International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 05 | May 2021 www.irjet.net p-ISSN: 2395-0072

AN EXPERIMENTAL STUDY ON THE STABILIZATION OF EXPANSIVE SOILS USING COIR FIBRE, EGGSHELL POWDER AND STEEL FIBRE

K. SRINIVASAN[*1], S. AGNUS VALENTINA SAGAYAM[2], P.JANANANDHINI[3], M.SHAARUMATHY[4]

*[*1]Assistant Professor, Dept. of Civil Engineering, Sri Manakula Vinayagar Engineering College, Puducherry.*
[2, 3, 4]Final year UG Students, Sri Manakula Vinayagar Engineering College, Puducherry.

Abstract - *Expansive soils form problematic sub-grade for pavements due to its low bearing capacity and strength. Wheel loads that are applied on the pavement may cause detrimental settlements and failures when the pavements are laid down above soft soils. This study investigates on the use of materials like eggshell powder (ESP), coir fibre (CF) and steel fibre (SF) for improving the mechanical strength of sub-grade soil beneath the pavement. The influence of these materials on the soil is manipulated and the proportions are determined for stabilizing the sub-grade soil. An extensive laboratory study has been carried out by conducting various tests like unconfined compressive strength test (UCS) and the California bearing ratio test (CBR). The optimum percentage of eggshell was found to be 10% from the preliminary tests conducted. The UCS and CBR tests values were found for a combination of material proportions and their performances were considered based on the effective mixing rates of stabilizers. The peak value of the proportions were found separately for the combinational proportions (i.e. steel fibres + eggshell powder and coir fibres + eggshell powder) at varying percentage of coir fibre and steel fibre. The combinations including these effective mixing rates have been further investigated on the UCS performance and stress–strain behaviour of pavements under fatigue loading. The combinations of 0.5%SF + 10%ESP and 0.5%CF + 10%ESP was found to have high UCS and CBR performances with Ariyur soil. The combinations of 1.0% SF + 10% ESP and 0.5%CF + 10%ESP was found to have high UCS and CBR performances with Madagadipet soil. Use of eggshell powder increased the binding property of soil. Using steel fibres and coir fibres enhanced the mechanical properties of soil such as tensile strength, flexural strength etc. Thus, stabilization of expansive soils using the above mentioned proportions showed that the safe bearing capacity of the soil is increased.*

Key Words: Soil stabilization, Subgrade, Eggshell powder, Steel fibre, Coir fibre.

1. INTRODUCTION

Pavements are subjected to various kinds of environmental and mechanical actions which include earthquakes, differential settlement, fatigue loads created by the traffic etc. The lifespan of a pavement depends on the conditions prevailing on the subgrade among many other factors. Soil lying beneath the pavement layers is the load-receiving material and hence it should be durable and stable to withstand the weight of the pavement layers and also the wear and tear action by the moving traffic. In India, the population count residing is larger in number and the availability of land is less hence these factors form the major defect to execute the construction process. This problematic situation makes engineers carry out construction on weak or soft soils [11]. Lots of problems and issues have been encountered when pavement structures were constructed above expansive soils. India comprises of 20% of expansive soil in the land areas. Hence, improving the properties of the expansive soil by stabilizing agents is one of the most important criteria for constructing durable pavements. To achieve the required strength of pavements different techniques such as physical method, mechanical methods, mixing materials, electrical method grouting etc., are adopted to strengthen the subgrade soil with different stabilizing agents [6]. Reinforcing the expansive soil with different fibre materials is found to be more effective and efficient. Generally, the use of geosynthetic fibres has proved to be more efficient than any other fibres. Geosynthetic fibres have improved the tensile strength, flexural property and also decreased the brittleness of the weak soils [13]. Usage of natural fibres like coconut coir improves the maximum dry density, angle of internal friction and the California bearing ratio (CBR) [17]. Humphrey Danso investigated the properties of three natural fibres like coconut coir, bagasse and oil palm to study their effects when they are reinforced with soil and was found to be ecofriendly and low cost stabilizing agents [10]. Austin T. Sabu showed in his study that combinational mixing of environmental waste like eggshell powder with coir fibre was identifiable to a greater degree of soil stabilization [2]. By stabilizing the soil with locally availing materials promotes the economy and also be non-hazardous to the environment. The usage of environment-related materials for stabilizing the soil would reduce the use of traditional stabilizing ways [2]. Mengshan Lee estimated that recycling and reusing had astounding environmental impacts like marine ecotoxicity, human toxicity, freshwater eutrophication and freshwater ecotoxicity [12]. Eggshell powder is a well-organized naturally calcified shells that contain about 96% of calcium carbonate ($CaCO_3$). Eggshells can be used as a replacement for limestone ($CaCO_3$) or lime (CaO) in various applications. As eggshells are rich in calcium content and have alkaline properties they can be utilized as a partial or total replacement for limestone ($CaCO_3$) or lime (CaO) [7]. Mengshan Lee findings suggested

