International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES),(UGC APPROVED)
Impact Factor: 5.22 (SJIF-2017),e-ISSN:2455-2585
"International Conference on Modern Trends in Civil Engineering"(ICMTCE-2019)
(Towards Sustainable Development Goals)
Volume 5, Special Issue 02, Feb.-2019

A REVIEW OF LITERATURE ON STABILIZATION OF EXPANSIVE SOIL USING SOLID INDUSTRIAL WASTE

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Abstract- Expansive soil is a term applied to any rock or soil that has a potential for shrinking or swelling under changing moisture condition (Nelson and Miller, 1992)[13]. Severe damage occur to structure founded on expansive soil. Soil stabilization is defined as process by which a soil material is improved and made more stable by increasing the bearing capacity of soil (Joel and Agbede, 2011)[8]. Black Cotton soil are inorganic clays and occur in central and western part of India and covers nearly 20% of the country's area. These soil are very high when dry but loses its entire strength when comes in contact with moisture. It is generally observed that these soil develop deep cracks of varying depth when dry. As a result of wetting and drying process, some vertical movement takes place of the soil mass and leads to failure of pavement, in form of settlement, heavy depression, cracking and unevenness.

These soils are highly clayey and is so hard that clods cannot be easily pulverized for treatment for its use in pavement and poses a problem regarding performance of road. Softened subgrade has a tendency to heave up into upper layers of pavement, when sub-base has a lot of voids. Roads laid on BC soil develop undulation on road surface due to loss of strength of subgrade due to being soft during monsoon. The black colour of the soil is due to presence of titanium-oxide in small quantity. BC soil has high percentage of clay, predominantly montmorillonite in structure and is blackish-grey in colour. Nearly 40-60% of soil is less than 0.001mm, and at liquid limit the volume change is of order of 200-300% which results in swelling pressure of 8-10kg/m^2. Therefore the soil has very low bearing capability and forms a very poor foundation material for pavement because of its high swelling and shrinking. Soaked CBR is between 2-4% and thus one can construct a pavement of it but one needs to provide excessive pavement thickness.

The objective of the paper is to review the literature on stabilization of expansive soil using Solid Industrial waste which includes Fly ash, Cement Kiln dust (CKD), Phosphogypsum (PG) and Granulated Blast Furnace Slag (GBFS).

KEYWORDS- PG, montmorillonite, subgrade, pavement

1. Stabilization of expansive soil using various Solid Industrial Waste

1.1. Stabilization of Expansive soil using Flyash.

It is produced by combustion of coal in a coal fired thermal and electric power plant. It is a waste product which finds its use in Cement industries as an additive to cement, can be used in flyash brick and also as a stabilizer in soil. When used in soil it improves soil's density, plasticity, water content and bearing capacity. Modification of soil properties is temporary enhancement of stability of soil subgrade to expedite construction. Class C flyash can be used as a standalone material, since it has self-cementitious properties while Class F needs a cementitious agents like Cement, Lime, CKD or LKD.

Pandian et.al. (2002)[15] had studied two type of Flyash, Class F (Raichur Ash) and Class C (Neyvalli Flyash) on CBR of Black Cotton Soil. Since CBR is linked with cohesion and friction. CBR of fine soil is attributed to cohesion while for flyash which is coarse it is with friction. With fine clayey soil, it has low CBR and flyash increases CBR. Adding Flyash to black cotton soil enhances its CBR. But when flyash exceeds its optimum concentration, it starts to reduce CBR and here the reduction is up to 60% and then increases to second optimum level. It also concludes that variation of CBR on Flyash **-** BC soil is due to frictional and cohesive resistance of soil and stabilizer. In class C flyash with increase in flyash strength increases due to additional pozzolonic reaction forming cementitious compound resulting in a good binding between BC soil and Flyash.

PhaniKumar and Sharma (2004)[17] carried out study on expansive soil and its engineering properties when Flyash is added to it on experimental basis. The effect on FSI, Plasticity index, swelling pressure and potential, hydraulic conductivity, compaction and strength were studied. The ash blended soil was made by adding Flyash at 0, 5, 10,20 % on dry weight basis and was concluded that additive reduces plasticity properties and FSI by 50% by adding 20% flyash. Hydraulic conductivity due to increase in maximum dry unit weight with increase in Flyash decreases. When Flyash increases, OMC decreases and unconfined compressive strength increases.

