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Load-Settlement Behaviour of a Granular Pile in Expansive Soil

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Abstract: Recently, the growth in population, especially in urban areas and industrial areas, has given rise to the price of land and unsuitable lands for development. By considering these factors, the construction industry needs to improve the use of unsuitable land for construction. The main problematic soil that is commonly identified was black cotton soil, which is also known as expansive or soft soil because of its shrink-swell property in the present study the concept of a single granular pile was used to construct a structure in black cotton soil. A cylindrical tank was used to perform all the tests. The granular pile was made up of laterite soil, lime and recycled aggregate with varying proportions and encased with woven polypropylene geotextile. The L/D ratio of the pile where L=length of granular pile, D =diameter of the granular pile, was varied as 1.5, 2, 2.5, 3, 3.5 to study the effect of load settlement behaviour of soil. The diameter of the granular pile was kept constant for all the tests. Based on the analysis of load-settlement value, it is found that the black cotton soil increases its load-carrying capacity when the granular pile was encased with geotextile and with an increase in the L/D ratio.

Keywords: *Granular Pile, Ground Improvement, Recycled Aggregate, Geotextile.*

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I. INTRODUCTION

For a development of country construction of road, tunnel, bridges, airports, and railways for transportation, buildings and other engineering works plays an important role. So now-a-days ground improvement is much needed as expansive soil was found 20% of the total area of our country. Generally, these types of soils are found in Maharashtra, Madhya Pradesh, Gujarat and part of Odisha. In India, these types of soil are also found in river valleys like the Tapi and Krishna, and in the north-western part. In India, these types of soils are mainly used for agricultural purposes.

While civil engineers design during last few decades due to swelling actions in expansive soil they face many challenges in irrigation system. Canal lining, foundation strata, pavement design, water lines, sewer lines etc. many problems are arisen for light loaded structure by changing volumetrically along dampness but in case of superstructure because of settlements basic components of building, establishment framework, structural elements may get damaged. In Odisha the expansive soil was covering a territory of 0.96million hectares of land, which is around 6% of the total geographical area of the state.

Devendra Rajput, Rakesh Kumar, P. K. Jain, Sareesh Chandra Wanshi Nov (2016) conducted tests on a single pile around which similar piles are surrounded. The water content of soft soil was kept constant throughout all the tests. In this study black cotton soil is used and sand is used as a granular pile material. The diameter of granular pile made up of sand column is 25.4mm. After construction of similar sand piles tests were conducted on a one pile and effective size of footing varied with different S/D ratio and L/D ratio of the sand pile. from the results getting from the single pile load test the bearing capacity increases with decrease of spacing between sand piles for all L/D ratio but increase of bearing capacity from S/D Ratio 2.5 to 2 is less than increase of load capacity from S/D ratio 3 to 3.5.

Kumar (2014) has investigated the improvement of expansive soil using granular pile. The aim of this study was to determine the load-settlement behaviour of granular pile in expansive soil. he has used sand as his granular pile material and further he used nylon fibres with sand to increase the effectiveness of the granular pile and the granular pile was encased by geogrid.

Uttam Kumar, Tandel Y K and Solanki C H (2013**)** this investigation is all about to study the effect of types of

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geosynthetics which is used as encasement of granular pile & different diameter. The result indicates that more efficiency has observed in case of larger diameter than the smaller. Due to geosynthetics encasement of granular pile lateral bulging gets reduced.

Surendra Dehariya, Rakesh Kumar and P.K. (2012) a single granular pile was arranged in Black cotton soil, the tests were conducted varying different diameter of granular pile. Granular piles are encased with geogrid encasement and load settlement behavior of the granular pile was conducted. In this study it is observed that load carrying capacity is more for encased granular pile than the without encasement.

Murugesan and Rajagopal (2006) and Lo et al. (2010) in this study to investigate the granular pile numerical method is used. if the bulging of granular pile gets reduced then automatically the bearing capacity will be improved. Hughes J.M and Withers N.J (2009) in this experiment radiographic techniques were used to determine the behavior of granular pile in a normally consolidated clay. Different patterns of radial and vertical deformations of granular pile are shown. results show that when the granular pile is loaded at top only it shows the ultimate strength**.**

Radhey S. Sharma, B.R. Phani Kumar, and G. Nagendra (2004) to investigate the effect of geogrid on a granular column and to calculate the load bearing capacity and reduction of bulging laboratory tests were performed. bulge diameter decreases gradually when granular pile was reinforced with geogrids.

