A Literature Review on Stabilization of Kuttanad Clay Soil

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Abstract- *Kuttanad is located in Alappuzha district of Kerala, India. It is an agricultural area and is known for underwater. The clay in this region is dark grey colour and the dominant clay minerals are kaolinite and illite. Kuttanad clay is characterized by its high compressibility and low shear strength. The low bearing capacity of the soil has lead to foundation failures and embankment failures. The foundation recommended for such area is raft or pile foundations but it is not economical. Thus the Kuttanad clay requires an effective and economic method of stabilization. The main aim of this paper is review the history, benefits, applications and possible executive problems of different types of stabilizers used in Kuttanad clay soil reference to published scientific data. On other words, this paper is going to investigate why, how, when, and which stabilizers have been used in Kuttanad clay soil stabilization projects.*

Keywords- Stabilization, Kuttanad soil.

I. NEED FOR SOIL STABILIZATION

Some buildings are constructed with foundations that are inadequate for the soil conditions existing on the site. Because of the lack of suitable land, homes are often built on the marginal land that has insufficient bearing capacity to support the substantial weight of a structure. Land becomes scarce with growing of cities and it often becomes necessary to construct buildings and other structures on the sites where unfavorable conditions are present. One of the most important characteristic of clayey soils is their susceptibility to the volume change sourced from swelling and shrinkage. Such volume changes can give rise to ground movements which may result in damage to buildings.

Clay is a natural material composed primarily of fine-grain minerals. It consists of little particles that have plastic and adhesive properties. Clay conjointly possesses little voids and pores. Therefore it is capable of holding water. During this condition clay tends to expand and shrink, that result in settlement. once exposed to increments of water, clay tends to melt and liquefy. Clay typically causes difficulties in construction with its low strength and stiffness. This has caused serious issues in geotechnical engineering as a result of weak soil might cause injury to the muse of buildings and cracks on the road pavement

However, recent technology has increased the number of traditional additives used for soil stabilization purposes. Such non-traditional stabilizers include Polymer based products, Copolymer Based Products, fiber reinforcement, calcium chloride, and Sodium Chloride.

1.1 Need of stabilization of kuttanad clay

Kuttanad is located in Alappuzha district of Kerala, India. It is an agricultural area and is known for underwater. The clay in this region is dark grey colour and the dominant clay minerals are kaolinite and illite. Kuttanad clay is characterized by its high compressibility and low shear strength. The low bearing capacity of the soil has lead to foundation failures and embankment failures. The foundation recommended for such area is raft or pile foundations but it is not economical. Thus the Kuttanad clay requires an effective and economic method of stabilization.

By the stabilization better soil gradation, increase in durability, increase in strength, reduction of plasticity index and reduction in swelling potential is achieved. Stabilization improves the properties of construction materials and gives the following attributes

a) After saturation with water substantial proportion of their strength is retained.
b) Resistance to erosion.
c) Surface deflection is reduced.
d) The elastic moduli of layers constructed above stabilized layer are increased.
e) The stiffness and strength of a soil layer can be increased through the use of admixture to reduce the thickness of the road pavement.

II. TYPES OF STABILIZATION

2.1 Stabilization Using Fibres

The fiber-reinforced soil behaves as a composite material. When loaded, the fibers mobilize tensile resistance, which in turn imparts greater strength to the soil. Both synthetic and natural fibers are widely used for this purpose.

2.1.1 Stabilization using Natural fibres

Use of these fibers in geotechnical engineering has been in the construction of pavement layers, road and railway embankments, and retaining walls as well as in the protection of slopes. Natural materials, such as bamboo, jute, banana and coir have been advantageously used over synthetic fibers as soil reinforcing materials for a long time in several South Asian nations. The main advantage of natural fibers is that they are locally available and are of low cost. They are biodegradable and hence do not create disposal problem in environment.

