# Effect of Sand column with and without encasement of Geosynthetics in Black cotton soil

## Harish C[1], M S Nagaraja Gupta[2], Radhika K N[3] and ManjunathItagi[4]

*[1] Assistant Professor, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.*

*[2] Associate Professor, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.*

*[3] Assistant Professor, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.*

*[4]Assistant professor, Department of Civil Engineering, East West Institute of Technology, Bengaluru, Karnataka, India.*

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**Abstract –** *Soil reinforcement can be an ideal solution for improvement of clay. Out of other conventional method, Sand columns are effectively being used for ground improvement, particularly for flexible structures such as road embankments, oil storage tanks, etc. The load capacity of the sand columns mainly depends on the shear strength of the surrounding Black cotton soil. The sand column is found useful in improving load capacity and reducing the settlement of clay deposit. In addition to this, the encasement of geosynthetics all-round the sand columns is suggested for enhancing the load carrying capacity of the sand column in treated ground which also ensures the easy formation of columns in weak strata. The present study investigates the effect of diameters of geosynthetics encased sand columns in Black cotton soil deposit during loading. The load responses of sand columns are also investigated with the variation of encasement length of the column and compare the response of sand column with and without encasement.*

**Key Words: Encasement, Improvement, Bearing Capacity, Black Cotton Soil, sand Column, Geosynthetics etc.**

## 1. INTRODUCTION

India has a large coastline area exceeding more than 6000kms. The large numbers of industries and ports were being built in the coastal area; the soil which is available in this area is of weak strata, where in geotechnical engineers faces a presence of different problematic soils with varied engineering characteristics. Among all these we considered the soft soil is one of the biggest problematic soil for geotechnical engineers because of low bearing capacity, high compressibility, low permeability etc. When the soft clay indicates strength sensitivity, the problem may be even severe. Sensitive soft clays often contain meta-stable structure and this structure may provide a high degree of compressibility to the soil. As the settlement of the sensitive soft clay is significantly high, ground improvement methods are needed. These methods include prefabricated vertical drain (PVD), surface and deep compaction**,** vacuum drainage, preloading, stone/sand columns etc. Among these methods, stone/sand columns method is one of the efficient ways of reducing both settlement and consolidation time.

Ground improvement techniques are normally preferred for economic considerations. Out of several techniques available stone/sand columns have been widely used. This ground improvement technique has been successfully applied to increase the bearing capacity and to reduce the settlement for foundation of structures. The stone/sand columns are vertical columnar elements formed below the ground level with compacted and uncemented stone fragments or gravels or sand.

The stone/sand columns are increasingly being used as ground reinforcement for supporting a wide variety of structures including buildings and flexible structures. Thus, in case of group pile, bulging is primary mode of failure. This drawback can be overcome by wrapping the individual sand columns with suitable geosynthetics. The geosynthetics encasement helps in easy formation of sand column and improves the strength and stiffness of columns. By reinforcing the sand column by geosynthetics, the ultimate bearing capacity of that column can be increased to a considerable amount.
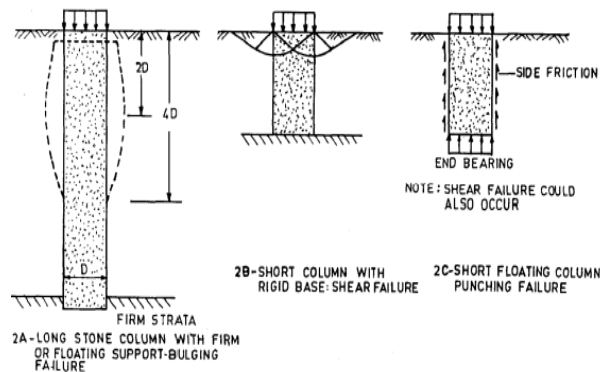
### 1.1 Failure mechanisms:

#### 1.1.1 Single sand columns:
Sand columns may be constructed as either end bearing on a firm stratum underlying soft soil, or as floating columns with the tip of the column embedded within the soft layer. In practice, however, end bearing sandcolumns have almost always been used in the past.