a future attempt in the egg product industries to focus on developing an efficient process of technologies for directly reusing the eggshells in land applications which would enhance favourable eco-friendly and efficient outcomes [12]. Anoop S P's experimental study showed that eggshell powder was able to replace 25% of lime which is usually used for stabilizing process [5].

2. MATERIALS

2.1 Expansive soils

The samples of expansive soil were collected from Ariyur and Madagadipet. At about a depth of 2.0 m soil samples were obtained. The properties of soil were determined by conducting preliminary tests and main tests for the soil samples.

Fig 1-Ariyur soil

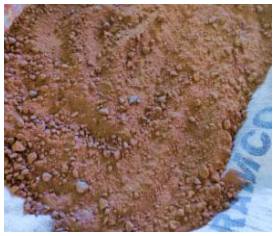

Fig 2-Madagadipet soil

2.2 Coir fibre (CF)

The extraction of this fibre is obtained from the husk of coconut; their dimensions vary which are dependent on the type of species, location and maturity of the coconut tree. These fibres are used because they are cheap, locally available, biodegradable, eco-friendly and have greater tearing strength among all natural fibres. They retain these properties in wet conditions and it takes 20 years to decompose below the ground. Therefore, coconut fibre is selected as a reinforcing material for the expansive soil used in our experimental study.

Table-1: Properties of coir fibre

SNO	PROPERTY	VALUE
1	Diameter	0.5 mm
2	Length	10 mm

2.3 Eggshell powder (ESP)

The Eggshell powder (ESP) used for our experimental study was purchased from an eggshell dealer of IndiaMart. About 2.0 Kg of ESP was bought for using it in different proportions for all the tests that were carried out. Eggshell powder is an alkaline material and it is found to be rich in nitrogen content. ESP mainly consists of limestone ($CaCO_3$) and less percentage of organic compounds; it is found that it acts as a good replacement to lime because they have similar chemical composition.

Table-2: Properties of eggshell powder

SNO	PROPERTY	VALUE
1	Specific gravity	1.04
2	Sieve used	425 micron
3	Free swell index	50

2.4 Steel fibre (SF)

The Steel fibre (SF) is a geosynthetic material used for our experimental study was purchased from a chemical shop in Pondicherry. The quantity bought for our experimental study was about half a kilogram. These steel fibres have a wire hooked end to increase their anchorage capacity with the soil. The addition of steel fibres as a stabilizing agent has proved to improve the CBR values and simultaneously the thickness of pavement layer gets reduced. Steel fibres with aspect ratios in between 40 to 80 are currently in use. The handling of a fibre becomes difficult when the aspect ratio is higher. These fibres are found to be available in various lengths from 20 mm to 40 mm but 30 mm and 35 mm fibres are currently applied most successfully.

