INFLUENCE OF NATURAL AND ARTIFICIAL FIBER ON THE STRENGTH AND DUCTILITY BEHAVIOUR OF LIME TREATED SHEDI SOIL

K.V. Manoj Krishna[1], Shivaprasad.H[2] and Darshan G.C[3]

Received 03 August 2021, Revised 30 September 2021, Accepted 21 November 2021, Available online 21 November 2021

Abstract. This paper describes the compaction , strength and ductility behaviour of shedi soil reinforced with fiber. Fiber in this study is the processed fiber from both natural and artificial material. Shedi soil reinforced with fiber shows only marginal increase in the strength of soil, inhibiting its use for ground improvement. In order to further increase the strength of the soil-fiber combination, optimum percentage of 4% of lime is added. The effect of percentage fiber on the behavior of the composite soil specimen with curing is isolated and studied. It is found that strength properties of optimum combination of shedi soil-lime specimens reinforced with fibers is appreciably better than untreated shedi soil or shedi soil alone with fiber. Lime treatment in shedi soil improves strength but it imparts brittleness in soil specimen. Shedi soil treated with 4% lime(by weight) and reinforced with fiber shows ductility behavior before and after failure. An optimum coir fiber content of 1.25%(by weight) in natural fiber group and 0.6%(by weight) in artificial fiber group in lime treated shedi soil is recommended for shedi soil for enhancing strength and ductility behaviour of matrix.

Key words: Natural fiber, Artificial fiber, Maximum dry density, Shear strength

[1*]Assistant Professor, Dept of Civil Engg, Govt. Engineering College, Hassan-573201, Karnataka(s), India
Email: shree_manoj@yahoo.com
[2]Research Scholar, Dept of Civil Engineering, UBDT College of Engineering, Davanagere-577004
Email:shivaprasad.h61@gmail.com
[3]Former PG Student, Dept of Civil Engineering, GSKSJTI, Bangalore, Karnataka(s), India

***Corresponding Author:** Shivaprasad.H
* Research Scholar, Dept of Civil Engineering, UBDT College of Engineering, Davanagere-577004
Email: shivaprasad.h61@gmail.com

DOI:10.53555/ecb/2021.10.4.18

1.Introduction

The lateritic group of soil occurs all over the world. India has large tracks of lateritic soil knows as Shedi soil (SS), covering 1 laks square kilometers in India.The major areas of world are India, Indonesia, central Africa, Brazil, Cuba and Australia. In India it is more in Karnataka state. In Karnataka south canara district 90% its area made up of this lateritic soil. It is available up to a depth of 2.5 meters on an average in the above parts of the India. Some of the beds are having size distribution between JEDI (Clay) and GODI(silt) soils, but do not show the behaviour of the clay nor silt. These soils dissolve and flow like water when water gushes through this layer during monsoon and many times washes off the fine soil, creates cavities and at time causes heavy settlement and sliding of the top layers after the application of load. This bed soil is termed as lithomargic shedi soil. (Ramesh et.al 2010 & 2011)The construction of foundation for structures on shedi soil poses a challenge to civil engineers. Chemical stabilization is one of the oldest methods of stabilization of shedi soil. In recent days it has been investigated that addition of fibers will improve the ductility behaviour of the soil there by reducing the development of breakage of bond in between soil during presence of moisture. Use of artificial fibers and natural fibers act as reinforcing material to soil. In order to increase the effectiveness of the ground improvement method, an attempt is made to study the influence of both artificial and natural fibers on compaction and strength properties of lime treated shedi soil and compared with the results obtained for shedi soil alone and shedi soil reinforced with artificial as well as natural soil along in its isolated conditions.

Several researchers have been carried out to investigate and assess the behaviour of treated ground with chemical or fibers along (Yagi R.K. and Gowda Ramakrishna 1995, Ramesh et al , 2004, Ramesh et.al., 2010 & Ramesh et al., 2011),Effect of artificial fiber on the strength behaviour of shedi soil says that marginal improvement in strength behaviour reported by Manoj et al 2019. Illamparuthi 2008 have reported on the performance of soil stabilization using various fibers and cementatious materials, Kaniraj and Gayathri(2003) reported on geotechnical behaviour of fly ash mixed with randomly oriented fiber inclusions. Ramesh et.al., 2010 have reported the compaction and strength behaviour of lime-coir fiber treated black cotton soil . In this paper, the effect of fibers along with lime addition on compaction and strength behaviour of shedi soil has been presented.

2.Experimental work

Shedi soil (SS) was collected from Shedi Gudda , Mangalore, Karnataka state, India by an open excavation from a depth of 2.5 meters below natural ground level. The shedi soil was air dried and pulverized in a ball mill after separating the pebbles. The pulverized soil which is passing through 425 micron IS sieve was used in the present investigation. The physical properties of the soil are presented in Table .1

For the present research work, Ca (OH) $_2$ [Hydrated lime] is obtained from Medilise Chemicals Pvt. Ltd.P.B.No.25804, Kannur-670099, Kerala, India.The chemical composition of lime is presented in Table 2.

Two Natural fiber were used in the present investigation namely coir and jute both the fibers were collected from local market., Bangalore,Karnataka state,India

Two artificial fiber were used in the present investigation namely Nylon and Polypropylene fibers were collected from Used Nylon and Polypropylene bags, collected from local market, Bangalore, Karnataka state, India. Basic properties of all fibers were presented in Table 3.