Consider a sand column loaded over just the area of the column as shown in Fig.1.1 Either end bearing or free floating sand columns greater than about three diameters in length fail in bulging as illustrated in Fig.2a. A very short

column bearing on a firm support will undergo either a general or local bearing capacity type failure at the surface (Fig.2b). Finally, a floating stone column less than about 2 to 3 diameters in length may fail in end bearing in the weak underlying layer before a bulging failure can develop (Fig. 2C). For the subsurface conditions generally encountered in practice, however, bulging is usually the controlling failure mechanism.



**Figure:** Failure mechanisms of a single column in a homogenous soft layer

### 1.1.2. Sand column groups:

A group of sand columns in a soft soil probably undergoes a combined bulging and local bearing type failure as illustrated in Fig. 1.2a. A local bearing failure is the punching of a relatively rigid sand column (or group) into the surrounding soft soil. Sand column groups having short column lengths can fail in end bearing (Fig. 1.2b) or perhaps undergo a bearing capacity failure of individual sand columns similar to the failure mode of short, single sand columns.
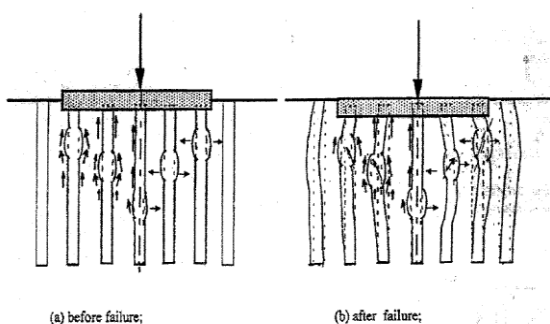


**Figure : Failure modes of sand column groups**

### 2. OBJECTIVE:

Need for engineering ground improvement arises when a project encounters difficult foundation conditions.
The main objective of the study is as follows
1.  To study the effect of sand column encased with Geosynthetics in improving the strength characteristics of Black cotton soil.

2.  To study the load bearing capacity of Geosynthetics encased Sand columns with group columns.
3.  To predict the settlement reduction factor of reinforced ground with the unreinforced ground.

The goal of this thesis work is to increase shear strength and provide required minimum bearing capacity, restrict total and differential settlements to accept magnitude of proposed loading and to provide acceptable long term performance.

### 4.  SCOPE OF WORK:

The purpose of this research is to investigate the performance of sand column encased with Geosynthetics, which is a new concept and to study the strength characteristics of Black cotton soil when used as a foundation material for floating, embedded depth, under different saturation condition. The research presents results of observations obtained from tests using group of columns for floating and embedded footing on a Black cotton soil which is essentially reinforced. Reinforced soil performs satisfactorily under monotonic loading, well-established literatures are available with respect to geosynthetics encasement. The Geosynthetics enwrapped sand columns subjected to static loads finds a tremendous potential in restoring the column for practical usage as the static loads comes into play. Studies and observations show that the settlements are greatly reduced and the load carrying capacity of encased columns is increased appreciably. These results triggered a series of studies to determine the load-settlement behavior of both unreinforced and reinforced soil under different conditions. Any decision to effectively use an improvement technique requires a clear understanding of material behavior subjected to static loading. Hence in the present investigation the efficacy of using the Geosynthetics as encasement to the sand column is investigated and experiments are conducted to know the load-settlement behavior of group of columns with different length reinforcement and different diameter of columns under different parameters.

### 4. Materials:

### 4.1 Black cotton soil:

The Black cotton soil is collected from the new railway station site of bypass road, near Hiremagalore village, Chikmagalore. The soil sample was collected by open excavation, from a depth of one meter below natural ground level leaving the surface soil. The soil is oven dried and used after sieving through IS 4.75 mm sieve, properties of the Black cotton soil is summarized in table 4.1
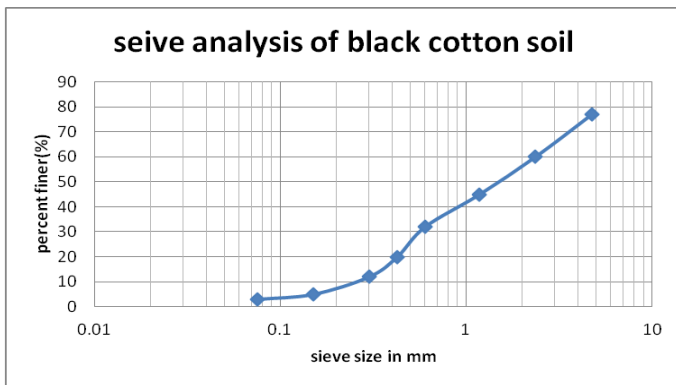
**Chart 4.1:** Sieve Analysis of black cotton soil