It is observed that many research have been carried out to study the load-settlement behavior of granular pile using experimental, numerical analysis but there is lack of variations seen in granular material.Very few studies were found in case of using geotextile encasement to granular pile and many researchers use the footing plate equal to diameter of the granular pile.so, in this study the laboratory tests were conducted using the concept of single granular pile made up of granular material with varying proportion encased with geotextile and with different L/D ratio i.e. from 3.5 to 1.5 keeping the diameter constant for all tests.

II. METHODOLOGY AND EXPERIMENTAL SETUP

For this study 5 basic material is used that are Black cotton soil, laterite soil, lime, recycle aggregate and geotextile. black cotton soil sample was collected from Balugaon, Khordha district in Odisha. Laterite soil sample and Recycled aggregate were collected from the CET campus, Bhubaneswar. Hydrated lime in powdered form was used and collected from a local shop. Geotextile was purchased from Sun Textiles Private Limited, Kolkata, and in our study, woven polypropylene geotextile was used. The geotechnical properties of expansive soil determined from lab tests are presented in Table 1. The soil is classified as highly compressible clay (CH), as per IS:1498 (1970).

Table 1 Properties of Black Cotton Soil

Physical Properties	**Test Value**
Sand	28.38%
Silt	65.85%
Clay	
Specific gravity	2.42
LL	60.60%
PL	31.713%
Shrinkage limit	21.38
I.S classification	CH
Coefficient of uniformity	10.45
Coefficient of curvature	0.735
MDD	1.79gm/cc
OMC	17.8%

The geotechnical properties of laterite soil determined from lab test are presented in Table2. The soil is classified as silty sandy soil (SM), as per IS:2720.

Table 2 Properties of Laterite Soil

Physical Properties	**Test Value**
Specific gravity	2.54
LL	24.2%
PL	2.43%
IS classification	SM
Coefficient of uniformity	54.28
Coefficient of curvature	7.386
MDD	2.057gm/cc
OMC	12.01%
California Bearing ratio	0.91%

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In this experiment geotextile have been used as reinforcement in granular pile**.** In our study woven polypropylene geotextile is used. The properties of geotextiles are given in Table 3. Recycled aggregate have been used to provide the body for granular pile. The properties of recycled aggregate are given in Table 4.

Table 3 Properties of Woven Polypropylene Geotextile

Properties	**Values**
Specific gravity	0.91
Unit weight	500 gm/m2
Thickness	2mm
Colour	White
Breaking strength	16 KN/M
Elongation Break	25 – 10 (%)
Tear strength	0.42 KN
Opening size	0.07-2 mm

Table 4 Properties of Recycled Aggregate

Properties	**Values**
ACV	39.38%
AIV	38.5%
Specific gravity	2.325
Water absorption	5.605%

➢ *Methodology*

To analyse the load-settlement behaviour of granular pile tests are conducted in laboratory using single granular pile concept on a cylindrical tank as shown in fig1. The test setup is similar to CBR mould. The cylindrical tank of diameter 150mm, 175mm height and the granular pile of 50mm was used. To make the granular pile replacement method was used. A/C to IS:2720(Part-16)-1987 soil sample weighing approx. 5kg was taken. Then sample is divided into 5equal parts and each layer is given 25blows each in 5 layers. A seamless steel pipe of 50mm outer diameter is used to construct the granular pile. The outer surface of the pipe was lubricated with grease for easy removal. The pipe was pushed into the soil up to the required depth of granular pile.to push the pipe manually force was applied. while applied force, care should be taken so that the disturbance in the clay can be minimized. The displaced soil was taken out. For reinforcement purpose a woven geotextile of 50mm diameter was rolled and placed vertically to encase the granular pile. Granular material (laterite soil) was mixed with recycled aggregate and lime in varying proportion randomly by weight and moistened with 5% water content of total weight of material required for granular pile. Granular material was inserted into the hole in 3layers in measured quantities and tamping was done to achieve the desired compaction. To load the granular pile, a circular footing plate (mild steel plate) of 150mm diameter was placed over the granular pile including soil sample. load was applied on the soil through plunger at the rate of 1.25mm/min. Laboratory tests are planned and conducted as shown in Table 5.in this investigation results were noted by varying the proportion of granular material with an increasing L/D ratio and analysed the load-settlement behaviour of granular pile.