Table 1 Basic properties of Shedi soil

Type of test	**Values**
Colour	Light pink
Specific gravity	2.41
Grain size analysis	
Fine sand (%)	00.00
Silt size fraction (%)	85.00
Clay size fraction (%)	15.00
Atterberg's Limits	
Liquid limit (%)	24.00
Plastic limit (%)	12.06
Shrinkage limit (%)	9.96
Plasticity index (%)	11.94

Classification of soil	Clay of lower compressibility	
Compaction characteristics (Proctor method)		
Optimum moisture content (%)	11.18	
Maximum dry density (kN/m³)	19.52	
Shear strength parameters		
Angle of internal friction (Ø)		5˚
Cohesion (c) (kN/m^2)		6.0
California bearing ratio value		
Soaked CBR (%)	3.8	

Table 2 Chemical composition of lime

Chemical Configuration	**Ca(OH)2**
Assay(min)	95%
Chloride (Cl) (max)	0.01%
Sulphate (SO_4) (max)	0.2%
Arsenic (As) (max)	0.0004%
Lead(Pb) (max)	0.001%
Insoluble matter (max)	1%

Table 3 Basic properties of natural and artificial fibers

Type of fiber	Coir	Jute	Nylon	Polypropylene
Colour	Brown	Brown	Blue	White
Length (mm)	1-38	1-38	1-38	1-38
Thickness (mm)	0.62	1.14	0.80	0.57
Specific gravity	0.95	0.56	1.05	0.10
Density (kN/m^3)	1.30	1.24	1.10	1.01
Water absorption (%)	12.00	51.28	0.00	0.00
Cost of fiber per Kg	70	75	85	40

Parameters considered in the present experimental work were percentage of fiber. Fiber-reinforced soil samples were prepared at maximum dry density (MDD) and optimum moisture content (OMC). Samples were prepared by mixing shedi soil with natural fiber 0.25%,0.5%,0.75% 1.00%,1.25%1.5%(by weight of soil) and another set of samples were prepared by mixing shedi soil with artificial fiber 0.2%,0.4%,0.6%,0.8% and 1.0% (by weight of soil). Optimum lime content was determined by mixing shedi soil (SS) with 1% to 6% lime (by weight of soil). Fibers were randomly mixed in soil to form homogenous mixture. Moist soil fiber mix was transformed to the mould and compacted. Compaction test were conducted using Mini compaction test apparatus (Sridharan and Sivapulliah,2005) and Light compaction test as per BIS 2720 part VII (1980) and Direct shear test were conducted for various combinations of soil sample compacted to their OMC-MDD as per BIS 2720 guidelines.

3.Results and Discussions

The compaction and direct shear tests were carried out for various percentages of lime and 4% lime was found to be optimum. The above test were also carried out with the natural and artificial fibers reinforced with Shedi Soil(SS) treated with optimum percentage of lime and the results were discussed.

3.1 Dry density-water content of Shedi soil reinforced with Fiber in presence and absence of optimum lime

It has been observed in general from Table 3 that, that addition of randomly distributed fiber to shedi soil with different percentages of fibers maximum dry density decreases and optimum moisture content marginally increases, similar observations were noticed by Kaniraj and Vasant (2001),Nataraj and Manis(1997), Kaniraj and Gayathri (2003) and Ramesh et al (2010) on clay soil/fly ash with natural and synthetic reinforcement. The present study reveals that coir fiber and jute fiber in shedi soil is more effective than the results obtained by

the use of artificial nylon and polypropylene fibers. This may be due to the fact that the cir fiber and jute fibers gets mixed randomly with soil and has improved frictional bond when compared with the use of artificial fibers.

Table.3 Dry density –water content of shedi soil reinforced with fiber in presence and absence of optimum lime

Mixture	**Optimum moisture content (%)**	**Maximum dry density(kN/m^3)**
Shedi Soil(SS) alone	11.18	19.52
SS + 0.25% RDCF	11.66	19.00
SS + 0.50% RDCF	12.00	19.10
SS+ 0.75% RDCF	11.30	18.50
SS + 1.00% RDCF	13.29	18.30
SS+ 1.25% RDCF	11.50	19.30
SS+ 1.50% RDCF	13.47	18.40
SS + 0.75% RDJF	13.35	19.41
SS+ 1.00% RDJF	10.22	19.00
SS + 1.25% RDJF	13.4	19.19
SS+ 1.50% RDJF	13.88	19.43
SS + 1.75% RDJF	15.12	18.70
SS + 2.00% RDJF	14.00	18.87
SS + 0.2% RDNF	15.73	19.10
SS + 0.4% RDNF	16.82	19.20
SS+ 0.6% RDNF	11.24	19.20
SS+ 0.8% RDNF	14.30	19.48
SS+ 1.0% RDNF	14.80	19.20
SS + 0.2% RDPPF	12.46	18.72
SS+ 0.4% RDPPF	12.56	18.96
SS+ 0.6% RDPPF	12.23	19.23
SS+ 0.8% RDPPF	14.23	19.40
SS+ 1.0% RDPPF	12.21	19.32
SS+ 4%lime + 0.25% RDCF	14.93	18.64
SS+ 4%lime + 0.50% RDCF	14.81	19.35
SS+ 4%lime + 0.75% RDCF	15.63	18.60
SS+ 4%lime + 1.00% RDCF	14.24	18.52
SS+ 4%lime + 1.25% RDCF	14.58	19.48
SS+ 4%lime + 1.50% RDCF	16.08	17.62
SS+ 4%lime + 0.25% RDJF	13.69	18.99
SS+ 4%lime + 0.50% RDJF	15.80	18.65
SS+ 4%lime + 0.75% RDJF	15.51	19.45
SS+ 4%lime + 1.00% RDJF	12.75	18.60
SS+ 4%lime + 1.25% RDJF	15.59	18.60
SS+ 4%lime + 1.50% RDJF	16.46	18.00
SS+4%Lime+0.2% RDNF	13.26	18.99
SS+4%Lime+0.4%RDNF	13.75	18.68
SS+4%Lime+0.6%RDNF	11.99	19.49
SS+4%Lime+0.8% RDNF	15.64	18.3
SS+4%Lime+1.0% RDNF	17.62	17.97
SS+4%Lime+0.2%RDPPF	13.12	19.48
SS+4%Lime+0.4% RDPPF	15.33	18.49
SS+4%Lime+0.6% RDPPF	11.52	19.40
SS+4%Lime+0.8% RDPPF	13.31	18.80
SS+4%Lime+1.0% RDPPF	14.26	18.60

