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IMPROVEMENT OF CLAY SOIL USING NATURAL FIBERS AND NANO SILICA : A REVIEW

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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. This review paper presents an investigation of behavior of clayey soil stabilized with varying percentages (0.5-10%) of coir fiber and Nano silica, by carrying out the index and engineering properties of soils. Coir is a natural biodegradable material abundantly available in some parts of south and coastal regions of India. Nano silica is small filler size materials increase ductility with no decrease of strength. The induced of the nano silica acted as a hydraulic binder with lesser swelling potential. The combination of coir fiber and Nano silica are used in expansive soils for sustainable development purpose.

Keywords *:* Expansive soil, coir fiber, Nano silica.

I. Introduction

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 2,00,000 square miles and thus form about 20% of the total area of India. Soil movement is usually in an uneven pattern and such a magnitude to cause extensive damage to the structures resting on them. Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are indentified in a project. The remedial measures can be different for planning and designing stages and post construction stages. Many stabilization techniques are in practice for improving the expansive soils in which the characteristics of the soils are altered or the problematic soils are removed and replaced which can be used alone or in conjunction with specific design alternatives.

II. Literature Review

Expansive soils swell when absorb water and shrink when water evaporates from them (chen-19888; Nelson and miller-1992). Due to alternate swell-shrink behavior of expansive soils causes distress in the structures foundation in them such as buildings pavements earth retaining walls. Different foundation techniques have been suggested for mitigating heavy of expansive soils. Some of them are sand cushion, granular pile-anchors (phanikumar, 1997; phanikumar et al, 2004). belled piers(chen1988), cohesive non-swelling soil(CNS)(Katti et al.2002) are some of the innovative foundation techniques adopted for expansive soils. The chemical stabilization of expansive soils using lime and fly ash has been found quite effective in controlling the volumetric changes in expansive soils (chen, 1988; Sharma and phanikumar, 2004; cokca (2001).Fly ash column recently developed foundation technique (phanikumar et al. 2009). Viswanadham (1989) and Ayyar et al. (1989) have reported about the efficacy of randomly distributed coir fibers in reducing the swelling tendency of the soil.

Clays are generally regarded as problematic soils due to their adverse consolidation settlement and volumetric change characteristics. During last few decades damage due to swelling action has been observed clearly in the region in the form of cracking and breakup of pavements, roadways, water lines, sewer lines, irrigation system. All these previous studies have shown that the addition of fiber reinforced caused significant improvement in the strength and decreased the stiffness of the soil.

A. Natural fibers

At the present time, there is a greater awareness that landfills are filling up, resources are being used up, the planet is being polluted and that non-renewable resources will not last forever. So, there is a need to more environmentally friendly materials. That is why there have been many experimental investigations and a great deal of interest has been created world wide on potential applications of natural fibers for soil reinforcement in

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recent years. The term ‘‘eco-composite’’ shows the importance role of natural fibers in the modern industry (Leflaive E.-1985). The fibers are normally 50–350 mm long and consist mainly of lignin, tannin, cellulose, pectin and other water soluble substances. However, due to its high lignin content, coir degradation takes place much more slowly than in other natural fibers. Coir retains much of its tensile strength when wet. It has low tenacity but the elongation is much higher (Babu S-2008) The degradation of coir depends on the medium of embedment, the climatic conditions and is found to retain 80% of its tensile strength after 6 months of embedment in clay. Coir geo-textiles are presently available with wide ranges of properties which can be economically utilized for temporary reinforcement purposes (Subaida A-2009). Mainly, coir fiber shows better resilient response against synthetic fibers by higher coefficient of friction. For instance, findings show that coir fiber exhibits greater enhancements (47.50%) in resilient modulus or strength of the soil than the synthetic one (40.0%) (Chauhan S,-2008),Ayyar et al. and Viswanadham have reported about the efficacy of randomly distributed coir fibers in reducing the swelling tendency of the soil (Ayyar R, Krishnaswamy R-1989). Black cotton soil treated with 4% lime and reinforced with coir fiber shows ductility behavior before and after failure. An optimum fiber content of 1% (by weight) with aspect ratio of 20 for fiber was recommended for strengthening the BC soil (Ramesh.N-2010).

B. Nano materials

Today Nano phase engineering expands in a rapidly growing number of structural and functional materials, both inorganic and organic, allowing to manipulate mechanical, catalytic, electric, magnetic, optical and electronic functions. The production of Nano phase or cluster-assembled materials is usually based upon the creation of separated small clusters which then are fused into a bulk-like material or on their embedding into compact liquid or solid matrix materials. e.g. Nano phase silicon, which differs from normal silicon in physical and electronic properties, could be applied to macroscopic semiconductor processes to create new devices. For instance, when ordinary glass is doped with quantized semiconductor "colloids," it becomes a high performance optical medium with potential applications in optical computing.

