USE OF NANO SILICA AND NYLON FIBER TO STRENGTHEN THE ENGINEERING PROPERTIES OF CLAYEY SOIL

Tasadaq hussain[1], Anoop Sharma[2]

[1]PG student, Dept. of Civil Engineering, Sri Sai College of Engineering& Technology, Badhani, Punjab, India
[2]Assistant Professor, Dept. of Civil Engineering, Sri Sai College Of Engineering& Technology, Badhani, Punjab, India
anoopsharma777r@gmail.com

---***---

Abstract - Expansive soil is one among the problematic soils that has a high potential for shrinking when it is dried and swelling due to change of moisture content. Expansive soils (clays) popularly known as black cotton soils in India. Due to alternate swell-shrink behavior of expansive soils causes, distress in the foundation structures such as buildings, pavements of earth retaining walls etc. Understanding the behavior of expansive soil and adopting the appropriate control measures have been great task for the geotechnical engineers. Extensive research is going on to find the solutions for black cotton Soils. In this study, Nylon Fiber has been used in the form of fibers. The effect of the stabilisation was evaluated through carrying out standard laboratory tests. The tests included the standard compaction test, unconfined compressive strength (UCS) test, California Bearing Ratio (CBR) test. The main motive of this research is to investigate the optimal combination of Nano-Silica and Nylon Fiber with clay soil. The engineering properties such as liquid limit, plastic limit, maximum dry density and unconfined compressive Strength (UCS) are analyzed with virgin soil, the soil with Nano-Silica and combination of soil with Nano-Silica and Nylon Fiber. Three different combinations of Nano-Silica at different percentages 2%, 4% & 6% are used in integration with Nylon Fiber is used in different percentages such as 2.0%, 3.0% and 4%. From these experiments, it has been analyzed that with the increase of Nylon Fiber content in addition to Nano-Silica, the UCS increases and maximum value of UCS is obtained at 6% of Nano-Silica with 2.5% of Nylon Fiber. The intermixing of Nylon Fiber with the soil acts as a reinforcing material in binding the soil particles and the 'bridge effect' of fiber reinforcement in soil impedes the further development of tension cracks.

Key Words: Compaction test, CBR, UCS, Nano Silica, Nylon Fiber

INTRODUCTION

To construct building using weak/soft soil is very risky because it is sensitive to differential settlements because of its weak shear strength. For improvement in certain properties such as carrier capacity, shearing soil capacity and permeability characteristics, a number of methods such as prefabricated vertical drains and soil stabilizations are followed by engineers. The chemical stabilization is the most commonly used strength improvement method for soil stabilization . The main intend of soil stabilization is to enhance the strength of the soil and to lessen its settlement. The utilization of recycled/ waste materials comprises of different benefits economically as well as environmentally . This also helps in minimising the construction cost of engineering projects. Thus, a lot of studies have been carried out to investigate the utilization of recycled materials as a novel stabilizer in the projects of soil stabilization. Nano technology revolves around to create a variety of collections of nano-materials. It basically covers nano-particles with nano objects. The particles of about 100 nm or less than are known as nanomaterials whereas nano objects is doubled lower than the same size . The nanotechnology was first come into existence in 1959 in a lecture provided by Feynman which was entitled as ‘‘There is a lot of space underneath”. It is important although at that time the term ’nanotechnology’ was not there yet. Years later, this technology made rapid and imperative progress in science. Due to its great features such as low cost, green environmental approach, it finds applications in different engineering fields such as biosynthesized nano-particles , agriculture, biomedical and engineering sector.

2. Literature Review

Datta et al. (2023)

Terrasil and coir fiber were utilized in this investigation in quantities of 0.5%, 0.5%, 1.0%, 1.5%, and 2.0%, respectively. According to analyses or test results, clay subgrade soil that has been stabilized with 0.5% Terrasil and 1.5% coir fiber displays specific strength and CBR value augmentation values. The number of layers required for the subgrade is reduced as a result of the treated soil's normally higher CBR estimated value, which is 90% more than the untreated soil.