Coir geotextiles serve as an effective filter and reinforcing material for the clay dykes and help in early consolidation of the clay, thereby minimizing the chance of early failure. Till the end of first month, the penetration resistance of coir geotextile protected clay dyke is more than that of the non-protected dyke after a certain load, the value of which increases with time. After 1 year with the draining out of flood water, the coir protected dyke offers more penetration resistance compared to the non-protected dyke. Thus, compared to conventional clay dyke, Coir geotextile protected dyke is found to be least affected by the effect of flooding. [11]

Environmental problems associated with Human hair fiber, a non- degradable matter can be minimized by using the same as a reinforcing agent in soil stabilization. Studies shows that Human hair fiber, as a cheap reinforcing agent, can be used for stabilizing clayey soil found in low lying areas of Kerala, India. Human hair of length 4-40mm and of diameter 40-110μm were used. The test result reveals that the strength significantly improves with the inclusion of Human hair and it further improved when optimum percentage of both lime and human hair were added together. The rate of strength increment by addition of lime follows a specific pattern. Rate of strength achievement in 2-14 days of lime curing is higher than that of 14 -28 days. [28]

Another method of reinforcement of kuttanad clay is by adding banana fibre as a reinforcement material in Kuttanad soil. The percentage of banana fibre by dry weight of soil was taken as 0.25%, 0.5%, 0.75% and 1% and the lengths of fibre were taken as 10 mm, 20 mm and 30 mm. This results the water absorption capacity of banana fibres reduces by 80% when the fibres are coated with bitumen. The unconfined compressive strength of specific length fibre reinforced soil increases with fibre content up to 0.5% and then reduces. The unconfined compressive strength of fibre reinforced soil is observed to increase with increase in the length of banana fibres. The optimum percentage of lime is obtained to be 6%. The unconfined compressive strength of soil reinforced with 0.5% bitumen coated fibres of random length and 6 % lime shows an increase by 75% compared to that with untreated fibres. Both untreated and bitumen coated fibres are more severely attacked by alkaline medium and water when subjected to alternate wetting and drying type exposure than continuous immersion type exposure. [19]

Quarry dust produced in aggregate crushing industry is a waste product which may cause serious environmental problems and its utilization in stabilization of Kuttanad soil is the best way to dispose it. The CBR value goes increasing as percentage of quarry dust increases up to 25%, then decreases on further addition. There had an increase in optimum moisture content with increase in percentage of bamboo fiber to the quarry dust treated soil. There had a decrease in maximum dry density with increase in percentage of bamboo fiber to the quarry dust treated soil. About 1% of bamboo fiber to quarry dust treated Kuttanad soil can improve soil properties much more than soil-quarry dust mix. [7]

Coir pith is used to stabilize the soil. The result of treated and untreated fibre pith within the compaction and therefore the shear strength characteristics of the soil, mixed with fibre pith in variable percentages of third to three by increment of 0.5% improve the characteristics of soil as the untreated fibre pith content will increase the maximum dry density decreases. The effect of treated and untreated coir pith in the compaction and the shear strength characteristics of the soil, mixed with coir pith in varying percentages of 0% to 3% by increment of 0.5% improve the characteristics of soil As the untreated coir pith content increases the maximum dry density decreases. This is due to the replacement of soil with coir pith of specific gravity lower than the soil. The maximum dry density increases with increase in the treated coir pith content. The optimum moisture content of treated soil specimen at first decreases and then increases with the addition of 1% coir pith. The maximum shear strength value increased. [1]

Rice straw reinforced bunds are built between paddy fields. These bunds are used for transport of both men and vehicles. The unconfined compressive strength of soil reinforced with 0.5% untreated straw of random length shows an increased with respect to that of unreinforced soil. The optimum percentage of lime is obtained to be 7%. The unconfined compressive strength of soil reinforced with 0.5%

untreated straw of random length and 7 % lime shows an increase with respect to that of unreinforced soil. The unconfined strength of reinforced soil with curing decreases because of deterioration of straw in alkali medium. The fibres are more severely attacked by alkaline medium and water when subjected to alternate wetting and drying type exposure than continuous immersion type exposure. [9]

Improvement of shear strength using locally available waste materials could be economical and eco-friendly. The effect of sisal fibre on dry density, moisture content and shear strength parameters is found out. The dry density was found to be decreasing while the optimum moisture content increased with respect to increase in percentage of sisal fibre added. Shear strength parameters also showed variation with addition of different percentage of sisal fibre. [15]