C. Nano-silica

Silicon Oxide Nanoparticles are used in many cases as paint, plastic, color rubber, magnetic materials, in addition, nano-silica can be widely used in ceramics (sugar) porcelain, gypsum, batteries, paints, adhesives, cosmetics, glass, steel, fiber, glass, and many other fields. The purity of amorphous silica nanoparticles used in this study is 99% produced by US Nano Company. The dosage of using nano silica, recommended by the manufacturer, ranges from 0.5 to 5.5%. Considering economical issues of nano silica usage and the results of this research applied in soil stabilization projects, we decided to use (0.5-10%) of nano silica in the mixtures. characteristics are given in Table I.

D. Classification of nanomaterials

Nanomaterials have extremely small size which having at least one dimension 100 nm or less. Nanomaterials can be nanoscale in one dimension (eg. surface films), two dimensions (eg. strands or fibres), or three dimensions (eg. particles). They can exist in single, fused, aggregated or agglomerated forms with spherical, tubular, and irregular shapes. Common types of nanomaterials include nanotubes, dendrimers, quantum dots and fullerenes. Nanomaterials have applications in the field of nano technology, and displays different physical chemical characteristics from normal chemicals (i.e., silver nano, carbon nanotube, fullerene, photocatalyst, carbon nano, silica). According to Siegel, Nanostructured materials are classified as Zero dimensional, one dimensional, two dimensional, three dimensional nanostructures.

TABLE I. Nano-silica characteristics

Silicon Oxide (SiO_2) Certificate of Analysis			
SiO_2	>99%	SSA(m^2/gr)	180-600
Ti	<120 ppm	Purity	99
Ca	<70 ppm	Size	20-30 nm
Na	<50 ppm	Colour	white
Fe	<20 ppm		

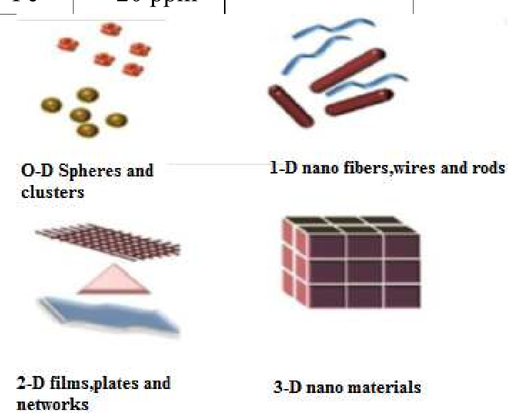

Fig.1.Classification of Nano materials

TABLE II. Studies on fibers in expansive soils

Length of fiber	Diameter of fiber	Fiber %	Reduction of swell potential and strength
15mm	Nylon 1mm	2.5%	21%
12mm	JUTE(0.55mm)	0.6%	UCC increased
20mm	Nylon 1mm	2.5%	38%

Length of fiber	Diameter of fiber	Fiber %	Reduction of swell potential and strength
25mm	Nylon(0.2mm) & palmrya(0.4mm)	5%	76%
50mm	Nylon (0.2mm) & palmrya (0.4mm)	5%	72%
75mm	Nylon(0.2mm) & palmrya(0.4mm)	5%	70%
100mm	Nylon(0.2mm) & palmrya(0.4mm)	5%	67%
15mm	coir fibers(0.35mm)	0.5%	29%
15mm	coir fibers(0.35mm)	1%	35%
15mm	coir fibers(0.35mm)	1.5%	44%

Table III. Combination of fiber and admixtures

Length Of fiber (Lld)	Diameter of fiber	Fiber %	Admixture	Reduction of swell potential
15mm	Polypropylene fiber	0.05%	lime (2,5,8%)	5% of lime of max swelling pressure.
15mm	Polypropylene fiber	0.15%	lime (2,5,8%)	5% of lime of max swelling pressure.
15mm	Polypropylene fiber	0.25%	lime (2,5,8%)	5% of lime of max swelling pressure.
	----	-----	Only Sand (30%) in expansive soils	67%

TABLE IV.Comprehensive studies on the polymer stabilization of soil

Sl no	Nano polymer	Nano particles %	Reduction of swelling potential
1	Polypropylene homopolymer (H030SG) Xylene Solution	15%	90%& stiffness increased 4.5 times
			of initial value .UCC increased 220%
2	Xanthan gum and Guar Gum	10%	Undrained shear strength and LL increased (chen et al 2013)

TABLE V. Percentage swell reduction for various fiber contents

Sl no	Fiber [a] content %	Percentage of swelling after 24 hours	Percentage reduced in swell
1	0	6.2	NA
2	0.5	4.4	29.0
3	1.0	4.0	35.0
4	1.5	3.5	44.0

fiber length = 15 mm; fiber diameter = 0.25 mm.