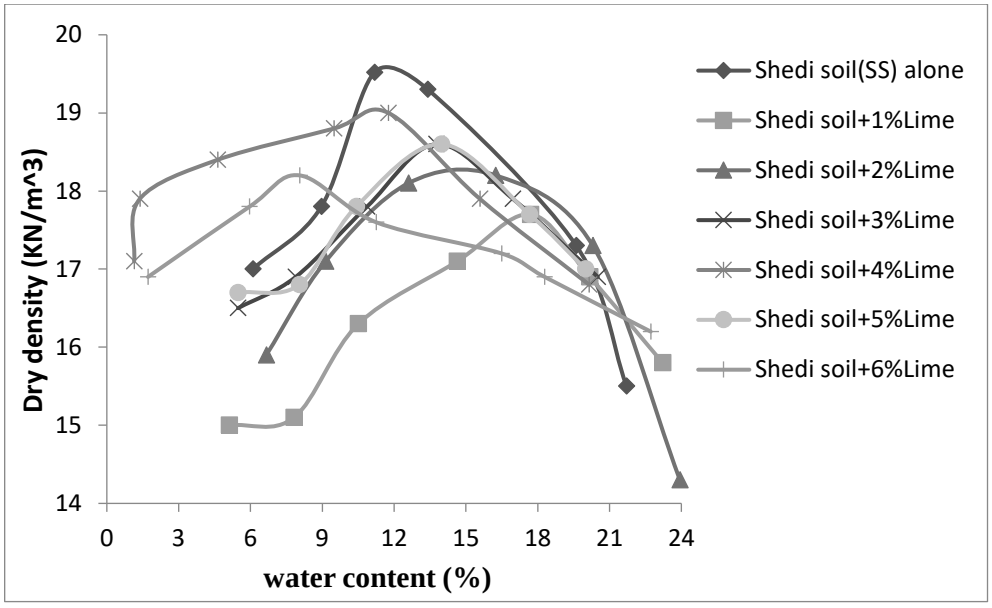

Fig. 1 Variation of Dry density Versus Water content for Shedi Soil reinforced with varying percentage of lime

It was observed that the ratio of maximum dry density of composite specimen mixed with coir fiber and jute fiber to that of untreated shedi soil specimen is in the range of 3.8% and 2.1% reduction on compared with shedi soil alone. Where as maximum dry density of composite specimen mixed with nylon fiber and polypropylene fiber to that of untreated shed soil specimen is in the range of 2.15% and 2.1% reduction on compared with shedi soil alone. This indicates that except coir fiber all fibers reduction in the density is almost same on compared with soil alone.

3.2 Dry density –water content of Shedi soil with various percentage of lime

It can be observed from the Fig.1. that Maximum dry density of shedi soil decreases with the addition of lime with corresponding larger increase in optimum moisture content. The increase in the maximum dry density is more with the addition of lime up to 4 %. Due to formation of cluster of soil particles in presence of lime up to 4% . With the further addition of lime beyond 4% maximum dry density reduces and optimum moisture content increases due to the disintegration of cluster of soil particles.

3.3 Dry density-water content of lime treated shedi soil with various percentages of natural and artificial fibers

Dry density –moisture content of lime treated shedi soil at various percentage of natural fiber as well as lime treated shedi soil with various percentage of artificial fiber were as shown in Table3 The optimum moisture content marginally increases and maximum dry density have been reduced for lime treated shedi soil reinforced with coir fiber /jute fiber/nylon fiber or polypropylene fiber. However, the optimum moisture content is more in lime treated shedi soil with natural fiber on compared with lime treated shedi soil with artificial fiber. This is due to observation of water by natural fiber porous cellulous structure increases optimum moisture content in natural fiber combination on compared with artificial fiber combination. The reduction of maximum density in both the fibers is due to disintegration of soil particles with the addition of fibers. Similar trend were observed by Neeraja et.al (2010) ,Ramesh et,al.,(2010),Manoj et.al(2018)

3.4 Shear strength of the shedi soil with fibers

A typical variation of shear strength with curing period is presented in Fig.2, It has been observed that addition of coir fiber to shedi soil strength increases with increasing in curing period up to 1.25% (by weight of soil) and from Fig.3,it has been observed that , shedi soil with jute fiber strength increases with increasing in curing period up to 1.5% (by weight of soil) . This is because as fiber added to soil inhibits passive inclusive shear resistance in soil fiber matrix, which increases the strength.

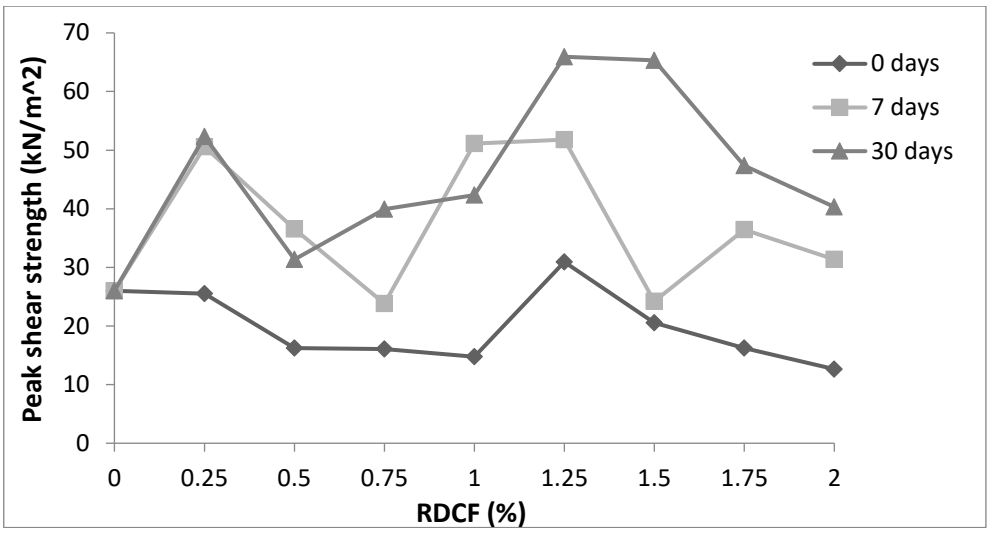

Fig.2 Variation of shear stress with respect to varying percentage of randomly distributed coir fiber