2.1.2 Stabilization Using Artificial fibres

The solid waste in future will be major problem and needed the solution. Otherwise an oversized area won't be utilized due to solid waste layer overtopping it. The solid waste is also utilized as a helpful material with the soil rather than high prices materials like lime, cement etc.
Out of various waste materials present, the suitable once are non-degradable waste that is plastic waste. This plastic waste has a vast variety to use the types of plastic that can be used effectively are PET, HDPE, LDPE, PP etc. The suggested proportion of the plastic waste to be mixed with soil in different proportions. The need uses to carry out the tests have the influential properties like Specific gravity, MDD, OMC, CBR, Permeability, Tri-axial test has to compared for the suggested proportions to see the effect for various plastic waste. This will pave the way to use these plastic wastes in an exceedingly additional technical manner for numerous engineering construction functions.[16]

Many studies shows that the result of random inclusion of polypropylene fibers on strength characteristics of Kuttanad soil impressive. They have conducted direct shear tests, unconfined compression tests and CBR tests on un-reinforced in addition as reinforced soil to research the strength characteristics of fiber-reinforced soil. The test results reveal that the inclusion of arbitrarily distributed polypropylene fibers in soil will increase peak and residual shear strength, unconfined compressive strength and CBR value of soil. This will pave the way to use these plastic waste in a more technical manner for various civil engineering construction purposes. [16]
CBR value of soil is improved by adding coir and polypropylene fibers. Coir fibers show very close percentile improvement in CBR value of soil when compared with polypropylene stabilized soil. Hence the inclusion of discrete coir fibers and polypropylene fibers in random fashion significantly improves the CBR value of clay and hence could be effectively used for pavement sub-grade purposes. [18]

2.2 Stabilization Using Waste Products

Land fill depletion can be prevented by means of utilising waste materials as additives. Metakaolin is a supplementary cementing material manufactured from kaolin. It is neither a by-product of any industrial process nor formed naturally. Crumb rubber powder a by-product of used automotive tyres that are recycled rubbers retrieved from discarded used truck scrap tyres by crushing and removal of the textiles and metal fibres are effectively used as a soil replacement material which not only solves environmental problems but also provides a new resource for construction industry and an economically feasible disposal method of waste tyres to conserve natural resources. Terrazyme is a natural, non-toxic, non-corrosive and non-inflammable liquid, produced by formulating vegetable and fruit extracts. By adding these three stabilizers in to the kuttanad clay, that improves the soil properties. With an increase in curing period the plasticity characteristics of Kuttanad clay treated with Metakaolin, Terrazyme and Crumb Rubber Powder progressively decreased to a minimum value. With an increase in curing period the Shear strength characteristics of Kuttanad clay treated with Metakaolin, Terrazyme and Crumb Rubber Powder progressively increased to a maximum value. Kuttanad clay treated with Traditional stabilizers showed maximum improvement in shear strength behavior, reduced plasticity and consolidation characteristics after 14 days of curing period when compared to Non-traditional and By-product stabilizers. [24]

RHA is pozzolanic in nature and is produced from rice husk by burning it at a controlled temperature. Effectiveness of combination of rice husk ash (RHA) and lime as stabilizing agents improves the strength properties of soil. various percentages of combination of RHA and lime are used in triaxial sample preparation and thus the optimum percentage of combination is finds out. It is observed that the addition of RHA and lime to Kuttanad clay alter its stress-strain response considerably. The maximum dry density diminished with increase in lime up to 6 regardless of rice husk ash content. beyond 6 June 1944 lime there's a rise in maximum dry density. The stress-strain behavior of Kuttanad clay improved with the addition of RHA and lime. The maximum dry density decreased with increase in lime up to 6% irrespective of rice husk ash content. Beyond 6% lime there is an increase in maximum dry density. The stress-strain

behavior of Kuttanad clay improved with the addition of RHA and lime. [13]

Quarry dust produced in aggregate crushing industry is a waste product which may cause serious environmental problems and its utilization in stabilization of this soil is the best way to dispose it. It was found that the liquid limit, plastic limit and plasticity index decreases irrespective of the percentage addition of quarry dust in the Kuttanad soil. It was noticed that there had an increase in maximum dry density and decrease in optimum moisture content with increase in percentage of quarry dust. It was found that the CBR value goes on increasing as percentage of quarry dust increases up to 25%, and then decreases on further addition. Addition of about 25% of quarry dust in Kuttanad soil can improve soil properties which enables it to be used economically for the improvement of soil and thus reducing the environmental problems. [7]