III. Conclusion

This paper provides an overview of the concept of using coir fiber and Nano silica in geotechnical engineering. The coir fiber material is used to reinforce soil with increase the strength, stiffness and decrease the vertical swelling pressure. Different nano silica exhibit different properties. Due to their smaller dimensions, nanoparticles possess a very high specific surface and react more actively with other particles in the soil matrix. The study found that coir fiber and Nano particles influence the strength, permeability, swelling potential and resistance properties of soil.

References

[1] Rowell M, Han S, Rowell S. Characterization and factors effecting fiber properties. Nat Polym Agr Compos 2000:115–34.

[2] Ghavami K, Filho R, Barbosa P. Behaviour of composite soil reinforced with natural fibers. Cement Concrete Compos 1999;21:39–48.

[3] Savastano H, Warden G, Coutts P. Brazilian waste fibers as reinforcement for cement-based composites. Cement Concrete Compos 2000;22: 379–84.

[4] Nilsson H. Reinforcement of concrete with sisal and other vegetable fibers, Swed Counc for Build Res, Document DIY, Stockholm, Sweden; 1975.

[5] Babu S, Vasudevan K. Strength and stiffness response of coir fiber-reinforced tropical soil. J Mater Civil Eng ASCE 2008;20:571–7.

[6] Subaida A, Chandrakaran E, Sankar N. Laboratory performance of unpaved roads reinforced with woven coir. Geotext Geomembr 2009;27:204–10.

[7] Chauhan S, Mittal S, Mohanty B. Performance evaluation of silty sand subgrade reinforced with fly ash and fiber. Geotext Geomembr 2008;26:429–35.

[8] Ayyar R, Krishnaswamy R, Viswanadham S. Geosynthetics for foundations on a swelling clay. Int work on geotex, Bangalore, India; 1989.

[9] Viswanadham S. Bearing capacity of geosynthetic reinforced foundation on a swelling clay master of technology dissertation. Madras (India): Indian Institute of Technology; 1989.

[10] Ravishankar U, Raghavan S. Coir stabilised lateritic soil for pavements. In: Indian geotech conf, Ahmedabad, India; 2004.

[11] Khedari J, Watsanasathaporn P, Hirunlabh J. Development of fiber-based soil– cement block with low thermal conductivity. Cement Concrete Compos 2005;27:111–6.

[12] Ramesh N, Krishna V, Mamatha V. Compaction and strength behavior of limecoir fiber treated Black Cotton soil. Geomech Eng 2010;2:19–28.

[13] B.P.Phanikumar, Ravideep singla, Swell-Consolidation characteristics of fiber –reinforced expansive soils. The Japanese Geotechnical society,16 September 2015.

[14] N. M. Al-Akhras, M. F. Attom, K. M. Al-Akhras and A. I. H. Malkawi, Influence of fibers on swelling properties of clayey soil. Geosynthetics International, 15, No. 4, 304–309. Thomas telford ltd. 07 February 2008.

[15] G. L. Sivakumar Babu, A. K. Vasudevan, M. K. Sayida, Use of coir fiber for improving the engineering properties of expansive soils. Journal of Natural Fibers, 11 october 2008.

[16] Yi Cai a, Bin Shi , Charles W.W. Ng , Chao-sheng Tang, Effect of polypropylene fibre and lime admixture on engineering properties of clayey soil. Elsevier,18 September 2006.

[17] B.V.S.Viswanadham, B.R.Phanikumar, R.Mukherjee, Effect of polypropylene tape fiber reinforcement on swelling behaviour of an expansive soils. Geosynthetices international 16, No 5 2009.

[18] Waseim Ragab Azzam, durability of expansive soil using advanced nanocomposite stabilization. Int. Journal of GEOMATE, Sept-2014.

[19] Dak R. M., Prakash B. N, Sanjay D. N. and Ravindra N, “Stabilization of black cotton soil using admixture”, International Journal of Engineering and Innovative Technology (IJEIT), Vol. 1, 2012, pp 1-3.

[20] Mukesh A. B., Patel H. S., “A Review on effects of stabilizing agents for stabilization weak soil”, Civil and Environmental Research. Vol. 2, 2012, pp 175 -182.