Fig 1 Arrangement of Single Granular Pile

Table 5 Tests Conducted on Granular Pile

Descripition	**L/d Ratio**	**Total No. of Test**
LATERITE (30%) + LIME (10%) +RECYCLE AGGREGATE	3.5,3,2.5,2,1.5	5
LATERITE (35%) + LIME (15%) +RECYCLE AGGREGATE	3.5,3,2.5,2,1.5	5
LATERITE (40%) + LIME (20%) + RECYCLE AGGREGATE	3.5,3,2.5,2,1.5	5
TOTAL		15

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III. RESULTS AND DISCUSSIONS

To analyse the load- settlement behaviour of granular pile load tests was conducted on soil as per above plan. It is worth mentioning that load carrying capacity increases when the granular pile was encased with woven geotextile. It will prevent the soil particles from migrating into the granular pile, enhancing drainage, or providing additional confinement to the granular material. All the load-settlement curves in the context of soil behaviour and the role of the geotextile are thoroughly explained in these sections.

- *Load-Settlement Behaviour for Laterite (30%) +Lime (10%) +Recycled Aggregate Varying Height*

It is observed that while comparing L/D Ratio 3.5 with 1.5, we get the soil can take 27.02% more load.

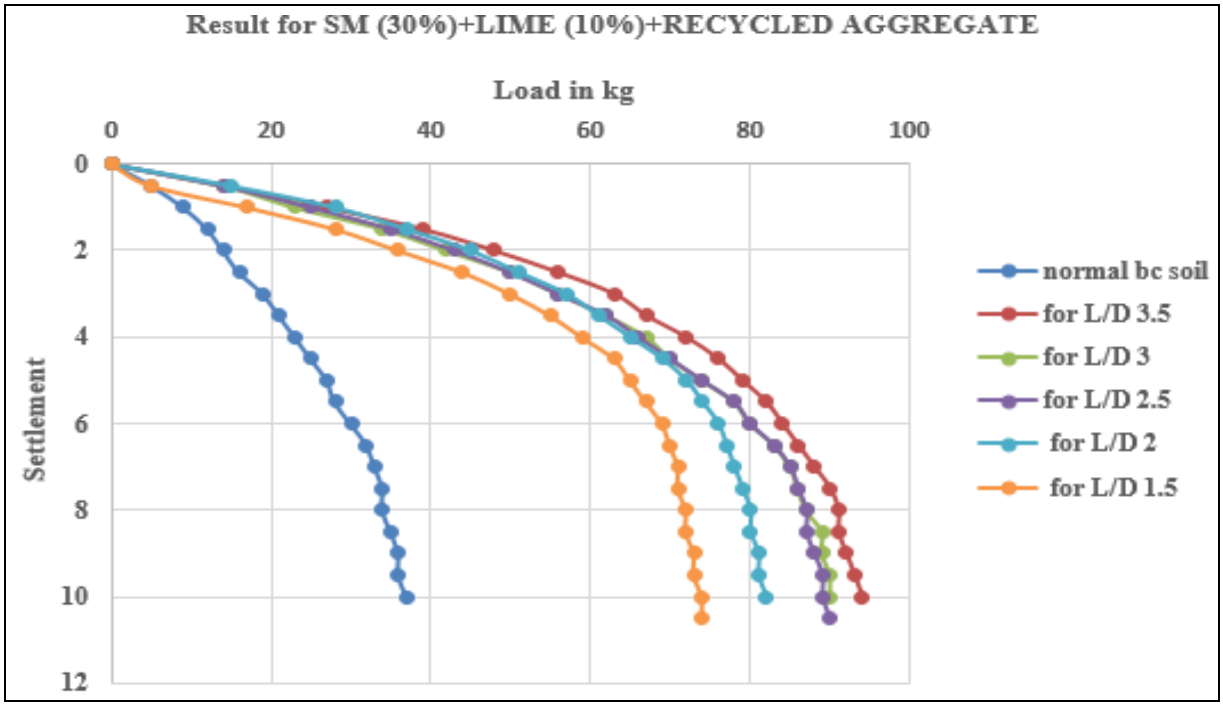

Fig 2 Graph for Laterite (30%) +Lime (10%) +Recycled Aggregate Varying Height

- *Load-Settlement Behaviour for Laterite (35%) +Lime (15%) +Recycled Aggregate Varying Height*

It is observed that while comparing L/D Ratio 3.5 with 1.5, we get the soil can take 22.5% more load.

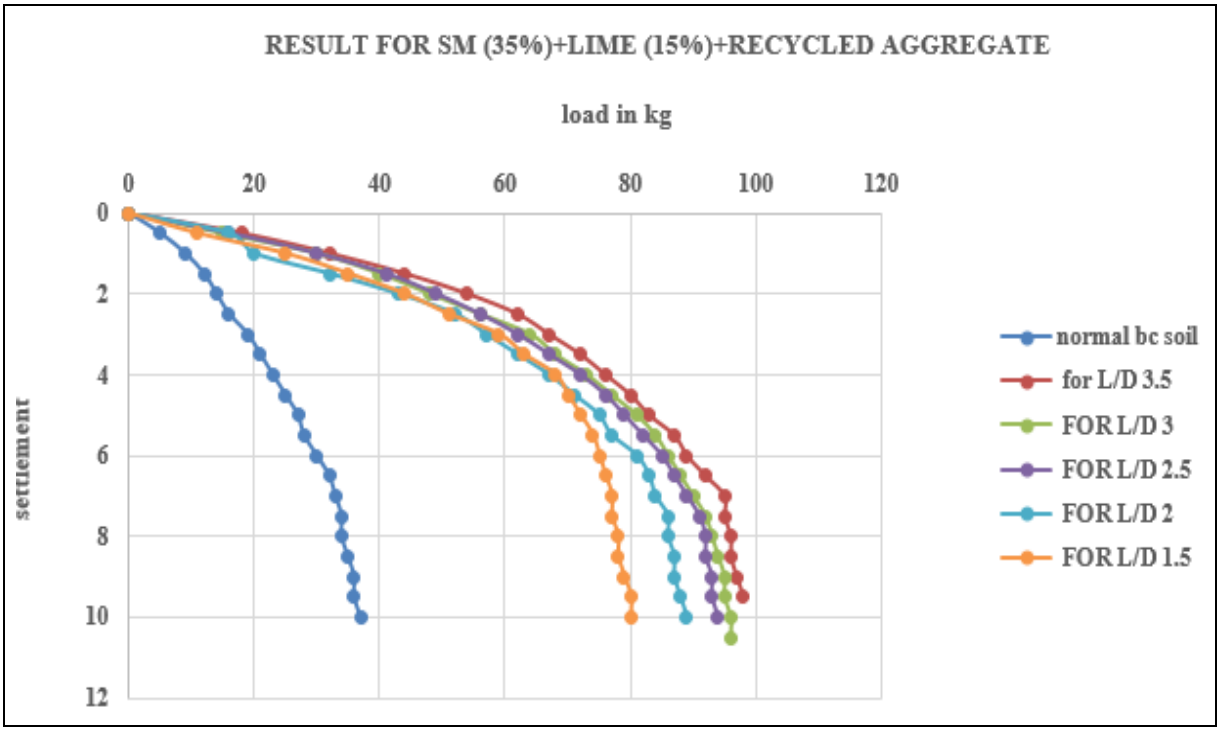

Fig 3 Graph for Laterite (35%) +Lime (15%) +Recycled Aggregate Varying Height

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➢ *Load-Settlement Behaviour for Laterite (40%) +Lime (20%) +Recycled Aggregate Varying Height*
It is observed that while comparing L/D Ratio 3.5 with 1.5, we get the soil can take 13.33% more load.

