"Experimental Study of Various Shaped Isolated Footings under Monotonic And Incremental Cyclic Loading On Sandy Soil"

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Abstract

In the present study behavior of six footing specimen when subjected to monotonic loading and incremental cyclic loading on sandy soil is investigated. Six footing specimens rectangular, circular, square, triangular, octagonal and hexagonal in shape having same surface area ($150cm^2$) with plate thickness equal to 8mm have been used. The loading arrangement consisted of a soil filled tank, reaction frame, jack, load cell, digital load indicator and dial gauges. A tank of size 125 cm x 75 cm x 45 cm was filled with soil. Total height of fill was kept as 40cms. It was divided in four parts and filling was done in four stages. In each stage soil was filled and compacted keeping density of each soil equal to field density. The intensity – settlement curves for all six footing are plotted under monotonic loading and incremental cyclic loading. Based on the test study conducted on various shaped footings under monotonic and cyclic loading on sandy soil, it is concluded that for same stratum and footing area under similar loading conditions the performance of footing is highly influenced by shape of footing under both types of loadings. In this case the settlement was found lesser in case of square and maximum in triangular footing. The intensity - settlement behavior improves and plastic deformation reduces with change in shape of footing from triangular shape to square shape footing.

Keywords: Shape of footing, monotonic loading, incremental cyclic loading, settlement, sandy soil, elastic rebound, ceuc, bearing capacity.

1. INTRODUCTION

Bearing capacity of soil is one of the classical problems in foundation engineering. Footings are used in a variety of fields such as wall foundations, offshore platforms, and machinery foundations. The bearing capacity varies with soil and also the settlement of footing. The settlement of soil also depends upon loading condition such as static loading, cyclic loading, and repeated loading. So far, the studies are limited to square, circular and rectangular footings under monotonic and cyclic loading. When structures are subjected to variable repeated loadings, they might fail due to loads much smaller than the collapse load. In case of cyclic loading the design of foundation needs special consideration compared to the static case.

The design of foundation requires adequate knowledge of settlement of footing. The method of foundation design requires that they must possess sufficient safety against failure and settlement must be kept within the tolerable limit. These requirements are dependent on the bearing capacity and compressibility of soil. It is commonly believed that the settlement criterion is more critical than the bearing capacity in the designs of shallow foundations. By limiting the total settlements, differential settlements and any subsequent distresses the structure are ensured to be safe. The shape of footing may also play an important role in settlement of footing. Two different shaped footing may behave differently on same soil with different loading condition. The study is carried out using sandy soil as strata. In this test study the density and moisture content of the soil were kept same as existing in the field. Load intensity -settlement curves under monotonic and incremental cyclic loading are plotted and studied.

2. OBJECTIVES OF THE STUDY

Experimental work is performed to study the following objectives.

a) To determine the suitability of different shaped footings by physical lab tests.
b) To compare the settlements of six various shaped footings under cyclic and monotonic loading on sandy soil.
c) To study the load intensity-settlement behavior of different shaped footing under monotonic and incremental cyclic loading on sandy soil.
d) To study the coefficient of elastic uniform compression (CEUC) for sand for all six footings specimen.
e) Compare the plastic deformation.

3. EXPERIMENTAL PROGRAME

3.1 General

In this experimental work six different shaped footing specimens with same cross sectional area is to be tested under monotonic and incremental cyclic loading on sandy soil.

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a) The footing specimens are circular, triangular, rectangular, square, hexagonal and octagonal in shape.
b) To account the applied load a load meter and a load cell is used.
c) Loading, unloading and reloading was done manually.
d) Settlements were recorded using dial gauges at appropriate positions.
e) The density and moisture content were kept same as existing on the field.
f) Load intensity –settlement curves are plotted to study the effect of shape of footing on settlement of soil for monotonic and incremental cyclic loading.

