A STUDY ON THE

EFFECT OF MOISTURE

ON

STRENGTH CHARACTERISTICS OF RIVER SAND

Thesis submitted in partial fulfillment of the requirements for the degree of bachelor of technology

By

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Under the Guidance of

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2009

CERTIFICATE

This is to certify that the thesis entitled, **"A study on the effect of moisture on strength characteristics of river sand"** submitted by **Miss DEEPTI KUMARI** in partial fulfillment of the requirements of the award of Bachelor of Technology Degree in Civil Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by her under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university / institute for the award of any Degree or Diploma.

Date: 11.05.09

Prof. N.R.Mohanty

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Date: 11.05.08 DEEPTI KUMARI

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ABSTRACT

The top most mantle of earth, which was once rock, has been transformed to soil by natural forces of weather .Texturally soil is not one material but a compound of three ingradients, derived from the same parental rock . They are sand, silt and clay. Though mostly soil occurs as a combination of the three materials, there are places where stretches of sand do occur alone where building activity has to be carried out.

Besides occurrence of sand in a soil (its percentage) mass influences its strength characteristics to a great extent. For example, while constructing piers and abutments (of a bridge) which mostly stand on a sandy base, the bearing capacity of sand becomes the most important criterion in deciding the size and depth of the construction. Besides strength of silt and clay get drastically affected when it comes in contact with water. But sand except very fine sand, is least affected with water. It is therefore very important to study the extent to which the strength of sand is affected with water.

Chapter 1: INTRODUCTION

Long stretches of land, sandy in nature are found in many estuaries and delta areas of rivers. Shifting courses of river in a delta area also decrease the area pertaining to sand along with silty soil. In such cases it becomes a compulsion to build houses on sandy soils. As such areas are prone to flooding , these sandy soils are subjected to action of water. It therefore very necessary how this water affects the strength properties of sand, especially the bearing capacity on which the stability of foundation depends.

The same thing is true in gulp countries where there is no river but vast stretches of sand. Therefore it is very much a burning topic to study the effect of water on the strength characteristics of sand.

In the present case the sandy soil used for our experiment is procured from a near by koil river bed. It was cleaned, washed and dried. Its grain size distribution was found by sieve analysis. Considering the importance of effect of water on the strength characteristics of a sand for the case when a structure is founded on a sandy soil , this study basically focused on determination of strength properties of moist sand .Hence direct shear test with a water content up to 5% and model footing test with a water content up to saturation state is carried out to find the strength parameters of moist sand including some basic experimental works like sieve analysis, specific gravity test and moisture content determination .

Chapter 2: REVIEW OF LITERATURE

2.1 CLASSIFICATION OF SOIL:

In the United States of America one of the earliest soil classification was put toward before 1856 by the Bureau of Soils, United State Department of Agriculture (USDA). The divisional soil fraction and particles size in mm in this system are shown in.

Table 2.1: USDA BUREAU OF SOILS CLASSIFICATION

Fractions	Size (in mm)
Gravel	> 2
Sand	2 - 0.05
Salt	0.05 - 0.005*
Clay	0.05- 0.0005
Colloids	< 0.0005

*In 1938 USDA Bureau of soil changed the 0.005mm size limit to 0.002mm but engineer follow the previous original.

2.2.1 : MOISTURE DENSITY RELATIONS OF SOILS:

Two quantities are needed for the calculation of the dry density of soil: wet density and moisture content.

2.2.2 MAXIMUM DENSITY AND OPTIMUM MOISTURE CONTENTS:

The moisture content corresponding to the peat, or maximum ordinate of the curve is termed the "optimum moisture content" of the compacted soil sample at a specified amount of energy on that soil.

The oven-dried soil weight in pounds per cubic foot of the soil tested at OMC is termed the "maximum dry density".

Depending upon the type of soil and the specified compaction method, the numerical values of the optimum moisture contents range from about 9% to about 35% dry weight per cu of soil as determined by the standard compaction test vary from about 75 to 130 lb.

2.3 QUICK SAND CONDITION:

2.3.1 Definition and explanation:

Quick sand condition is a hydraulic condition in soil when there is an upward flow of water at a critical velocity. In this condition the soil particles are loosened, buoyed and lifted up, resulting in a "boiling" or "quick" condition.

Hydrodynamic pressure condition of seepage water in soil:

Here D = seepage force or hydrodynamic pressure

$$= \gamma_w i$$

Where $i = \frac{dh}{dl}$ is the hydraulic gradient.

when the flow through a dam body is upward and vertical, the hydrodynamic pressure acts vertically upward against the submerged unit weight of soil, γ_{sub}:

$$\gamma_{eff} = \gamma_{sub} - D$$

Here when γ_{sub}>D i.e when velocity exceeds critical velocity or V> V_C then γ_{eff} becomes negative. That means the soil particles are loosened, buoyed, and lifted up, resulting in a "boiling" a "quick" condition.

Structures founded on soil where quick condition exists sink down by their own weight because at quick sand condition the loosened soil loses its bearing capacity.

2.3.2 OCCURRENCE OF QUICK CONDITION:

Quick conditions of soil brought about by seepage forces are frequently encountered at the bottoms of foundation excavations in fine sand below the water table of a nature water basin.

It is quite possible that a foundation pit excavated in a fine sand soil during the late summer, when the position of the ground water table is low, is almost dry. But in early spring when position of the ground water table is high, seepage caused by the increased hydrostatic head of the raised ground water table may create a quick condition.

2.4 SHEAR STRENGTH AND SHEAR STRENGTH OF SAND

2.4.1 Definition:

The shear strength of soil is the resistance to deormation by continuous shear displacement of soil particles or on masses upon the action of shear stress.

The failure conditions of a soil may be expressed in terms of limiting shear stress, called shear strength or function of principal stresses.

The shearing resistance of soil is constituted basically of the following components

1. The structural resistance to displacement of the soil because of the interlocking of the particles.
2. The frictional resistance to translocation between the individual soil particles at their contact points and
3. Cohesion or adhesion between the surface of the soil particles.

   The shear strength in cohesionless soil results from inter granular friction alone while in all other soils it results both from internal friction as well as cohesion.

2.4.2 DETERMINATION OF SHEAR STRENGHT OF SOIL

The shear strength of soil is usually determined experimentally by the following method:

Direct shear test:

Controlled stress and controlled strain shear testing apparatus:

Controlled stress type

In controlled shear test apparatus the shear stress is applied at a constant rate or in equal increments by means of dead weight, for instance till failure occurs:

The shear displacement is given by a dial gages. It is used for most practical purposes in soil engineering

Controlled strain type

This type is mostly used in research, but can also be used for solving practical problems. The controlled strain (shear displacement) is applied to the shear box horizontally at a constant rate by means of a screw and a calibrated testing ring. The constant rate of shear displacement is observed on the dial gage. The testing ring with a calibrated force dial gage shows the shear resistance of the soil at any rate of horizontal strain applied to the soil viz, shear box.

2.4.3 SHEAR STRENGTH OF SAND

The principal advantage of the shear test apparatus of the controlled strain type is that in this test of a dense sand the peak shear resistance, as well as shear resistance smaller than the peak, can be observed and plotted.

2.4.3Behaviour of loose sand and dense sand during the process of shear:

Loose sands in the controlled strain shear test usually do not exhibit a peak shear stress on a graph as the dense sand do. Here with increase in shear strain the shear stress increases curvilinearly until an ultimate (failure) shear stress is attained. After this, a continuous, unlimited shear displacement may prevail without any change in shear stress.

During the process of shearing of a dense sand the following phenomenon can be observed: the soil particles move over one another in the shear strains. Loose sands on the contrary, decrease in volume upon shearing because, being in loose state of packing, the sand particles can readily readjust their position under the applied strain. An increase in volume means decrease in the density of the packing of the soil particles. A decrease in volume means an increase in density of packing of the soil particles.

At some intermediate state or degree of density in the process of shear, the shear stress do not bring about any change in volume viz, density. The density of sand at which no change in volume is brought about upon application of shear strains is called the critical density.