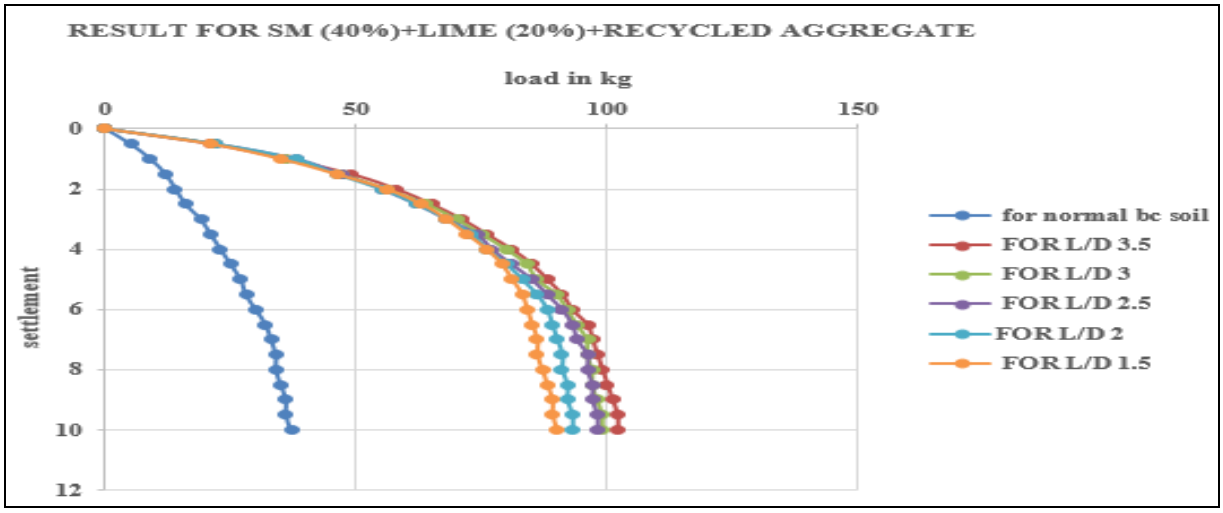

Fig 4 Graph for Laterite (40%) +Lime (20%)+Recycled Aggregate Varying Height

➢ *Load-Settlement Behaviour of Footing for L/D = 3.5*
The highest Ultimate load is 1.75 times than the untreated black cotton soil.

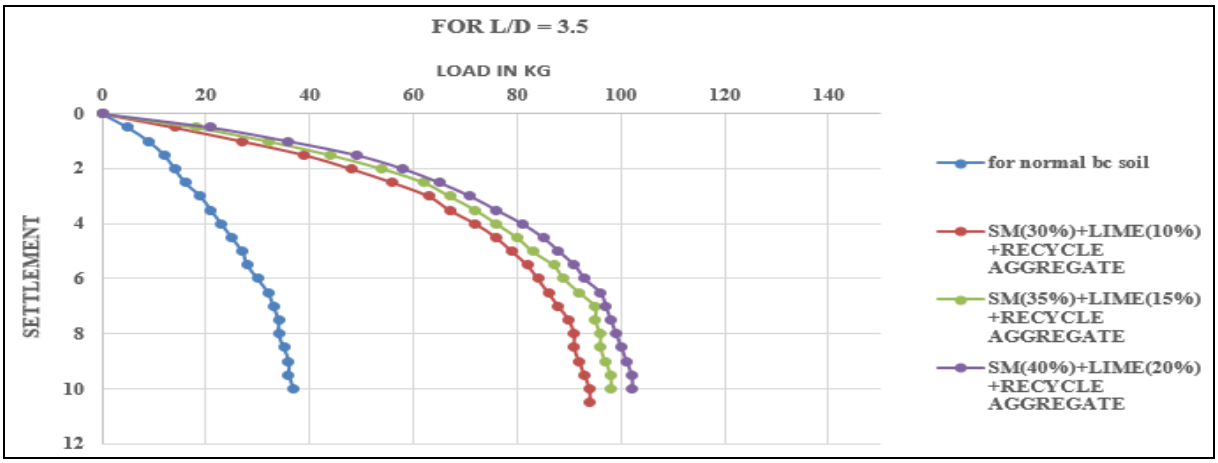

Fig 5 Graph for Load-Settlement Behaviour of Footing for L/D = 3.5

➢ *Load-Settlement Behaviour of Footing for L/D = 3*
The highest Ultimate load is 1.67 times than the untreated black cotton soil.

