INFLUENCE OF SUBMERGENCE ON THE BEHAVIOUR OF SHALLOW FOOTING

Salini.V[1], Jayamohan.J[2], Satheesh Chandran R[3]

[1]M.Tech Student in Translational Engineering, Translational Research and Professional leadership centre, Govt.Engineering College, Trivandrum, Kerala, India.
[2]Associate Professor, Department of Civil Engineering, LBS Institute of Technology for Women, Trivandrum, Kerala, India.
[3]Associate Professor, Department of Civil Engineering, Govt.Engineering College, Trivandrum, Kerala, India.

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Abstract - *Many states of our nation experienced unprecedented floods in the past few years, causing widespread damage to structures and embankments. This paper investigates the impact of floods on the settlement behaviour of shallow foundation in different types of soil. The results of a series of laboratory scale load tests to determine the influence of sudden submergence and drawdown on the settlement of footings are presented. The effects of three types of submergence are studied; due to sudden rise of ground water, drawdown and due to sudden inflow of surface water. Laboratory scale load tests on model circular footings are carried out in a masonry tank, which has arrangements for pumping in water and drawdown. The influence of rate of submergence on settlement is studied by varying the discharge of inflow of water. It is observed that the settlement of footing considerably increases due to sudden submergence of footing.*

***Key Words*: Flood, Rise of ground water, Drawdown, Laboratory scale load test, Settlement.**

1. INTRODUCTION

Urban flooding is a phenomenon that occurs where there has been a man-made development within the existing floodplains or drainage areas (e.g., new residential communities, retail establishments, commercial buildings, parking lots, etc). Damages to the building during inundations can be the result of not only the direct activity of the flood wave and surface water, but also changes in groundwater flow conditions, including the increase of their piezometric level . In the past few decades many researches have been carried out to investigate the analysis of settlement in foundation due to rise of ground water. It has been proved that there is an increase in settlement resulting in decrease in bearing capacity during inundation. Bearing capacity and the settlement are the two important parameters in the field of geotechnical engineering. Civil engineering projects such as buildings, bridges, dams and roadways require detailed subsurface information as part of the design process. Bearing capacity is affected by various factors like change in level of water table, eccentric loads, inclined loads, dimensions of the footings; etc Change in the degree of saturation can cause significant changes in volume, shear strength and hydraulic properties, consequently bearing capacity. Eventually the soil may get submerged and bearing capacity will get reduced.

Rise of ground water level is believed to increase the settlement significantly and had been a topic of research for many years. Some of the studies which have been conducted in this field are the effect of Submergence on Settlement and Bearing Capacity by Monir Kazi et.al (2015). They conducted simple laboratory experiments and have shown that the sand bed settles significantly when it is submerged under water for lower values of relative density. Terzaghi (1943) postulated that the submergence of the sand reduces the soil stiffness by half, which in turn doubles the settlement. Stress and pore water pressure changes in partially saturated soils under strip footings had been studied by Mohammed Yousif Fattah et.al(2014) They reported that there are two phenomena governing the behavior of footing represented by settlement (negative vertical displacement) and heave (positive vertical displacement). An increase of load on the foundation will increase the settlement and the failure surface will gradually extend outward from the foundation in heave behavior. Adel asakereh et.al (2015) evaluated the effect of water table rise on settlement of footing in coarse grain soil ,also the effect of soil elasto-plastic parameters include the effect of changes in modulus of elasticity, cohesion, internal friction angle and dilation angle of soil on the bearing capacity and settlement efficiency was calculated. Amy B. Cerato et.al(2007) were investigated the scale effects of shallow foundation bearing capacity on granular materials to further evaluate the trend of decreasing bearing capacity factor, Nγ, with increasing footing width, B. Ernesto Ausilioet.et.al(2017) They derived the analytical expression, allowing the bearing capacity of strip footings resting on a soil where the water table is at some depth below the footing base to be calculated. There is a scope for further investigations to identify the effect of other important factors (e.g. depth of embedment, footing width, soil gradation and different intensities of discharge in settlement behaviour of shallow footings with changing groundwater level. Many researchers have carried out numerical and experimental work to study the settlement and bearing capacity of soil in the past decade.