Table -3: Properties of steel fibre

SNO	PROPERTY	VALUE
1	Length	30 mm
2	Diameter	0.55 mm
3	Density	7850 kg/m^3
4	Tensile strength	1050 Mpa
5	Elasticity modulus	200 Mpa
6	Specific gravity	7.8

Fig 3-Steel fibres

3. METHODOLOGY

3.1 Experimental procedure

- The soil selected for the experimental study was collected from areas inside Pondicherry such as Ariyur and Madagadipet. The soil was collected from a depth of about 2m. The soil was sundried to remove the Moisture content and the soil lumps were powdered using a rammer.
- Literatures were collected related to our experimental study; detailed study and review was made on soil stabilization techniques adopted, materials used and equipment required for stabilizing the expansive soils.
- The study disclosed various techniques like physical, chemical and mechanical methods were adopted to enhance the basic properties of the weak soils.
- From the study made from various sources, decision was made to use materials like coir fibre (CF), eggshell powder (ESP) and steel fibre (SF) as the stabilizing agents for expansive soils that were collected from different areas.
- The Engineering and Index properties such as specific gravity, free swell index, sieve analysis, liquid limit, plastic limit, plasticity Index, Standard proctor test, Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) were determined as per Indian Standards (IS 2720) for the soils collected from different areas.
- According to IS standards the soil collected are classified as CH because they have high plasticity. Hence it should be modified to improve the engineering properties of collected expansive soil. The specimens are prepared by addition of various ecofriendly materials at various proportions.
- The proportions are designed under the knowledge of literatures and specimens are made by adding various materials collected with the expansive soil. Various tests were conducted to determine the strength and compressibility characteristic of the soil.
- The Combinational proportions of materials were made by the above tests conducted on the soil to improve the strength, stability and compressibility characteristic of soil. The materials are made in the combinational proportions at varying percentage.

Thus, the results of the preliminary experiments to determine index properties of the two soils collected are given in table 4. According to the IS standards the following tests given in table 4 are conducted and the test values are tabulated. These tests results are further discussed and summarized in the following chapter.

3.2 Experimental values

Table-4: Properties of expansive soils

SNO	TEST NAME	TEST VALUES		IS CODES
		Ariyur	Madagadi-pet	
1	Specific gravity	2.72	2.78	IS 2720 - 3(1980)
2	Sieve analysis A) Clay %	75%	65%	IS 2720-4 (1985)
	B) Silt %	25%	35%	
3	Free swell index	40	35	IS 2720-40(1977)
4	Degree of expansiveness	High	High	IS 2720-40(1977)
5	Soil classification	CH	CH	IS 1490 (1970)
6	Liquid limit	52.04%	50.67%	IS 2720-5(1985)
7	Plastic limit	23.37%	22.45%	IS 2720-5(1985)
8	Plasticity index	28.67%	28.22%	IS 2720-5(1985)
9	Compaction properties A) OMC	14%	14%	IS 2720-7(1980)
	B) MDD	17.3kN/ m^3	19.2 kN/m^3	

4. RESULTS AND DISCUSSIONS

4.1 UCS and CBR tests without materials

The Unconfined compression test and California bearing ratio test are conducted for the expansive soils collected. The stress and strain values for each soil are calculated. The optimum moisture content is found to be 14% for both the soils through the preliminary test conducted. This test is conducted according to IS-2720 part 10 (1991). Hence the values of the soil samples are given in table 5.

Fig 4-UCS testing machine

Table-5: Main tests without adding stabilizers

SOIL SAMPLE	UCS VALUES		CBR VALUES (%)
	Stress (kN/m²)	Strain (%)	
Ariyur	14.7	9.21	5.23
Madagadipet	20.8	9.87	4.65

4.2 UCS and CBR tests with materials

The Unconfined compression test (UCS) is conducted for the expansive soils combined with the stabilizing materials at different combinational proportions. The optimum content of eggshell powder is found by conducting UCS test for different percentage like 5%, 10%, 15% and 20% of eggshell powder with the soil. The UCS test values for eggshell powder are tabulated below:

Table-6: UCS test values for eggshell powder

Percentage of Eggshell powder (%)	UCS values (kN/m²) with soil 1 (Ariyur)	UCS values (kN/m²) with soil 2 (Madagadipet)
5	14.56	13.47
10	**17.59**	**16.98**
15	15.12	16.45
20	14.63	15.64

From table 6 it is observed that the UCS values after addition of 10% percent of eggshell powder with soil decreased steadily. Hence the optimum percentage of eggshell powder is taken to be 10% for the experimental study