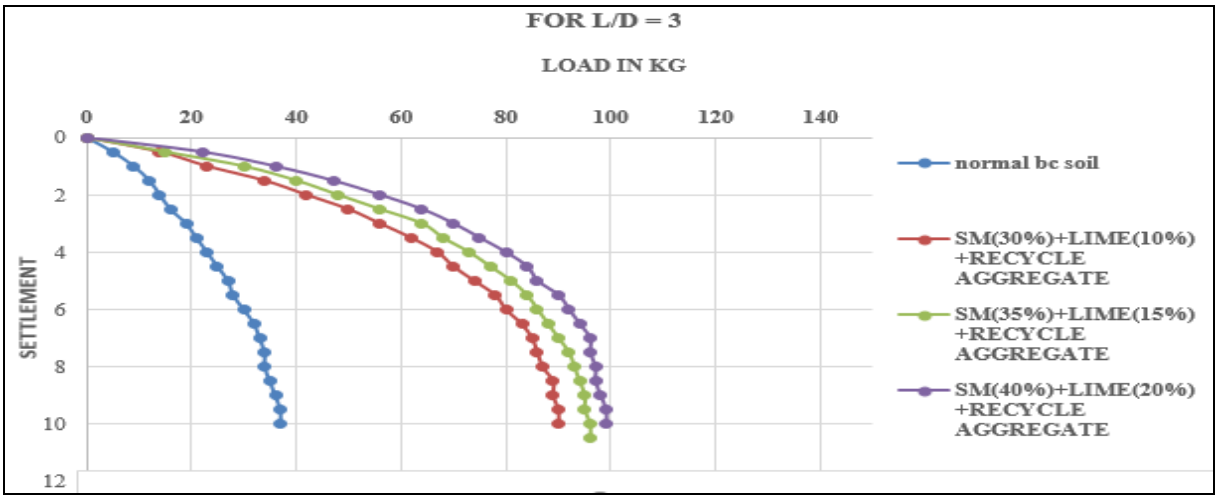

Fig 6 Graph for Load-Settlement Behaviour of Footing for L/D = 3

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➢ *Load-Settlement Behaviour of Footing for L/D = 2.5*
The highest Ultimate load is 1.64 times than the untreated black cotton soil.