**Table 4.1:** Properties of black cotton soil
A .Index properties of soil

| Water content | 21.66% |
|---|---|
| Specific gravity | 2.44 |
| Liquid Limit | 63.29% |
| Plastic Limit | 26.41% |
| Plasticity Index | 36.88% |
| Shrinkage Limit | 22.49% |
| Free swell index | 84% |

The soil classification based on Index properties belongs to "**CH**" group in which Inorganic clay with high compressibility.

B. Engineering properties of soil

| OMC | 19% |
|---|---|
| MDD | 15.30kn/m$^3$ |
| Undrained cohesion | 0.02kn/m$^2$ |

## 4.2 Sand as Fine Aggregate:

The sand sieved through IS 2.36mm used for experimental work. The sand is collected from the construction site near East West Institute of Technology in Bangalore.
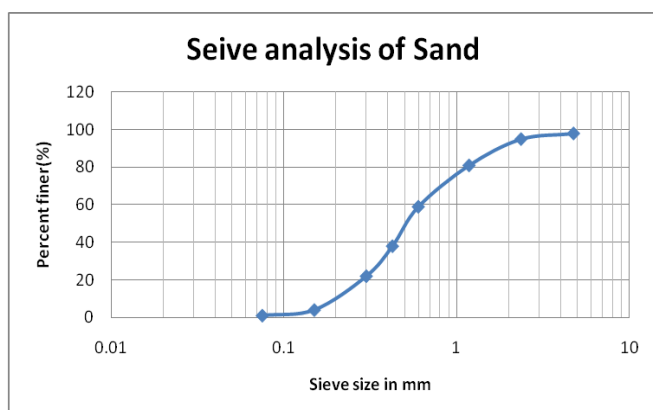


**Chart 4.2**: Sieve analysis of sand

**Table: 4.2. Properties of sand**

| Specific gravity | 2.53 |
|---|---|
| Coefficient of Uniformity | 5.33 |
| Coefficient of curvature | 1.47 |

## 4.3 Lime:

The lime is used which will directly get in the market .And the lime is stored in place to prevent its carbonation.

## 4.4 Geosynthetics

For our project we have used different grades of geotextiles and geogrids such as.
   a) Geogrids
   b) Geotextiles

**Geotextiles (Non oven) of different grades**
   1. PE-1202EF
   2. PE-1302EF
   3. PE-1250EF



**Figure :** Geotextiles

**Table 4.3:** Properties of geotextiles as per company details.

| PROPERTY | PE-1202EF | PE-1252EF | PE-1302EF | UNIT |
|---|---|---|---|---|
| Mass per unit area | 200 | 250 | 300 | g/m$^2$ |
| Thickness | 1.20 | 1.60 | 2.00 | Mm |
| Grab tensile strength | 485 | 630 | 816 | N |
| Grab elongation at break | 131 | 122 | 110 | % |
| Trapezoidal tear | 129 | 169 | 220 | N |
| CBR puncture | 1585 | 2435 | 3013 | KN |
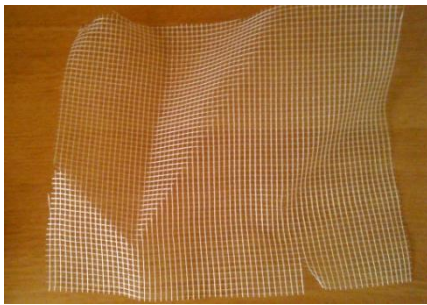
**Figure :** Geogrids

**Table 4.4:** Properties of geogrids as per company details

| Weight | 45 | g/m$^2$ |
|---|---|---|
| Mesh size | 2.5*2.5 | mm |
| Coating content | 18 | % |
| Tensile strength | 400(MD) | N/5cm |

## 5.  Experimental work and methodology

### 5.1 Methodology:

1) The Model footing test is conducted for different lengths of sand columns with geosynthetics as encasement for various D/B ratios where 'D' denotes the diameter of test tank and 'B' denotes the diameter of the circular model footing. The results are observed for different diameter columns.

