Stabilization Of Black Cotton Soil for Road Construction Using E-Waste – Review Paper

[1]**Nikhil T R**, [2]**Sachin Mattihal**, [3]**Sharanabasava Gadad,** [4]**Shilpa Harish,** [5]**Aishwarya S Wali**

[1] Assistant Professor, [2,3,4,5] Student
[1] Department of Civil Engineering,
[1] M S Ramaiah university of applied sciences, Banglore-560058, India

Abstract: Soil can be considered as very first element of construction industry as no construction work can be done without it. Soil plays an important role in construction industry such as in foundation works, pavement subgrade etc. Soil used in construction industry is first treated and convert into a technically sound which fulfill the ācriteria of good foundation soil. Black cotton soil that's one of the most important soil deposits in India becomes especially problematic due to its property of higher degree of swelling and shrinkage. These soils are used in subgrade of pavement and also in construction of structures. Soil stabilization is a technique that involves mixing an external chemical or compacting the soil to enhanceā its qualities such as strength, stress parameters, and Atterberg's limit. Hence the requirement of engineering soil can be achieved by such processes. In recent years, soil stabilization by the use of numerous minerals like quarry dust, saw dirt, copper dust and fly ash were most generally used. In this study, soil stabilization of natural soil collected from local site is done by using E-waste. For soil stabilizing, the percentages of E-waste chosen in a definite aspect ratio. Liquid limit test, Proctor compaction test, CBR tests are performed on the soil alone and when mixed with E-waste. The liquid limit of soil decreases and CBR value increases in these experimental investigations. To recognize the performance of stabilized soil, its residences like Atterberg limits, compaction characteristics, swelling, shear strength, CBR value and other Index & Engineering properties have been discussed.

Index Terms: Strength, E-waste, Black cotton soil, Soil stabilization, Swell-Shrinkage properties, CBR value, direct Shear Test, Unconfined compressive strength.

1. INTRODUCTION

Stabilization of soil is mainly a process of altering the soil properties to meet its engineering properties in order to make stable. The Black cotton soil which is not suitable for the constructions make it to suitable for constructions like Road, infrastructure, buildings etc. It is not suitable for construction because of it Expansive when it come contact with water, and it shrink when it is dry. This property of the soil makes distribution of load from the structure to substrata unstable. Therefore, structure constructed on black cotton soil fails early.

Black cotton soil is made of varying properties of minerals like Montmorillonite and kaolinite, chemicals like iron oxide and calcium carbonate and organic matters like humus.

The presence of Montmorillonite, which is created by the alteration of basic igneous rock including silicates rich in Ca and Mg, results in a high swelling/shrinking potential due to weak cation linkage (e.g., Na+, ca++). A gibbsite sheet is sandwiched between two silica sheets in montmorillonite, which is a three-layer sheet. The van der Waals force bonding that holds the repeating layers together is exceedingly weak, allowing water to penetrate freely. Minerals absorb a great amount of water, producing swelling, and shrinking in dry conditions.

Black cotton dirt has collected on around 20% of the land. The black cotton soil encompasses the plateaus of Karnataka, Maharashtra, Saurashtra, Malwa, Madhya Pradesh, and Chhattisgarh, and extends roughly 300,000km2 in India along the Godavari and Krishna basins.

E-waste (electronic trash) is defined as electronic equipment such as mobile phones, laptops and home appliances that have failed or are no longer fit for their original use. Everyday technological innovation has resulted in an ever –increasing glut of electronic garbage throughout the world. as of now the developing countries like India is generating the more waste which is used in day-to-day life. So, it is important to look over that and think it can be reusable. Around 50 million tonnes of E-waste are generally accumulated globally in India per year. Developing nations such as India are being utilized to dump massive amount of e-waste without sifting or destroying it.

The waste PCBs (Printed circuit board) consist of 28-30% metal, of which 10%-20% is Copper, 1%-5% lead, 1%-3% nickel, and 0.3%-0.4% metals such as silver, platinum and gold. The presence of metals is more in E-waste (PCBs). When the E-waste is crushed and converted into powder form. And powder form E-waste can be added in the different dosage to the soil. when black cotton soil is mix with E-waste it alters the property of black cotton soil. PCBs contain metals in very wide range of concentration makes to reduce absorption of water and shrinkage in dry of black cotton soil.