2.5 BULKING OF SAND:

2.5.1 Bulking of loose, moist sand in the increase in its volume as compared to dry sand. Bulking is a well known phenomenon particularly in the trade of aggregate for proportioning of concrete. This phenomenon has been known since 1892 when it is was investigated by Feret at French school of Bridges and Roads.

This bulking phenomenon of sand is explained by moisture hulls or films which surround the sand particles. The contact moisture films, adsorbed to the sand particles by moisture surface tension forces, tend to cause the sand particles to occupy a larger volume as compared to their dry state. Generally bulking of sand increases as the particle size of sand decreases. This is because of the increase in the specific surface area of the sand. Upon further subsequent increase in moisture content in sand, when a maximum increase in bulking volume is attained, bulking in its turn decreases, and upon the inundation of the sand the surface tension forces are neutralized, and most of the bulking, in such a case vanishes. As a consequence, the sand particles now rearrange themselves into a denser packing.

2.5.2. Effect of bulking on sand

Bulking of sand in a loose state of packing decreases the bearing capacity of sand considerably. In compacting sandy soils, low densities are usually achieved because of bulking.

Chapter 3: EXPERIMENTAL TEST SETUP

1. The experimental set up consists of the following units:
2. Masonary tank – 1 no.

   Length= 58.8 cm, Breadth= 51.2 cm, Height= 37 cm.

3. Dial gauges – 2 nos

   Least count – 0.01mm, 5cm range.

4. Loading frame.
5. Footing models

   Steel square footing-size = (i) 3.8 cm

   (ii) 6.3 cm

3.1 DESCRIPTION OF THE TEST SET UP

1. The masonary tank

The tank is made of 10 cm thick brick work which is cement plastered on all sides and has an internal dimension of 58.8 cm* 51.2 cm* 37 cm.

2. The loading frame

A mild steel loading frame was used, to the centre of which hollow vertical shaft (guide pipe) has been welded. The solid iron rod passes through the metal shaft which carry the loading platform on its top. The bottom of the iron rod is threaded so that the steel footing can be screwed. There is horizontal bolt connected to the hollow vertical shaft to clamp and unclamp the iron bar which carry the loading platform. To accommodate higher intensity of loading a wooden platform has been attached to the steel loading platform by nut and bolt arrangement. The weight of the loading platform was 6.649 Kg.

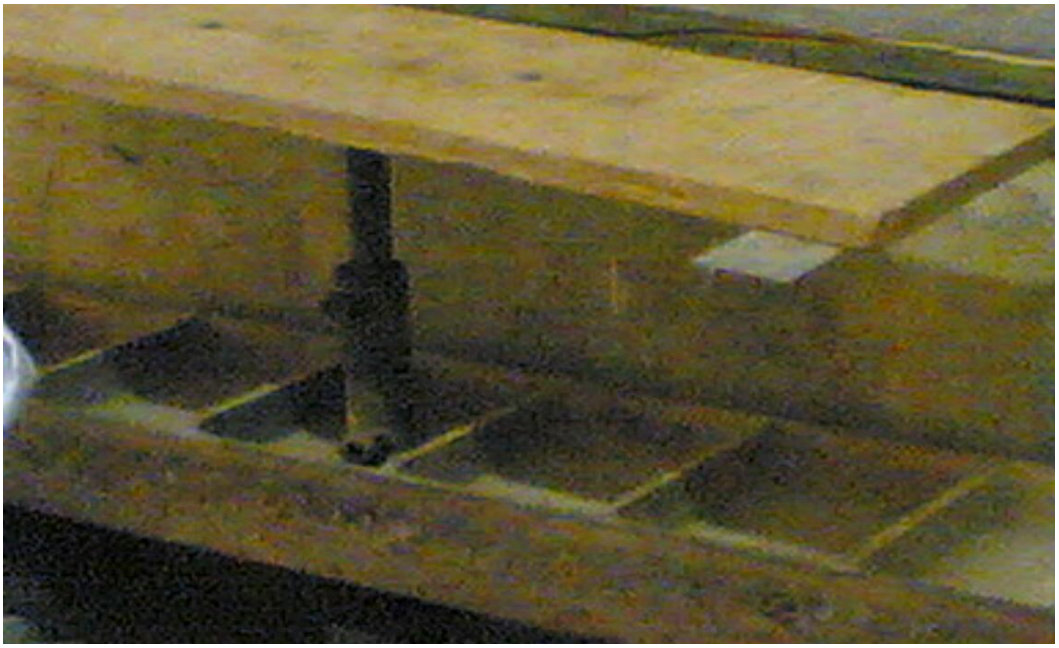


Fig 1: Loading frame and loading platform

3. Dial gauges

Two dial gauges with magnetic base were used. The dial gauges used had a least count of 0.01mm and rang of 5cm. The dial gauges were mounted on two opposite sides of the wooden platform to measure the settlement of the footing.

4.Footings

Steel (smooth base) footings of square shape were used. Footings were of two different sizes-3.8cm and 6.3cm.

SAND

In the present case the sandy soil used for our experiment is procured from a near by koil river bed. It was cleaned, washed and dried. Its grain size distribution was found by sieve analysis.

Fig 2: Experimental set up

3.2 EXPERIMENTAL TESTS AND PROCEDURES:

3.2.1 SIEVE ANALYSIS

Sieve analysis of the sand was carried out to plot the particle size distribution curve (also known as gradation curve) which represents distribution of particles of different sizes in the soil mass. The percentage finer than a given size is plotted as ordinate (on natural scale) and the particle size as abscissa (on log scale).

For sieve analysis about 300 gm of oven dried sample was taken and weighed. The sand was sieved through a set of sieves i.e by 4.75 mm, 2mm, 600u, 425u, 212u, 75u. Sieving was carried out for 10 minutes. The soil fraction retained on each sieve was collected in separate container and weighed. The percentage retained, cumulative percentage retained and the percentage finer based on the total mass taken was obtained.Necessary calculation were made and recorded in tabular form.

3.2.2 MOISTUTRE CONTENT TEST OF THE SAMPLE

The natural moisture content of the sand was found out by taking a small mass, weighing that then weighing the sample after oven drying, then necessary calculation were made.

The moisture content of the sand was determined by using the relation:

% Moisture content = $[(W_1-W_2)/(W_2-W_3)]*100$

Where W_1= Weight of pan and sand.

W_2= Weight of pan and dry sand.

$W_{3=}$ Weight of pan.

3.2.3 SPECIFIC GRAVITY TEST:

For determination of specific gravity of sand Pycnometer method was used. Three clear dry pycnometer of 250 ml capacity was used and weight of each was measured (M_1). Sufficient amount of clean, de-aired water was taken and the pycnometer was then filled upto the mark and weight of the pycnometer plus water was measured and designated as (M_4). 50 grams of oven dried sample was added to pycnometer and weight was measured as M3.

The specific gravity of sand was determined by using relation.

$$G = \frac{W_D}{W_d - W_8 + W_4} * \ Gw$$

Here W_d = 50 grams

And $G_w = \frac{\sqrt{W}\,(at\ test\ temperture\ )}{\sqrt{W}\,(at\ room\ temperture)}$

$$= \frac{\sqrt{W}\,(at\ 30^0 C)}{\sqrt{W}\,(at\ \ 27^0 C)}$$

3.2.4 DIRECT SHEAR TEST AND DETERMINATION OF SHEAR STRENGTH PARAMETERS

Direct shear test was carried out for the dry sand and for the sand with different percentage of water content (upto 5%). Three different normal loads of 5lb,10lb and 15 lb were taken and for each normal load the corresponding shear load was measured by means of proving ring. The test results have been given in tabulated .Normal loads were plotted in the x- axis and corresponding shear loads were plotted in the y- axis for each set of test. The cohesion parameter (c) was given by intercept of curve on y- axis and internal friction (Φ) was obtained by the slope of the curve.