3.2 Test specimens:

Six different shaped footing specimens having same surface area (150cm^2) with plate thickness equal to 8 mm have been used. For the study the details of test specimens are given in table-1

Table–1 Details of specimens

S.NO.	SHAPE OF FOOTING	SIZE(CM X CM)
1	CIRCULAR	Dia 13.8 cm
2	TRIANGULAR	Each Side of 18.16
3	SQUARE	12.3 cm X 12.3 cm
4	RECTANGULAR	15 cm X10 cm
5	HEXAGONAL	7.6 cm Each
6	OCTAGONAL	5.3 cm Each Side

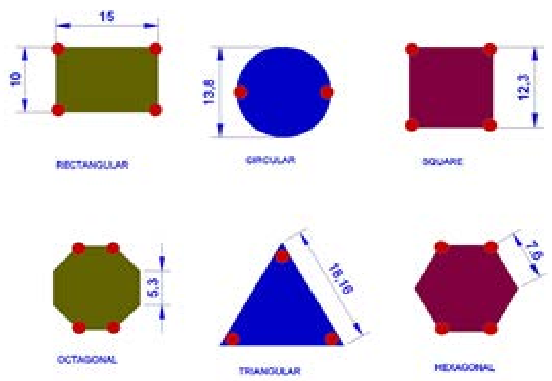

Fig -1 Details of test specimen

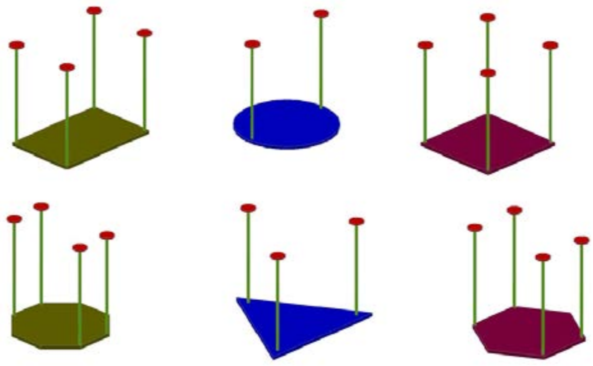

Fig -2 3-Dimensional representation of test specimens

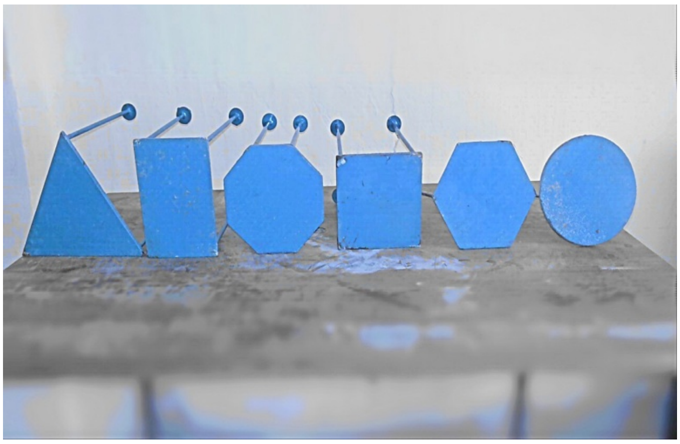

Fig-3 photograph of footing specimens

3.3 Soil Used

a) Each specimen has been tested on sandy soil.
b) Density of sandy soil was kept equal to 14 KN/m^3.

3.4 Instrumentation

The footing specimens are tested under monotonic and incremental cyclic loading, load was applied axially at center of footing. A load cell is used to apply load while settlements are measured using dial gauges. The loading arrangement and instrumentation is as follows.

a) Load meter and load cell:

Load cell is pressure transducers of capacity 20KN used to record load applied. The load cell was connected to load meter to measure the applied load.

b) Dial gauges:

Dial gauges are fixed at appropriate position to measure the deflection. It can measure up to 25mm with least count of 0.01mm.

c) LVDT:

The linear variable differential transformers (LVDT)also called differential transformer is a type of electrical transformer used for measuring linear displacement has been used to record settlement.

3.5 Loading arrangement:

The loading arrangement consisted of a soil filled tank, reaction frame, jack, load cell, digital load indicator and dial gauges. A tank of size 125 cm x 75 cm x 45 cm was filled with soil. Total height of fill was kept as 40cms. It was divided in four parts and filling was done in four stages. In each stage soil was filled and compacted keeping density equal to field density. The reaction frame was fitted to the tank keeping center of frame vertically above the center of tank. The specimen was also leveled. The jack was placed on the specimen and the load cell was inserted between jack and reaction frame. Dial gauges were fitted at opposite points on the specimens. The loading arrangement is shown in Fig.4(a)