2) The model footing test is conducted for group of columns encased with geosynthetics for embedded depth, floating depth & intermediate depths.

3) Load settlement characteristics of black cotton soil using sand columns wrapped with geosynthetics is analyzed for group of arrangement and encased columns using model footing tests.

4) Based on the experimental results conclusions are drawn for D/B ratios of 1, 2, 3 and for different length and for different pattern of arrangement of sand columns.

### 5.2 Preparation of black cotton soil deposit:

Oil is applied to inside wall of tank to reduce any friction between soil and tank wall. Required quantity of soil is mixed with 19% water content to maintain the density of 15.3kn/m$^3$ and thoroughly mixed soil is filled in the tank in 5 layers by compacting each layer thoroughly with the help of tamping hammer design for the work.

### 5.3 Preparation and construction of Sand column:

By mixing the different percentage of lime and sand with Black cotton soil the UCS and direct shear test is conducted the maximum percentage is selected as a sand column material.

### 5.4 Spacing of sand column:

As per IS standards, spacings are provided in between columns ranges from 1.5d to 3d where 'd' represents the diameter of sand column. According to IS: 2911(Part me /Sec2)-1979. The spacing of columns is followed here by providing single & group columns at centre and along periphery. The four numbers of columns are arranged along the periphery with spacing of 3d c/c and five numbers along centre & periphery by providing appropriate spacing of 1.5d c/c.
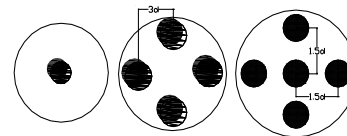


**Figure 5.1:** Spacing of encased columns

### 5.5 Testing Procedure:

1. A circular small steel test tank of diameter 250mm and height 300mm is used as model test tank. The side walls of the tank were made smooth by coating with a lubricating gel to reduce the boundary effects. The black cotton soil which is used for work is kept for 24hr to reach its maturity period.

2. The required weight of soil sample is calculated for the lowest density of 15.03kn/m$^3$ as obtained from the compaction test results is mixed thoroughly with 20% water content and filled in 5 layers into the test tank using rainfall technique.

3. The soil sample is filled into the test tank with maintaining its density throughout the procedure.

4. The different diameter of holes is created with different pattern without disturbing the density of soil in the tank.

5. A cylindrical hole enwrapped with the geosynthetics formed in the test tank.

6. The sand column material is then filled into the holes through a cone made of paper.

7. The circular model footing of 225mm dia is placed exactly on top of the constructed sand column.

8. The footing was placed exactly at the centre of the loading jack to avoid eccentric loading. Calibrated proving ring is used to measure the load transferred to the footing. The load was applied in small increments at constant rate of strain. Each load increment is maintained constant until the footing settlement stabilized.

9. Three dial gauges are fixed on footing and deformations are measured through dial gauges (Dg$_1$, Dg$_2$, and Dg$_3$). The Load improvement ratio and settlement reduction factor are calculated for different settlement levels.

10. The above procedure is repeated for different lengths of encased sand columns and for different pattern of arrangement of sand columns.

**Figure :** Preparation of mould and inserting diameter



**Figure :** Group of columns in mould



**Figure :** Inserting geosynthetics



**Figure :** Filling the sand column materials



**Figure :** Final setup mould

## 5. RESULTS AND DISCUSSIONS

To evaluate the beneficial effects of providing sand columns encased with geosynthetics in Black cotton soil, experiments are conducted on embedded; floating columns constructed in black cotton soil subjected to monotonic loads. The effects of group of sand columns of different length in different pattern of arrangement are found out.

Black cotton soil is mixed with varying percentage of lime and sand and unconfined compressive and direct shear tests are conducted and for all the combination the direct shear test is conducted with encasement of the geosynthetics.

### 6.1 Model footing test results:

The load deformation behavior of the encased sand column is studied by loading it in a Triaxial loading frame at a strain rate of 1.25mm/minute. To load the stone column area alone a circular model footing of 225mm diameter is placed exactly at the center of the column and the load is applied. Settlement is observed for equal intervals of load up to an average deformation of 40mm.

Model footing test is carried out on black cotton soil which is compacted to lower density without reinforcement, the load-settlement characteristics of soil are plotted in the different graphs above. The curve shows that the soil undergoes settlement at lower points of load which is not appreciable and hence requires reinforcement.