2.3 Stabilization with cement and flyash

In Kuttanad region of Kerala, clay deposit extends to terribly giant depths that construction in these areas while not applying stabilization techniques typically lead to failure of structures. The effectiveness in exploitation cement and bio accelerator stabilization as a way for up the strength of Kuttanad clay. The increase in cement content and curing period resulted in strength gain of the soil, due to the formation of cementitious products in soil. [12]. An attempt was made to obtain a relation between the water cement ratio, curing period and unconfined compressive strength. This enables prediction of water cement magnitude relation to be adopted in field for attaining needed strength when a given solidification amount. The water cement ratio to be adopted in field can be expressed by the relation,

$$W/C = 0.297(qu/d) + 21.64$$

Where w = water content, c=cement content in percentage of dry weight of soil, qu = unconfined compressive strength required after a curing period of d days. [6]

The presence of the Sodium Silicate additive along with cement has a marked influence on the cement hydration process, leading to substantial strength development of treated soil. It accelerates the formation of calcium silicate hydrate, which is responsible for binding the soil particles, thereby producing a hardened matrix with appreciable strength characteristics. The addition of Sodium Silicate to the soil results in the silicate ions getting adsorbed on the positively charged sites in the clay. With the addition of cement and the subsequent reactions, the fabric gets thoroughly bonded by the cementitious products formed. The strength of the cement treated soil improves with increasing dosage of Sodium Silicate additive, and the effect of adding Sodium Silicate along with cement as binder becomes more significant with reducing water content ratios. [25]

Industrial advancement has merits and demerits. one in all the demerits is discharge of various waste materials within the kind of effluents. This effluent sweeps in to the soil and therefore pore fluid properties get altered. The changes within the properties of pore fluid have a good impact within the soil behavior. When this soil is used for infill or foundation for the structures it is necessary for a geotechnical engineer to understand changes in engineering properties of soil and taking necessary precautions according to the variations in the soil behavior. There is an increase in the liquid limit and plasticity index properties of the Acetic acid and NaOH contaminated sample. Acetic acid contaminated sample shows a reduction in swelling and compression index. [3]

Organic content in clay is a key factor which affects the index properties, unconfined compressive strength and compaction behavior. Fly ash stabilization of clay is a normally used stabilization methodology in pavement construction. Presence of organic content affects the stabilization of clay using fly ash, as a result of organic content influences the ph of clay and therefore the pozzolanic reaction is additionally affected. Optimum percentage of fly ash for stabilization of kaolinite decreases with increase in organic content. additionally the maximum shear strength of fly ash stabilized kaolinite is decreasing with increase in organic content. Index properties, compaction behavior and shear strength of kaolinite are plagued by the presence of organic content. Index properties, compaction behavior and shear strength of fly ash treated kaolinite also varies with organic content. Organic content is an important parameter to be considered during fly ash stabilization. [21]

2.4 Stabilization Using Soil Reinforcement

EKG reinforcement or soil nails not solely offer reinforcement, however additionally increase the shear strength of the soil in which they're placed in addition as improving soil-reinforcement bond. The development of EKG materials offers slope stabilization of embankments and cuttings in fine grained soils, which is able to considerably increase the factor of safety, address pore pressure changes and additionally avoids importing earthwork materials or aggregates. EKG reinforcement or soil nails not only provide reinforcement, but also increase the shear strength of the soil in which they are placed as well as

improving soil-reinforcement bond. The development of EKG materials offers slope stabilization of embankments and cuttings in fine grained soils, which will significantly increase the factor of safety, address pore pressure changes and also avoids importing earthwork materials or aggregates.

By inserting a grid of anodes and a cathode into the ground and applying an electrical potential difference across the slope drives water away, via the cathodes and creates physical changes in the embankment, promoting consolidation of the slope materials. Anodes and cathodes were connected to a DC power circuit and electrified for a calculated period based on water content, strength and electrode spacing. The liquid limits and plasticity indices decrease significantly with increasing applied voltage. In the case of UCC, it increases with increase in voltage. The EKG treatment is an effective method for slope stabilization. Sustainability benefits including reduced carbon footprint and elimination of the use of primary aggregates. [21]

Reinforced earth technique is taken into account as an efficient ground improvement technique owing to its costeffectiveness, simple adaptability and reliability. in this context, a close study is undertaken to review the result of exploitation waste plastic bottle (PET bottle) strips as a reinforcement material in kuttanad clay. the maximum dry density increase with the increase in the strip content up to optimum strip content then decreases. CBR value will increase with the increase within the strip content up to optimum strip content and so decreases. The optimum strip content corresponding to maximum improvement in CBR value is found to be 0.6%.[23]

