International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 10 | Oct -2016 www.irjet.net p-ISSN: 2395-0072

Improving Strength of Soil using Fiber and Fly ash -A Review

Mamta Mishra*, U. K. Maheshwari and N. K. Saxena

Department Civil Engineering,
Kamla Nehru Institute of Technology, Sultanpur, (U. P.), India.
*Email: mishramamta512@gmail.com **

---***---

Abstract - *Soil is very important in civil engineering constructions. The poor engineering properties of the local soils may present many difficulties for construction and therefore need to improve their engineering properties. Stabilization techniques can be used to improve the properties of soil. Soil stabilization improves various engineering properties e.g. bearing capacity, compressibility, strength, and various other properties of soil. In this paper we study the impact of fly ash and coir fiber to improve the strength of soil.*

Key Words: Stabilization; Strength of soil; Fly ash; Coir fiber; engineering properties.

1. INTRODUCTION

Soils are complex mixtures of minerals, water, air, organic matter, and countless organisms. Various types of soil available in India like alluvial soils, black cotton soils, laterites soils, mountain soils, desert soils, red soils. Soil is the upper most part of earth and it is cheapest and readily available construction material. Soil is generally categorizes into four basic types (such as): Gravel, Sand, Clay and Silt. Out of them, few possess montmorillonite in high amount resulting in sudden swelling and shrinkage upon contact with water. Such soils are not useful in construction directly but can be made useful after their stabilisation.

Soil is defined as an unconsolidated material, composed of soil particles, produced by the disintegration of rocks and chemical decomposition. On the basis of shear strength, soil can be divided into three types: cohesion less soils, purely cohesive soils and cohesive soils.

Soil stabilisation is used for foundation, embankment and highway construction, airport and village roads to highways or expressway. Soil stabilisation improves the bearing capacity, compressibility, strength, and other properties of soil. Soil stabilisation is the popular method of soil improvement. Various methods of soil stabilisation are used like mechanical method, chemical method, thermal method, additive method (fiber reinforcement). In case of road construction the aim of stabilization of soil is to increase the stability by increasing its bearing capacity and hence increasing its strength and reduction in pavement thickness. Soil stabilisation improves the strength of the soil, thus, increasing the soil bearing capacity, used to decrease the permeability and compressibility of the soil mass in the earth structures, more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation, improves the workability and the durability of the soil and maximize the lifecycle costs of projects.

Synthetic (man-made) fibers: Synthetic fiber can be categorized as Polypropylene (PP) fiber and Polyester (PET) fibers. Polypropylene is polymer and all polymer products made of thermoplastics. Polypropylene produce by polymerization of propylene gas. It is high-temperature cracking of petroleum hydrocarbons and propane (CH_3). Polypropylene has a lower density and higher service temperature. Polypropylene is harder and rigid. Polyester is also made by thermoplastics variety and polyester is polymer product. It is produce from DMT and MEG (mono-ethylene glycol) and contains ester functional group in their main chain. It is reaction of alcohols with acids via a chemical bonding. Synthetic fibers are strong so they can take up heavy things easily, retain their original shape so it's easy to wash and wear and more strong than natural fibers.

Natural fibers: The Coir fiber and Bamboo fiber is natural fiber. Coir fiber - Coir fiber or plant fiber or fruit fiber is a natural fiber. Coir fiber is also called the coconut fiber. Coir fibers are collected from the fruit (coconut) of the coconut tree. Coconut fiber is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fiber is: Coir, Cocos nucifera and Arecaceae (Palm). Coconut fibers can be categorizes as brown fiber and white fiber. Brown fiber extracted from matured coconuts and it is thick, strong and has high abrasion resistance. White fibers extracted from immature coconuts. White fibers are smoother and finer, but also weaker. It is renewable resource and CO_2 neutral material and non-toxic in nature, biodegradable, low density and very cheap. Coir fiber diameter is approximately 0.1 – 1.5 mm and length is 3 – 15 cm.