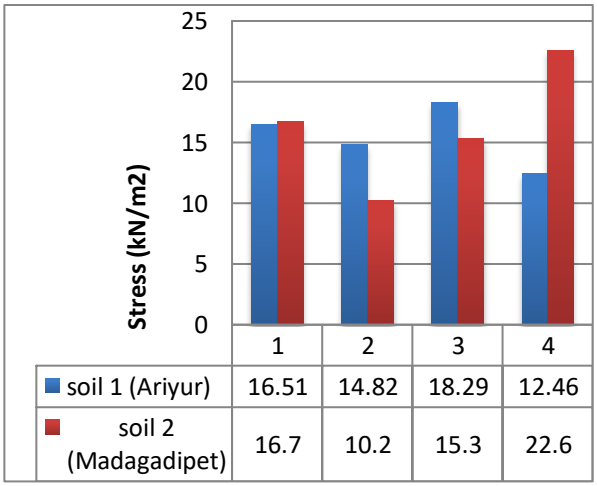

Chart 1: UCS Test values with materials

By trying different combinational proportions like 1) 10% ESP + 0.5% CF, 2) 10% ESP + 1.0% CF, 3) 10% ESP + 0.5% SF, 4) 10% ESP + 1.0% SF the UCS values are determined and the peak values are calculated. The final combination of proportion is adopted to determine the UCS value and CBR value for all the three materials combined together in a proportion. The calculated combination from the peak value obtained from the above combination is tabulated below:

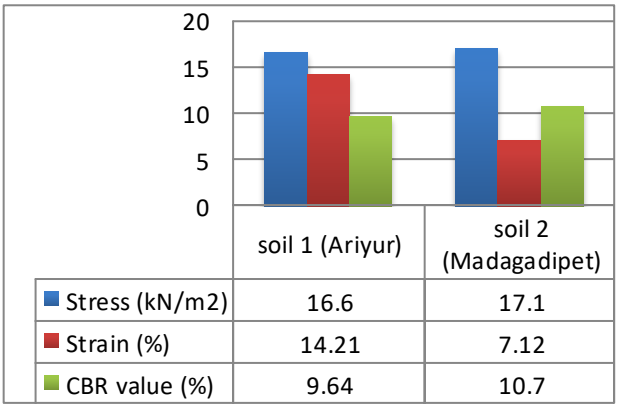

Chart 2: UCS and CBR values for final combination

Discussion

The attempt of different proportions improved the strength of the expansive soil with different percentage of the stabilizing materials. By calculating the UCS values for different proportion of materials the peak values were obtained, 10% ESP + 0.5% CF + 0.5% SF for Ariyur soil sample and 10% ESP + 0.5% CF + 1.0 % SF for Madagadipet soil sample.

Fig 5- Ariyur sample

Fig 6- Madagadipet sample

5. CONCLUSION

The main objective of this present experimental study is to upgrade the index properties and the soil characteristics. The main purpose of making use of these materials is that they have high tendency to improve the properties of soil economically, eco-friendly and efficiently. The outcome of the results shows improved stress-strain property of the soil and thus bringing in quality construction of pavements. This experimental study also focused on the reduction of

pavement thickness by improving the quality of the subgrade soil beneath the pavement.

- Free swell index is calculated for both the soil samples collected. The value is found to be 40 for Ariyur soil and 35 for Madagadipet soil. Hence from the values it is observed that both the soils have high degree of expansiveness.

- Dry sieve analysis is conducted for both the soils. The results from table 4 show that more amounts of soil particles passes through 75 micron sieve hence sedimentation analysis is carried out.

- Atterberg limits are determined according to procedure mentioned in IS standards for both the soil samples. The liquid limit of Ariyur soil was found to be 52.04% and 50.67%for Madagadipet soil. The plastic limit for Ariyur and Madagadipet soil samples are 23.37% and 22.45%. The plasticity index of Ariyur and Madagadipet soil samples are 28.67% and 28.22%.

- Standard proctor compaction test was carried out to determine the optimum moisture content (OMC) and maximum dry density (MDD). The OMC of 14% was obtained for both Ariyur and Madagadipet soil samples. The maximum dry density for Ariyur and Madagadipet soil samples are 17.3% and 19.2%.