Proverbs says that "kill two birds with one stone "stabilization of black cotton soil using E-waste. It solves to major problems. One is to make black cotton stable and one more is dump massive amount of E-waste.

2. Literature Review

Prof. P. Suresh Praveen Kumar et.al(1) has conducted research on black cotton soil containing copper dross and fly-ash in various proportions. The liquid limit, plastic limit, malleability index, free swell, compaction check, and cosmic microwave background (unsoaked) of the soil were all determined. The addition of copper dross 30 percent and 10 percent (percent by weight of soil) inside the soil enhanced the dry density, cosmic microwave background values, and decreased swelling, according to the results.

Prof. Shazan Khan[2] reviews in the paper about soil stabilization by using E-waste. Materials used here is percentage of e-wires chosen is 5% and 7% in definite aspect ratio. E-wires the waste electric wires, which are used for electrification in building & other structures. Soil it is collected from locally site available. Methodology for the test is the soil which is collected from the nearby location have to air-dry after collecting. After this screening of soil has to be done. After this soil has to be kept ready. The collected e-wires are cut into specific ratio(L/D=2) and then mixed into soil for further testing. Test like Atterberg's limit, specific gravity, compaction test, unconfined compression test, California bearing test & direct shear test. The ratio taken for mixing is 5%and 7% by weight of soil.

Prof. R. Udhayasakthi[3] investigated the properties of clay soil using copper slag stabilization, and in this study, he examined the CBR and liquid limit, dry density, and OMC connection. He observed that 30% substitution of copper slag resulted in greater CBR values, as well as almost as excellent conformance for the flexible pavement with synchronous reduction in sub base course thickness. He eventually concluded that combining 30 percent copper scoria with 70 percent Black Cotton soil was the proper stabilization magnitude relationship for doubling all subgrade requirements.

Prof. A. Harmin Nisha et.al[4] has focused in the paper about soil stabilization is the process of changing the qualities of an existing soil to suit engineering specifications, strength, volume stability, durability and permeability are the primary attributes that may need to be adjusted by stabilization. The main goal of the foundation is to improve soil stability while lowering construction cost. In this paper E-waste is reused as soil stabilizer. Several concentrations of E-waste were including 1%, 2% and 3% are used to soil stabilizer. specific gravity, sieve analysis, liquid, plastic, and shrinkage limit, Standard proctor test, Atterberg limit, field density, CBR test. Soil stabilization is the process of improving the load bearing capacity of the subgrade to sustain pavements and foundations by enhancing the shear strength of the soil and managing its shrink-swell properties. The goal is to improve soil strength while lowering building costs.

Prof. K. Sameer V.T. et.al[5] had investigated soil stabilization using tile waste, and experiments were carried out on UCC, CBR liquid limit, plastic limit, compaction test, and shrinkage limit in this work. She concluded that adding tile waste reduced the price of liquid limit, plastic limit, and OMC while increasing the price of shrinkage limit, MDD, UCS, and CBR by up to 30%.

Prof. Vikas D. Patel et.al[6] Copper slag extraction was used to explore the evolution of soil characteristics in Expansive soil. Grain size analysis, liquid limit, plastic limit physical property index, compaction look at direct shear look at, and CMB were all determined as soil attributes. He concluded that a combination of 40% copper scoria and 60% black cotton soil was optimal, as evidenced by the growth in relative density and CMR prices. He eventually concluded that such soil would be useful in road hill sub base and sub grade.

Prof. Jinka chandrashekar et.al[7] had looked at the use of waste "copper slag" in geotechnical applications. The relative density, grain size distribution, free swell index, compaction problem, and CMI of the soil sample were all determined. The findings for 60 percent copper scoria and 40 percent black cotton were discovered, and it was concluded that the subgrade, subbase, and engineering behaviour of soil were enhanced, as well as hill building and land reclamation of soil conditions.

Prof. Aniket Ravindra Ingole, et.al[8] This paper presents the result of associate in nursing experimental program undertaken to analysis the impact of E-waste with lime at completely different dosages on black cotton soil. Behavior of soil was observed through adding different dosages of combination of E-waste & lime. The performance of E-waste & lime stable soil was evaluated victimization physical & strength performance tests namely, Atterberg's limit, relative density, compaction check, unconfined compressive check, CBR, & direct shear test. E-waste and lime treated soil will improve the soil's strength, sturdiness, and workability. The soil compressibility is improved by this treatment. E-waste successfully manages the disposal technique—improvement in soil qualities may be noticed, resulting in soil stability.