3.2.5 TESTING OF ISOLATED FOOTING

3.2.5.1 DETERMINATION OF DENSITY OF FILL

To determine the density of fill following steps were carried out:

(i) An empty cylindrical mould was taken and its volume and empty weight was calculated.

(ii) Sand was poured in the mould up to the top with a funnel through fixed height of 60cm to have a uniform fill density.

(iii) Weight of filled mould was taken and weight of sand required was calculated.

(iv) Weight of sand required divided by volume of the mould gave the density of fill.

3.2.5.2 PREPERATION OF SAND PIT AND TEST SET UP:

(i) The weight of the sand required to fill the calculated volume of the tank at the placement density was calculated and the sand was poured through a funnel in a steady stream from a height of approximately 60cm to form a soil layer of uniform thickness.

(ii) The sand pit was filled in five layers, lower four of 7cm depth and top most of 9cm depth. The top surface of sand was checked by means of sprit level for having a uniform leveled surface. Sand required to fill each layer was obtained.

(iii) The loading frame was put across the masonary tank so that the axial loading shaft occupied the central position.

3.2.5.3DETERMINATION OF SATURATION WATER CONTENT

Saturation water content was determined with necessary calculations which are described later.

3.2.5.3 TEST CONDUCTION:

(i)Test was conducted with two different sizes of square footings of sides 3.8cm and 6.3cm.The steel footing was screwed with the threaded tip of the iron rod sand surface and the rod was lowered so that the footing just touched the sand surface.

(ii)The loading platform was clamped at this position. Dial gauges were mounted on both sides of the platform so that their tips touched the lower surfaces of the platform.

(iii)Then the load of the platform was released by unclamping the screw and after 5minutes settlements were observed with the help of two gauges each of least count 0.01mm .

(iv)This procedure was repeated with a load increment of 5kg till the soil failed.

(v)Test was done over dry sand, sand containing 1%,2%,3%,4%,5%,6%.10% moisture content and at saturation water content with both sizes of footings .For each set of test above procedures were repeated.

(vi) Load settlement graph for each set of the test were plotted and bearing capacity was determined.

Chapter 4: RESULTS OF THE TESTS

Table 4.1 Determination of particle size distribution of sand by sieving :

Sieve size	Mass of sand retained in grams	Cumulative mass of sand retained in grams	Cumulative % retained	% Finer
4.75 mm	0	0	0	100
2.00 mm	0	0	0	100
0.6 mm	29.2	29.2	9.73	90.26
0.425mm	68.46	97.66	32.55	67.44
0.212 mm	195.54	293.2	97.73	2.26
0.075 mm	4.2	297.4	99.13	0.866

Table 4.2 Determination of specific gravity:

Observation and calculation	1	2	3
Mass of empty pycnometer in grams (W_1)	120.44	113.88	109.81
Mass of pycnometer plus water (W_4) in grams	368.38	361.72	358.02
Mass of pycnometer plus water and sand (W_3) in grams	399.85	392.14	388.84
Specific gravity $G = [W_D/(W_D - W_3 + W_4)] * G_w$	2.699	2.554	2.507

Specific gravity of sand at room temperature was found to be 2.62.

Table 4.3: Determinatin of natural water content:

Wt of pan plus sand (W_1) in grams	90.13
Wt of pan plus dry sand (W_2) in grams	85.22
Wt o pan(W_3) in grams	12.29
Natural water content=$[(W_1-W_2)/(W_2-W_3)]*100$	6.73%

Table 4.4 Determination of angle of internal friction and unit cohesion by direct shear tests.

Proving ring constant: 51 div= 50 lb

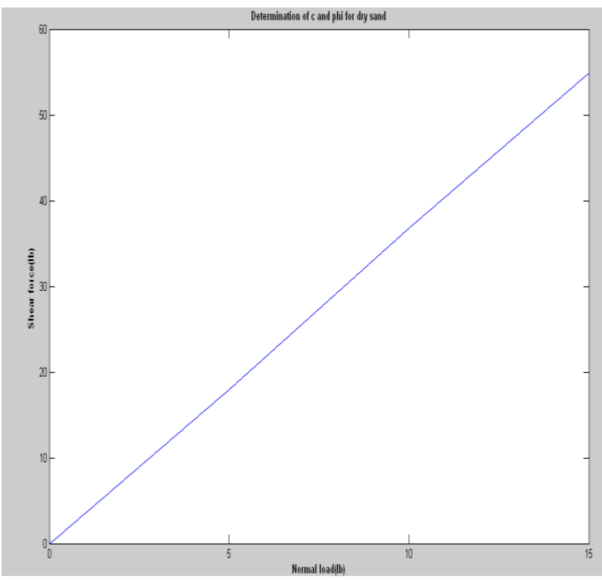
Table 4.4.1 Proving ring readings:

% of water	Sl no.	Normal load in lbs	Proving ring reading	Shear force in lbs
Oven dry sand	1	5	19	18
	2	10	38	36.78
	3	15	56	54.90
1% m.c	1	5	28	27.45
	2	10	44	42.54
	3	15	59	57.84
2% m.c	1	5	28	29.58
	2	10	49	48.04
	3	15	68	66.67
3% m.c	1	5	28	31.26
	2	10	45	44.12
	3	15	60	58.82
4% m.c	1	5	28	27.45
	2	10	46	41.31
	3	15	54	52.94
5% m.c	1	5	26	25.49
	2	10	45	39.78
	3	15	67	65.68

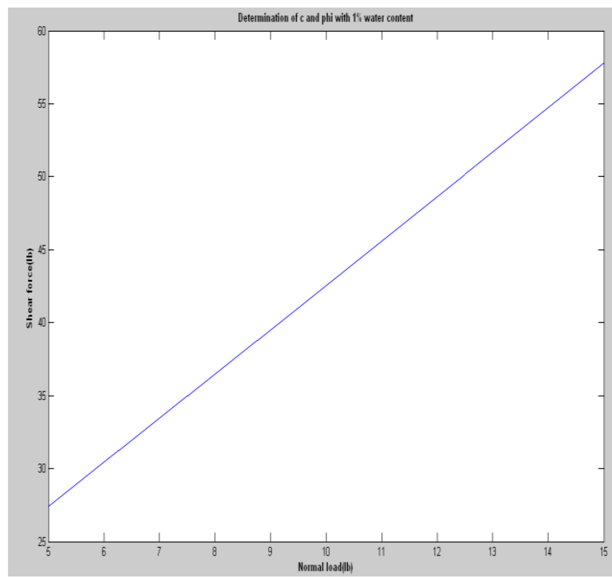
Table 4.4.2 Values of c and Φ:

% of water	Unit cohesion, 'c'(Kg/cm^2)	Internal friction, 'Φ'
Oven dry sand	0	74.72
1% m.c	0.151	71.87
2% m.c	0.157	44.43
3% m.c	0.201	71.07
4% m.c	0.198	68.19
5% m.c	0.062	73.30

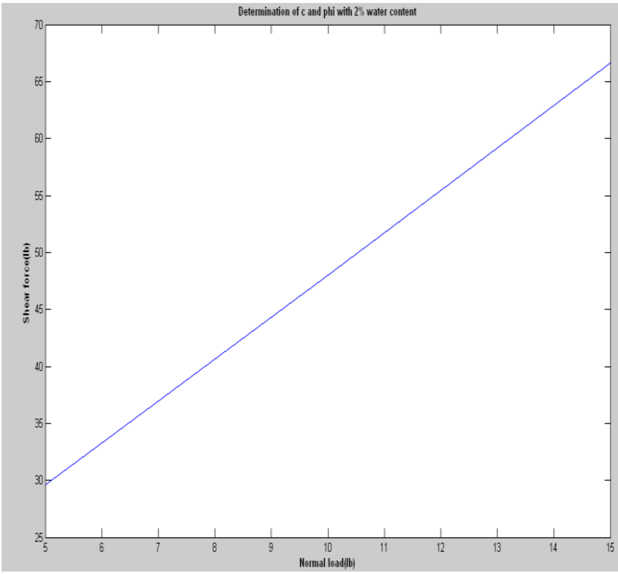
4.4.3 Plots of shear force vs normal load