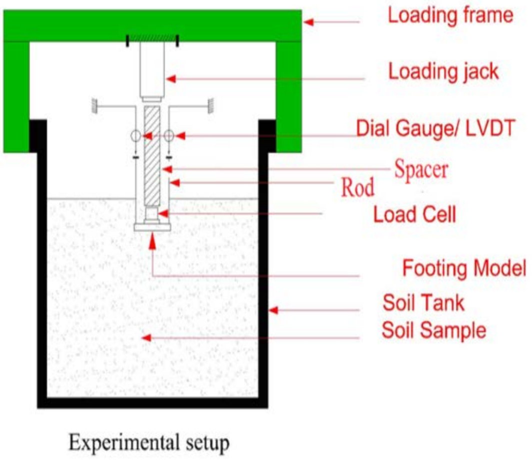

Fig -4 (a) Experimental Setup

Fig -4 (b) Photograph of experimental setup

3.6 Test procedures:

3.6.1 Testing under monotonic loading :

The testing under monotonic loading has been carried out as follows:

a) The soil sample taken from the field was filled up to a height of 15cm and then compacted and again a second layer of 15cm is filled and compacted. Top layer being of 10cm.The compaction was done to achieve field density.
b) The footing specimen was placed centrally and load was applied vertically through hydraulic jack.
c) The load was applied at an increment of 50kgs.
d) The rate of loading was kept 1kg/sec.
e) Readings of the dial gauge were noted at each increment of load. The load intensity is kept constant for 90 sec or reading in dial gauge becomes stable.
f) After each testing the soil was again disturbed and then again compacted for next specimen. The same procedure has been followed for all the six footing specimen.

3.6.2 Testing under cyclic loading :

a) The maximum load obtained from monotonic test was divided in equal parts of 50kg for applying cyclic loading.
b) The rate of loading and unloading is selected as 1kg /sec.
c) The entire load was removed so that soil can rebound and then again soil is reloaded up to next cycle.
d) The readings were taken at an interval of 25kgs for more accurate results.
e) After each testing soil was disturbed and again compacted up to field density.

4. TEST RESULT:-

The study was been carried out on six different shaped footing as described above. The Load Intensity vs Settlement behavior of these footings obtained under sandy soil has been presented in the form of Load Intensity vs Settlement curve under monotonic and cyclic loading.

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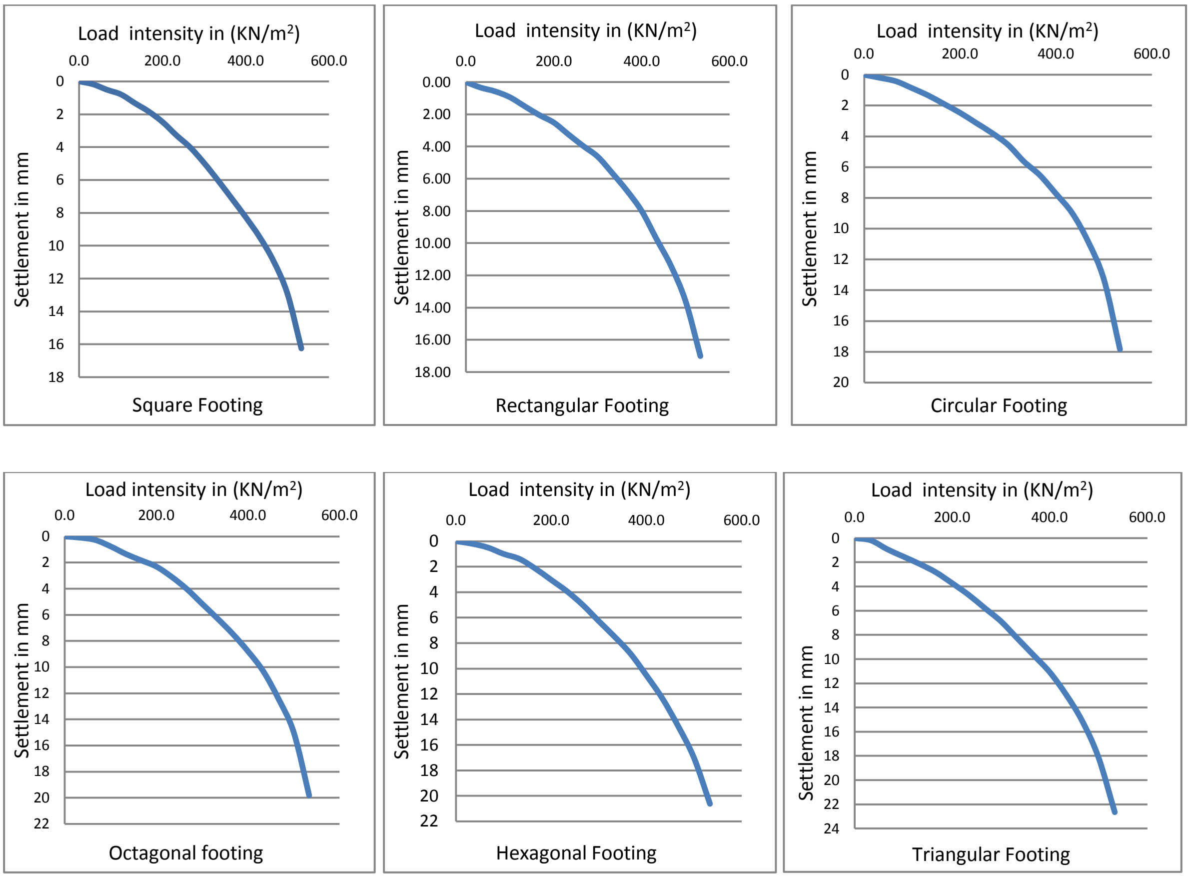