Bhubneswari et al. (2005)[3] had studied on engineering properties of soil through experimental programme. In large infrastructure projects of highways, railways and earth dam require hauling of soil and urban areas do not provide us with that luxury. And much of the soil is expansive and high plasticity. Through extensive laboratory and field trials they came to a solution that flyash can stabilize the soil. Flyash is freely available in locality of a thermal power plant. Flyash was added at varying percentage of 10, 20, 25, 30, 40, 50 and a major problem was to mix the soil and flyash to form a uniform mass. The adopted method was placing these material in layers and operating a "Disc Harrow". Following it an embankment of side 30 by 6 and 0.6 m was successfully adopted and the various insitu test carried out to find suitability of embankment.

Amu et al. (2005)[2] used Class F flyash to stabilize expansive soil and found out that 3% Flyash with 9% cement is a better stabilizer than 12% cement. Both Cement and Flyash were increased at increment of 1%.

Gopal Krishna et al. (2013)[7]had studied the effect of class F flyash and Zycosil on soaked and unsoaked CBR of BC soil. Zycosil is a water-proofing liquid. Both Flyash and Zycosil were added upto 5% at increment of 1% keeping other constituent constant and was found that unsoaked CBR is highest for 2% Zycosil+3% Flyash and for soaked CBR its 2% Zycosil+4% Flyash.

Sabat and Pradhan (2014)[19] had studied effect of polypropylene fiber (content and length) on compaction properties, UCS, soaked CBR and swelling pressure of highly expansive BC soil as a subgrade material, Fibers having length of 6, 12, 24mm were used and were added upto 1.5% at an increment of 0.25%. The main objective was that only adding flyash though increases strength and bearing capacity of soil but its swelling pressure does not reduce substantially. So polypropylene fibres were introduced as reinforcement. It was found that optimum quantity of flyash at 20% and optimum content and size of fiber as 1% and 12mm. Class F flyash was used. These flyash belongs to Odisha. Only adding 20% fibre leads to 58% increase in UCS and 91% increase in soaked CBR and 38% reduction in swelling pressure. When 1% fibres were introduced with 12mm length then, 70% increase in UCS, 81% increase in soaked CBR with respect to only Flyash based stabilization and increase upto 170% in UCS and 247% in soaked CBR with respect to virgin soil.

From economic criteria, saving of 7% and 13.6% in cost of construction/m^2 of pavement area for subgrade stabilized with 20% flyash and subgrade stabilized with 20% flyash and reinforced with 1% fibres respectively as compared to virgin soil.

Karthik et al. (2014)[9] conducted experiment on locally available red soil near Tirupur District. Flyash was added at 0, 3, 5, 6, 9% and it was found that at 6% Flyash can be used as optimum as MDD was maximum, UCS increases by 228%. The bearing capacity of soil escalates from 10.93 to 35.06 Kg/mm^2 but every parameter rapidly falls at 9% Flyash. Inference concluded states that had a flexible pavement constructed on natural soil, it would be 12 inches which gets reduced to 8.5 inches by adding 6% Flyash to soil.

Mohanty and Roy (2015)[11]studied the effect of BC soil from Khairi in Nagpur and flyash from Thermal plant at Jharsuguda, Odisha. The soil was categorized as CH. Flyash added at 10, 20, 30, 40, and 50%. It was observed that on adding flyash initially MDD, UCS decreased and then increased. At 30 and 20% MDD and UCS obtained maximum value, and further addition of Flyash only decreased them. Unsoaked CBR at 20% was maximum while soaked CBR at 30% was highest. FSL also decreased with Flyash and it was concluded that with addition of Flyash strength increases while swelling decreases.

1.2. Stabilization of expansive soil using Cement Kiln Dust (CKD)

CKD is a fine-powdery material, portion of which contains some reactive calcium. It highly depends on the location within of dust collecting system, dust collecting facility and the type of operation and fuel used. The advantages of CKD includes pore refinement and early strength in soil. CKD varies wth every plant and its mineral composition must be evaluated before using it. It contains high alkali levels and is incorporated with grounded GBFS to prevent silica-alkali reaction properties.