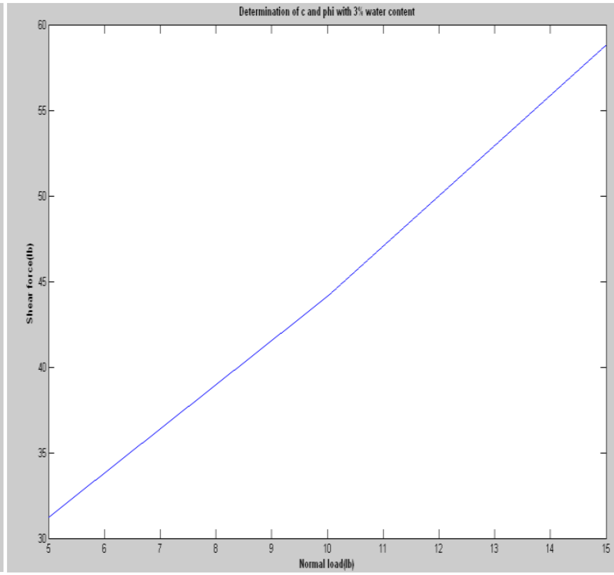


For dry sand

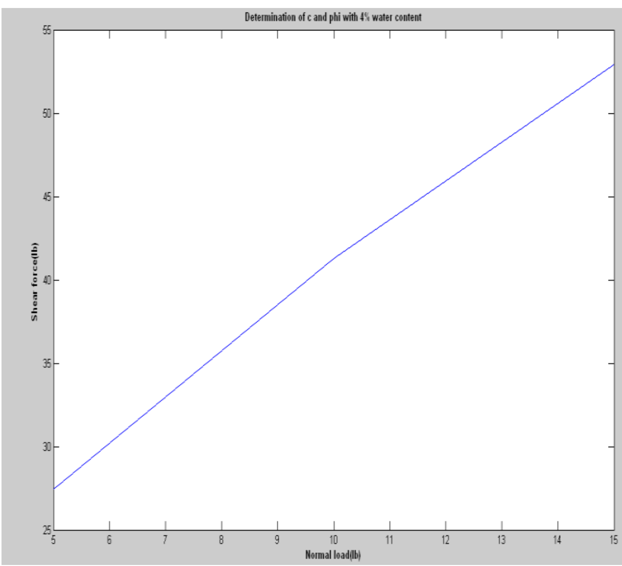


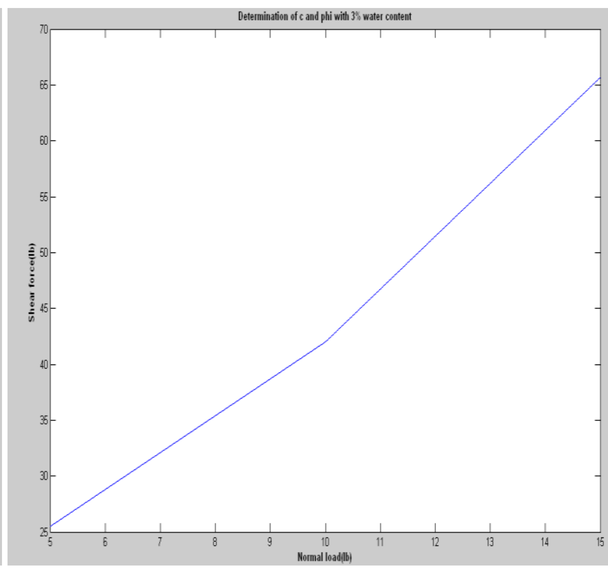
For 1% water content





For 2% m.c **For 3% m.c**





For 4% m.c **For 5% m.c**

4.5: Determination of ultimate bearing capacity:

4.5.1: Determination of density of fill:

Diameter of mould = 10 cm

Height of mould = 12.8 cm

Volume of mould = 1005.31 cm^3

Weight of mould = 4.21 Kg

Weight of mould and sand = 5.740 Kg

Weight of sand required to fill = 1.53 Kg

Density of fill = 1.53/1005.31=1.52 Kg/cm^2

4.5.2 Determination of saturation water content:

Volume of solids in the tank = [Total wt of sand(in grams)]/Specific gravity

=159000/2.62=60687.02 cm^3

Volume of water at saturation water content = Total volume -Volume of solids

=50703.7 cm^3

Mass of water at saturation =50703.7 ml

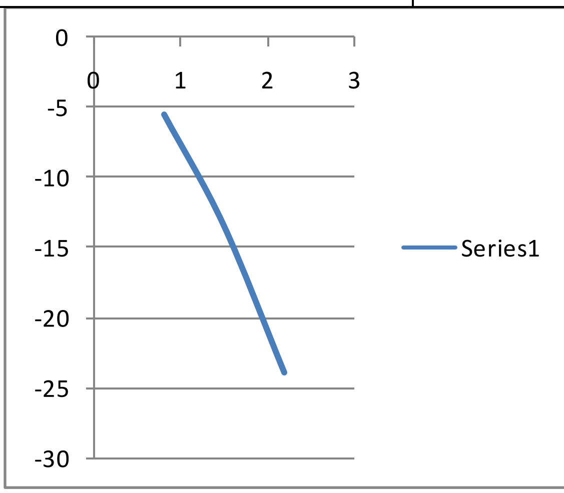
Saturation water content =31.88%

4.5.3 Settlements of footings:

Table 4.5.3.1: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in dry sand:

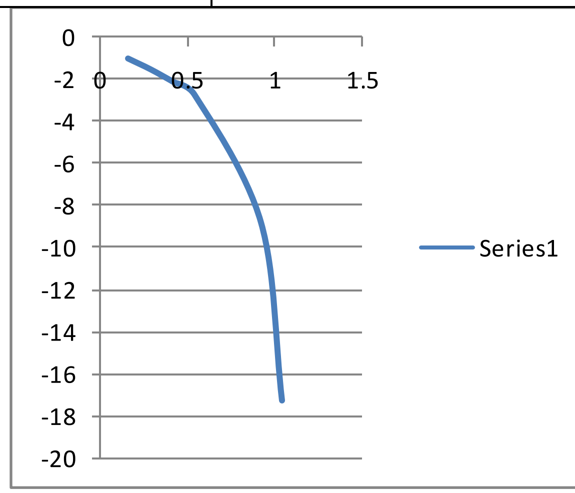
Load settlement in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	2.75	0.98
11.65	7.59	1.5

16.65	11.29	2.1
21.65	16.5	2.7
26.65	22.05	4.73
31.65		3.24
36.65		8.78
41.65		17.25



-Ve of settlement vs load intensity

3.8 size footing with dry sand

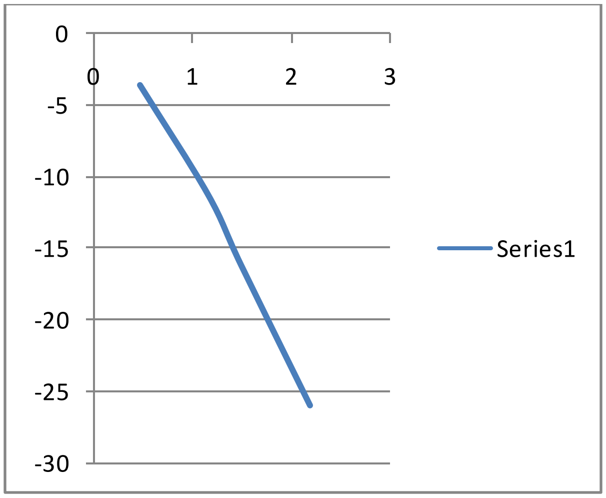


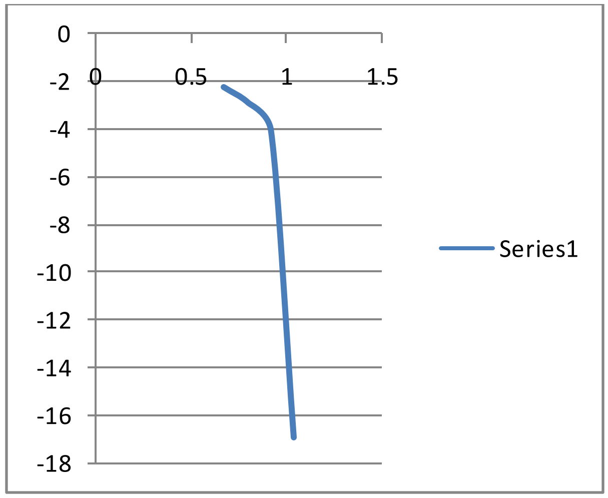
-Ve of settlement vs load intensity

6.3 size footing with dry sand

Table 4.5.3.2: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 1% moisture content :