Samin et al. (2021)

In this study, PE and PP have been used in the form of fibres. The effect of the stabilisation was evaluated through carrying out standard laboratory tests. These tests have been conducted on natural and stabilised soils with four fibre contents (1%, 2%, 3%, and 4%) of the soil weight. The tests included the standard compaction test, unconfined compressive strength (UCS) test, California Bearing Ratio (CBR) test, and resilient modulus (Mr) tests. In all these tests, the fibre content was added in two lengths, which were 1.0 cm and 2.0 cm. Laboratory test results revealed that the plastic pieces decrease maximum dry density (MDD) and optimum moisture

content (OMC) of the stabilised soils, which are required for the construction of embankments of lightweight materials. In addition, there was a significant improvement in the UCS of soils by 76.4 and 96.6% for both lengths of PE fibres and 57.4% and 73.0% for both lengths of PP fibres, respectively. Results of the CBR tests demonstrated that the inclusion of plastic fibres in clayey soils improves the strength and deformation behaviour of the soil especially with 4% fibre content for both lengths 1.0 cm and 2.0 cm, respectively, to a figure of 185 to 150% for PE and PP, respectively. Furthermore, the results of the Mr tests demonstrated that the mechanical properties improved to an extent. For an increase in fibre content, the resilient modulus increased by about 120% at 4% fibre content for PE. However, for PP, improvement in resilient modulus declined at 3% fibre content. Therefore, for soil stabilisation with fibre material, optimum fibre content shall be sought.

Singh et al. (2019)

The main motive of this research is to investigate the optimal combination of Nano-Silica and Polypropylene fiber with clay soil. The engineering properties such as liquid limit, plastic limit, maximum dry density and unconfined compressive Strength (UCS) are analyzed with virgin soil, the soil with Nano-Silica and combination of soil with Nano-Silica and polypropylene fiber. The Durability test is performed to understand the durability of stabilized soil by analyzing wetting–drying cycles Also, Scanning Electron Microscopy (SEM) test is carried out and images are obtained to understand micro-structural modification towards mixture of Nano-SiO2 and PPF. Four different combinations of Nano-Silica at different percentages 1%, 3%, 5% and 7% are used in integration with polypropylene fiber is used in different percentages such as, 0.1%, 0.4%, 0.7%, 1%, and 1.3%. From these experiments, it has been analyzed that with the increase of PPF content in addition to Nano-Silica, the UCS increases and maximum value of UCS is obtained at 7% of Nano-Silica with 0.7% of PPF. The intermixing of PP fiber with the soil acts as a reinforcing material in binding the soil particles and the 'bridge effect' of fiber reinforcement in soil impedes the further development of tension cracks.

Sharma et al. (2019)

In the present study, therefore we have investigated the influence of waste polypropylene fibers on the resilient modulus of clay soil. Under this investigation, several cyclic CBR tests were performed on soil specimens by reinforcing the clay soil with polypropylene fibers which were added in different percentages i.e. 0.3%, 0.4%, 0.5%, 0.6% by weight of soil. The outcomes show that the experimented technique is very effective to improve the resilient modulus of clay soil. It is found that for the best results, optimum percentage of waste polypropylene fibers to be added is 0.4 % by weight of soil. Finally, it has been concluded that reinforcing the clay soil with polypropylene fibers provides positive influence on resilient modulus of the soil.

Al.-Jaberi et al. (2017)

In their study, they improved the properties of poor subgrade soil using Cement Kiln Dust. They investigate the effects of CKD on the properties of the poor subgrade soils using CBR testing method with different doses of CKD (5%, 10%, 15%, 20%, 25%, and 30%bythedry weight of the selected soil) in combination with different curing periods (1 day,3 days, 7 days, 14 days, and 28 days). They concluded that the optimum amount of CKD to be used is 20% and the optimum curing period for this came to be 14 days.

Keerthi et al. (2017)

The stabilization of clayey soil is done using CKD. In which the CKD proportions is varied from 0 to 50% by weight of soil. In their study, it is found that the Unconfined Compressive Strength of soil is increased when CKD is added 50% as compared to 0% CKD. They also concluded that the optimum quantity of CKD for light applications is varied between 12-30% however for heavy applications, CKD content of upto 50% can be used.

Rokade et al. (2017)

Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

Ajit kumar et al. (2016) The study is an experimental investigation on the use of HDPE (High Density Polyethylene) mixed with a CL-ML soil. The HDPE sheets were cut into 5mm wide strips and then into three aspect ratios as 1, 2 and 3. Such strips were then randomly mixed in the soil in different proportions (0.5%, 1.0%, 1.5% and 2%) by dry weight of soil. The paper reports results obtained on dry density and CBR behaviour of the soil. A decrease in the dry density of soil with increasing aspect ratio as well as percentage of HDPE content was obtained. On the other hand, CBR value is found to increase with increase in aspect ratio, the maximum CBR value obtained at 1.5% HDPE content. Increasing HDPE to 2%, resulted in reduction of CBR. In view of HDPE, being relatively less expensive as compared to other reinforcing materials; the results find application in designing base material for highway construction and reducing compressibility of soil. Also, it will certainly lead to safe disposal of the waste in eco-friendly manner.