- The unconfined compression strength test (UCS) and California bearing ratio test (CBR) tests values are determined for both the soil samples without mixing of materials. The UCS values for Ariyur and Madagadipet soil samples are 14.7 kN/m2and 20.8 kN/m2. The CBR values are 5.23% and 4.65%.

- The optimum mixing content of eggshell powder with soil is calculated by conducting UCS test with different percentage of eggshell powder (i.e. 5%, 10%, 15%, 20%) with soil. From the test results the optimum content of ESP to be combined with both the soil samples is 10%.

- UCS test was conducted for different combinational proportions of ESP, CF and SF. Combinational proportions like 10% ESP + 0.5% CF, 10% ESP + 1.0% CF, 10% ESP + 0.5% SF, 10% ESP + 1.0% SF the UCS values are determined. The peak values of UCS were determined from the stress values.The final proportion for Ariyur and Madagadipet soil samples are 10% ESP + 0.5% CF + 0.5% SF and 10% ESP + 0.5% CF + 1.0 % SF. From the results obtained it is observed that strength is acquired in Ariyur soil sample is comparatively higher than that of Madagadipet soil sample and percentage of materials used are effective and efficient.

- Coconut coir and steel fibres were found to be the best suitable stabilizing materials for improving tensile and flexural properties of the expansive soil. Eggshell powder improves the binding property of the soil. Steel fibres provides an interlocking system by holding the soil stiff and prevents looseness of the soil. Addition of coir fibre decreased the swelling potential of the expansive soil.

ACKNOWLEDGEMENT

We would like to thank our guide **Mr. K. Srinivasan**, Assistant professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry for his constant support, valuable advices, suggestions and tremendous help in carrying out this study successfully. We would also like to extent our thanks to **Dr. S. Sundararaman,** Professor and Head, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry for his continuous support, constant encouragement and incalculable help for conducting this study. We would like to express our sincere thanks to **Dr.S.Jayakumar**, Senior Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry for his constant support and kind supervisions in the completion of our project. We would like to put on record our deep sense of gratitude and indebtedness to **Dr.V.S.K. Venkatachalapathy**, Director cum Principle, Sri Manakula Vinayagar Engineering College, Pondicherry, for all the facilities that he has extended throughout our project.

REFERENCES

[1] Anandhamurugan A, Karuppasamy K, JaganS (2017) "***Study on the Stabilization of Soil Using Coir Fibers***", International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST), Vol-3, 2456-5717.

[2] Austin T. Sabu(2017)"***Experimental Study On The Stabilization Of Soil With Environmental Waste And Coir Fibres***", International Journal of Civil Engineering and Technology (IJCIET), Vol-8, 0976-6308, 0976-6316, pg.679-688.

[3] Ahmed HilalFarhan, Andrew Robert Dawson, Nicholas Howard Thom (2018), "***Damage propagation rate and mechanical properties of recycled steel fiber-reinforced and cement-bound granular materials used in pavement structure***", Construction and Building Materials, Volume 172, Pages 112-124.

[4] AbdulazizAlsaifa, Reyes Garciaa, Fabio P. Figueiredo, KyriacosNeocleous, Andreas Christofe, Maurizio Guadagnini, KyprosPilakoutas (2019), "***Fatigue performance of flexible steel fibre reinforced rubberised concrete pavements***", Engineering structures, Vol-193, pg.170-183.

[5] Anoop S P, Hizana Beegom, Jwoleena P Johnson , Midhula J, Tharis Muhammed T N, Prasanth S (2017), "***Potential of Egg shell powder as replacement of Lime in soil stabilization***", International Journal of Advanced

Engineering Research and Science, Vol-4, Issue-8, page:86-88.

[6] Chaitanya D.V.S.K, Neeharika. P (2019)"***Soil Stabilization using Geosynthetic Material (Steel Fibres)*** ",International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol-8, 2278-3075.

[7] Diana Johns, Naveena Joseph, S Naveen Prasath (2017), "***Improvement of Subgrade Clayey Soil using Eggshell***", International Journal for Research in Applied Science & Engineering Technology, Vol 5 Issue III.