Fig.5 Load intensity v/s settlement curve for all footing specimens under monotonic loading.

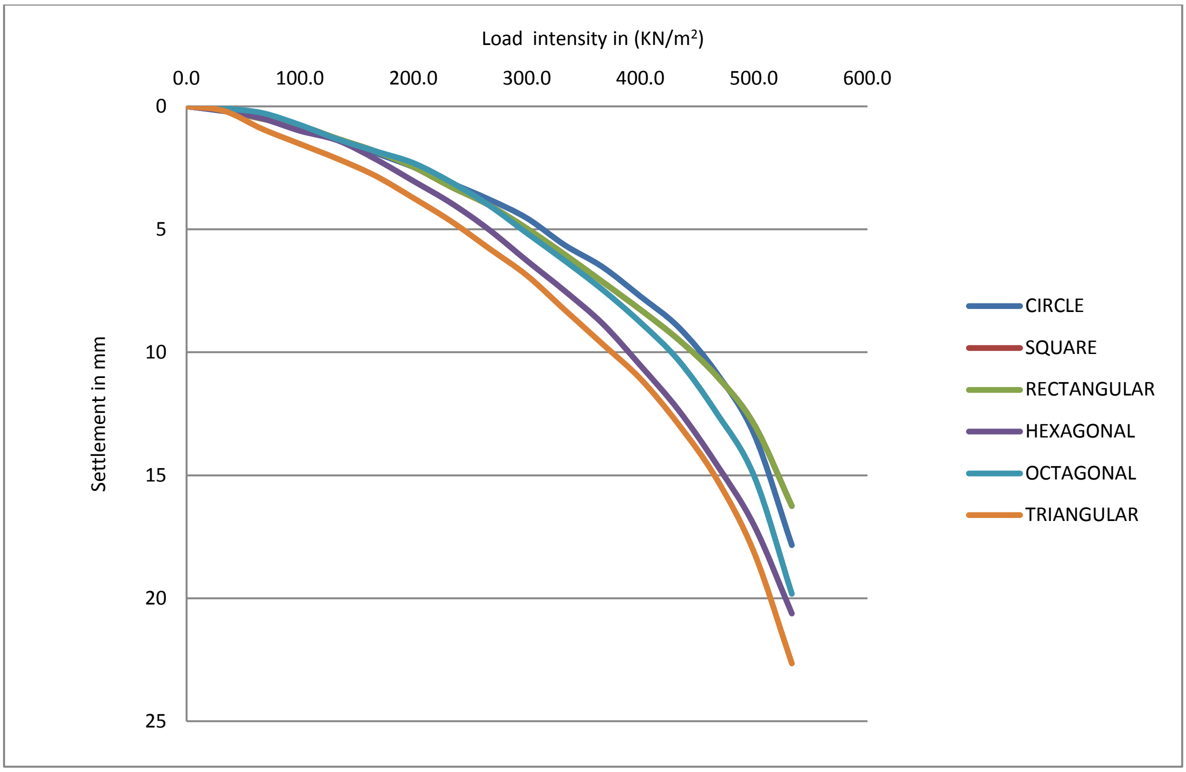

Fig.6 Comparison of load intensity v/s settlement curve for all footing specimens under monotonic loading on sandy soil.