Peethamparan and Olek (2008)[16] examined effects of four cement kiln dust of various physical and chemical properties on Na-Montmorillonite clay. The main focus was to study about feasibility of using CKD as potential stabilizer for Na-Montmorillonite rich soil. The Atterberg's limit, pH values, stiffness, UCS and stability were measured as a function of CKD content and curing period and were compared to that of untreated clay to determine enhancement extent. CKD decreases plasticity index and improving workability of clay, increased initial pH of clay and provides favourable environment for further chemical reactions to take place. The addition of CKD and subsequent compaction increased UCS and stiffness of clay and its structural properties. The extent of improvement is a function of chemical composition of the free lime. It was also inferred that length of curing after compaction played a major role in the stabilization process of the clay.

Moses and Saminu (2012)[12] found effect of CKD (upto 16%) on engineering properties of expansive clay. CKD added by dry mixing at 0, 4, 8, 12, and 16%. The soil were compacted using energies of British Standard Light and West African Standards. The virgin soil was classified as CL. The soil showed improvement but falls short of values specified for base material stabilization using OPC. CBR showed a rise from 2 and 3% to 12 and 16 according to BSL and WAS but failed to meet the minimum of 30 sub-base course at 12% CKD. Theyconcludedthat the stabilized soil failed in UCS, CBR and durability test for sub-base and base of pavement.

Salahudeen et al. (2014)[21] Stabilized expansive soil using CKD and concluded that it can improve subgrade for light traffic road and in lime stabilization as an admixture, but CKD has high loss on ignitionand should be avoided in expansive soil. BC soil was treated with 10% CKD and was evaluated for use in flexible pavement. BSL (standard proctor) showed improvement. Reduction in particle size with curing period was also observed when viewed through an electronic microscope. This was concluded that CKD can stabilize BC soil for use as a subgrade in flexible pavement only for light traffic roads.

Amadi and Lubem (2014)[1] studied the effect of CKD (upto 16%) on 10% quarry fine stabilized BC soil and found reduction in plasticity index, MDD and increase in OMC and CBR.

1.3. Stabilization of expansive soil using Phosphogypsum (PG)

PG Refers to gypsum formed as by-product when phosphate ore is processed into fertilizer with sulphuric acid. Due to presence of naturally occurring uranium and radium in ore, PG can be radioactive. Though gypsum is widely used, PG is stored indefinitely for its weak radioactive nature. Approximately 4-6 tonnes of PG generated to produce a tonne of phosphoric acid an 85% of the total PG is discarded into ocean beds, ponds and river or stored (Rashad, 2017)[18]

Misra and Mathur (2004)[10] stabilized expansive soil with phosphogypsumand found its optimum percentage as 40%

Yilmaz and Civelekoglu (2009)[23] studied effect of gypsum on atterberg's limit, UCS at 7days, Swelling potential and cation exchange capacity of bentonite and inferred that by adding 5% gypsum the properties of expansive soil improved significantly. Gypsum was added in increment of 2.5% upto 10% and the soil and stabilizers were dry-mixed.

Divya Krishnan et al. (2014)[6] studied combined effect of Flyash (class C) and phosphogypsum on expansive soil specifically on UCS parameter and concluded that by adding these two stabilizers the UCS increases. The UCS further increase with increase in curing period. Flyash was kept constant at 5% and PG was added at 2, 4, and 6%. Soil excavated from a depth of 0.6m below NGL. Two different virgin soil samples were taken from different sites but are categorized as CH and UCS was done at 3 and 7 days of curing and strength was increasing and it was assumed at 28 day check since curing is a governing factor in UCS test, strength would be even higher. The two soil samples S_1 and S_2 showed as increase in 1.72 and 2.25 times UCS at 3day of curing at 5% Flyash and 2% PG.

1.4. Stabilization of expansive soil using Granulated Blast Furnace Slag (GBFS)

Ground GBFS is obtained by quenching molten iron slag. The slag is a by-product of iron and steel-making from blast furnace in water or steam, to produce a glassy, granular product which is then dried and powdered. GBFS is near-white in appearance. GBFS has a good resistance against sulphate and now has effectively replaced sulphate resisting cement. GBFS has cementitious properties and replacement varies from 30-85%.