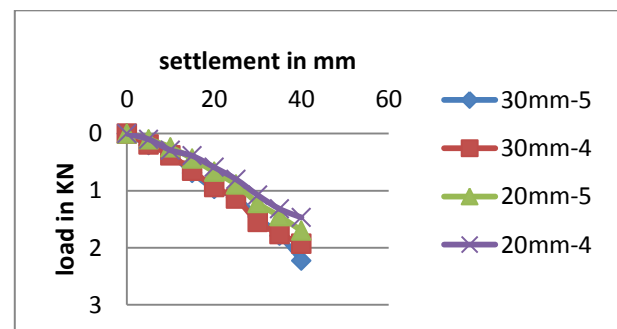| Length(mm) | Diameter(mm) | Pattern(no of column) | Load(KN) |
|---|---|---|---|
| 300 | 30 | 5 | 2.236 |
| 300 | 30 | 4 | 1.925 |
| 300 | 20 | 5 | 1.697 |
| 300 | 20 | 4 | 1.941 |



**Chart 6.1:** Load - Settlement characteristics graph of reinforced black cotton soil.

Load - Settlement characteristics of encased reinforced (PE-1202EF 100% length) sand columns for different lengths and different diameters for 40mm settlement.

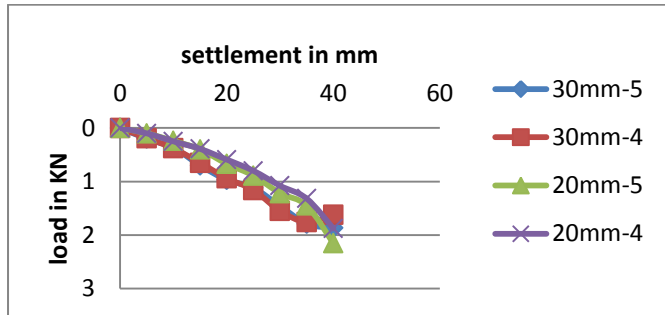| Length(mm) | Diameter(mm) | Pattern(no of column) | Load(KN) |
|---|---|---|---|
| 300 | 30 | 5 | 1.867 |
| 300 | 30 | 4 | 1.615 |
| 300 | 20 | 5 | 2.157 |
| 300 | 20 | 4 | 1.888 |



**Chart 6.2** Load - Settlement characteristics graphs of reinforced black cotton soil.

Improvement with respect to Geogrids.

| Length mm | No | diameter mm | Failure load(KN) | | | | Contribution (KN) | | | Improvement strength % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | With out | 100% | 50% | 75% | 100% | 50% | 75% | 100% | 50% | 75% |
| 300 | 5 | 30 | 1.51 | 2.23 | 1.66 | 2.01 | 0.72 | 0.15 | 0.5 | 47.6 | 10 | 33.1 |
| 300 | 4 | 30 | 1.28 | 1.92 | 1.32 | 1.81 | 0.64 | 0.04 | 0.53 | 50 | 3.12 | 41.4 |
| 300 | 5 | 20 | 1.23 | 1.69 | 1.68 | 1.51 | 0.46 | 0.45 | 0.28 | 37.4 | 36.6 | 22.7 |
| 300 | 4 | 20 | 1.47 | 1.74 | 1.56 | 1.61 | 0.27 | 0.09 | 0.14 | 18.4 | 6.12 | 9.5 |

**Improvement with respect to PE-1202EF.**

| length mm | No | diameter mm | Failure load(KN) | | | | Contribution (KN) | | | Improvement strength % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | With out | 100% | 50% | 75% | 100% | 50% | 75% | 100% | 50% | 75% |
| 300 | 5 | 30 | 1.51 | 1.86 | 1.64 | 1.72 | 0.35 | 0.13 | 0.21 | 23.2 | 8.6 | 14 |
| 300 | 4 | 30 | 1.28 | 1.61 | 1.51 | 1.49 | 0.33 | 0.23 | 0.21 | 25.7 | 18 | 16.4 |
| 300 | 5 | 20 | 1.23 | 2.15 | 1.74 | 2.01 | 0.92 | 0.51 | 0.78 | 74.8 | 41.5 | 63.4 |
| 300 | 4 | 20 | 1.47 | 1.88 | 1.52 | 1.76 | 0.41 | 0.05 | 0.29 | 27.8 | 3.4 | 20 |