Mahesh et al. (2016)

Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highways and airfields. CBR value is high at 10% lime + 1.5% fiber when compared to the remaining proportions. CBR value for (soil +10% lime) and (soil + 40% lime) is same. CBR gradually increases with increase in fibers upto 2% (soil + 5% lime).

3. Materials

3.1 SOIL

Source of soil

The soil required for the project is taken from an empty field in Jammu. The soil is alluvial in nature and contains high amounts of clay. The total quantity of soil collected is about 120 Kg.

All the soil that is used is sieved using 4.75mm sieve before start of the tests. The soil is oven dried for 24 hours before use to eliminate presence of any moisture in the soil. Firstly, Virgin soil without any admixture is tested for its properties and strength value and after that it is tested along with the addition of various proportions of Nano silica and Nylon Fiber.

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	36
2.	Plastic limit (%)	21
3.	Plasticity Index (%)	15
4.	Specific Gravity	2.59
5.	Maximum Dry Density (KN/m³)	17.69
6.	Optimum Moisture Content (%)	15.10
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	2.41
9.	CBR (%) (Unsoaked)	4.1
9.	UCS (kN/m²)	169.71

3.2 NANO SILICA

Source of NANO SILICA

Nano Silica used in this research work was collected from Ludhiana.

Table 2: Physical properties of Nano Silica

Physical properties	Value
Diameter (nm)	20 – 30
Surface volume ratio (m2 /g)	193
Density (g/cm3)	1.7
Purity (%)	>99

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 07 | July - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Table 3: Chemcial properties of Nano Silica

Sr. No.	Compound	Value (%)
1	Silicon Oxide(SiO2)	99.88
2	Al_2O_3	0.05
3	Iron Oxide (Fe2O3)	0.01
4	Carbon content	0.06
5	Chloride content	0.09

3.3 NYLON FIBER

Source of NYLON FIBER

Nylon fibre that is used in this project is kNown as Gujcon-CRF and is manufactured by Gujrat state fertilizers and chemicals limited which was collected from their warehouse in New Delhi.

Table 4:- Physcial Properties of Nylon Fiber

S.No.	Property	Value
1.	Density	1.14gm/cc
2.	Melting point	215℃
3.	Length(L)	20mm
4.	Specific gravity	0.90
5.	Diameter(D)	0.50mm
6.	Aspect ratio(L/D)	40

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: Results of OMC and MDD for mix proportions of Soil, Nano Silica and Nylon Fiber

SOIL:NS:NF	MDD (kN/m³)	OMC (%)
100:00:00	17.69	15.10
92.5:06:1.5	16.72	16.27
92.0:06:2.0	16.28	16.51
91.5:06:2.5	15.79	16.85

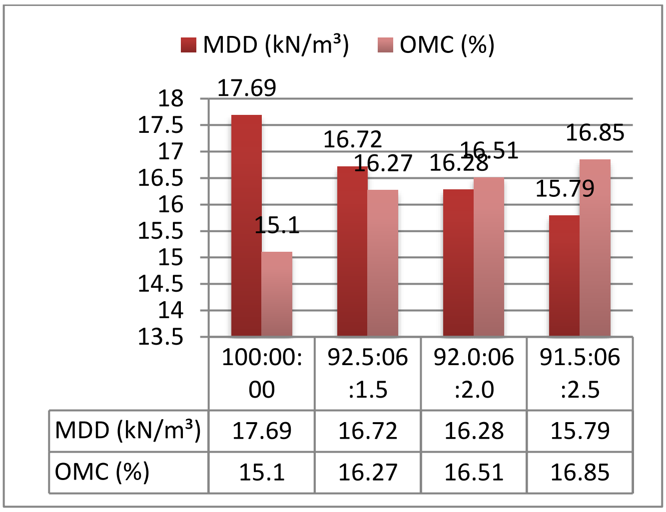


Fig:-1 variations b/w MDD and OMC of Nano Silica, Nylon Fiber & soil with different proportions