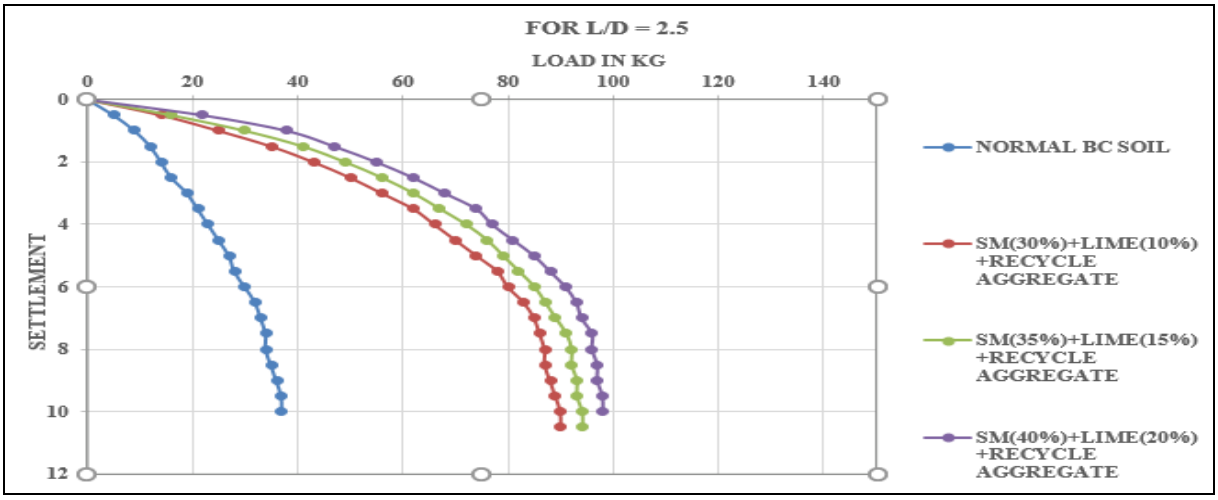

Fig 7 Graph for Load-Settlement Behaviour of Footing for L/D 2.5

➢ *Load-Settlement Behaviour of Footing for L/D 2*
The highest Ultimate load is 1.51 times than the untreated black cotton soil.

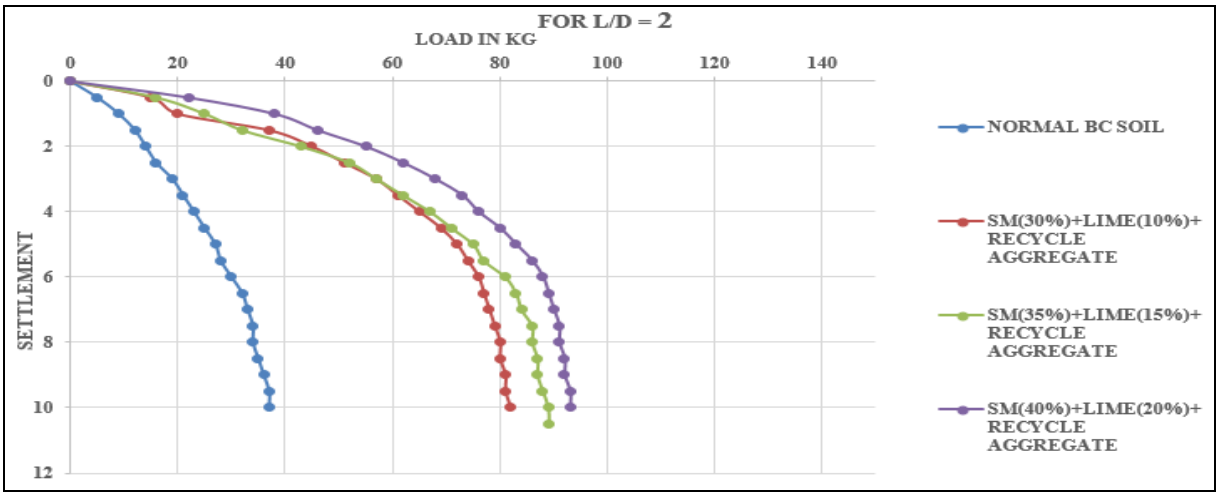

Fig 8 Graph for Load-Settlement Behaviour of Footing for L/D 2

➢ *Load-Settlement Behaviour of Footing for L/D = 1.5*
The highest Ultimate load is 1.43 times than the untreated black cotton soil.