**Improvement with respect to PE-1252EF.**

| length mm | No | diameter mm | Failure load(KN) | | | | Contribution (KN) | | | Improvement strength % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | With out | 100% | 50% | 75% | 100% | 50% | 75% | 100% | 50% | 75% |
| 300 | 5 | 30 | 1.51 | 1.93 | 1.67 | 1.81 | 0.42 | 0.16 | 0.3 | 27.8 | 10.6 | 19.8 |
| 300 | 4 | 30 | 1.28 | 1.52 | 1.45 | 1.43 | 0.24 | 0.17 | 0.15 | 18.7 | 13.3 | 11.7 |
| 300 | 5 | 20 | 1.23 | 1.98 | 1.62 | 1.83 | 0.75 | 0.39 | 0.6 | 60.9 | 31.7 | 48.7 |
| 300 | 4 | 20 | 1.47 | 1.76 | 1.59 | 1.69 | 0.29 | 0.12 | 0.22 | 19.7 | 8.2 | 15 |

**Improvement with respect to PE-1302EF.**

| length mm | No | diameter mm | Failure load(KN) | | | | Contribution (KN) | | | Improvement strength % | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | With out | 100% | 50% | 75% | 100% | 50% | 75% | 100% | 50% | 75% |
| 300 | 5 | 30 | 1.51 | 2.08 | 1.78 | 1.97 | 0.57 | 0.27 | 0.46 | 37.7 | 17.8 | 30.4 |
| 300 | 4 | 30 | 1.28 | 1.67 | 1.38 | 1.58 | 0.39 | 0.1 | 0.3 | 30.4 | 7.8 | 23.4 |
| 300 | 5 | 20 | 1.23 | 1.75 | 1.58 | 1.86 | 0.52 | 0.35 | 0.63 | 42.3 | 28.4 | 51.2 |
| 300 | 4 | 20 | 1.47 | 1.89 | 1.50 | 1.78 | 0.42 | 0.03 | 0.31 | 28.6 | 2.0 | 21 |

**Load improvement ratio:** It is the ratio of load of reinforced to the load of unreinforced soil. The effect of length of sand column on load carrying capacity is measured in terms of load ratio. The load improvement ratio is analyzed for two different patterns of columns for 40mm settlement.
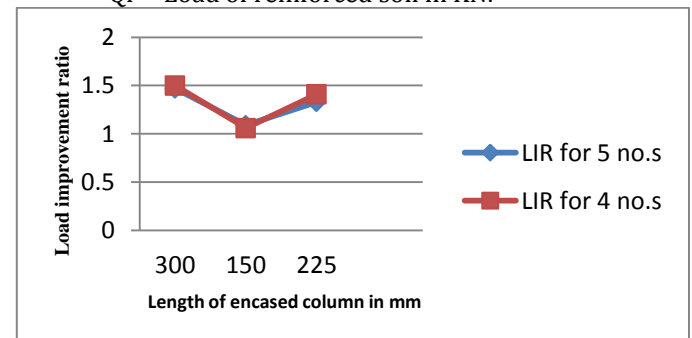Load improvement ratio is given by equation,
LIR = Qur/Qr
Where,

Qur = Load of encased reinforced soil in KN.
Qr = Load of reinforced soil in KN.



Load improvement V/S length for encasement of geogrids.

**Settlement analysis for group encased columns.**

A suitable foundation system should satisfy the settlement criteria. A week ground treated with sand column will settle less than an untreated ground hence the settlement reduction factor is the main objective in the ground improvement technique.

Settlement reduction factor (β) can be calculated by the relation

$$\beta = (S_0 - S_r) / S_0$$

Where,

So = Settlement of unreinforced soil in mm compared to unreinforced soil.

Sr = Settlement of reinforced soil in mm compared to unreinforced soil.

The settlement analysis for columns of different length and different Numbers. From the above table graph is plotted with respect to SRF V/S length of encasement. The settlement reduction factor for five numbers is less compare to four numbers for 40 mm settlement.