Table 6: Results of UCS of Nano Silica and Nylon Fiber Mix with Soil

SOIL:NS:NF	Curing Period (Days)	UCS (kN/m²)
100:00:00	7	330
92.5:06:1.5	7	450
92.0:06:2.0	7	550
91.5:06:2.5	7	640

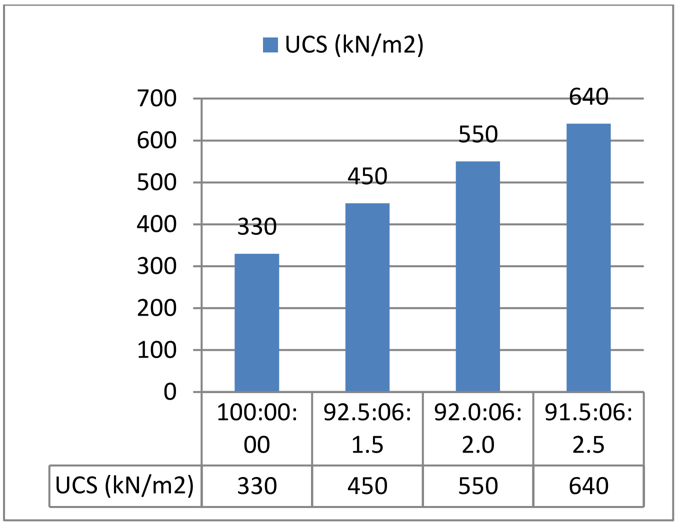


Fig:-2 Variations b/w UCS Values of Clayey soil, Nano Silica and Nylon Fiber with different proportions

Table 7: Results of CBR of Nano Silica and Nylon Fiber Mix with Soil

SOIL:NS:NF	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.1	5.2
92.5:06:1.5	4.3	6.8
92.0:06:2.0	5.2	8.3
91.5:06:2.5	6.1	9.8

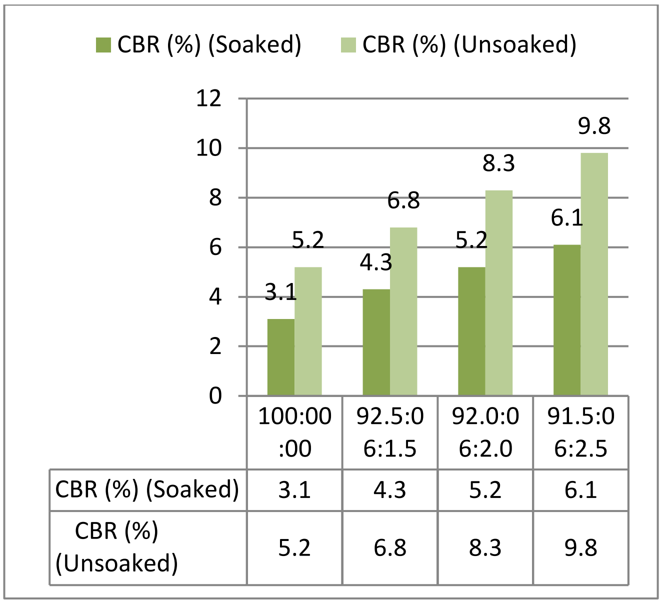


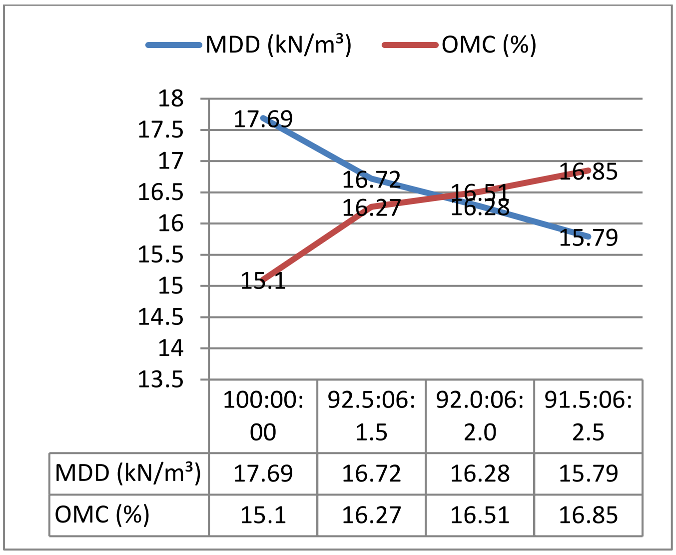
Fig:-3 Variations b/w CBR Values of Clayey soil, Nano Silica and Nylon Fiber with different proportions