Bamboo fiber is a natural fiber (plant fiber: Stalk fiber). Stalk fibers are actually the stalks of the plant. E.g. straws of wheat, rice, barley, and other crops including bamboo and grass. Bamboo fiber is softer than cotton with a texture similar to silk and blend of cashmere. It is tensile strength is very low and bamboo fibers are remarkably strong in tension but have low modulus of elasticity about 33–40 kN/mm^2 and high water absorption about 40–45%. The bamboo fiber has a high degree of retaining water and also rich in micronutrients. Natural fiber reduced wear of tooling, healthier working condition, and no skin irritation, higher specific strength and stiffness than glass fiber, have good thermal and acoustic insulating properties and has a high degree of retaining water and also rich in micronutrients

Fly ash - There are three types of ash produced by thermal power plants: Fly ash, bottom ash and pond ash. The waste product produced on combustion of pulverized coal at high temperatures in power plants is known as fly ash. Fly ash is the by-product of coal fired electric power generating plants. Fly ash has a high amount of silica and alumina. It is increase the soil strength. To control the swell characteristics caused by moisture changes. Improvement of soil strength by using this waste material in geotechnical engineering has been widely recommended from environmental point of view. The waste product produced on combustion of pulverized coal at high temperatures in power plants is known as fly ash. Due to rapid growth of urbanization and industrialization, minimization of industrial waste is serious problem in present days. The utilization of this waste product safely is gaining importance now-a-days. Fly ash is used for brick construction. It is called the fly ash brick. Manufacture of Portland cement. It is also used to Land fill and dyke rising, Structural fill for reclaiming low areas, soil stabilizing in pavement and sub-base. Fly ash increase strength and bearing capacity of soil, increase durability of soil and increase the resistance to erosion, weathering or traffic loading, used to control the swell-shrink characteristics caused by moisture changes and used to reduce the pavement thickness as well as cost.

2. LITERATURE REVIEW

Few research scholars carried their investigations on mixing soil with polypropylene, polyester fibers, coir fibre, Bamboo fibre and fly ash. Plenty of work has been done by different researchers; some of them are as follows:

Beeghly J. H. et al. (2003) investigated for appropriate soils, lime- fly ash can offer cost saving by reducing material cost by up to 50% as compared to Portland cement stabilization. For low cohesive soil used with lime and fly ash stabilization can be economically engineered for long term performance. **Bhuvaneshwari et al. (2005)** investigated the study in the properties of expansive soil with fly ash in varying percentages. Both laboratory test and field tests have been carried out and results are reported in this paper. One of the major difficulties in field application is thorough mixing of the two materials such as expansive soil and fly ash is required proportion to form a homogeneous mass. The proper describes a method adopted for placing these materials in layers of required thickness and operating a "Disc Harrow". The trial embankment of 30m length by 6m width by 0.6m high was successfully constructed and the in-situ tests carried out proved/proved its suitability for construction of embankment, ash dykes, highway constructions filling low-laying areas, etc. **Mehul and Kulkarni (2013)** used fibrillated polypropylene fiber of length 12mm and diameter 34 micron and low density of 0.9 kN/m3, in percentages of 0.5%, 1% and 1.5% in high strength concrete. Super plasticizer Conplast-Sp430 was used. They investigated the compressive strength of concrete increased with added of fibers. **Kumar et al. (2006)** investigation to highly compressible clay in UCS test with 0%, 0.5%, 1.0%, 1.5% and 2.0% flat and crimped polyester fibers with Three lengths like 3 mm, 6 mm and 12 mm were chosen for flat fibers, while crimped fibers were cut to 3 mm long. The results indicate that as the fiber length and /or increase the percentage of fiber, the UCS value will improve. Crimping of fibers leads to increase of UCS slightly. **Nithin and Sayida (2012)** reports the results of the laboratory study performed on silty sand admixed with fly ash and reinforced with coir fibres and demonstrates that discrete and randomly distributed coir fibres are useful in improving the bearing capacity of soil. The silty sand (low plasticity soil) has been considered using different percentage of fly ash ranging from 5 to 20% by weight of given soil and the impact of curing period is also considered. Coir fibres are added ranging from 0.5 – 5% and having different aspect ratio such as l/d=40, 80, 120, 160 to investigate the relative strength gain in terms of unconfined compression. **Hejazi et al. (2012)** examined the improve the engineering characteristics of soil. In this way, using natural fibers like grass, leaf etc. to reinforce soil is an old and ancient idea. Consequently, randomly distributed fiber reinforced soils have recently attracted increasing attention in civil engineering and geotechnical engineering for the second time. The main aim of this paper, therefore, is to review the history, advantages, applications; and possible executive problems of using different types of natural and synthetic fibers in soil reinforcement through reference to published scientific data. As well, predictive models used for short fiber (or aspect ratio) soil composite will be discussed. On other words, this paper is going to investigate different fiber different methods and different percentages fibers have been used in soil reinforcement projects. **In 2013 Meshram et al.** solved a variety of problems related to drainage, separation and reinforcement of pavement structure. They investigated that the geo-textiles made of natural fibers such as coir, jute etc., are emerging as alternatives to polymeric geo-textiles. They also described that in dry weather conditions, cracks develop at the soil surface due to tensile stresses induced as a result of drying and shrinkage and in wet weather conditions the water starts to rise in the sub-base by capillary action from soil sub-grade. For pavement they described that material like coir, lime etc. are needed to improve the compressive, tensile strength and permeability characteristics of the sub-base for a better performance of the pavements. **Soosan et al. (2013)**