Prof Jayapal[9] During this article, admixtures such as quarry dirt, ash, and lime were studied in regards to the comparison of various admixtures exploitation poor soil stability. Liquid limit, plastic limit, altered proctor compaction, sieve analysis, differential free swell, and CMB tests were all carried out. He concluded that adding quarry soil, time, and ash had not stopped the nature from expanding. He also concluded that there was a rise in the CMB price due to the partial replacement of 20% quarry soil, which lowered the building's pavement thickness.

Prof. Dr. Pradeep Purohit[10] Soil stabilization is achieved in this study using a combination of coir fibers and E-wires in varied amounts. Engineering parameters of stabilized soil such as optimal moisture content, maximum dry density, and CBR values were found. The ideal percentage of soil when mixed with coir fibre is merely 2%, with further stabilizing provided by blending E wires in various proportions. Soil is the fundamental basis for every civil engineering construction that must withstand loads without failing. Coconut (Coir fibers), Sisal fibers, Palm fibers, Jute, and Bamboo are some of the natural fibers utilized in soil reinforcement. Polypropylene (PP) and Polyethylene (PE) fibers are examples of synthetic fibers (PE).

Prof. Saint George Rowland Otoko[11] had looked at the use of soy soil ash to stabilize Nigerian Deltaic Laterites. Liquid limit, shrinkage limit, free swell index, physical property index, MDD with OMC, UCC, and CMB tests were used to determine the soil characteristics. He eventually concluded that adding 4 percent saw soil ash to Nigerian deltaic laterites enhanced physical qualities and engineering features, as well as increasing CMB and UCC values by 14 percent. He also concluded that the use of solid waste reduced the cost of building.

Prof. Satyendra Bhaskar[12] in this paper they have used randomly distributed plastic fibers from waste to stabilize the soil. Improvements in shear strength parameters were emphasized and comparative studies were conducted using various methods of shear strength measurement. The increased use of plastics by everyday consumers has resulted in municipal waste. It is used only for a short time and the percentage of plastic materials that are subsequently discarded continues to grow. It's possible that the idea of strengthening a mass of dirt with a strip of plastic cover is new. The use of random materials to fortify the earth, on the other hand, is probably not as old as recorded history, although it is only poorly documented.

Prof. Dinesh. S[13] This research describes the stabilization of black cotton soil using PET (Polyethylene Terephthalate) bottles, which are efficiently employed to meet societal issues, minimize the amounts of plastic waste, and enhance the physical qualities of the soil. Controlled compaction improves soil properties such as shear strength and bearing capacity. PET (Polyethylene Terephthalate) bottles with a size of less than 0.5 mm are used in various proportions (3 percent, 5 percent, and 7 percent). The index Qualities test, Standard Proctor, Unconfined Compressive, Moisture Content, and California Bearing Ratio are next performed to determine the soil properties that will enhance the soil's bearing capacity.

Prof. Tusshar Baraskar[14] has investigated the relationship between CA carrying magnitude and Black cotton soil. He replaced a portion of the soil with discarded copper slag in various amounts and conducted multiple studies, including grain sieve analysis, compaction characteristics, and CMB. He concluded that the highest CMB price is attained in black cotton soil with a 28 percent copper scoria replacement. He also concluded that such soils would be suitable for use as the sub-base layer of road pavement.

Prof. Karthik[15] has conducted research on soil stability by the partial replacement of red soil with Fly Ash. CBR, relative density, MDD with OMC, UCC, liquid limit, and plastic limit were among the experiments he performed. He eventually concluded that a 9 percent partial replacement of ash in the soil results in enhanced characteristics, and that such soils also demonstrated smart bearing capabilities.

Prof. Austin T. Sabu[16] experimental investigation on soil stabilization utilizing environmental waste and coir fiber is the subject of this research article. Eggshell powder was the environmental waste that was considered. Calcium Oxide is the main component of eggshell powder. Atterberg's limits, compaction parameters, California bearing ratio, and unconfined compressive strength were all determined for virgin soil. The ideal proportion of eggshell powder for the soil was established after treating the soil sample with various percentages of eggshell powder. The soil was then treated with the right amount of eggshell powder and different amounts of coir fibers. With the addition of eggshell powder and coir fiber, the soil's strength increased significantly. Use of locally accessible resources such as eggshell powder and coir fibres to enhance the environment.