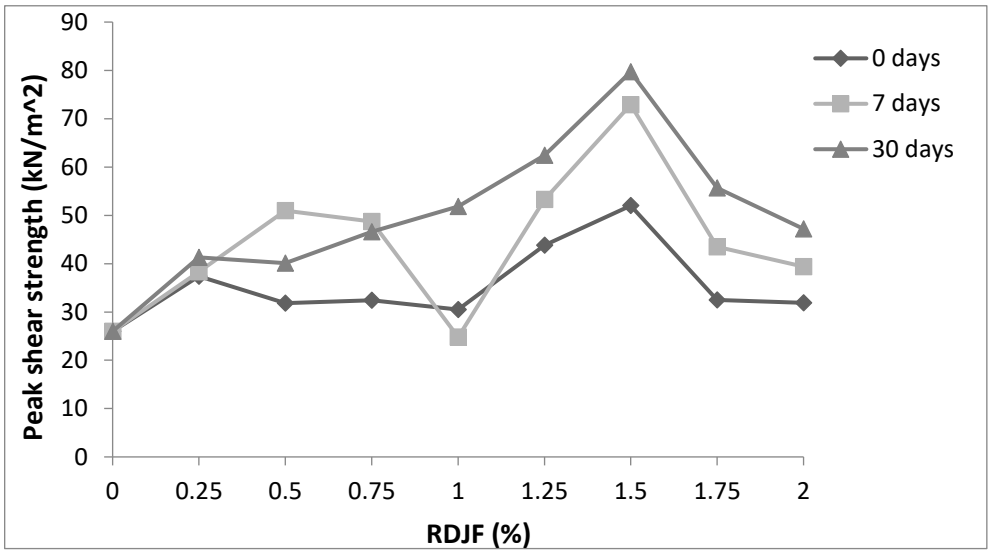

Fig.3 Variation of shear stress with respect to varying percentage of randomly distributed jute fiber

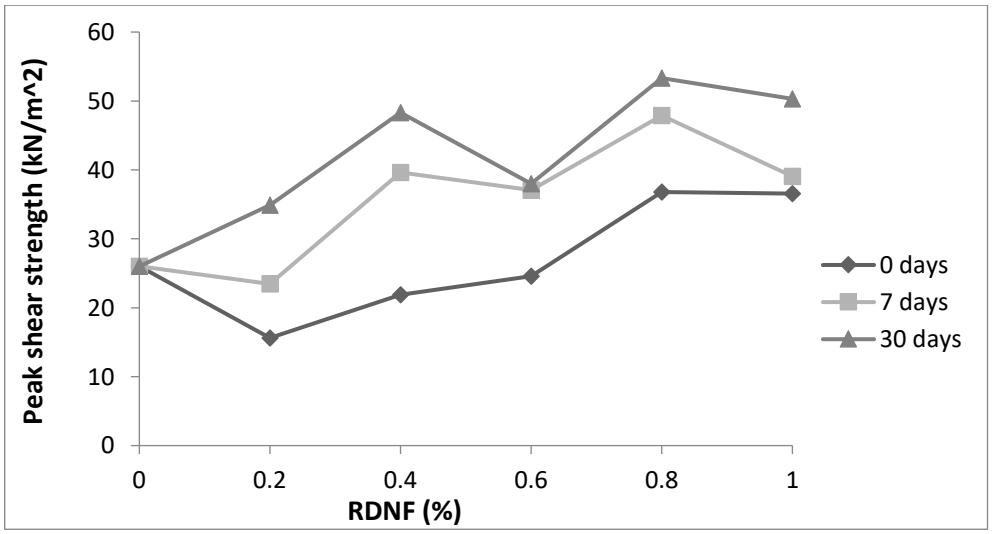

Fig.4 Variation of shear stress with respect to varying percentage of randomly distributed nylon fiber.

Fig .4, shows the shedi soil reinforced with randomly distributed nylon fiber with curing. Addition of Nylon fiber up to 0.8%(by weight of soil) strength increases and beyond 0.8% nylon fiber content in the matrix, strength reduces. The increase in the strength is due to soil-fiber interaction dominates up to optimum beyond optimum fiber-to fiber interaction reduces the strength of matrix.

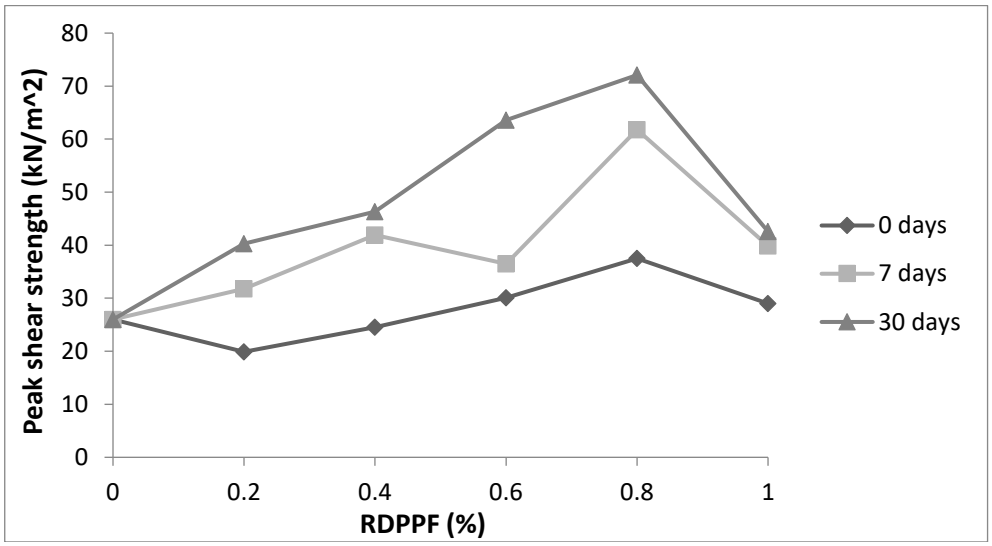

Fig. 5 Variation of shear stress with respect to varying percentage of randomly distributed polypropylene fiber.

Fig.5 shows strength behaviour of shedi soil reinforced with varying percentage of randomly distributed polypropylene fiber. According to them Pradan et.al (2012), increase in strength mainly due to increase in the surface area of polypropylene fiber. However the increased surface area of polypropylene fiber in matrix leads to increase in strength as the friction developed between soil particles and surface area of fiber in mixture up to 0.8%. Beyond 0.8%, there will be fiber to fiber interaction develops and leads to decrease in strength. From above discussion, shedi soil reinforced with 0.8% randomly distributed polypropylene fiber (by weight of soil) is found to be optimum.