5. DISCUSSIONS

STANDARD PROCTOR TEST:

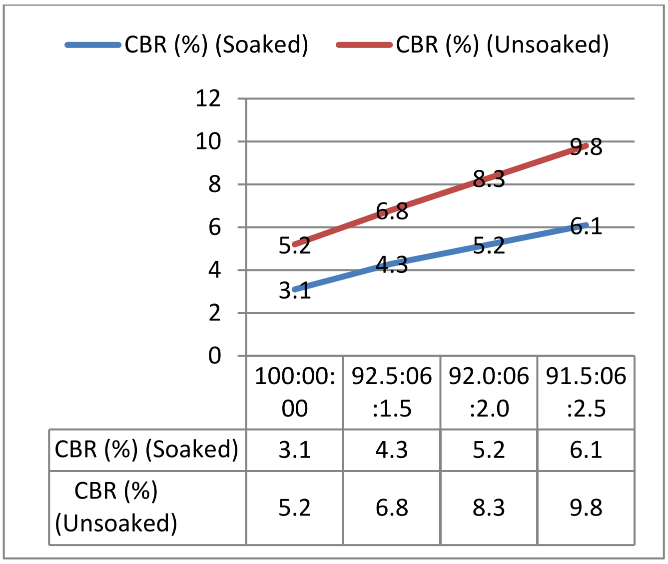
- There is a decrease of MDD from 17.69 to 15.79 kN/m³ and increase of OMC from 15.10 to 16.85% when the percentages of Nano Silica fixed 6% and Nylon Fiber is Vary from 1.5% to 2.5%.
- There is a decrease in MDD of modified soil with increase in percentage of Nano Silica, due to the lower specific gravity of Nano Silica as compared to the unmodified soil and OMC of modified soil is increase as the percentages of Nano Silica increases, due to the increase in cohesive property of soil.

Fig:-4 Variations b/w MDD and OMC values of Nano Silica and Nylon Fiber Mix with Soil



	100:00:00	92.5:06:1.5	92.0:06:2.0	91.5:06:2.5
MDD (kN/m³)	17.69	16.72	16.28	15.79
OMC (%)	15.1	16.27	16.51	16.85

Fig: 5 Variations b/w CBR Values of Nano Silica and Nylon Fiber Mix with Soil



	100:00:00	92.5:06:1.5	92.0:06:2.0	91.5:06:2.5
CBR (%) (Soaked)	3.1	4.3	5.2	6.1
CBR (%) (Unsoaked)	5.2	6.8	8.3	9.8

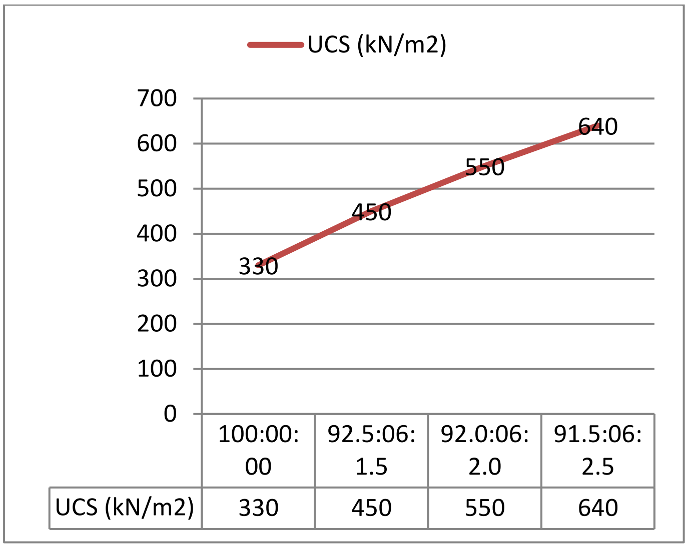
CBR TEST:

- The CBR value of untreated soil is 3.1 and it increases to 1.83 times with addition of 6% Nano Silica when observed in soaked conditions.
- The CBR value of untreated soil is 3.1 and it increase to 1.96 times when Nano Silica 6% and Nylon Fiber 2.5% is added to untreated soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

UCS TEST:

- The UCS values of untreated soil also improve considerably with expansion of Nano Silica 6% and Nylon Fiber 2.5%. The value increases from 330kN/m² to 640kN/m² with addition of Nano Silica and Nylon Fiber.
- The reason behind of this when Nano Silica and Nylon Fiber comes in contact with water, Because Nano-silica wraps the outer surface of the fiber and hence form better bond between the soil particles and the fiber surface which results in improving soil characteristics.