[21] Ramaji A. E, “A Review on the Soil Stabilization Using Low-Cost Methods, ” Journal of Applied Sciences Research, Vol. 4, 2012, pp 2193-2196.

[22] Anday, M.C., 1961. "Accelerated Curing for Lime Stabilized Soils." Transportation Research Record,(304): 1-13.

[23] Babushanker N. (1986), “What Techniques other than under reamed piles have? Proven to be Effective in Minimizing Foundation Problems in Black Cotton Soils”, IGC-86, New Delhi, Vol 1, pp.155-158.

[24] Chandra, S. "Stabilization of Clayey Soils With Lime, Cement and Chemical Additives Mixing." International Symposium on Prediction and Performance in Geotechnical Engineering, 177-181.

[25] Zaid Hameed Majeed and Mohd Raihan Taha," A Review of Stabilization of Soils by using Nanomaterials " , Australian Journal of Basic and Applied Sciences, 7(2): 576-581, 2013.

[26] Kumar, P., and Singh, S. P. (2008). “Fiber reinforced fly ash sub bases in rural roads.” J. Transp. Eng., 10.1061/(ASCE)0733-947X(2008)134: 4(171), 171–180.

[27] Loehr, E. J., Axtell, P. J., and Bowders, J. J. (2000). “Reduction of swell potential with fiber reinforcement.” Proc., GeoEngineering Conf., Australian Geomechanics Society and the Institution of Engineers, Melbourne, Australia, 19–24.

[28] Malekzadeh, M., and Bilsel, H. (2012). “Swell and compressibility of fiber reinforced expansive soils.” Int. J. Adv. Technol. Civ. Eng., 1(2), 42–46.

[29] Freitag D. R. 1986. Soil randomly reinforced with fibers. J. Geotech. Eng., 112(8): 823–826.

[30] Gray, D. H., Ohashi, H. 1983. Mechanics of fiber reinforcement in sand. Journal of Geotech. Eng. 109(3): 335–353.

[31] Gray, D. H., Al-Refeai, T. 1986. Behavior of fabric—versus fiber-reinforced sand. Journal of Geotech. Eng. 112(8): 804–820.

[32] Li, G. X., Jie, Y. X., Jie, G. Z. 2001. Study on the critical height of fiber reinforced slope by centrifuge test. Land marks in earth reinforcement. In Proceedings of the International Conference on Earth Reinforcement, Japan, 2001; 239–241. Maher, M. H., Ho, Y. C. 1994. Mechanical properties of kaolinite/fiber soil composite. Journal of Geotech. Eng. 120(8): 1381–1392.

[33] Nelson, J. D., Miller, D. J. 1992. Expansive Soils-Problems and Practice in Foundation Engineering and Pavement Engineering. John Wiley & Sons, Inc., Hoboken, NJ. Rao, G. V. Balan, K. 2000. Coir Geotextiles Emerging Trends. Alappuzha, Kerala India:

[34] Sivakumar, Babu, G. L., Vasudevan, A. K. 2007. Evaluation of strength and stiffness response of coir fiber reinforced soil. Journal of Ground Improvement. 11(3):111–116.

[35] Wahab, Heckel, G. B., Al-Qurna, H. H. 1997. Total and effective strength parameters of fiber reinforced soils. In Proceedings of the 14th International Conference on Soil Mechanics and Foundation Eng. 423–426.

[36] Prabhakar, J., and Sridhar, R. S. (2002). "Effect of random inclusion of sisal fiber on strength behavior of soil." Constr. Build. Mater., 16(2), 123–131.

[37] Punthutaecha, K., Puppala, A. J., Vanapalli, S. K., and Inyang, H. (2006). "Volume change behaviors of expansive soils stabilized with recycled ashes and fibers." J. Mater. Civ. Eng., 10.1061/(ASCE)0899-1561 (2006)18:2(295), 295–306.

[38] Puppala, A. J., Pathivada, S., Bhadriraju, V., and Hoyos, L. R. (2001). "Shrinkage strain characterization of expansive soils using digital imaging technology." Expansive soils: Recent advances in characterization and treatment, A. A. Al-Rawas and M. F. A. Goosen, eds., A. A. Balkema Publishers, Rotterdam, Netherlands. Ramesh, H. N., Manoj Krishna, K. V., and Mamatha, H. V. (2010). "Compaction and strength behavior of lime-coir fiber treated black cotton soil." Geomech. Eng., 2(1), 19–28.

[39] Ranganatham, B. V., and Satyanarayana, B. (1965). "A rational method of predicting swelling potential for compacted expansive clays." Proc., 6th ICSMFE, Vol. 1, International Society for Soil Mechanics and Foundation Engineering, Montreal, Canada, 92–96.