Load intensity in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	3.66	0.6
11.65	8.1	0.96
16.65	11.25	1.39
21.65	16.2	1.59
26.65	20.19	2.25
31.65	25.95	2.91
36.65		4.08
41.65		16.95





-Ve of settlement vs load intensity

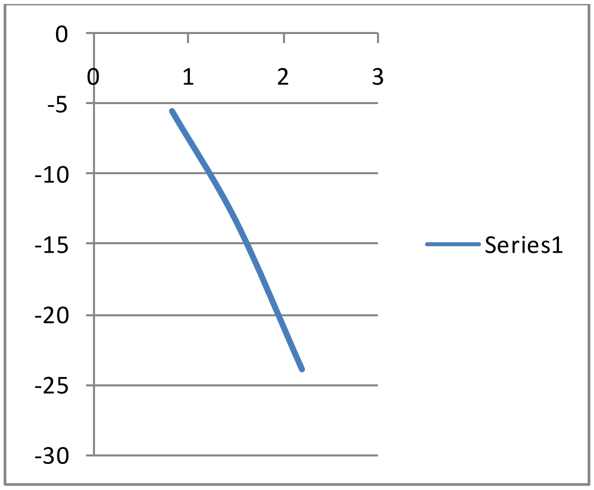
3.8 size footing with 1% m.c

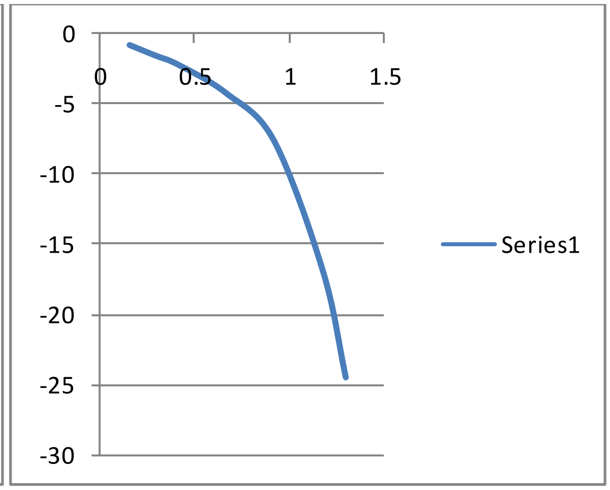
-Ve of settlement vs load intensity

6.3 size footing with 1% m.c

Table 4.5.3.3: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 2% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	2.1	0.75
11.65	5.55	1.47
16.65	9	2.18
21.65	13.35	3.3
26.65	19.2	4.2
31.65	23.85	4.74
36.65	28.5	7.56
41.65	33.9	11.03
46.65		16.94
51.65		24.53



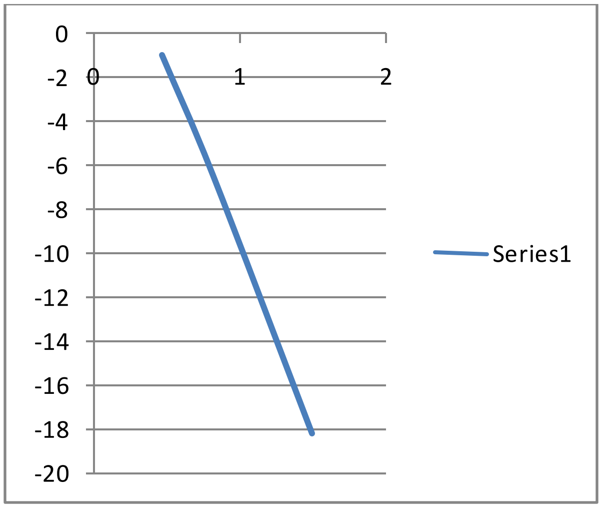


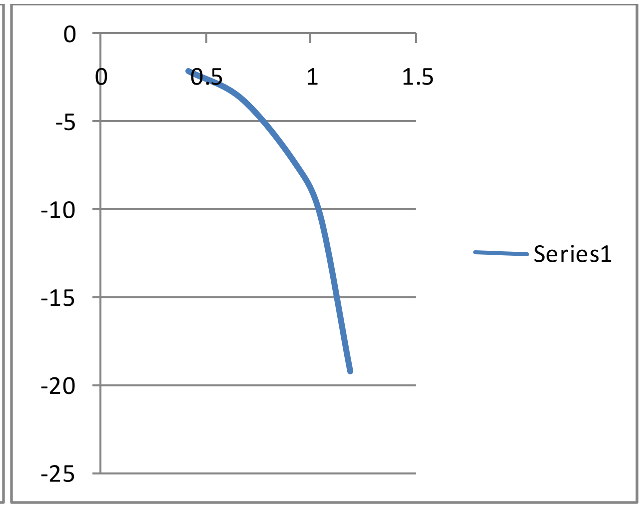
-Ve of settlement vs load intensity **-Ve of settlement vs load intensity**

3.8 size footing with 2% m.c **6.3 size footing with 2% m.c**

Table 4.5.3.4: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 3% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	1.01	1.385
11.65	6.48	1.12
16.65	8.32	2.1
21.65	18.24	3.28
26.65	22.5	3.68
31.65		6.75
36.65		7.35
41.65		10.38



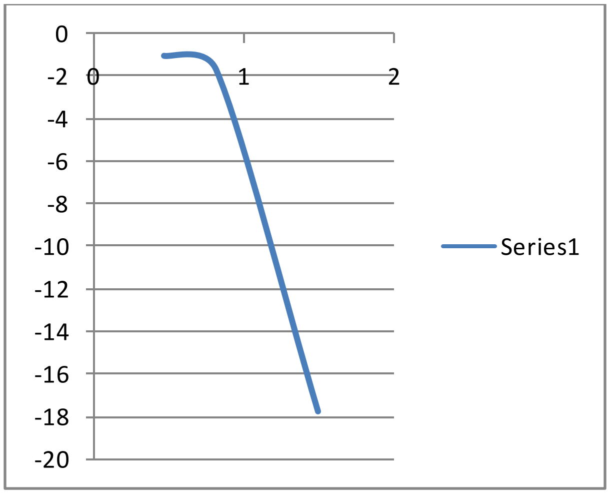


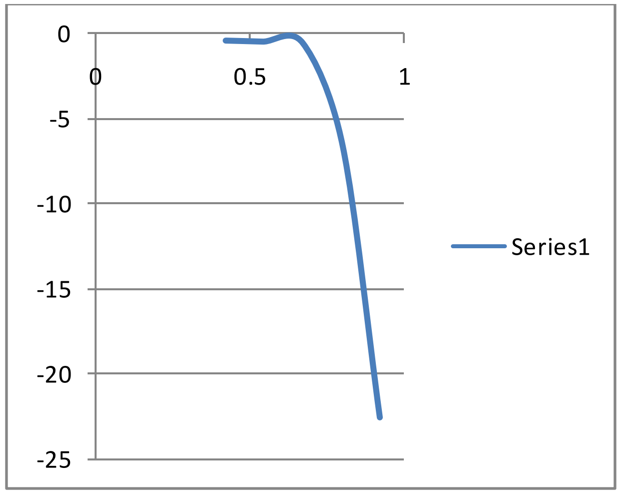
-Ve of settlement vs load intensity **-Ve of settlement vs load intensity**