Cokra et al. (2009)[5] used GBFS and grounded GBFS-cement to stabilize an artificially prepared expansive soil. GBFS and grounded GBFS were added in proportion of 5% and 25% increment of 5%. These stabilizers decreased the amount of swell whereas increased the rate of swelling. After leachates analysis it was concluded that that if expansive soil existed near drinking water wells, these stabilizer should not be used.

Sharma and Sivapullaiah (2012)[22] studied effect of ground GBFS on UCS of expansive soil at 7, 14 and 28 days of curing and found that strength development depends more on ground GBFS content and effect of curing is less pronounced. There was also an increase in tangent modulus values with increase in ground GBFS content. The main objective was to substitute lime or cement with GBFS and to alter it to take more load from foundations. Only modified proctor and UCS test were done. BC soil was obtained from Belgaun in Karnataka cut out from a depth of 1m through open excavation with montmorillonite as a key player and GBFS obtained from cement industry and were dry-mixed. It was observed that on adding GBFS, the OMC decreased and MDD increased due to decrease in clay minerals and increased frictional resistance. And at 20% maximum MDD and minimum OMC. The strength of specimen increased by 20% at 7 and 14 days of curing, at 40% for 28 days and upto 20% increase in Tangent Modulus with 20% GBFS stabilized soil.

Osinubi et al. (2012)[14] studied effect of stabilization delay in strength characteristic of BC soil stabilized with blast furnance slag and cement and concluded that compaction delay reduces the strength of stabilized soil.

Celik and Nalbantoglu (2013)[4]studied effect of grounded GBFS on plasticity index, linear shrinkage, swelling potential of lime stabilized sulphate-bearing expansive soil. Ettringite is an expansive mineral which develops in presence of sulphate, calcium and aluminum compounds of clay. Lab test were performed on lime treated expansive soil with varying concentration of added sulphate and then same test was repeated on lime treated soil with same amount of sulphate but with 6% Slag, and three different concentration (2000, 5000 and 10000 ppm) were used in the study and atterberg limit, linear shrinkage and swelling were investigated. Test result showed that presence of sulphate in soil resulted in abnormal increase in plasticity as well as shrinkage and swelling of the soil at 5000 and 10000 ppm of sulphate. At 10000 ppm of sulphate the rate of swelling becomes nearly three times to the virgin soil. On scanning it was found that there was a growth of Ettringite minerals. It was found that adding grounded GBFS to the lime stabilized expansive soil prevents growth of ettringite mineral. These minerals leads to increase in plasticity index, linear shrinkage, swelling potential of the specific soil. At 6% slag, the lime treated expansive soil showed a decrease in swelling potential from 8% to 1% at 10000ppm of sulphate content whereas in 5000ppm sulphate concentration there was no swelling found.

2. CONCLUSION

From the review of literature on stabilization of expansive soil using solid waste, the following conclusion can be drawn

1. Stabilization of expansive soil improves the geotechnical properties of the expansive soil.
2. Majority of researchers have discussed the effects of stabilization on index properties, compaction properties, UCS, CBR and swelling properties of expansive soil.

3. The effect of stabilization on mechanical properties (shear strength, splitting tensile strength, stiffness, compressive strength), hydraulic conductivity, consolidation properties of expansive soil have not been studied by most researchers.
4. Investigation of contaminants on geotechnical properties of stabilized soil, mineralogical studies, durability, feasibility and viability aspect of stabilization are limited in literature.
5. Behavior of stabilized soil subjected to cyclic loading is hardly covered in the literature.
6. Methods of construction utilizing these stabilizers are hardly found in literature.
7. Results of field studies are hardly touched in the literature.
8. Very limited research regarding Sulphur rich expansive soil.
9. Studies regarding use of solid waste as stabilizer have been mostly confined to subgrade of pavement. Studies regarding its use as liner material in landfills, canal, backfill material in retaining wall and as a sub-base material in pavement is negligible in the literature.
10. Future research on stabilization of expansive soil using industrial waste should take into consideration the above mentioned issues.

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