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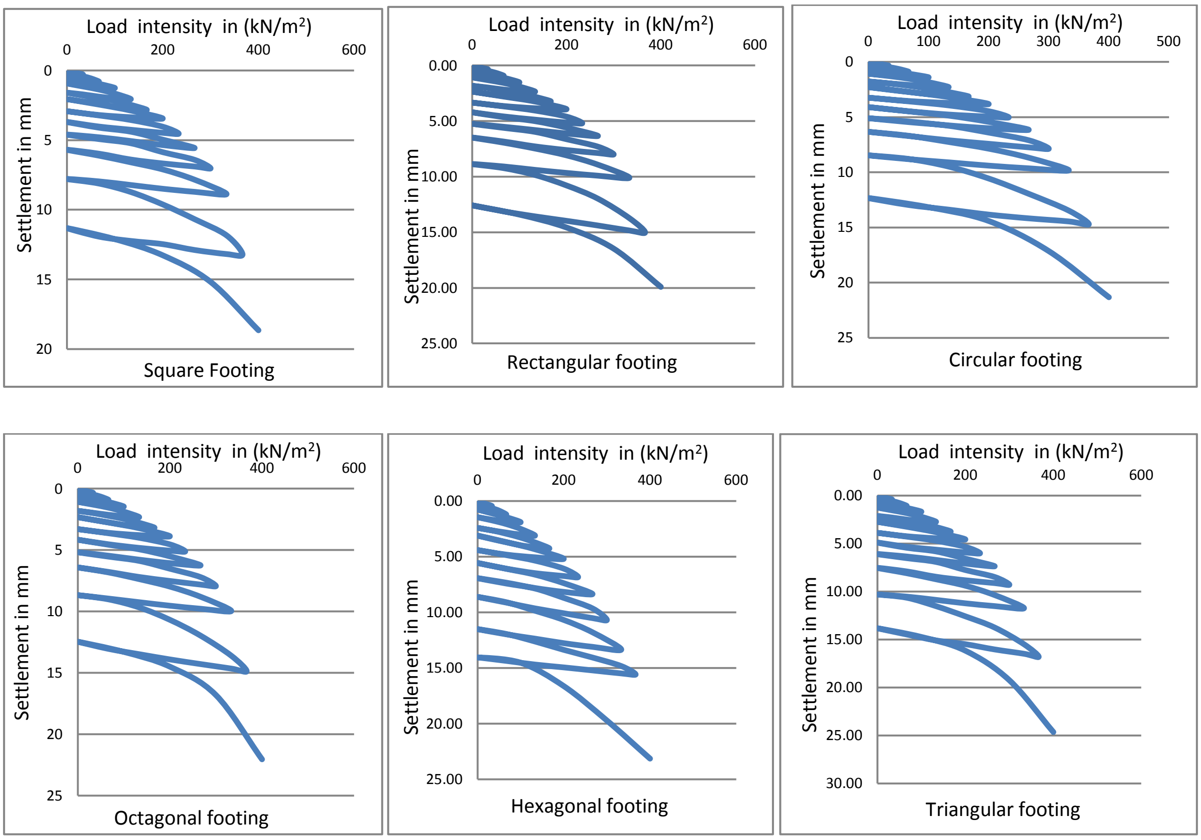

Fig.7 load intensity v/s settlement curve for all footing specimens under incremental cyclic loading