examined the improvement in strength of kaolinite clay with addition of quarry dust and coir fiber. They showed that only use of coir fiber there is no any improvement in the strength of soil while using the combination of coir with quarry dust there is significant improvement in the strength of soil.

Momoh et al. (2013) investigated the use of coir fibre reinforcement to improve the strength properties of black cotton soil sub-grade and cement kiln dust (CKD) as stabiliser. Black cotton soil was mixed with optimum of CKD along with different proportions of discrete coir fibres (0%, 0.25%, 0.5%, 0.75% and 1.0% by dry weight of soil cut to 25mm size). Test results indicated that the inclusion of fibre in stabilised specimens resulted in reduced maximum dry unit weight, higher optimum moistures content relatively to UCS and therefore increases load carrying capacity of the sub-grade. The results further demonstrated that randomly distributed coir fibres can be used to reduce the brittleness of stabilised soil which is the drawback associated with high lime content stabilisers. Thus, strength of black cotton soil can be successfully improved by the combined action of CKD and coir fibre. **Tiwari et al. (2014)** analyzed the characteristics of soil such as Atterberg's Limits, Proctor Compaction test (O.M.C. and M.D.D.), Shrinkage Limit, California Bearing Ratio test, Swelling Pressure, Permeability test and direct shear test, effect of Fly Ash, Coconut fiberand crushed Glass with various percentages with Black cotton Soil, combination on the above proportion of ingredients, use of waste products instead of conventional construction materials like cement, lime, etc. and how to increase cost benefit ratio. To achieve the experimental data with 48 trial soil samples test were carried in two phase such as in first phase, the physical properties of soil such as specific gravity, Atterberg's limits, grain size analysis, proctor compaction test, swelling pressure, CBR test, Direct shear test and permeability test values are determined. In second phase, all test performed for black cotton soil using different percentages of Fly Ash , coir fiber and crushed glass fiber (FA: 10%, 15%, 20% and 25%, CF: 0.25%, 0.5%, 0.75% and 1%, CGF: 3%, 5% and7%, glass crushed to have gradation of sand size).