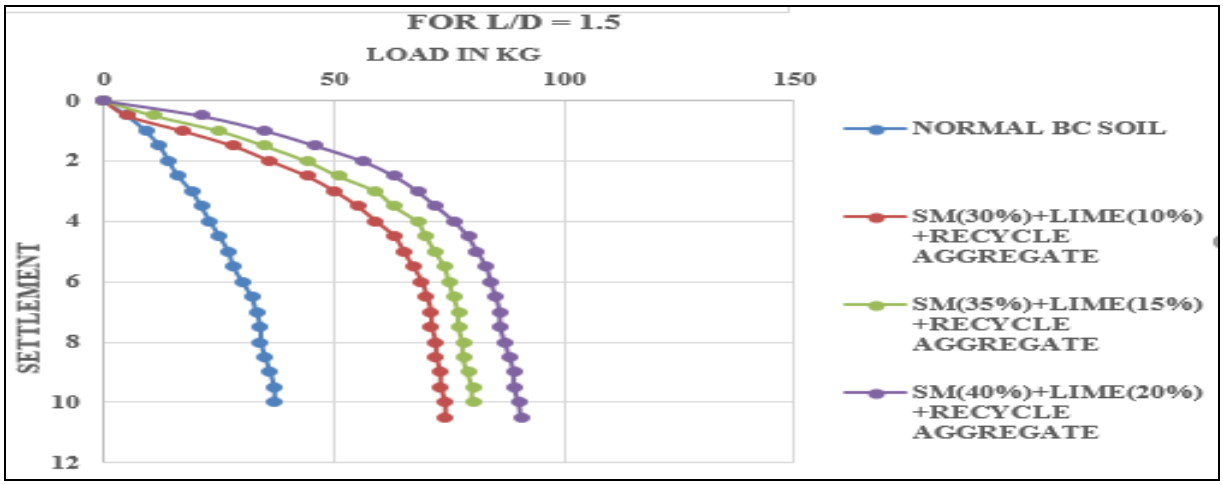

Fig 9 Graph for Load-Settlement Behaviour of Footing for L/D 1.5

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➢ *Variation of Ultimate Load with L/D*

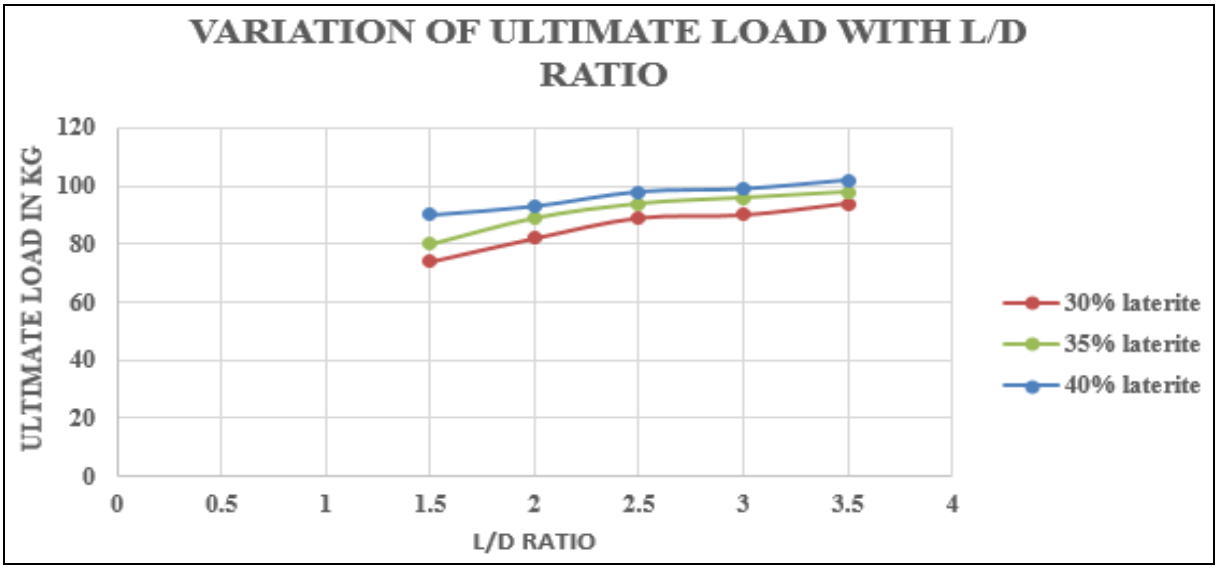

Fig 10 Graph for Variation of Ultimate Load with L/D

IV. CONCLUSION

Based on all the results and material properties the outcome of the investigations is as follows:

The granular pile in black cotton soil reduces settlement in compare to the footing immediately placed on the expansive soil. As we increase the L/D ratio we can notice a significant reduction in the settlement. The settlement is reduced when I encased the granular pile in comparison to untreated black cotton soil. Also, the L/D ratio also affects the depth of influence of the granular pile. A longer pile can extend its influence to deeper layers of soil, potentially improving overall settlement performance. A higher L/D ratio typically results in more surface area in contact with the surrounding soil, leading to increased skin friction and, consequently, lower settlement. By seeing the above results, we can make a conclusion that, combination of this material for granular pile while increasing the proportion in this manner the soil settlement is getting lower but at a very low rate.

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