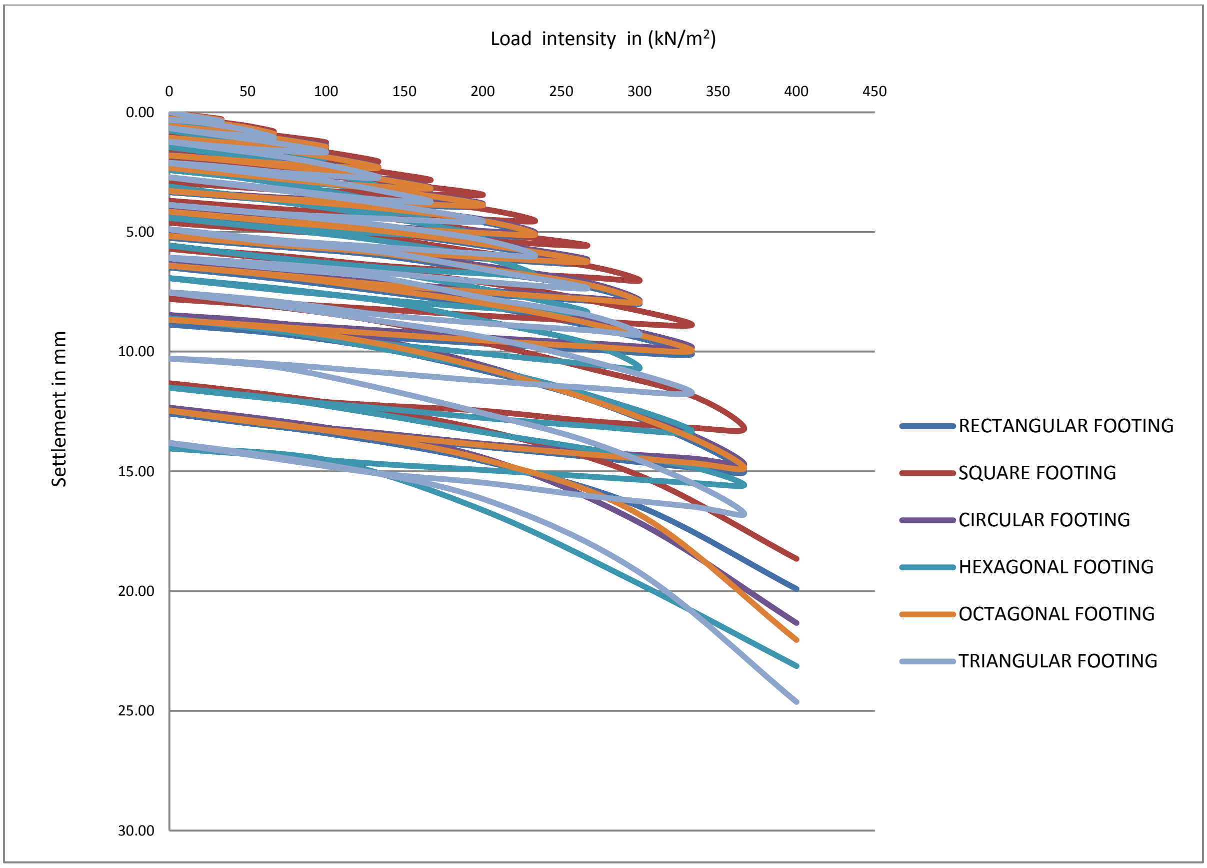

Fig.8 comparison of load intensity v/s settlement curves for all footing specimens under incremental cyclic loading on sandy soil.

5. DISCUSSIONS

5.1 Under Monotonic loading

Load intensity – settlement curve the nature of load intensity – settlement curve is similar for all types of footings considered. From graph it can be seen that initial path is linear and then it drops rapidly.

Settlement

The settlement for triangular footing is more pronounced than other footings. In sandy soil the settlement recorded for triangular footing at 800kg (533KN/m^2) is 22.65 mm which is maximum and for square footing it is 16.25mm which is minimum at same loading intensity.

Footing	**Loading intensity KN/m^2**	**Settlement (mm)**	**% increase**
Square	**400**	**18.65**	**-**
Rectangular	**400**	**19.91**	**6.41**
Circular	**400**	**21.33**	**13.90**
Octagonal	**400**	**22.04**	**17.64**
Hexagonal	**400**	**23.12**	**23.52**
Triangular	**400**	**24.63**	**31.55**

Table–2

5.2 Under incremental cyclic loading

Load intensity – settlement curve. In case of incremental cyclic loading the loading curve for each cycle is parallel to previous curve. The unloading curves also trace curve parallel to previous unloading curves. Reloading curve crosses the unloading curve. The loops formed in this loading are similar for each type of footing considered. At higher load intensity the loop tends to enlarge as settlements increases. For comparison the settlement are found at 600 kg (400KN/m^2). In case of incremental cyclic loading also triangular footing when compared with other footing shapes shows poor behavior. The settlement in triangular footing is much higher as compared to other footing. The settlements recorded at 600kg (400KN/m^2) for triangular footing are 24.63mm which is maximum as compared to square footing which gives minimum settlement 18.65mm.