Prof. Brajesh Mishra[17] had looked at the engineering behavior of black cotton soil and the usage of time to stabilize it. Atterberg limit and CBR value were among the characteristics tested. Compression problem and free swell index He eventually concluded that a 5 percent partial lime replenishment of the soil is the best way to stabilize the black cotton soil. He concluded that a 5% partial replacement of fly ash resulted in a lower liquid limit (15.27%) and swelling, as well as doubling the CMB readings.

Prof. Surya Muthukumar[18] investigated the results of an experimental study on flexible pavement with partial replacements of coarse aggregate with E-waste and bitumen with recycled HIPS (High impact polystyrene). They used recycled polystyrene in molten form as a partial replacement for bitumen. Because of the presence of numerous substances such as lead and bromine, e-waste is harmful. E-waste in the form of PC boards is crushed to a nominal size of 20 mm and utilized to replace coarse aggregates. The coarse aggregate and bitumen are used to replace varying amounts of E-waste and HIPS. Initially, the ideal bitumen proportion is established based on aggregate parameters. The number of aggregates is specified using the bitumen ratio, a control mix is cast, and then the replacements with HIPS and E-waste are produced. The stability test is performed on all samples to assess their stability, including Atterberg's limits, compaction properties, California bearing ratio, and unconfined compressive strength, with the results analyzed.

Prof. Bandna Kumari[19] here the author tells us about Chir pine needles are a flexible material with appealing properties and benefits. In steep locations, there is an abundance of Chir pine needles. Predominance is observed in the Indian states of Himachal Pradesh, Uttarakhand, and Jammu and Kashmir in the northwestern Himalayan area. Chir Pine Needles offer a variety of engineering features that can aid in the improvement of soil parameters, including as compaction attributes, unconfined compressive strength, and California bearing ratio. All of these qualities will be assessed based on the percentages and lengths of the pine needles.

Prof. K. Sirajudin[20] investigated about nature, soil deposits and occurs in an irregular fashion, resulting in an endless number of potential combinations that impact the strength of the soil. For many years, researchers have attempted to enhance the mechanical characteristics of soil to meet the needs of engineering constructions. Because new approaches are either accessible or continually being developed. Sites that were formerly deemed inappropriate are now being repurposed for the development of new and difficult structures. Buildings built in cohesive soils may be prone to structural settlement. It is critical to enhance the shear strength, bearing capacity, and soil behavior in order for the structure to endure the load.

Prof. Chaugule[21] provides the findings of an experiment aimed at determining the influence of trash at various doses on black cotton soil. Different amounts of E-waste Le were introduced to the soil, including 2%, 3%, and 8%. Physical and strength) performance tests were used to assess the performance of E-waste stabilized soil. Rose as the percentage of E-waste increased. Because bearing capacity is influenced by sand, an increase in soil bearing capacity has been reported.

Prof. Y. Ramakrishna Reddy[22] Their work on soil stabilization utilizing waste fiber material was presented. The goal of their research is to look at the usage of waste fiber materials in geotechnical applications and to assess the impact of waste polypropylene fibres on unsaturated soil shear strength using direct shear tests and unconfined compression tests on two distinct soil samples. Fibers are useful and can be employed in deep foundation operations, according to their findings.

Prof. Gupta[23] had studied performance of E-waste stabilized soil and were evaluated using various physical and strength performance tests on different dosages of E-waste i.e., 3, 6, 9, and 12 were used to stabilize. Based on strength performance tests, it was observed that replacement of E-waste increases the strength of expansive soils.

Prof. Hu Yuan Zhang[24] gives a study on the use of lime and four different types of fiber to improve the mechanical qualities of soil. The ideal fiber length and content were determined using wheat straw, rice straw, jute, and polypropylene fiber. The shear strength, deviatoric stress-strain characteristics, and sample failure pattern of fiber-lime-soil were investigated using a triaxial compressive test. The results reveal that strengthening enhanced cohesiveness and improved the internal friction angle just little. Polypropylene fiber-lime-soil, jute-lime-soil, rice straw-lite-soil, and wheat-lime-soil cohesion increments were all reduced. They determined that all four types of fibre improve soil and lime soil strength and stress-strain qualities, with polypropylene fibre for reinforcement being the most effective.

