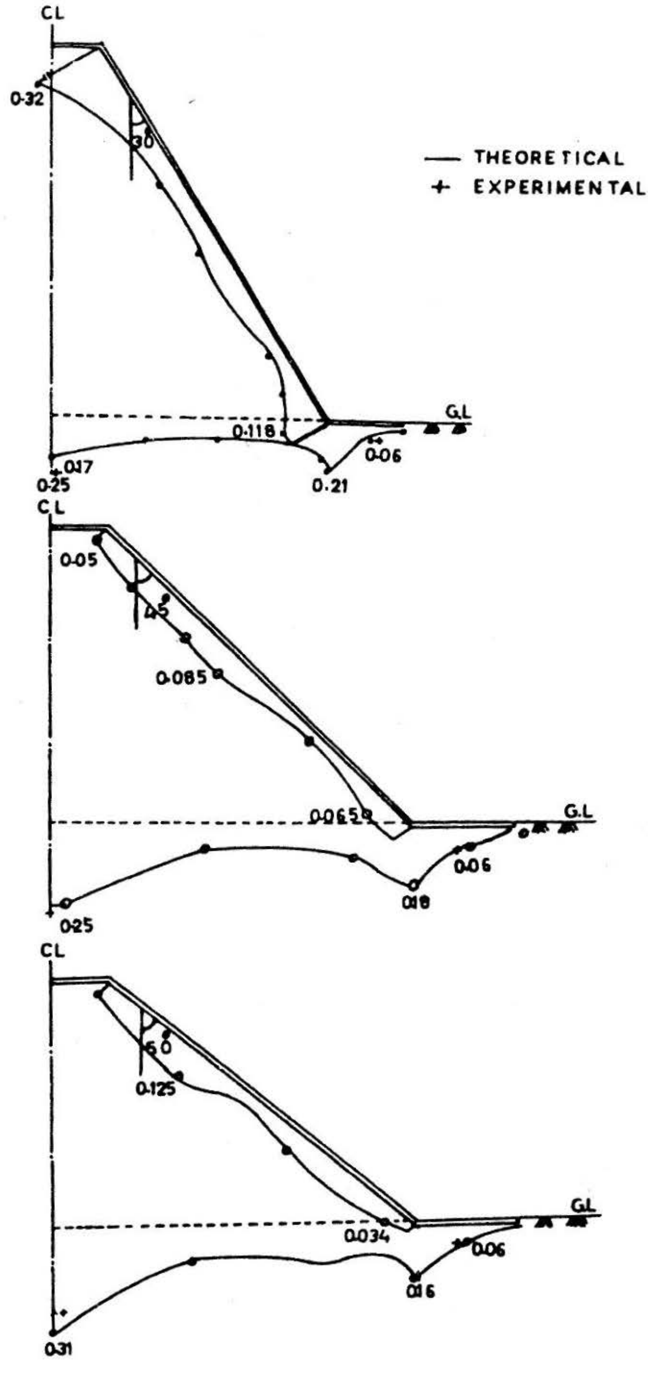

FIGURE 5 : Contact Pressure and Vertical Soil Pressure Distribution (MPa) for a Conical Shell Footing