Effect of length of encase (PE-1202EF) column in settlement reduction for 40mm settlement for 30 mm dia.
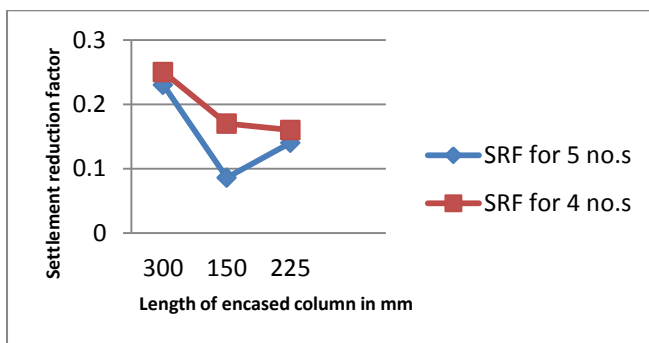


Settlement reduction factor V/S length for encasement of PE-1202EF

# 7. CONCLUSIONS

From above discussions following conclusions are drawn

- It is concluded that the lime and sand combination, i.e. lime 15 % and sand 15 % will give a better shear strength.
- The reinforced sand column 30 mm dia of 5 number columns will give a better strength of 1.5 Kn.
- Geogrids encased with 100 % will give a higher strength of 2.234Kn for 30mm dia of 5 number columns.
- As the different material is used as encasement, in that geogrids will give a better result in all percentage of encasement.
- There is a marginal reduction in settlement when the sand column is encased with geosynthetics.

- There is an improvement in LIR with the 5 numbers of sand columns with encasement of geosynthetics.
- The group of column in which five numbers diameter will give better result compare to 4 number of column in larger length and larger diameter.
- More number of closely spaced layer affect homogeneity of soil mass and ultimately the band between soil and reinforcement this results in decreasing rate improvement of black cotton soil.

## REFERENCES

[1] Ahmet Demir1, et al.,(2013), "An experimental study on behaviour of geosynthetic reinforced stone columns".2nd International Balkans Conference Of Civil Engineering,BCCCE,23-25 May2013,Epoka University.

[2] Ali, K et..al (2010), "Behaviour of reinforced stone columns in soft soils: an experimental study".Indian GeoTechnical conference 2010, Geotrends

[3] Chungsik Yoo, A.M.ASCE (2010), "Performance of Geosynthetic-Encased Stone Columns in Embankment Construction:Numerical Investigation".A.M.ASCE1J.Geotech.Geoenviron.Eng.2010.136:1148-1160

[4] Gupta.R and A. Trivedi (2010), "Behavior of model circular footings on silty soils with cellular supports".

[5] Hamed Niroumand, et al.(2011), "Soil Improvement by Reinforced Stone Columns Based on Experimental Work". EJGE VOL.16[2011],BUND,L

[6] Joel Gneil,Abdelemalek Bouazza (2008), "Improvement of soft soils using geogrid encased stone columns".

[7] J.A Black, Sivakumar, et al.,(2007), "Reinforced Stone Columns in Weak Deposits: Laboratory Model Study".

[8] Kameshwar Rao et al., (2012), "Comparative study of experimental and theoretical load carrying capacity of stone column with and without encasement of geosynthetics" IJAET ISSN:2231-1963

[9] Murugesan.S and Rajagopal.K (2009), "Shear load tests on stone columns with and without geosynthetic encasement".Geotextiles and Geomembranes 24(2012) 349-358 ASCE(20),

[10] S. Murugesan and K.Rajagopal (2007), "Model tests on geosynthetic-encased stone columns".ASCE9(1),30-35

[11] Mohammed Y. et.al., (2010), "Improvement of soft clays by end bearing stone columns encased with geogrids".

[12] Mereena K.P. et.al., (2009), "Triaxial compression of clay reinforced with quarry dust fibre column".

[13] Sujit kumar Dash, Mukul Chandra Bora (2013), "Influence of geosynthetic encasement on the performance of stone columns floating in soft clay".

[14]    Y.F. Leung, A, Klar(2010), " Theoretical Study on pile Length Optimization of Pile Groups and Piled Rafts " Geotech.Geoenviron, Engg, 2010.136:319-330[14]

[15]    Zahmatkesh. A & Choobbasti.A.J (2010), "Settlement evaluation of soft clay reinforced by stone columns, considering the effect of soil compaction"