3.8 size footing with 3% m.c **6.3 size footing with 3% m.c**

Table 4.5.3.5: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 4% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	1.06	2.95
11.65	1.73	0.46
16.65	14.06	0.42
21.65	17.78	0.38
26.65		0.56
31.65		0.30
36.65		6.64
41.65		0.10
46.65		22.56





-Ve of settlement vs load intensity

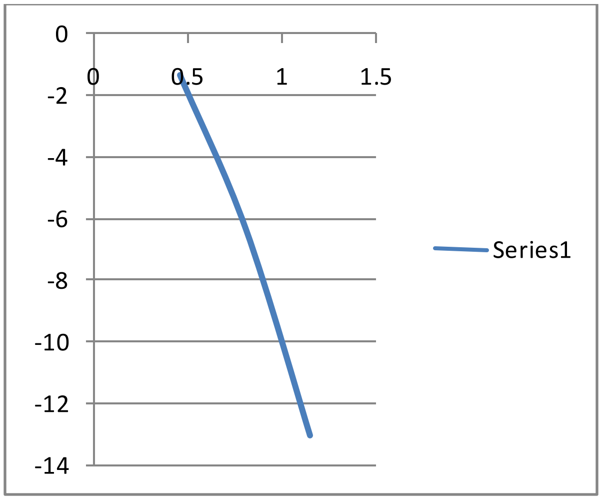
3.8 size footing with 4% m.c

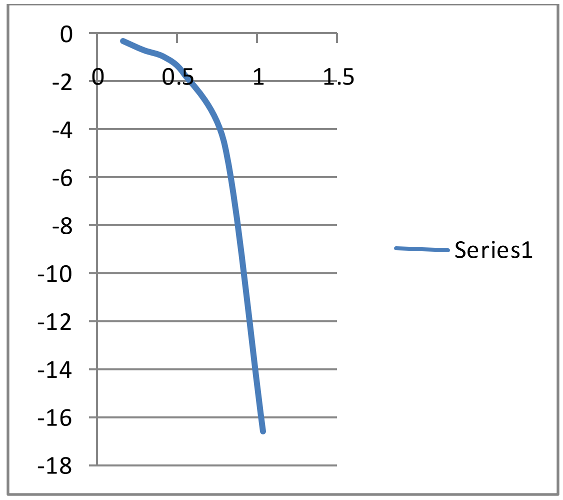
-Ve of settlement vs load intensity

6.3 size footing with 4% m.c

Table 4.5.3.6: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 5% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	1.35	0.32
11.65	6.36	0.7
16.65	13.06	0.99
21.65	8.71	1.66
26.65		0.94
31.65		4.68
36.65		0.17
41.63		16.62
46.65		0.27
51.65		0.225
56.65		13.57





-Ve of settlement vs load intensity

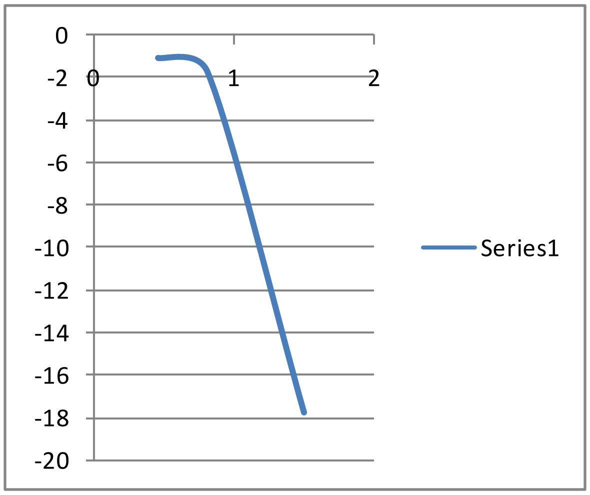
3.8 size footing with 5% m.c

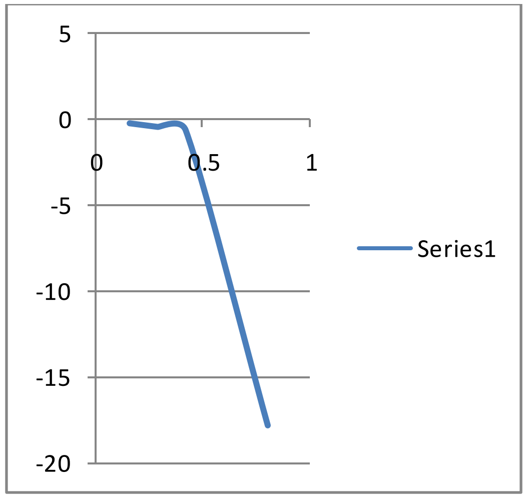
-Ve of settlement vs load intensity

6.3 size footing with 5% m.c

Table 4.5.3.7: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 6% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	1.17	0.21
11.65	1.575	0.42
16.65	4.35	0.62
21.65	7.24	12.77
26.65	9.55	0.02
31.65		17.78
36.65		0.14
41.65		0
46.65		13.44





-Ve of settlement vs load intensity

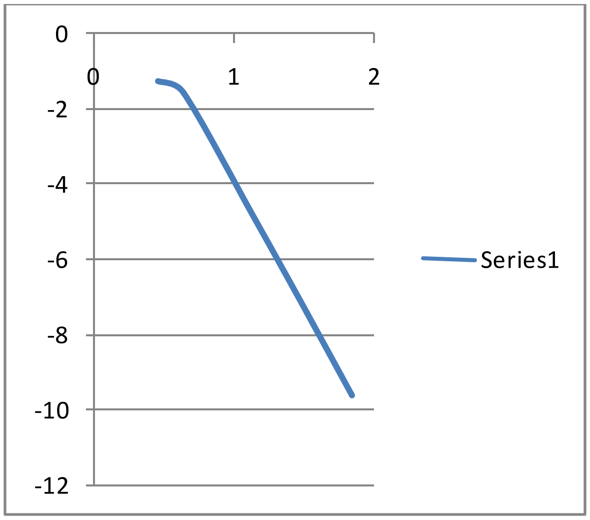
3.8 size footing with 6% m.c

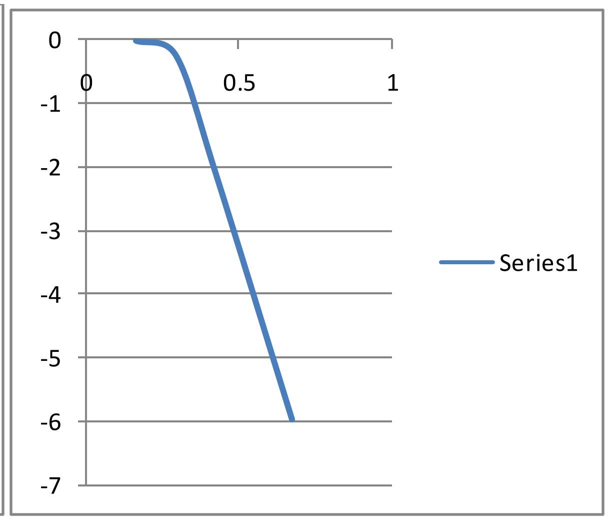
-Ve of settlement vs load intensity

6.3 size footing with 6% m.c

Table 4.5.3.8: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of 10% moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	1.28	0.028
11.65	1.58	0.255
16.65	4.95	2.1
21.65	7.24	4.38
26.65	9.64	5.97
31.65		6.24
36.65		4.65



