International Journal of Interdisciplinary Innovative Research &Development (IJIIRD)

ISSN: 2456-236X

Vol.04 Issue 01|2019

A Review of Soil Stabilization Using Polymers

Dr.Bharati Shete[1], Ms.PoojaAmzare[2]

[1]*Assistant Professor, Department of Civil Engineering, Dr.Sau.KamaltaiGawai Institute of Engineering &Technology, Darapur Amravati*

[2] *M.Tech Scholar, Department of Civil Engineering, Dr.RajendraGode college of Engineering and Technology Amravati*

ABSTRACT

Soil is extremely complex, heterogeneous substance which has been subjected to varieties of nature. Properties of soil do not change only with location to location but also with respect to depth, climate and drainage condition of soil. Soil stabilization is the process by which strength properties of soil can be improved with the use of adding some materials like polymer. There is a rapid increase in waste quantity of plastic fibers, if this waste can be utilize for stabilization of soil than problem of solid waste can be resolve and also cost of soil stabilization can be reduced. Polymer soil stabilization is advanced soil stabilization technique which deal with civil construction polymer soil stabilization contain Nano polymer technique which is contain vary fine particle .that's why the void filled with polymers and stabilization is possible .

Polymer material is characterized by long chain of repeated molecules unit known as mars. These long chains interline to from the bulk of plastics. the naturals by which the chain interline is determine the plastics macroscopic properties and binding strength. This study presented a review of literature on soil stabilization using polymers.

***Keyword** - Soil Stabilization, Polymers, SoilTech, DustTech.*

1. INTRODUCTION

Soil is one of the most commonly encountered materials in civil engineering. All the structures except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face huge issues, when structures founded on the soil which is expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals like montmorillonite, illite, kaolinite etc. in considerable amount. Due to the clay minerals, the swelling soils expand on wetting and subjected to shrinkage on drying. These soils are commonly unsaturated.

The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season. Due to this cavity formed, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement.

Foundation is very important part of any civil engineering construction work. Load of any structure is ultimately taken by foundation; hence it is very necessary to prepare a sufficient strong base for any structure. Bottom most portion of structure is consist of natural earth surface, this earth surface is known as soil. For successfully transfer of load of structure on the soil it is necessary to prepare soil with desirable bearing capacity, also it is not possible every time to get soil having sufficient strength at every place. Process of increasing strength of soil by artificial process is known as stabilization of soil. The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Soil stabilization is important for road construction, and other concerns related to the building and maintenance of infrastructure. Stabilization of soil is carried out by adding lime, coconut coir, fly ash, plastic fiber etc. with the soil.

Investigation into the properties of SoilTech and DustTech treated expansive soils would assess thesuitability of using SoilTech and DustTech as stabilizer to reduce swelling of expansive soils. This review study presents the effect of polymers on soil stabilization on engineering properties of expansive soil.

There are two types of Polymers as discussed below

SoilTech Mk. III is a third generation Nano polymer binder used for stabilizing soils for improving the strength of the soil and thereby improving the stability.

DustTech is a water based polymer emulsion which is sticky to touch apparent odour; totally non-flammable. It is a combination of various water based copolymers including ethelyne glycol, polyvinyl acetate, polyvinyl alcohol stabilizer and colanyl pigment for coloring. DustTech is totally miscible with water and will be progressively diluted if admitted to waterway. The base polymer is slowly biodegraded. DustTech is nonflammable, not hazardous, nontoxic, and environmental free.

1.1 Problem Related To Soil

Problems occurring with existing soils are that which encountered by geotechnical engineers. They are considered as a high natural hazardous, which can cause extensive damage to structures such as foundations, roads, highways, building, airport runways and earth dams if not adequately treated. Damage caused by expansive soils exceeds the combined average annual damage from floods, cyclone and earthquake. Some remedial measures can be taken to prevent the damages. These are exchanging the soil under the foundation with the other soil, controlled compaction of expansive soil, moisturizing, structure of moisture barriers, lime stabilization and cement stabilization, modification of the structure and lowering the foundations from upper layer to the lower level.

1.2 Remedial Measures for Above Discussed Problem

Soil Stabilization is the process of making something physically more secure or stable. Soil stabilization is process of blending and mixing material with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of additive that change the properties of soil.

1.3 Classification of Soil Stabilization Techniques

Soil stabilizations are classified on the method ofstabilization.

1.3.1 Mechanical stabilization - The old method of stabilization is mechanical in nature. Mechanical methods involve physically changing the property of the soil, in order to affect its grade, proportion, and other characteristics. Portable compaction is one of the major types of soil stabilization; in this procedure a heavy weight is put repeatedly onto the ground at regular intervals. Vibrating compaction is another useful technique that works on similar principles; it removes voids between the soil particles by vibrator.

1.3.2 Chemical stabilization - Chemical methods are the methods which use chemicals to increase the strength of soil. Chemicals are used to change the proportion of soil particle. All of these techniques rely on adding an additional material to the soil that will physically interact with it and change its properties. There are a number of different chemicals that utilize cement, lime, flyash, orkiln dust for soil improvement.

1.3.3 Soil Stabilization by using Polymer - Researchers invent some innovative techniques for soil stabilization like using polymer, and polypropylene etc. These new polymers and substances have a number of important benefits over traditional mechanical and chemical solutions; they are economic and more effective in general than mechanical methods, and significantly less dangerous for the environment than many chemical tend tobe.

1.4 Polymers

1.4.1 SoilTech Polymer -It is a stabilization agent and was specifically designed & developed for mine haul road stabilization, where excessive loading occurs and where all-weather roads are required. This technology is now used in commercial road design.