[8] GeethuSaji, Nimisha Mathew (2016) "***Improvement Of Clayey Soil By Using Egg Shell Powder And Quarry Dust***", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 2278-1684, 2320-334X, pg. 46-54.

[9] HamzaGüllü, Ali Khudir (2014),"***Effect of freeze–thaw cycles on unconfined compressive strength of fine-grained soil treated with jute fiber, steel fiber and lime***", Cold Regions Science and Technology, 106-107, pg.55-65.

[10] Humphrey Danso (2017),"***Properties of Coconut, Oil Palm and Bagasse Fibres: As Potential Building Materials*** ", Procedia Engineering, Vol-200, pg.1–9.

[11] Humphrey Danso, Dorothy Manu (2019),"***Influence of coconut fibres and lime on the properties of soil-cement mortar*** ", Case Studies in Construction Materials, Vol-12.

[12] Leema Peter, Jayasree P K, Balan K, Alaka Raj S (2016) "***Laboratory Investigation In The Improvement Of Subgrade Characteristics Of Expansive Soil Stabilised With Coir Waste***",Transportation Research Procedia, Vol-17, pg.558 – 566.

[13] Mengshan Lee, Wen-Shuo Tsai, Shyi-Tien Chen (2020),"***Reusing shell waste as a soil conditioner alternative? A comparative study of eggshell and oyster shell using a life cycle assessment approach*** ", Journal of Cleaner Production, 265.

[14] Paulo J. Venda Oliveira, António A.S. Correia, João M.N.P.C. Teles, António M.G. Pedro (2017), "***Effect of cyclic loading on the behaviour of a chemically stabilised soft soil reinforced with steel fibres***", Soil Dynamics and Earthquake Engineering, vol-92, pg.122-125.

[15] Piti Sukonta sukkul., UdomvitChaisakulkiet, PitthayaJamsawang, SuksunHorpibulsuk, Chai Jaturapitakkul, PrinyaChindaprasirt (2019) "***Case investigation on application of steel fibers in roller compacted concrete pavement in Thailand***", Case Studies in Construction Materials, Vol – 11.

[16] PoojaUpadhyay, Yatendra Singh **(**2017)" ***Soil Stabilization Using Natural Fiber Coir*** ",International Research Journal of Engineering and Technology (IRJET), Vol-4, 2395-0056 , 2395-0072.

[17] Rama Susheel Kumar V , Vikranth J (2014) "***Application of Coconut Coir and Fly ash in Sub grade strengthening*** ",The International Journal Of Engineering And Science, Vol- 3, 2319 – 1813, 2319 – 1805, pg.48-54.

[18] J.M. Rasul, M.P.N. Burrow, G.S. Ghataora (2016), "***Consideration of the deterioration of stabilised subgrade soils in analytical road pavement design, Transportation Geotechnics***", doi: https://doi.org/10.1016/j.trgeo.2016.08.002

[19] G.V. Praveen, PanduKurre, T. Chandrabai (2020), "***Improvement of California Bearing Ratio (CBR) value of Steel Fiber reinforced Cement modified Marginal Soil for pavement subgrade admixed with Fly Ash***", Materials Today: Proceedings,Vol 39,Pages 639-642.

[20] Oluwatuyi OE, Adeola BO, Alhassan EA, Nnochiri ES, Modupe AE, Elemile OO, Obayanju T, Akerele G, "***Ameliorating Effect of Milled Eggshell on Cement Stabilized Lateritic Soil for Highway Construction***", Case Studies in Construction Materials (2018), doi: https://doi.org/10.1016/j.cscm.2018.e00191

[21] IS 1498 : 1970 – Classification and identification of soils for general engineering purposes (First revision).

[22] IS 2720 (Part 5) : 1985 – Determination of liquid and plastic limit (Second revision).

[23] IS 2720 (Part 7) : 1980 – Determination of water content – dry density relation using light compaction (Second revision).

[24] IS 2720 (Part 10) : 1991 - Determination of Unconfined Compressive Strength (second revision).

[25] IS 2720 (Part 16) : 1987 - Laboratory determination of CBR (Second revision).