Prof. Liet Chi Dang[25] The behavior of expanding soils stabilized by hydrated Time and bagasse fibres was investigated. The results of a series of laboratory tests undertaken to assess the effects of bagasse fibres and hydrated lime addition on the engineering characteristics and shrink-swell behavior of stabilized expansive soils are presented in this report. Various proportions of randomly distributed bagasse fibres of 0.5 percent, 1.0 percent, and 2.0 percent were added to expansive soil and hydrated lime-expansive soils mixed with different bagasse fiber proportions were also investigated to investigate the influences of bagasse fibres on the engineering behavior of expansive soil. Based on the reasonable laboratory test findings, it can be concluded that a combination of hydrated lime and bagasse fibres may successfully stabilize expansive soils while also improving strength metrics.

3. MAJOR FINDINGS FROM LITERATURE REVIEW:

a) The paper is focused about soil stabilization, is the process of changing the qualities of an existing soil to suit engineering specification, strength, volume stability, durability and permeability are the primary attributes that may need to be adjusted by stabilization.
b) The main goal of foundation is to improve soil stability while lowering construction cost.
c) From the review paper E-waste is reused as soil stabilizer.
d) several concentrations of E-waste were including 1% 2% and 3% are used to stabilizer.
e) specific gravity, sieve analysis, liquid, plastic and shrinkage limit, standard proctor test, maximum Dry density (MDD), unconfined compression test (UCS), direct shear test, CBR test this many tests are done.
f) The investigation of black cotton soil with various percentages of e-waste (PCBs). The liquid limit, malleability index, free swell, compaction check, and cosmic microwave background (unsoaked) of the soil were all determined.

4. CONCLUSION:

1. It increases the Strength of the soil, thus, increasing the soil bearing capacity.
2. It is economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for replacing the expansive soil.
3. It helps in reducing the soil volume change due to change in temperature or moisture content.
4. Stabilization improves the workability and durability of the soil.
5. The dry density, cosmic microwave background readings, and swelling were all improved, according to the findings.
6. With the addition of E-waste, the soil's liquid capacity is significantly reduced.
7. For a particular proportion mix of E-waste, the strength measured by the CBR test is raised.
8. With the addition of E-waste, the optimal moisture content (OMC) drops.
9. With the addition of E-waste, the maximum dry density (MDD) rises.
10. With the addition of E-waste, the strength measured by unconfined compression test rises.
11. With the addition of E-waste Strength, cohesion and angle of internal friction, which are assessed by direct shear tests, also improve.
12. The findings indicate that E-waste has a significant influence on soil.

REFERENCES

1. P. Rajendra Kumar, P. Suresh Praveen Kumar, G. Maheshwari, "Laboratory Study of Black Cotton Soil Blended with Copper Slag and Fly Ash". International Journal of Innovative Research in Science, issue No.2. February 2017.
2. Prof. Shazan Khan Department -of-civil-engineering Lucknow, India. Soil stabilization by using E-waste. International journal of technical research and application e-ISSN: 2320-8163 www.ijtra .com volume 7, issue 6 (November-December, 2019), pp.01-06
3. Prof. Ravi, R. Udhayasakthi, T. Senthil Vadivel, "Enhancing the Clay Soil Characteristics using Copper slag Stabilization Journal of Advances in Chemistry, Vol.12. Issue No. 26, December 2016.
4. A. Harmin Nisha, M. Mahavidhya, R. Nithyarajasri, C. Pragati, K.Dharani, and "SOIL STABILIZATION BY USING E-WASTE" ISSN: 2456-172X | Vol. 4, No. 1, Mar. - May, 2019 Pages 40-45 | Cosmos Impact Factor (Germany): 5.195 Received: 06.03.2019 Published: 29.03.2019
5. K.P. Summaya, Mohammed Refeequedheen. K. Sameer V.T. Firoz. Khais P.T. Jithin. K. "Stabilization of expansive soil Treated with Tile Waste", International Journal of Civil Engineering, Vol. 3, Issue No. 03, March 2016.
6. Mohammed A. Qureshi, Hevin M. Mistry, Vikas D. Patel, "Improvement in Soil Properties of Expansive Soil by Using Copper Stag", International journal of Advance Research in Engineering in Science and Technology, Vol 2, Issue No.07, July 2015.
7. Jinka chandrashekar, Timir A Chokshi, "A Review on Utilization of Waste Material Copper Slag in Geotechnical Applications, International Journal for Innovative Research in Science and Technology, Vol. I, Issue No. 12. May 2015.
8. Prof. Aniket Ravindra Ingole, Rasheed Ullah Khan, Sharuq Ullah Khan, Suraj Hemant Oza, Umer Raza Hafizulla Khan Rizvee, Chetan Anilrao Yerawar "Stabilization of soil by E-waste with Lime" International journal of engineering research and technology, Vol. 5, Issue No. 2 July 2016.
9. Jayapal, S. Boohathiraja. M.Samuel Thamara, K. Priyadarshini, "Weak soil stabilization using different admixtures A comparative study", International Journal of engineering research and technology, Vol 3, Issue No.10, October 2014.
10. Prof. Chandan Singh Athiya, Dr. Pradeep Purohit "Soil Stabilization using E-waste and Coir fibers "international journal of research, Vol. 9, Issue No. 34, October 2012
11. George I Rowland otoko, Braide K Honest. "Stabilization of Nigerian deltaic laterites with saw dust ash", International Journal of scientific research and management, Vol 2, Issue No.8 7 August 2014.
12. Prof. Prince Kumar, Raj Kamal, Satyendra Bhaskar, Rahul Gupta, Mukesh Maurya "Soil Stabilization using plastic fibers" International Journal of Science and Research, Vol. 3. Issue 12, July 2013