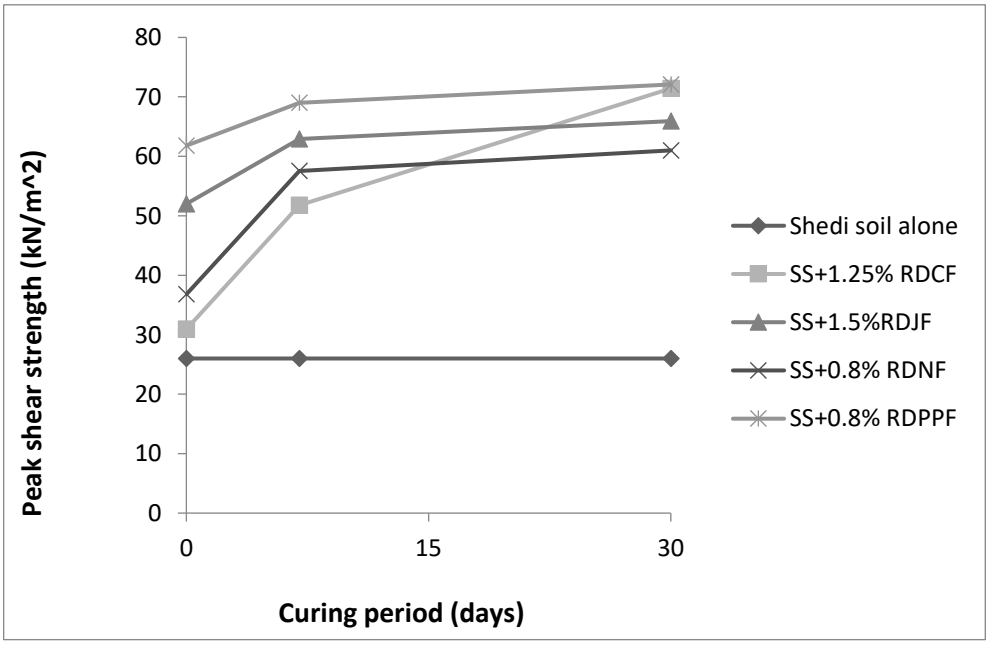

Fig. 6 Variation of peak shear strength shedi soil reinforced with optimum percentage of all fibers with curing (30days)

Fig. 6. it is observed, addition of optimum percentage of each of fibers in the shedi soil individually and analyzed up to 30 days , it has been found that increases the peak shear strength in all fiber combination on compared to shedi soil alone. It is also found that, shedi soil with optimum percentage of randomly distributed coir fiber has a higher peak shear strength on compared to soil alone as well as other fibers. It is observed that among natural fibers, shear strength carrying capacity is more in shedi soil reinforced with randomly distributed coir fiber and also among artificial fibers; shedi soil with polypropylene fiber has a higher strength carrying capacity.

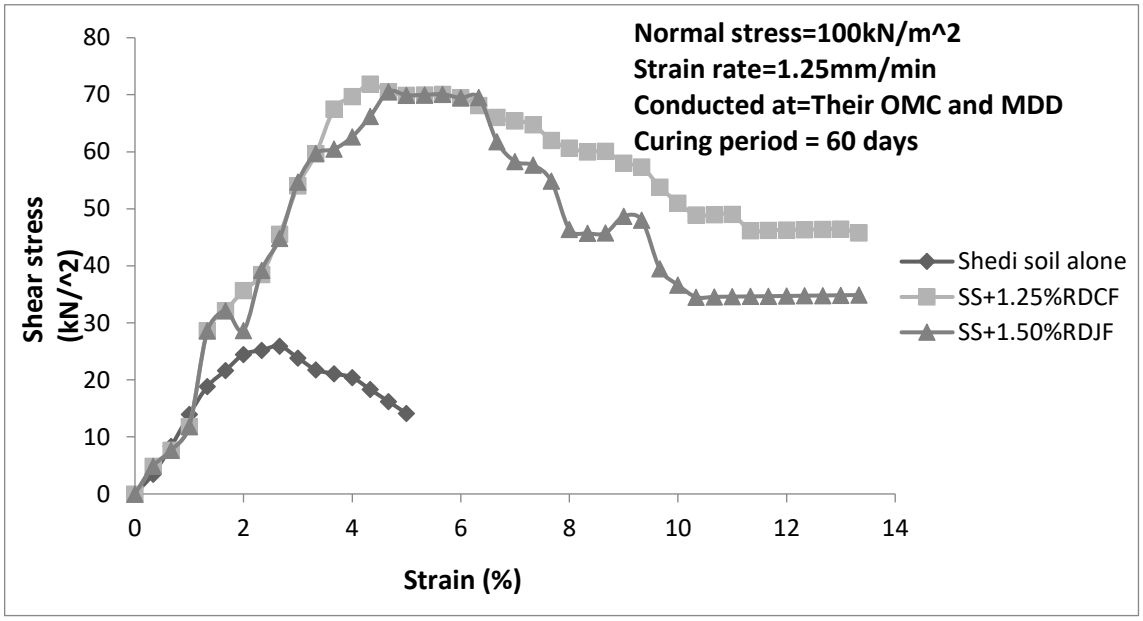

Fig. 7 Stress-strain behaviour of shedi soil reinforced with optimum percentage of natural fibers with curing (60days)

Fig. 7, it is observed that, strain at post peak fail of shedi soil alone is 5%. On addition of natural fibers coir or jute, strain is increased by 13%. This is increased by 2.6 folds more on compared to shedi soil alone. This indicates it exhibits ductile behaviour in soil-fiber combination.