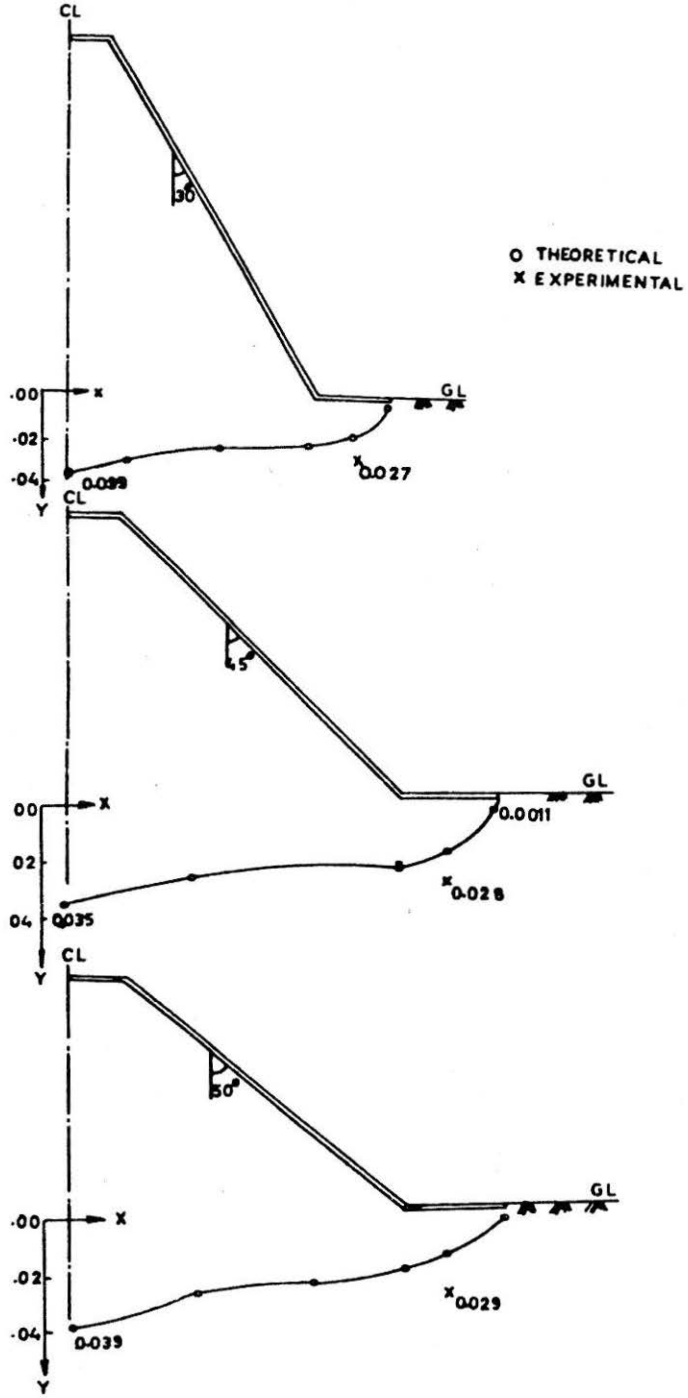

FIGURE 6 : Settlement Curve (MM) for a Conical Shell Footing

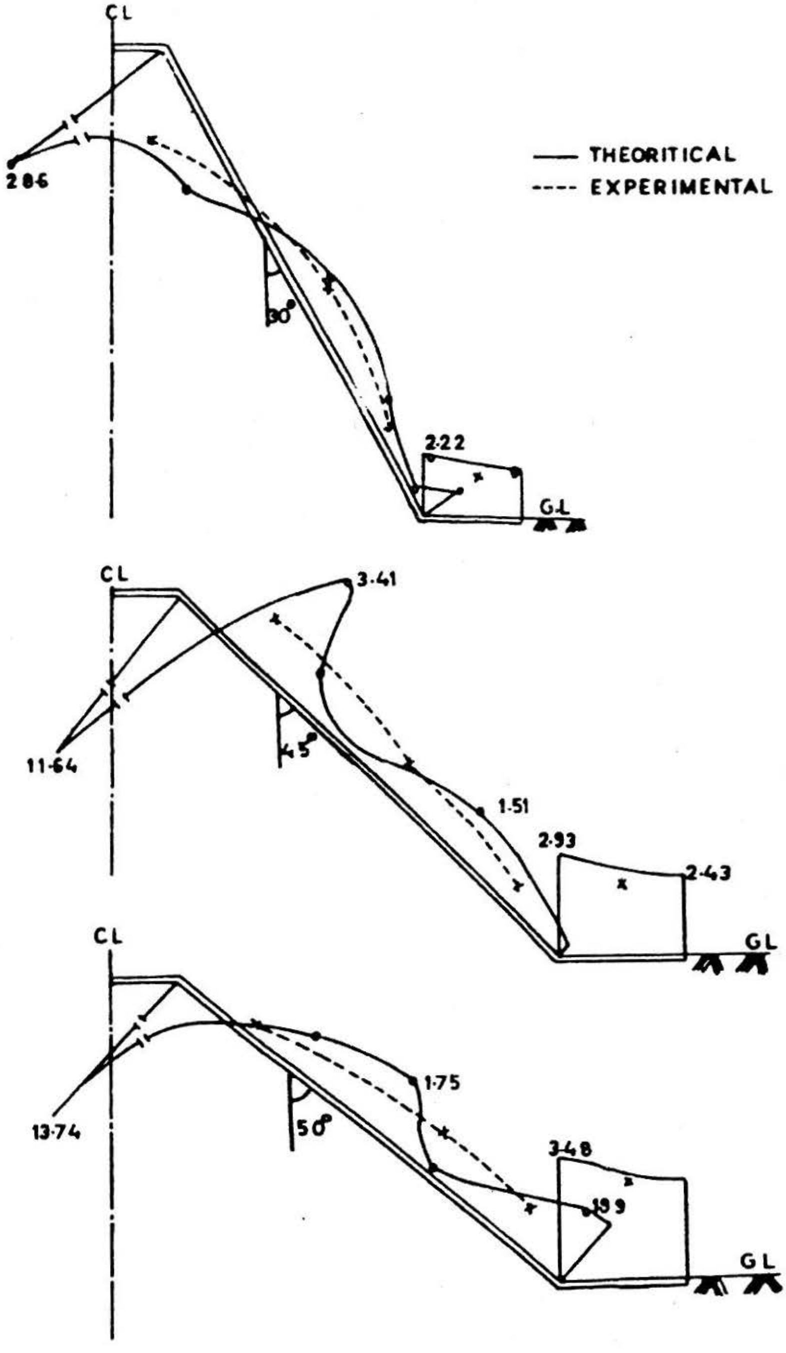

FIGURE 7 : Variation of Hoop Stress (MPa) in Conical Shel Footing

(6) The meridional and hoop stresses measured at the junction of shell with the column base and as well as at junction of shell with the ring beam, are minimum for 45° at both these locations (Fig.s 7 and 8).

Out of three conical shells considered, the one with semi-vertex angle of 45°, is most suitable as the stresses are minimum in this case and it is easy to make at the site.

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