13. Prof. Kirubakaran. K, Dinesh S, Ranjith Kumar G, "Soil Stabilization using PET (polyethylene terephthalate) Bottles" International journal of advanced technology and innovative research, Vol. 8,Issue 14
14. Tusshar baraskar, S.K. Ahirwar, "Study on California bearing ratio of black cotton soil use waste copper slag, International Journal of structural and civil engineering research". Vol.3, Issue no.4. November 2014.
15. Karthik S. Ashok Kumar. F. Gowtham. P. Flango, G, Gokul. D. Thangaraj. S. "Soil Stabilization by Using Fly Ash", 10SR Journal of Mechanical and Civil Engineering, Vol. 10, Issue No:6, Jan 2014. PP 20-24.
16. Prof. Austin T Sabu, Mary Rebekah Sharmila" Soil Stabilization using Egg Shell and Coir fibers" International journal of civil engineering Vol. 5, Issue 8, march 2019
17. Brajesh Mishra, Ravi Shanker Mishra, "A Study on Stabilization of Black Cotton Soil Use of Fly Ash, ferric Chloride and Stone Dust, International Journal of Engineering and Science, Vol.5. Issue No. 10, PP-20-25, October 2015.
18. Prof. Bavithran O K C, Surya Muthukumar, Nandhagopal A R, Snehasree "Soil Stabilization using E-waste and Bitumen" international journal of research Vol. 4, Issue 9, June 2014.
19. Prof. Bandna Kumari, Vinod K Sonthwal, Jasvir S Rattan "Soil Stabilization using Chir Pine niddles" International journal of engineering research Vol. 4, Issue 8, October 2018
20. Prof. S Abdul Gafoor, K. Sirajudeen, R. Nasar Ali, Sabeena Begum, D. Zunaithur Rahman" Soil Stabilization using E-waste" journal of research and technology, Vol. 6, Issue No.8, August 2017
21. Chaugule. M, Deore. S, Gawade. K, Tijare. A, Banne. S, 2017.Improvement of black cotton soil properties using E-waste. IOSR journal of mechanical and Civil Engineering, Vol.14, Issue 3 ,Ver.1.PP 76-81 .
22. Y. Ramakrishna Reddy, T. Ram. Prasanna Reddy 2016. Stabilization of soil by using waste fiber materials. International journal of advanced technology and innovative research Vol. 8, Issue 15. PP 2963-2966
23. Gupta, Rahul, Raghuwanshi, A.K 2016. Utilization of E-waste in Strength enhancement of Black cotton soil. Journal of environmental sciences and Engineering, Mantech Publication, Vol.1, Issue 3, PP 9-19
24. Shou Xi, Li Wei, Zhang. H.Y, Shi. Q 2018.Mechanical properties of soil reinforced with both lime and four kinds of fiber. Construction and Building Materials journal, Elsevier publications, PP 300-308.
25. Dang. L. C, Fatehi. B, Khabbaz.H 2016. Behavior of expansive soils stabilized with hydrated lime and bagasse fibres. Procedia Engineering Journal. Elsevier publication, Vol.143, PP 658-665.