Singh et al. (2014) represents a study to analyze both unsoaked and soaked CBR value of soil increases with the increase in fiber content. Both CBR value are increases such as Soaked CBR value increases from 4.75% to 9.22% and unsoaked CBR value increases from 8.72% to 13.55% of soil addition with 1% coir fiber. Unconfined compressive strength of the soil increases from 2.75 kg/cm^2 to 6.33 kg/cm^2 upon addition of 1% randomly distributed coconut coir fiber. Adding of coconut coir fiber results to reduce the pavement thickness as well as cost and it is more economical both in terms of cost and energy to increase the bearing capacity of the soil. Hence economy of the construction of highway will be achieved. It is used to improve the strength of soil and behavior of soil. **Singh and Arif (2014)** conducted an experimental study on silty sand (SM) (local soil) mixed with varying percentage of coal ash (20%, 30%, 40% and 50%) and coconut coir fibre (0.25, 0.50, 0.75 and 1.0%). They conducted unconfined compressive strength (UCS) and California bearing ratio (CBR) tests on the soil mixed with coal ash/coir fibre/ both. They observed the significant improvement in UCS and CBR value by adding 20% of coal ash in the soil. Their results showed that the UCS value is maximum (1.81 kg/cm^2) for 20% coal ash mixed with soil and the un-soaked and soaked CBR values was increased from 10.5% and 5.6% to 27.7% and 14.6%, respectively. Rate of increase in CBR values decreased after further addition of coal ash beyond 20%. Randomly mixed coconut coir fibre is included in optimum soil-coal ash mix (i.e. 80% soil and 20% coal ash) and varied as 0, 0.25, 0.50, 0.75 and 1.0%. UCS value increases substantially with inclusion of coconut coir fibre in soil - coal ash mix. The optimum percentage of soil-coal ash-coir fibre mix is arrived at 79.75:20:0.25 (by weight). **Kumar and Vikranth (2015)** investigated the improvement in strength of black cotton soil by mixing varying percentage of coconut coir and fly ash such as 0%, 0.25%, 0.50%, 1% and 0%, 5%, 10%, 15%, 20% respectively based on a series of unconfined compression strength and California bearing ratio (CBR) tests. **Asaduzzaman and Islam (2014)** investigated the soil improvement by reinforcement having a length of 12 inch and 0.5 inch in diameter distributed in soil (uniform medium dens) at different depths (0.75 inch, 1.5 inch and 2.25 inch) below the footings. The three square footings have been used (3x3 inch, 3.5x3.5 inch, 4x4 inch) to carry the above investigation for such purposes. They found that the initial vertical settlement of footing was highly affected in the early stage of loading in unreinforced soil with compared to bamboo reinforced soil. The failure load value for their model in any case of loading increased compared with the un-reinforced soil by increasing the depth of improving below the footing. The load carrying capacity of single layer of reinforced soil is increased up to 1.77 times and 2.02 times for multiple reinforced soil system than the load carrying capacity of unreinforced condition of soil. Improvement in load carrying capacity was observed considerable in reinforced soil over the unreinforced soil. For single layer system, load carrying capacity is maximum and settlement is minimum when the reinforcement layer placed at 0.30B. For multilayer system, BCR increases with increasing number of reinforcing layer.

Karthik et al. (2014) represents of this study was to evaluate the effect of Fly Ash is the waste product produced on combustion of pulverized coal (sub-bituminous coal) at high temperatures in power plants in stabilization of soft fine-grained red soils. The soil is classified with plasticity based, with plasticity chart ranging between 25 and 30. Tests were conducted on soils and soil with fly ash mixtures prepared at optimum water content of 9%. Addition of Fly Ash resulted in appreciable increases the CBR values of the original soil sample. For water contents 9% wet of optimum, CBRs of the soils are found in varying percentage of fly ash such that 3,5,6 and 9%.We will found the optimum CBR value of the soil sample is 6%.Increment of CBR value is used to reduce the pavement thickness, decreases the cost of pavement materials and increasing the bearing capacity of soil. **Raut et al. (2014)** study carried out to check the improvements in the geotechnical properties of expansive soil mixed with fly ash, murrum in varying percentages. The laboratory tests have been carried out and results are reported in this paper. As fly ash and murrum is freely available, for projects in the in nearby vicinity, it can be used for stabilization of expansive soils for various uses. Recently **John and Rachel (2016)** investigation the effect of random distributed of bamboo fibers on strength behavior of fly ash improving black cotton soil. The optimum percentage of fly ash was found to be 20% by weight of soil. Bamboo fiber of average diameter 0.45 mm and 25 mm length is used in this study. It was randomly included into the fly ash treated soil at four different percentages of fiber content, i.e. 0.25, 0.5, 0.75 and 1% (by weight). The reinforced soil samples were subjected to unconfined compression test and compaction tests. They found that strength properties of optimum combination of BC soil-fly ash specimens reinforced with bamboo fibers is appreciably better than untreated BC soil. An optimum fiber content of 1% (by weight) is recommended for strengthening fly ash treated BC soil.