2.5 Stabilization Using Lime

Effect of Rice Husk Ash & Lime can make changes in the Properties of Soft Clay. Kuttanad clay is very soft in its character so it is necessary to adopt a suitable method to improve the bearing capacity of clay. Rice husk ash (RHA) and lime are mixed with the soil to improve its load bearing capacity. The studies showed that 15 % RHA and 6% lime gave the optimum CBR values. [29]

The eggshell primarily contains lime, calcium and protein. It has been in use as a supply of lime in agriculture that confirms that lime is present in extencive quantity in shell. Whwn egg shell powder is added to the soil the optimm moistre content decreases and the dry density decreases.[27]

Heavy laden loads of vehicles conveying heavier stresses concentrates especially on roads running in clayey soil zones which create significant problems for pavements and hence need to be stabilized. Insecure soils make huge issues for asphalts and henceforth should be settled. increase of sea shell powder, maximum dry density goes on increasing while optimum moisture goes on decreasing which is a good sign of soil as more dense and hard. A large difference in the cost of the pavement construction was recorded before and after the stabilization. Cost optimization was done. [4]

Addition of lime reduced the linear shrinkage to a greater degree than the same percentage of bagasse ash. When lime and bagasse ash are combined at the optimum ratio of 4:1 reduces the linear shrinkage. Bagasse ash can be used to partially replace lime in clay stabilization. [17]

2.6 Stabilization Using Micro Organism

An innovative different approach to effectively improve engineering properties of soils lies with the combined use of microorganisms, nutrients and biological process naturally present in subsurface soil.. Microorganism bacillus pasteuri was used to study the effect on Atterberg's limit and unconfined compressive strength of Kuttanad clay, bentonite and laterite soil. The liquid limit and plasticity index for all clay soils decreased and the unconfined compressive strength increased. Decrease in plasticity index was very high for Kuttanad clay followed by bentonite and laterite. The soil treated after sterilization shows an improvement in the properties but that was less than the unsterilized soil. Naturally present microbes may also be taking part in calcite precipitation leading to cementation of the soil. Nutrient solution has very less impact on cementation process of Kuttanad clay and bentonite. But for laterite soil the nutrient solution without microbes made the soil more plastic. [22]

III. REVIEW ON GYPSUM

Gypsum used as a stabilizer to improve the some engineering properties of the clays. As reported by Yilmaz and Sendir (2002), Yilmaz (2007) and Yilmaz and Yuksek (2008). Microscopic determinations on the gypsum revealed that gypsum contains very low clay, calcite and anhydrite

For solving problems of expansive soil it is necessary to stabilize it with any of additive substance such as lime, gypsum etc. After stabilization soil properties are altered such as bearing capacity, shear strength & stability of soil which are increased and the shrinkage, swelling are decreased. Also the cost analysis of different mixtures is studied and it is found that the mixture (2% Lime + 4% Gypsum) is quiet suitable for reduction in plasticity and swelling at possible lowest cost [2].

The effect of gypsum stabilization on dispersive (erodible) soils particularly in earth dam wall construction, and reported that gypsum in a very finely divided powder form can be used as a stabilizing material due to its relatively cost and reasonable solubility in water. The rate of base exchange [30]
The effect of gypsum on the improvement of the soil depends on numerous factors, curing period being particularly important. Appropriate curing time for optimum improvement was determined by obtaining the swell percent variation with cure time up to 2 months using the considered maximum gypsum content. gypsum is a good additive for improvement of the swelling clays, contamination of the groundwater by the gypsum should also be considered, as well as the use of sulfate resistant cement for adjacent concrete structures. [10]

Hence there is a possibility to stabilize the clay (kuttanad clay) soil with gypsum.

IV. CONCLSION

The literature contains a vast number of stabilizing techniques such as lime, cement, waste products, fibres, reinforcement, microorganism and fly ash for treatment of kuttanad clay soils. However it is very difficult to find significant literature on gypsum as a stabilization agent for kuttanad clays. Stabilization of the bentonite clay with gypsum and influence of the gypsum on the physical, swelling and strength characteristics of bentonite was studied by Işık Yilmaz, Berrin Civelekoglu. So there is a possibility to stabilize the clay (kuttanad clay) soil with gypsum.

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