This paper investigates the impact of floods on the settlement behaviour of shallow foundation by carrying out a series of laboratory scale load tests. The influences of sudden submergence and drawdown on the settlement of footings are investigated. The effects of three types of submergence are studied; due to sudden rise of ground water, sudden inflow of surface water and draw down of water.

2. EXPERIMENTAL STUDIES

2.1Materials and methodology

Table 1: properties of soil

SAND		**CLAY**	
Property	Values	Property	Values
Specific gravity, G	2.65	Specific gravity	2.68
Effective grain size, D_{10} (mm)	0.13	Percentage of clay (%)	68
D_{60} (mm)	0.9	Percentage of silt (%)	30
D_{30} (mm)	0.34	Percentage of sand (%)	2
Coefficient of Uniformity, C_u	6.92	Liquid Limit (%)	58
Coefficient of Curvature, C_c	1	Plastic Limit (%)	22
IS specification	SW	Shrinkage limit (%)	16.2
Percentage of silt and clay (%)	6	Plasticity Index (%)	36
Percentage of fine sand (%)	31	IS Classification	CH
Percentage of medium sand (%)	47	Permeability, k (m/s)	3.03×10^{-6}
Percentage of coarse sand (%)	16	Optimum Moisture Content (%)	18
Permeability, k (m/s)	1.07×10^{-4}	Maximum Dry Density (g/cm^3)	1.59
Angle of internal friction, Φ (	31.2	Unconfined Compressive Strength, UCC (kN/m^2)	140.08
Cohesion, c (kPa)	0	Friction angle, Φ (^{0})	5
Bulk density, γ (kN/m^3)	18.436	Cohesion , c (kPa)	25

The load tests are conducted in a combined test bed and loading frame assembly. The test beds are prepared in a tank of internal dimension 1000 mm length x 750 mm width x 750 mm depth. The test tank is constructed with 230 mm thick brick masonry walls on the three sides. The model circular footing has a diameter of 100 mm, thickness 20 mm and is fabricated with mild steel. The sand is filled in the test tank to the required level with compaction done in layers of 50 mm thickness. To achieve the desired density of the soil, the layered filling technique is used. The clay was compacted by ramming. The loading tests are carried out in a loading frame fabricated with ISMB 300. The vertical load is applied using a hand operated- mechanical jack of capacity 50 kN. The applied vertical load is measured using a proving ring of capacity 100 kN.

Fig 1: Loading frame

The initial test is conducted with sand alone in the test tank. Sand is filled in layers of 5 cm thickness and is compacted using a plate vibrator. Piezometers are placed between these layers on opposite side of footing for measuring the head of water. After the preparation of sand bed, the circular footing is placed at the centre of the tank. Two dial gauges are fixed diametrically opposite to each other to measure the deformation. The given load measured by means of a proving ring, simultaneously the settlement measured by means of two dial gauges placed diametrically opposite to each other.

2.1 Parameters used in the study

The parameters used to vary in this study are shown in Table 2. The two inlet pipe at the bottom of the tank is opened for the full discharge, when the water level reaches the significant depth, the measurement of settlement commences. Tests are carried out at different discharges.

Fig 2: Plumbing arrangement

The inlet pipe at the top of the tank is opened and fills the tank just above the level of footing there by creating the surface flooding. The settlement values are then measured from the dial gauges corresponding to the time intervals. The corresponding head can be measured by means of the level of water in the piezometers. Then the outlet valve is opened for simulating the drawdown condition.