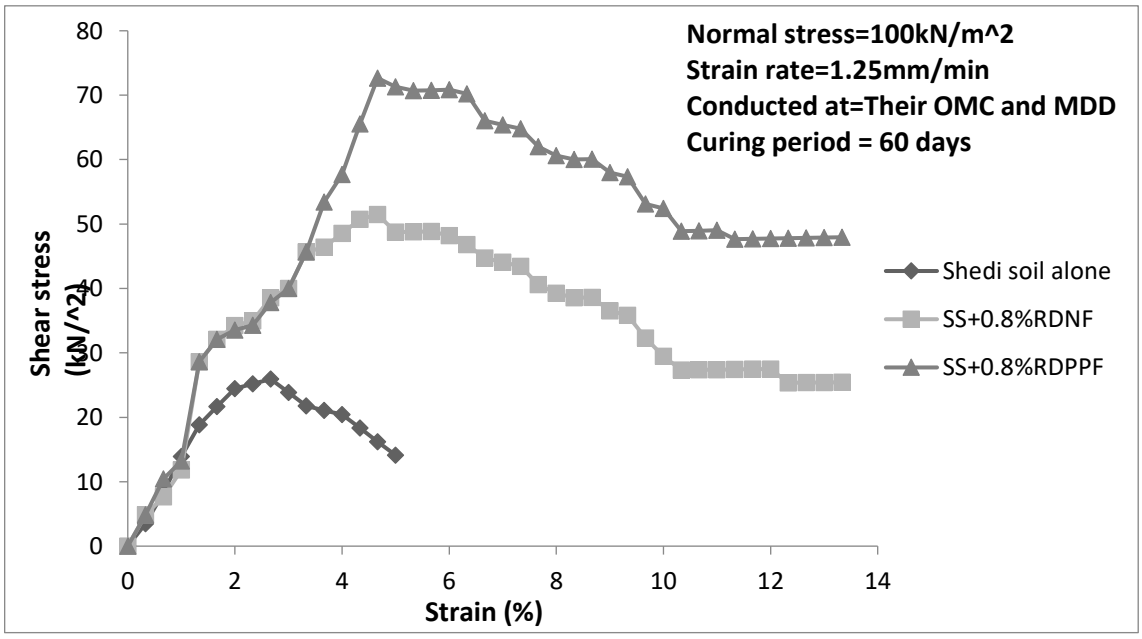

Fig. 7 Stress-strain behaviour of shedi soil reinforced with optimum percentage of artificial fibers with curing (60days)

Fig. 7, it is observed that, strain at post peak fail of shedi soil alone is 5%. On addition of artificial fibers nylon and polypropylene, strain is increased by 14%. This is increased by 2.6 folds more on compared to shedi soil alone. This indicates it exhibits ductile behaviour in soil-fiber combination.

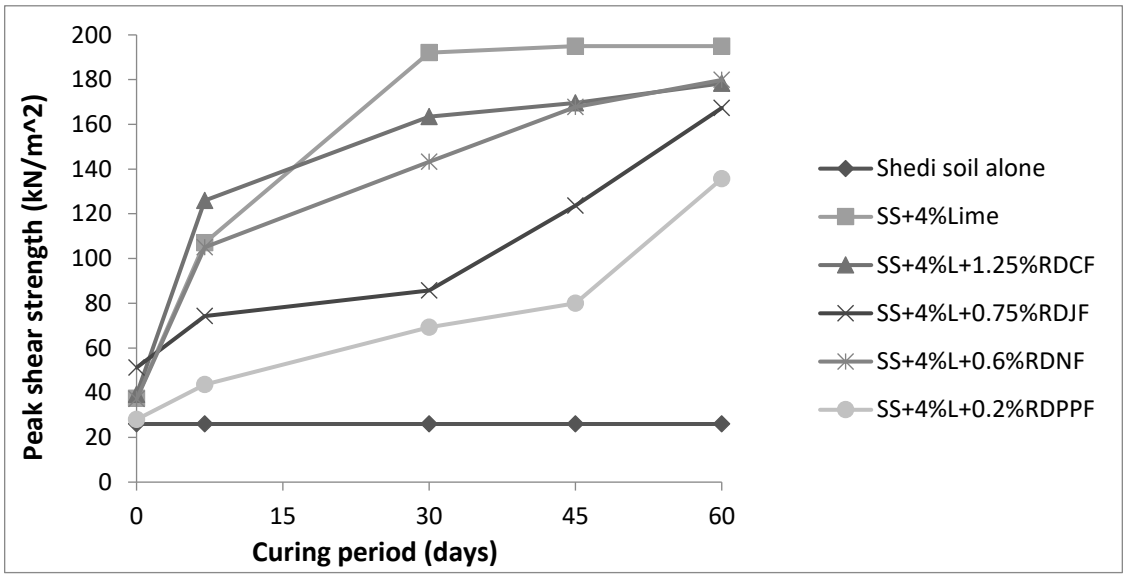

Fig. 8 Variation of peak shear strength of lime treated shedi soil with optimum percentage of all fibers with curing (60days)

Fig.8. shows lime treated shedi soil reinforced with various fibers combinations and direct shear test conducted with various curing periods, it has been found that in case of coir fiber optimum is 1.25% , jute fiber 0.75% , nylon fiber 0.6% and polypropylene fiber 0.2 % on compared with other percentages of fibers in each mix. Hence a comparative study was carried out for respective optimum combinations on compared with shedi soil alone for long term curing period to find the long term lime treated shedi soil reinforced with various optimum fiber combinations. It has been found that among all fibers lime treated shedi soil reinforced with randomly distributed coir fiber in natural fiber category and lime treated shedi soil reinforced with randomly distributed nylon fiber in artificial fiber category was performed actively even up to 60 days curing on compared with other fibers.