3. ANALYSIS

Polypropylene is mixed with soil- fly ash mixture is improving the soil properties like permeability, strength etc. The moisture - density relationship of soil-fly ash mixtures significantly affected due to addition of fibers. The relative benefit in CBR values due to fibers increases only up-to 1.00 % by dry weight and length up to 12mm for all soil-fly ash specimens. The results of study of a randomly oriented fiber reinforced soil- fly ash mixtures indicted that a maximum performance was achieved with 12 mm fibers in optimum dosage of 1.00 % by dry weight of soil- fly ash mixtures. Polypropylene fibers reduce the water permeability, plastic, shrinkage and settlement and carbonation depth.Polypropylene is used to USC and CBR other test is performed is increases the soil strength optimum soil-fly ash sample mixes with randomly distributed coir fiber in different percentages (in the mixed proportion range from 0 to 1.5% by weight). The analysis is done as per IS code provisions. Polypropylene fibers with different fiber length (6mm, 12mm and 24 mm) were used as reinforcement.Polyester is used to USC test and other test increase the percentage is increases the strength of soil. Polyester is mixed with soil proportion range from 0.5% to 2% by weight with different length like 3 mm, 6 mm, and 12 mm.

When we mix soil with fly ash 4%, 8%, 12% and 16% than CBR value increase with increase in percentages of fly ash and we find out that maximum strength gain is done when mix soil with 16% fly ash. So in phase two, soil-16% fly ash mix with 0.25%, 0.50%, 0.75% and 1.0% coir fiber than CBR value is a first increase with increase in percentage of coir fiber than decrease and find maximum CBR value is soil-16% fly ash-0.75% coir fiber is 234.64%. The maximum CBR value achieve by 0.75% coir fiber w. r. t. soil and decreases CBR value for 1.0% coir fiber because increase silty particles are increase. The CBR value increases to 130.11% to 207.11%with increases percentage of fly ash with respect to soil.

The load bearing capacity of soil increases when the bamboo reinforcement placed within the depth of failure envelope. The load bearing capacity is increased up to 1.77 times for single layer reinforced soil and 2.02 times for multiple layer reinforced soil system than the load bearing capacity of unreinforced condition of soil. Improvement in load bearing capacity is observed considerable in reinforced soil over the unreinforced soil. For single layer system, load bearing capacity is maximum and settlement is minimum when the reinforcement layer placed at 0.30B. In multi-layer reinforcing system, settlement is considerably decreases with the increasing number of reinforcing layer.

Addition of fly ash to BC soil increases the strength. It has been observed that 20% fly ash by weight is found to be optimum. Addition of randomly distributed bamboo fiber to BC soil increases the unconfined compressive strength and the optimum percentage of fiber obtained for 20% fly ash content is 1% by weight. Fly ash treated BC soil reinforced with 1% bamboo fiber increases the strength and reduces the brittle behavior of soil specimen, where as the other percentages of fibers used shows a marginal increase. Based on the studies conducted bamboo fiber can be used as a strengthening material for fly ash treated BC soil. Fly ash is widely used as a stabilization material for soft soils. Since there is much more fly ash that is disposed of rather than utilized, making more productive use of fly ash would have considerable environmental benefits, reducing land, air and water pollution. Waste bamboo fibers from cottage industries can also be utilized in stabilization.

4. CONCLUSION

On the basis of literature review we reached on following observations:

- The reinforcement of soil mixed with fly ash further increases the strength of soil used for construction activity.
- Fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soils where it can

act as a substitute to deep/raft foundations, reducing the cost as well as energy.

- Both the length and content of coir have important role in developing the strength properties of stabilized soil. But the strength properties are mostly affected by coir content than by size of coir fiber.
- The C.B.R. value is increased. Therefore the inclusion of fiber is helpful in augmenting the soaked CBR and hence, resulting in less thickness of pavement crust in high rainfall area.
- Fly ash and coir fiber is also available and cheap material. If fly ash and coir is used for soil stabilization it will reduce the environmental hazard caused by coir waste. It will be the one of cheapest method for ground improvement.