Fig:-6 Variations b/w UCS Values of Nano Silica and Nylon Fiber Mix with Soil



6. CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. Because nano-silica wraps the outer surface of the fiber and hence form better bond between the soil particles and the fiber surface which results in improving soil characteristics.
2. Surface cracks in the form of narrow and Nano-cracks on the compressed soil surface are visibly observed. The minimization of cracks in the soil shows that the Nano silica and Nylon Fiber material acts as bridge between the particles of soil and hence results in increasing soil strength. As a result, the Nylon Fiber material strengthens the spreading soil site and maintains it during load transfer condition.
3. Nylon fiber on the other hand is a cheaply available material which can be added to soil in less quantities to make big changes in its strength parameters.
4. The optimum value of Nano Silica came out to be 6% while performing the CBR test and then it is kept constant in further experiments. So, keeping Nano Silica constant at 6%, Nylon Fiber is then varied and found the optimum content of fiber which came out to be 2.5%.
5. The Unconfined Compressive Strength of soil mixed with 6% Nano Silica and 2.5% Nylon Fiber came out to be maximum which is 1.93 times of virgin soil. So, the optimum mix also has the maximum strength which the soil can after treatment.
6. These materials help in improving the bearing capacity of soil effectively with very low cost and also make the soil suitable for construction works.

References

1. Hussain Jalal Aswad Hassan (2021) "Effects of Plastic Waste Materials on Geotechnical Properties of Clayey Soil". Transportation Infrastructure Geotechnology (2021) 8:390–413.
2. Anuj tomar, Tarun Sharma (2019) "Strength properties and durability of clay soil treated with mixture of nano silica and polypropylene fibre". Elsevier, 25 December 2019.
3. T. Sharma, R. Kaushik, Effect of polypropylene fiber on properties of bagasse ash-cement stabilized clay soil, Inter. J. Emerging Technol. 10 (2) (2019) 255– 266.
4. A. Tomar, T. Sharma, A review study on strength properties of different soils treated with different materials including nanomaterials, Inter. J. Manage. Technol. Eng. 9 (5) (2019) 1769–1774.
5. Ahmed Mancy Mosa, Amer Hasan Taher, Layth A. Al-Jaberi (2017) "improvement of poor subgrade soil using cement kiln dust".