Footing	**Loading intensity KN/m^2**	**Settlement (mm)**	**% increase**
Square	533	16.25	-
Rectangular	533	17.01	4.67
Circular	533	17.84	9.78
Octagonal	533	19.82	21.96
Hexagonal	533	20.62	26.89
Triangular	533	22.65	39.38

Table–3

5.3 Elastic rebound

Elastic rebound for these six footing models is less at initial load intensity and then increases as load intensity increases. From the data recorded for settlement elastic rebound curves are plotted. Fig.7 shows variation of elastic rebound with load intensity.

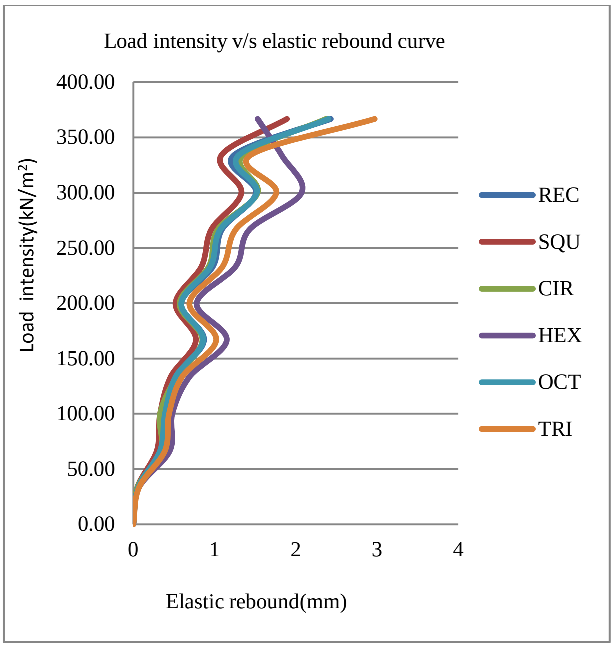

Fig.9 Elastic rebound curve for sandy soil

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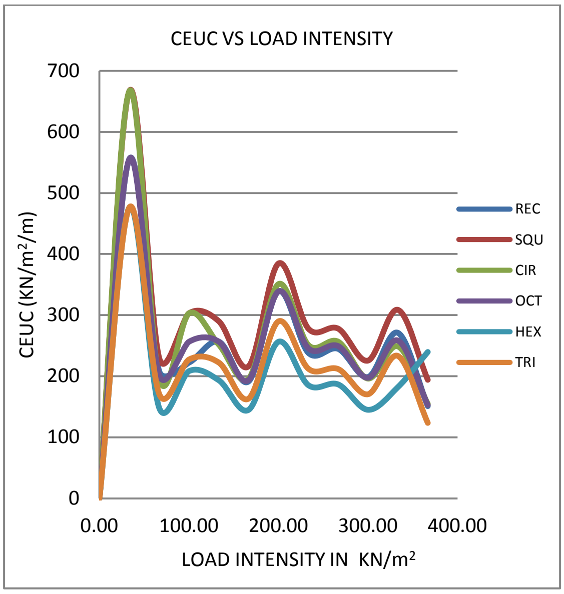

Fig.10 CEUC for sandy soil

6. CONCLUSION

This experimental program is conducted to compare the behavior of circular, square, rectangular, hexagonal, octagonal and triangular shaped footing model when they are subjected to monotonic and incremental cyclic loading on sandy soils as strata. Based on the results obtained from the above test studies following conclusions are drawn:

1. SETTLEMENT
From the settlement shown in table-2 and table-3 in previous pages it can be concluded that triangular footing shows maximum settlement at a given load for both monotonic and incremental cyclic loading.

2. ELASTIC REBOUND CURVE
From fig.7 elastic rebound curve it is observed that the slope of elastic curve for hexagonal footing is maximum and slope of elastic line for circular footing is minimum.

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