REFERENCES

[1] **Amadi A. A., Eberemu A. O., Momoh O. H.,** "Use of coir reinforcement technique to improve strength of cement kiln dust treated black cotton soil sub-grade", in proceedings of *geosynthetics* 2013, 223-229, 2013.

[2] **Asaduzzaman M. and Islam M. I.,** "Soil Improvement By Using Bamboo Reinforcement", *American Journal of Engineering Research (AJER)*, 3(8), 362-368, 2014

[3] **Beeghly J. H.,** "Recent experiments with lime – fly ash stabilization of pavement sub-grade soils, base, and recycle asphalt", in proceedings of *International ash utilization symposium, center for applied energy research, university of Kentucky*, 2003.

[4] **Bhuvaneshwari S., Robinson R. G., Gandhi S. R.,** "Stabilization of expansive soils using fly", in proceedings of *Fly Ash Utilization Programmed (FAUP), New Delhi*, India, 2005.

[5] **John Paul V.and Antony Rachel Sneha M.,** "effect of random inclusion of bamboo fibers on strength behavior of fly ash treated black cotton soil", *International Journal of Civil Engineering and Technology (IJCIET),* 7(5), 153–160, 2016.

[6] **Karthik S., Kumar A., Gowtham P., Elango G., Gokul D., Thangaraj S., "**Soil stabilization by using fly ash", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* , 10(6), 20-26, 2014.

[7] **Kumar A, Walia B, Mohan J.**, Compressive strength of fiber reinforced highly compressible clay, *Construction and Building Materials*, 20(10), 1063-1068, 2006.

[8] **Kumar V. R. S., Vikranth J.**, "Application of coconut coir and fly ash in sub grade strengthening", *The International Journal of Engineering And Science (IJES)*, 3(12), 48-54,2014.

[9] **Mahdi H. S., Sheikh Z. M., Mahdi A. S. and Ali Z.**, "A simple review of soil reinforcement by using natural and synthetic fibers", *Construction and Building Materials*, 30, 100-116, 2012.

[10] **Mehul J. Patel, S. M. Kulkarni**, "Effect of Polypropylene Fiber on the High Strength Concrete", *Journal of Information, Knowledge and Research in Civil Engineering*, 2(2), 125-129, 2012-13.

[11] **Meshram K., Mittal S. K., Jain P. K., and Agarwal P. K.**, "Application of coir geotextile in rural roads construction on black cotton soil subgrade", *International Journal of Engineering and Innovative Technology*, 3(4), 264-268, 2013.

[12] **Nithin S.** and **Sayida M. K.** "Stabilization of silty sand using fly ash and coir fiber", *in the proceedings of Recent Advances in Civil Engineering, ,* Kerala, India, 2012.

[13] **Raut J. M., Bajad S. P., Khadeshwar S. R.,** " Stabilization of expansive soils using Fly ash and murrum", *International Journal of Innovative Research in Science, Engineering and Technology* 3(7), 14280-14284, 2014.

[14] **Singh R. R., Mittal S.,** "Importance of local sub grade soil for road construction by the use of coconut coir fiber", *International Journal of Research in Engineering and Technology*, 3(5), 707-711, 2014.

[15] **Singh S. K., Arif S. M.**, "Inclusion of coconut coir fiber in soil mixed with coal ash", *International Journal of Research in Engineering and Technology,* 3(11), 209-213, 2014.

[16] **Soosan George T, Alice T V, Mini M I,** "Improvement of kaolinite clay sub-grade using coir fibre waste", *International Journal of Engineering Technology and Advanced Engineering*, 3(3), 988-995, 2013.

[17] **Tiwari A., Mahiyar H. K. ,** "Experimental study on stabilization of black cotton soil by fly ash, coconut coir fiber and crushed glass", *International Journal of Engineering Technology and Advanced Engineering.*, 4(11), 330-333, 2014.