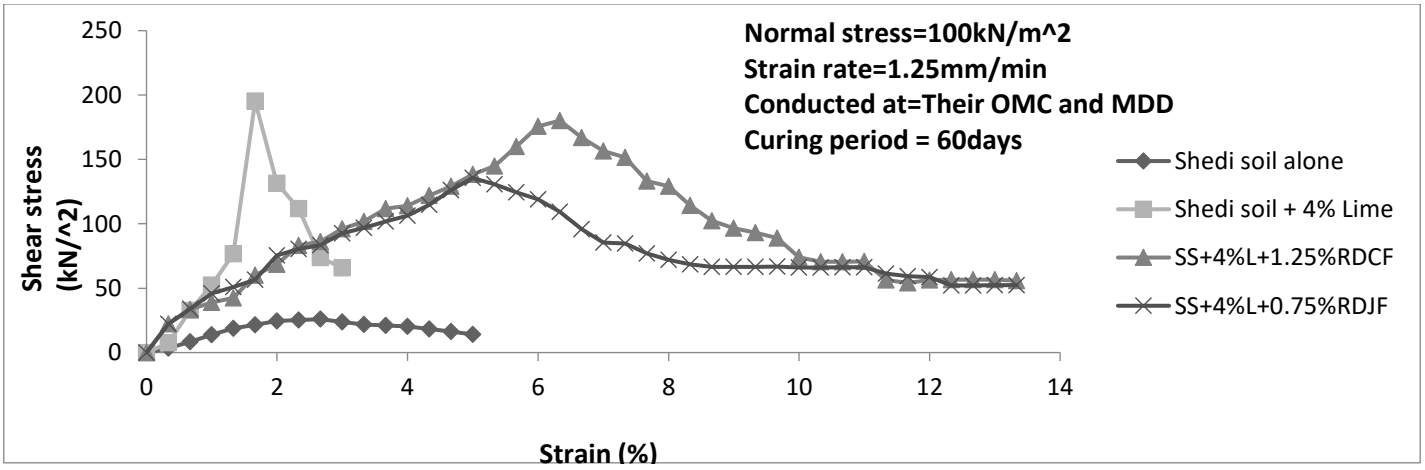

Fig. 9 Stress-strain behaviour of lime treated shedi soil reinforced with optimum % of natural fibers with curing (60days)

Fig.9 shows, strain at post peak fail of shedi soil alone is 5% and strain at post peak fail of shedi soil with optimum percentage of lime is 3%. On addition of natural fibers coir and jute content to lime treated shedi soil, strain is increased by 2.6 folds on compared to shedi

soil and strain increased by 4.4 folds on compared to lime treated shedi soil. This indicates it exhibits ductile behaviour in soil-fiber combination.

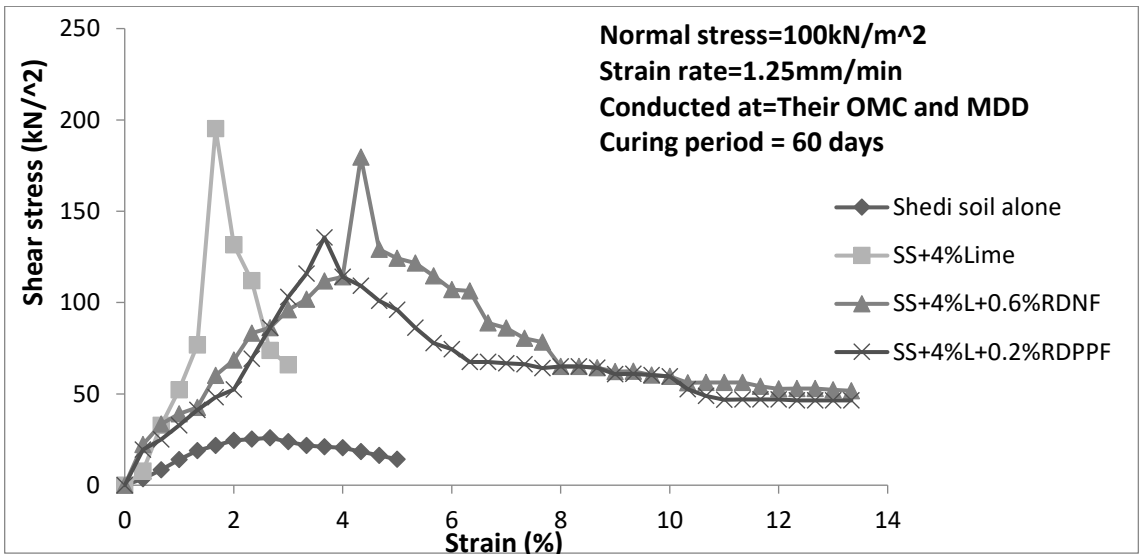

Fig. 10 Stress-strain behaviour of lime treated shedi soil reinforced with optimum % of artificial fibers with curing (60days)

Fig.10 shows that, strain at post peak fail of shedi soil alone is 5% and strain at post peak fail of shedi soil with optimum percentage of lime is 3%. On addition of artificial fibers nylon and polypropylene content to lime treated shedi soil, strain is increased by 2.6 folds on compared to shedi soil and strain increased by 4.4 folds on compared to lime treated shedi soil. This indicates it exhibits ductile behaviour in soil-fiber combination. Similar observations were made by Prathap and Jairaj(2014)

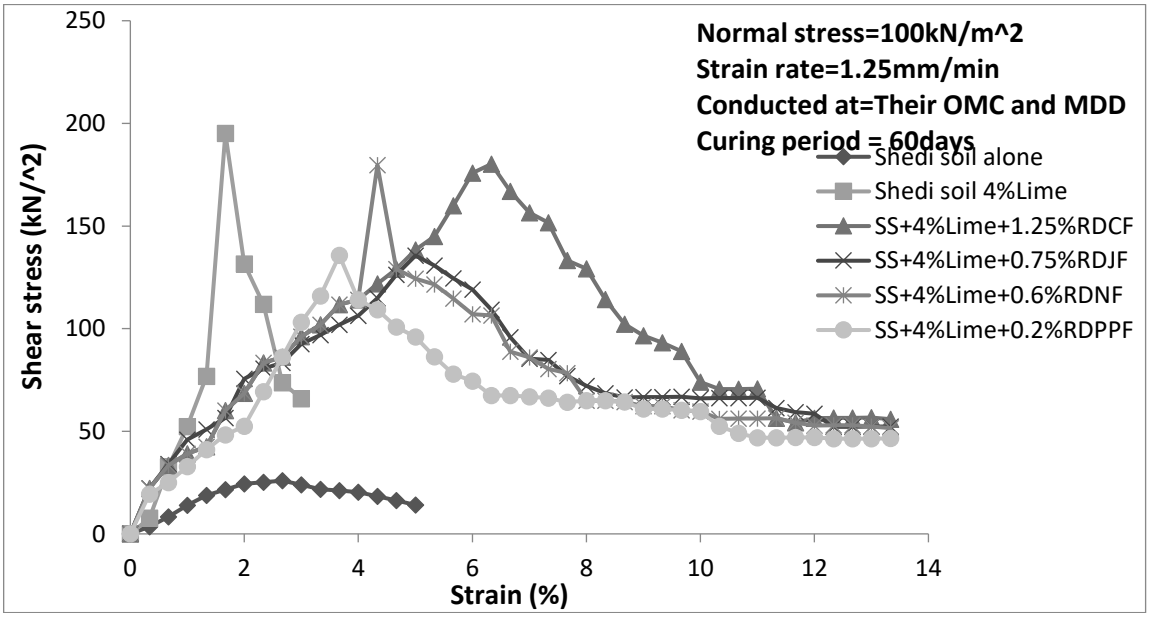

Fig 11 Stress-strain behaviour of lime treated shedi soil reinforced with optimum % of natural and artificial fibers with curing (60days)