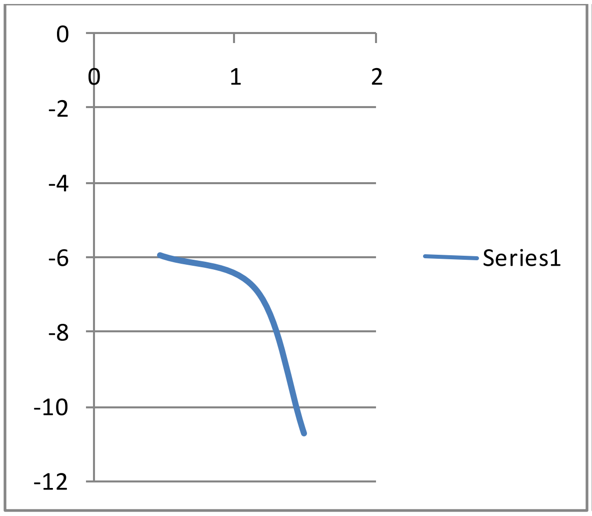


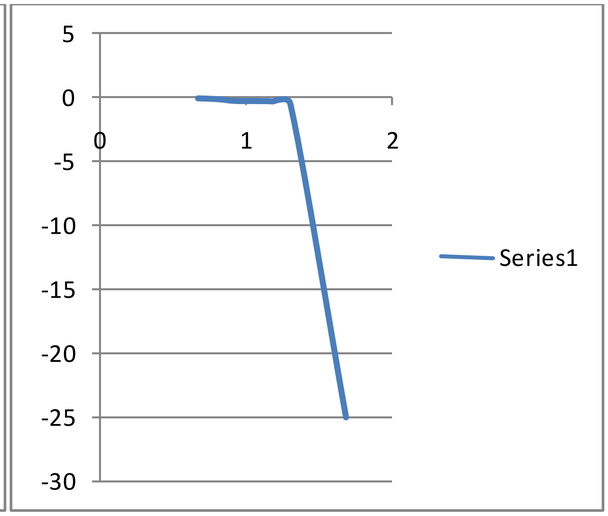
-Ve of settlement vs load intensity **-Ve of settlement vs load intensity**

3.8 size footing with 10% m.c **6.3 size footing with 10% m.c**

Table 4.5.3.9: Load vs settlement for steel square footing of size 3.8cm and 6.3cm in sand of saturation moisture content :

Load in Kg	Settlement in mm(3.8cm*3.8cm)	Settlement in mm(6.3cm*6.3cm)
6.65(load due to loading platform)	5.96	0.69
11.65	10.46	0.04
16.65	6.898	0.52
21.65	10.74	0.34
26.65		0.08
31.65		0.14
36.65		0.28
41.65		0.29
46.65		0.32
51.65		0.50
56.65		0.36
61.65		0.21
66.65		24.96



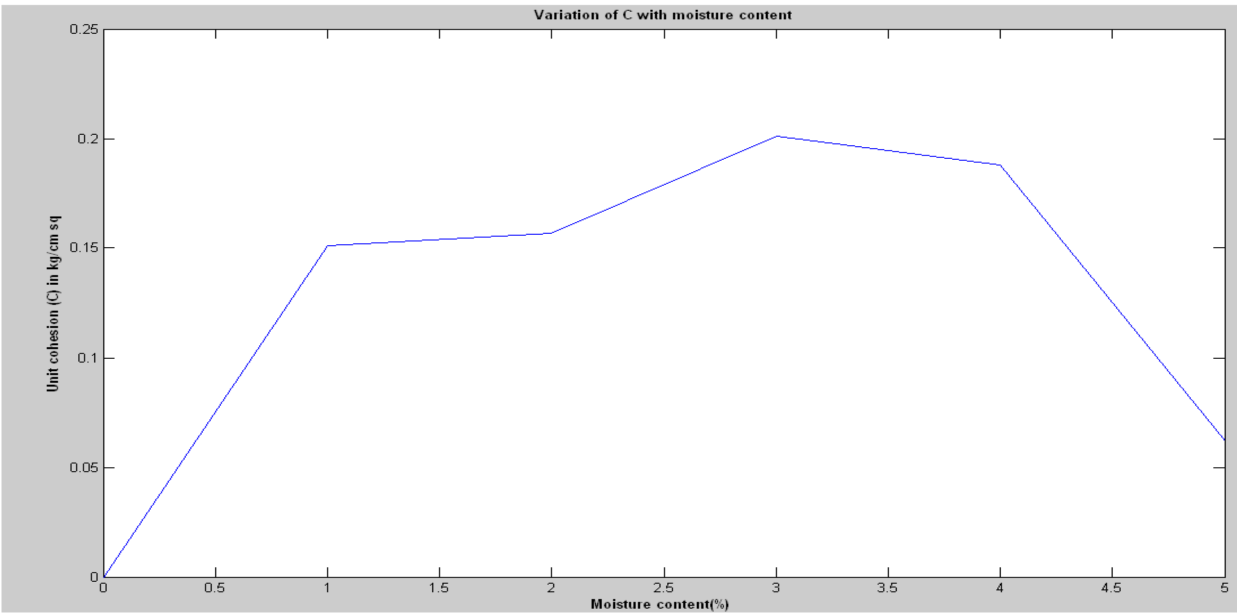


-Ve of settlement vs load intensity 3.8 size footing with saturation water content.

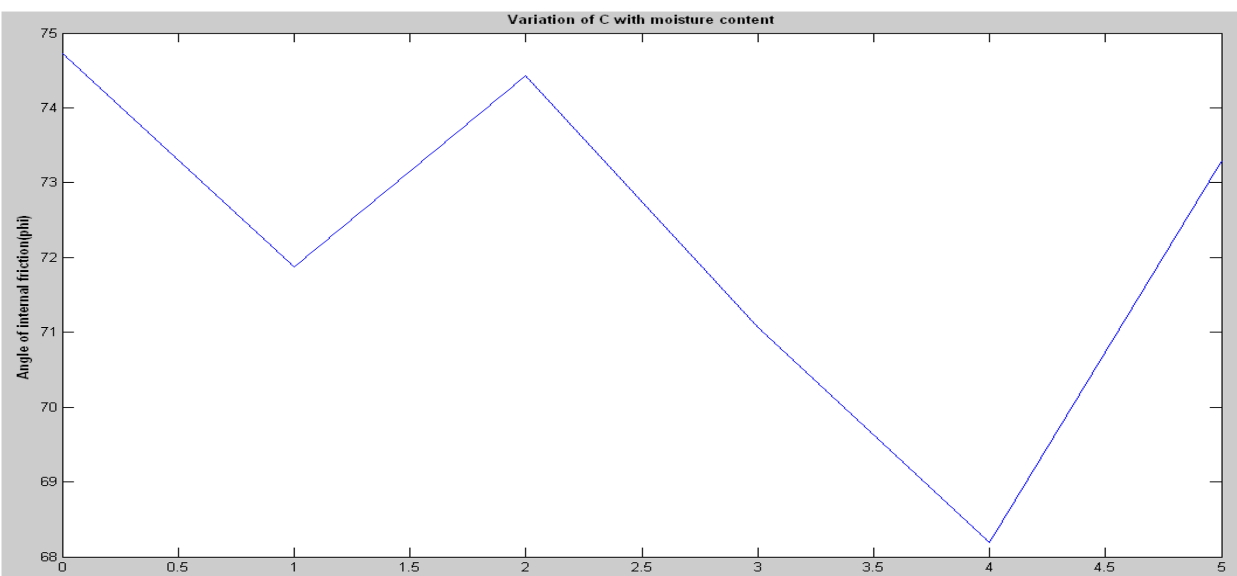
-Ve of settlement vs load intensity 6.3 size footing with saturation water content.