6. M. Boko, T. Sharma, An experimental study on effects of compaction energy on strenght improvement of chemically stabilized soil, Inter. J. Civil Eng. Tech. 8 (7) (2017) 188–193.
7. R. Kaushik, T. Sharma, Influence of waste polypropylene fibers on resilient modulus of clay soil, Inter. J. Res. Adv. Technol. 7 (1) (2019) 251– 255.
8. B.R. Phanikumar, Ravideep Singla (2016) "Swell-consolidation characteristics of fibre reinforced expansive soils".
9. Dr. Siddhartha Rokade, Rakesh Kumar, Dr. P.K. Jain (2017) "Effect of Inclusion of Fly-Ash and Nylon Fiber on Strength Characteristics of Black Cotton Soil". EJGE Vol. 22 [2017].
10. Hesham A. H. Ismaiel (2013) "Cement Kiln Dust Chemical Stabilization of Expansive Soil Exposed at El-Kawther Quarter, Sohag Region, Egypt".
11. M.Heeralal, G.V. Praveen(2011) " A study on effect of fiber on cement kiln dust stabilized soil". JERS/Vol. II/ Issue IV/October-December, 2011/173-177
12. M.K. Rahman, S. Rehman & O.S.B. Al-Amoudi(2011) "Literature review on cement kiln dust usage in soil and waste stabilization and experimental investigation".
13. Kameshwar Rao Tallapragada, Anuj Kumar Sharma, (2009) "laboratory investigation of use of synthetic fibers to minimize swell in expansive subgrades". IGC 2009, Guntur, INDIA
14. Pallavi, Pradeep Tiwari, Dr P D Poorey(2016) "Stabilization of Black Cotton Soil using Fly Ash and Nylon Fibre". IRJET Volume: 03 Issue: 11 | Nov -2016
15. Gyanendra Kumar, Dr. Ran Vijay Singh (2022) "Stabilisation of Soft Soil using Ground Granulated Blast Furnace Slag (GGBS) and Lime". IRJET
16. G. Ramachandran, S. Monisha (2019) "Experimental Study On Soil Stabilization Using Basalt Fiber And Ground Granulated Blast Furnace Slag In Organic Soil" (IJARI).
17. Abhlilash Devanoor and Dr. M. S. Nagakumar (2014) "STUDIES ON SOIL STABILIZATION USING BLAST FURNACE SLAG. (IJAERT), ISSN: 2348–8190 ICRTIET-2014 Conference Proceeding, 30th -31st August 2014.
18. B.R. Phanikumar, RavideepSingla (2016) "Swell-consolidation characteristics of fibre reinforced expansive soils".http://dx.doi.org/10.1016/j.sandf.2016.01.011
19. Dr. Siddhartha Rokade, Rakesh Kumar, Dr. P.K. Jain(2017) "Effect of Inclusion of Fly-Ash and Nylon Fiber on Strength Characteristics of Black Cotton Soil".EJGE Vol. 22 [2017].
20. KameshwarRaoTallapragada, Anuj Kumar Sharma, TarulataMeshram(2009) "laboratory investigation of use of synthetic fibers to minimize swell in expansive subgrades".IGC 2009, Guntur, INDIA.
21. LaxmikantYadu& Dr. R.K. Tripathi(2013) " Effect of Granulated blast furnace slag in the engineering behavior of stabilized soft soil.www.elsevier.com Procedia Engineering 51 (2013) 125 – 131.
22. NoorinaTarannum, R.K. Yadav (2013) "Influence of Blast Furnace Slag on the Consistency Limits of the Black Cotton Soil. Volume 4, Issue 4, April-2013, ISSN 2229-5518.
23. Pallavi, PradeepTiwari, Dr P D Poorey(2016) "Stabilization of Black Cotton Soil using Fly Ash and Nylon Fibre".IRJET Volume: 03 Issue: 11 | Nov -2016.
24. RangaSwamy, Purushotham G Sarvade, Deepak Nayak(2015) "Utilization of GGBS and Lime to Improve the Compaction and Unconfined Strength Properties of Clay. Volume 03 – Issue 04, Special issue for ICETTAS'15.
25. Indian Standard Code IS 2720-16, IS 2720-10.

26. Amin Esmaeil Ramaji., (2012) "A Review on the Soil Stabilization Using Low-Cost Methods" Journal of Applied Sciences Research, 8(4)
27. Arpita V Patel.,(2011) "Study of Geotechnical properties of black cotton soil contaminated by castor oil and stabilization of contaminated soil by sawdust" National Conference on Recent Trends in Engineering & Technology
28. Eric.,(2012) "cementitious materials like cement and flyash for soil stabilization"construction and building materials journal
29. Gerald Miller,A.,U, Shahriar Azadb.,(2000) "Influence of soil type on stabilization with cement kiln dust" construction and building materials journal pp 89-97
30. Jayalekshmi et al.,(2012) "study of polymer based chemical Renolith with lime as soil stabilizer" International Journal of Engineering Research & Technology
31. Lekha, B. M., Goutham,S., Ravi Shankar, A. U.,(2013)., "Laboratory investigation of soil stabilized with nano chemical" Proceedings of Indian Geotechnical Conference
32. Madhavi Vedula., Pawan Nath G.,(2012) "A critical review of innovative rural road construction Techniques and their impacts" NRRDA, New Delhi
33. Indian Standard Code IS 2720-16, IS 2720-10.
34. IS 2720 (Part III) (1980) "Determination of Specific gravity" Bureau of Indian Standards, ManakBhavan, New Delhi .
35. IS 2720 (Part IV) (1975) "Determination of Grain Size" Bureau of Indian Standards, ManakBhavan, New Delhi.
36. IS 2720 (Part V) (1985) "Determination of Liquid and Plastic limit" Bureau of Indian Standards, ManakBhavan, New Delhi.
37. IS 2720 (Part VII) (1980) "Determination of Moisture content and Dry density" Bureau of Indian Standards, ManakBhavan, New Delhi.
38. IS 2720 (Part XVI) (1979) "Determination of California Bearing Ratio "Bureau of Indian Standards, ManakBhavan, New Delhi.