Fig.11 shows that,strain at post peak fail of shedi soil alone is 5% and strain at post peak fail of shedi soil with optimum percentage of lime is 3%. On addition of coir, jute, nylon and polypropylene fiber content to lime treated shedi soil, strain is increased by 2.6 folds on compared to shedi soil and strain increased by 4.4 folds on compared to lime treated shedi soil. This indicates it exhibits ductile behaviour in all soil-fiber combination.

4.Conclusions

Based on the results presented in this paper , the following conclusions are drawn:

1.Addition of lime to shedi soil increases the strength. It has been observed that 4% lime by weight of soil is found to be optimum.

2. Addition of randomly distributed either natural fiber or artificial fiber to shedi soil increases the strain after reaching peak strength. Thus it shows the ductile behaviour of the soil sample.

3. Addition of shedi soil with 1.25% coir fiber , shedi soil with 1.5% jute fiber, shedi soil with 0.8% nylon fiber and shedi soil with 0.8% polypropylene fiber is found to be optimum.

4.Addition of optimum lime to shedi soil increases the strength and the sample becomes brittle with curing.

5.Optimum lime treated shedi soil reinforced with 1.25% Randomly distributed coir fiber, ,lime treated shedi soil reinforced with 0.75% randomly distributed jute fiber,lime treated shedi soil reinforced with 0.6% Randomly distributed nylon fiber and lime treated shedi soil reinforced with 0.2% Randomly distributed polypropylene fiber is found to be optimum which carrying higher strength on compared with other fiber combination .

6. Addition of 4% lime to shedi soil with 1.25% coir fiber or 4% lime to shedi soil with 0.6% nylon fiber increases strength almost same and improves ductility. Hence lime treated shedi soil reinforced with coir fiber will perform same as lime treated shedi soil reinforced with artificial fiber in field.

References

1. Kaniraj.S.R. and Vasanth G.H. (2001)," Behaviour of cement-stabilized fiber reinforced fly ash soil mixture",Geotech Geoenviron Eng.J,574-584.
2. Kaniraj, S.R. and Gayathri.V. (2003)," Geotechnical Behaviour of fly ash mixed with randomly oriented fiber inclusions", *Geotext, Geomembrances*,**21**,123-149.
3. Manoj Krishna.K.V., ,Ramalinga Reddy.Y and Darshan .G.C ,(2019), "Effect of artificial fiber on the compaction and strength behavior of sheid soil", *International Journal of Engineering and Techniques*,.**5**,(1),100-107.
4. Mahammed Mahdi Shaichaian ,M Arabani (2022),"A review of soil Reinforcement with Planetary Fibers", Journal of soil science and plant Nutrition"
5. Nagu,P.S.,Chandrakaran,S. and Sankar, N. (2008),"Behaviour of lime stabilized clayey soil reinforced with Nylon fibers", Proceedings of *'08 Internatinal conference on Geotechnical and Highway Engineering* Geotropic, Kuala Lumpar, Malaysia, May.
6. Neeraja,D. (2010) "Influence of lime and plastic jute on strength and CBR characteristics of soft clayey (Expansive soil)," Global Journal of Researches in Engineering , **10,** (I),16-24
7. Pradhan, P.K., Kar, R.K. and Naik, A. (2012) "Effect of random inclusion of Polypropylene fibers on strength characteristics of cohesive soil." Geotechnical and Geological Engineering, Springer; **30** (1):15-25
8. Prathap Kumar M.T.and Jairaj (2014). "Shear Strength Parameters of BC Soil Admixed with Different Length of Coir Fiber". IJERT, ISSN: 2278-0181, **3** (4,)
9. Rahul Rai , Mahima Upreti , Mohneesh Nayal (2019)," Soil Stabilization using Polypropylene Fiber**",** International Journal Of Engineering Research & Technology (Ijert),7(1)
10. Ramesh H.N, Nanda H.S and Manoj Krishna K.V. and Muddu raj H.C ,2004, Characterisation of sheidi soil, *Indian Geotechnical Conference-2004*, IISc, Bangalore,.**1,.**257-260
11. Ramesh. H. N. ,Nanda.H.S. and Manoj Krishna.K.V. (2011), "Effect of soaking on the strength behaviour of shedi soil treated with NFA", Proceedings of Indian Geotechnical conference-2011, .**1** 753-754.
12. Ramesh H.N,Manoj Krishna K.V. and Mamatha .H.V. (2010),"Compaction and Strength behavior of lime-coir fiber treated Black cotton soil", Geomechanics and Engineering ,**2** (1),19-28.
13. Sridharan .A and Sivapullaiah P.V (2005) Mini compaction test on determination of compaction characteristics of fine grained soil, Geotechnical testing journals, **28**,,240-246
14. Vivi Anggrainia (2016) ,"Potential of coir fiber as soil reinforcement
15. Yagi R.K. and Gowda Ramakrishna. (1995), "Effect of contamination by some chemicals on

the engineering behaviour of shedi soil", *proceedings of Indian Geotechnical Conference*,95 .**1**

Notations

BIS: Bureau of Indian Standards
FIG: Figure
IS Sieve: Indian Standard Sieve
L: Lime
MDD: Maximum Dry Density
OMC: Optimum Moisture Content
RDCF: Randomly Distributed Coir Fiber
RDJF: Randomly Distributed Jute Fiber
RDNF: Randomly Distributed Nylon Fiber
RDPPF: Randomly Distributed Poly Propylene Fiber
SS: Shedi Soil