Chapter 5: DISCUSSION OF RESULTS:

5.1: Variation of unit cohesion with moisture content:



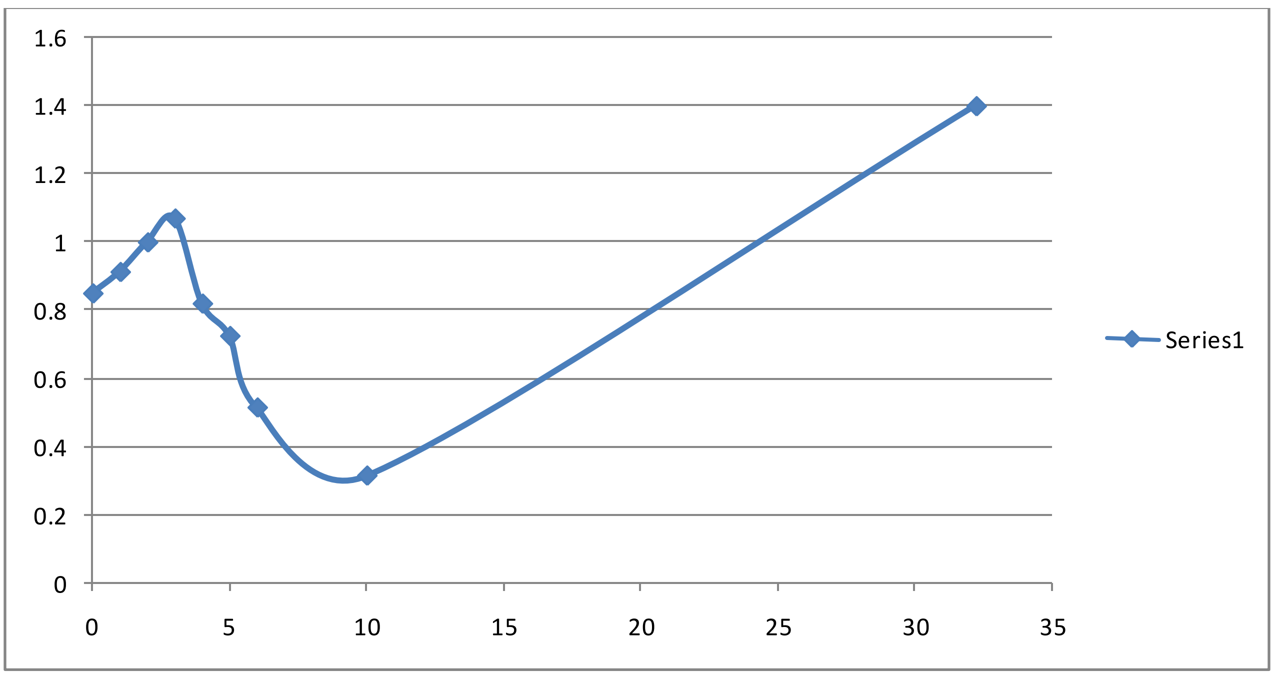
5.2: Variation of angle of internal friction with moisture content:



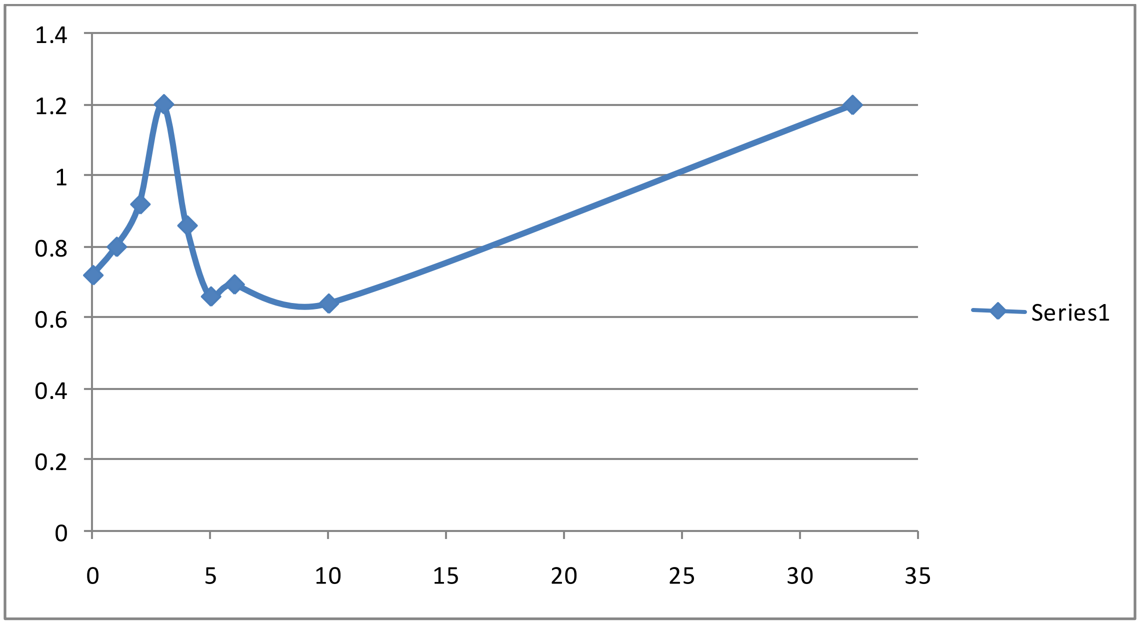
5.3: Effect of increasing moisture content on bearing capacity :

Footing size	3.8cm * 3.8cm	6.3cm *6.3cm
Dry sand	0.72 Kg/cm^2	0.85 Kg/cm^2
1% moisture content	0.8 Kg/cm^2	0.913 Kg/cm^2
2% moisture content	0.92 Kg/cm^2	1 Kg/cm^2
3% moisture content	1.202	1.07 Kg/cm^2
4% moisture content	0.86	0.82 Kg/cm^2
5% moisture content	0.66	0.725 Kg/cm^2
6% moisture content	0.649	0.515 Kg/cm^2
10% moisture content	0.64	0.315 Kg/cm^2
Saturation water content	1.2	1.4 Kg/cm^2

5.3: Variation of bearing capacity of 6.3cm*6.3cm size footing w.r.t to water content:



5.4: Variation of bearing capacity of 3.8cm*3.8cm size footing w.r.t to water content:



With the reference to the above table and variation plots it is very clear that the dry sand possessed zero cohesion and on addition of water, cohesion started adding to the sand, this may be due to surface tension effect of the water suspended between the pores. Unit cohesion reached a peak value of 0.201Kg/cm^2 at 3% moisture content, at 4% moisture content its value dropped to 0.198Kg/cm^2.

As the sand started possessing cohesion on addition of water, bearing capacity of both the footings increased between 0 to 3% moisture content, for larger footing it increased from 0.85Kg/cm^2 to 1.07Kg/cm^2 between 0 to 3%. On addition of more water surface tension force breaks and at 4% moisture content the bearing capacity of the larger footing decreased to a level slightly lesser than that of the dry sand, for the smaller one the decrease of the bearing capacity was less as compared to the larger footing. As the moisture content was increased further to 10%, the bearing capacity dropped down to a level of 0.315Kg/cm^2 and 0.64Kg/cm^2 for the larger footing and the smaller footing respectively. At saturation water content when sufficient compaction had taken place the bearing capacity increased to a level of 1.4Kg/cm^2 and 1.2Kg/cm^2 for the larger footing and the smaller footing respectively.

Chapter 6: CONCLUSION:

1. Due the presence of water in a sand sample, it becomes slightly cohesive and consequently its bearing capacity increases but this happens up to a certain limit of moisture content until the surface tension force of the moist film when the moisture is suspended between the pores breaks. On subsequent addition of water sand again starts loosing its gained cohesiveness and bearing capacity.
2. As the results shows bearing capacity decreases at 4% moisture content, the surface tension effect of the moist film around the sand particles breaks at this moisture content. This also proves that bulking effect starts at some water content in between 3 to 4%.As the moisture content increases further bulking rises and density steadly go on decreasing. Since density is a part of the bearing capacity equation, this progressive decrease of density decreases the bearing capacity.
3. Since addition of water is also a method of compaction therefore at saturation water content when the sand gets saturated, its bearing capacity increases to a great extent as compared to its bearing capacity in completely dry state.

Chapter **7: REFERENCES:**

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