Table 2. Discharge parameters

Variation of discharge	Full	3/4	1/2	1/4
Longitudinal discharge (x10-6m3/s)	1.63	1.48	1.36	1.16
Lateral discharge (x10-6m3/s)	1.63	1.4	1.28	1.11

Fig 3: Test setup for Laboratory Scale Load Test

3. RESULT AND DISCUSSION

3.1. Rise of ground water

The rise of ground water corresponding to the longitudinal and lateral discharges of water is shown in figure 4

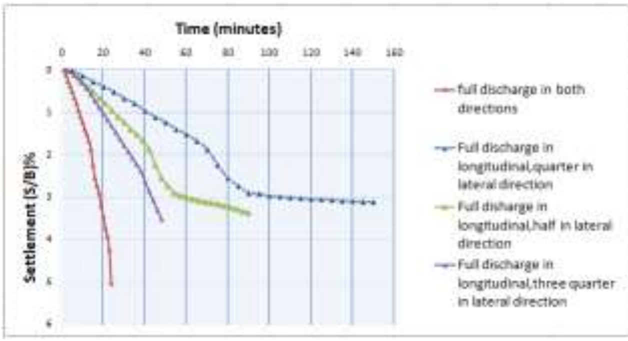

Fig 4: Rise of ground water in sand

From figure (4) it is observed that within a short span of 30minutes, settlement rate is more than 5%, when there is full discharge on the lateral and longitudinal direction. Then the discharge on the longitudinal direction kept constant at full rate and varying the discharge at three quarter opening of valve in lateral direction gives a settlement of 4% in 50 minutes, correspondingly, half discharge in lateral direction shows a settlement of more than 3% in 90minutes.The settlement rate is comparatively less for the quarter discharge, ie 3% in 150minutes. In case of ground water rise, the discharge on the longitudinal direction is kept constant and varying the rates of discharge on the lateral direction, it is observed that rate of settlement increases with increase in discharge

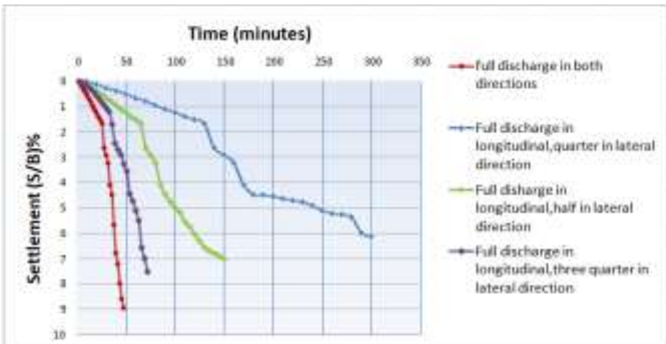

Fig 5: Rise of ground water in clay

From figure (5) it is observed that within a span of 50minutes, settlement rate is 9% for clayey soil, when there is full discharge on the lateral and longitudinal direction. Then the discharge on the longitudinal direction kept constant at full rate and varying the discharge at three quarter opening of valve in lateral direction gives a settlement of 7.5% in 70 minutes, correspondingly, half discharge in lateral direction shows a settlement of 7% in 150minutes, correspondingly for quarter discharge 6% in 300minutes.Clay soil shows more settlement.

3.2Draw down of water

The drawdown condition of sand in figure (6) shows the settlement increases with time.

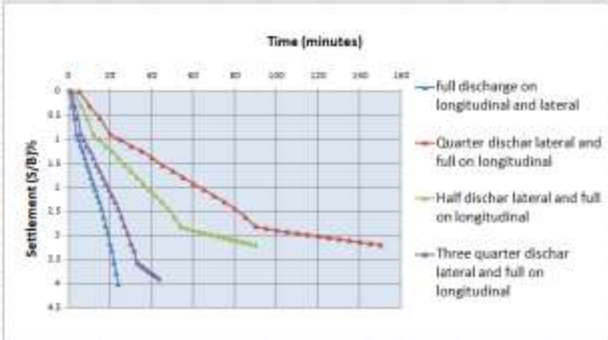

Fig 6: Drawdown condition in sand

The value (4% in 30minutes) goes on increasing at a rapid rate for the full discharge condition. It is observed that the draw down settlement rate is less when compared to the rise of ground water.

4. CONCLUSIONS

- In case of rise of ground water in sand, the rate of settlement increases with increase in discharge.
- Higher settlement values are obtained for the clayey soil
- In drawdown condition, settlement increases with time. The time taken to reach the settlement values is almost same for the ground water rise condition.
- The settlement increases at a rapid rate for the full discharge condition in rise of ground water and draw down condition
- The increase in settlement is due to hydrostatic pressure that develops with increase in head.

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