SoilTech Mk. III stabilizing polymers are elastomers, which gain strength from mechanical compaction and do not become brittle when cured. The elastomers are flexible in nature and allows certain amount of flex under load and does not become brittle unlike cement stabilization, will not crack under excessive loading – one aspect in reducing layer work in design phases.

In most cases, the in-situ soils in the area can be used for stabilization. The in-situ materials which would normally be classified as unusable or waste materials, can be transformed into suitably modified aggregates for use in base and sub-base layer construction. The SoilTech Polymers are the forefront of binding marginal soils and turning these materials into useable road construction aggregate. SoilTech Mk. III has been extensively tested with in-situ materials in various parts of the world. SoilTech Mk. III has been extensively utilized in base and sub-base stabilization using in-situ materials, throughout the developing world.

1.4.2 Benefits of SoilTech Polymer - Reduce the consumption ofqurry aggregate in road and there by the minimize the significant environment impact. In situ material can be usd. Reduced road crust speed up to construction time Reduce construction cost. Reduce maintenance . Increase the strength and stability of base &subbase layer

1.4.3 Advantage of dust tech - Control dust –keep livable thing healthy. Open road to traffic immediately after applying DustTech, Stabiles dust and sand road and prevent them becoming slippery when wet, Improve productivity through better road, Cost effective, Environmentally friendly and skid proof when wet, Easy application, Long life strength, Non- flammable

1.4.4 Problem with many dust tech polymer alternative - Water can be effective short term solution but when the moisture dries if leave the soil more fragile creating even more dust Oil base emulsion continuously percolate and leaches through the soil, never binding with the road bed particle to stabilize the surface .

2. REVIEW OF LITERATURE

Following literature were studied related to soil stabilization using polymers**.** This unit contains review of soil stabilization using polymers.

2.1.T.Raghavendra , et.al (2018) studies the stabilization of black cotton soil using Terrasil and Zycobond. The variation experiment specific gravity, liquid limit, plastic limit, sieve analysis, hydrometer analysis. IS light compaction, unconfined compression test , direct shear test, California bearing ration test , free swell index are conducted on the soil. Cement is used in the constant proportion of 3% of amount of soil and the Nano chemicals terrasil and zycobond are used are 0.6kg/m3, 0.8kg/m3 , 1kg/m3 , 1.2kg/m3 of each. Chemical soil mixing with cement and unconfined compression test is performed. soil mixed with cement and chemical with the respective proportion to the OMC calculated to the soil and mixed .unconfined compressive strength test is performed after the curing period of 7 days ,21 days ,28 days free swell index is performed . for the same proportion of terrasil and zycobond . terrasil is nanotechnology based water dissolvable , bring appears in pale yellow colour in the form of afield.

From the result of investigation conducted, the following conclusion can be made.

• Free Swell index is decreases from 30% to 27.5% with the addition of 0.6kg/m3 of Terrasil and Zycobond and decreased to 26.3%, 25%, 21.05% with the addition of 0.8kg/m3 ,1.0kg/m3 ,1.2kg/m3 when compared to 0% of Terrasil and Zycobond.

• Unconfined compressive strength is decreased when the dosage of the Nano chemicals (Terrasil and Zycobond) is increased.

• But many of journals say that Unconfined compressive strength should be increases by adding cement, Terrasil and Zycobond. Further investigation need to be done why the unconfined compressive strength is decreases.

2.2. P.K.KOLAY, et.al (2016) studies" the effect of liquid polymer stabilozer on geotechnical properties of fine grained soil", there are Two types of soils were selected in this study i.e., Carbondale soil (clay with high plasticity (CH)) and Galatia soil (silt of low plasticity (ML)) for stabilization purpose. A copolymer liquid stabilizer 'Soiltac' has been selected for this study. According to the Two types of soils were selected in this study i.e., Carbondale soil (clay with high plasticity (CH)) and Galatia soil (silt of low plasticity (ML)) for stabilization purpose. A copolymer liquid stabilizer 'Soiltac' has been selected for this study. According to the manufacturer, the polymer used in the present study is non-toxic and non-hazardous. The pH value of the polymer is 5.5. Typically, polymer stabilizers are vinyl acetates or acrylic copolymers suspended an emulsion by surfactants.

The polymer added on 0.5%, 1%, 1.5%, 3%into the both soil and various test to occur .the result get positive and fulfil the conclusion of this study. From the result of investigation conducted, the following conclusion can be made:

- Atterberg limit for Carbondale soil (CH) and Galatia soil (ML) were slightly decreased with the addition of polymer, and no significant changes were observed for both soil.
- With the addition of polymer, MDD increases and OMC decreases for Carbondale soil (CH) and Galatia soil (ML).
- For Carbondale soil (CH), UCS values increases upto the addition of 1.5 % of polymer by weight and thereafter decreases for 3.0 % polymer addition. Also, UCS values increases with the increase in curing period for all soil-polymer mixture. The maximum increase in UCS value (with 1.5 % polymer stabilizer and 28-days of curing period) was 220% with polymer. For Galatia soil (ML), no significant changes in UCS were observed for all soil-polymer mixture at any curing periods. Maximum increase in UCS value was approximately 23% with polymer.
- Unsoaked CBR value for Carbondale soil (CH) increases upto 1.5% of polymer addition and then decreases with 3.0% polymer stabilizer. The increases in unsoaked CBR values from untreated soil are 200% for 2.54

mm deformation and 195.5% for 5.08 mm deformation with 3-days of curing. Almost similar unsoaked CBR values are obtained for 7 and 28 days of curing.

2.3.Sameervyas et.al (2016)studies stabilisation of dispersive soil by blending polymer.to stabilisation of dispersive soil from Udaipur 0.5 % and 1 % polyvinyl alcohol (PVA) andurea formaldehyde (UFR), 0.5% polyurethene (PU) and epoxy resin (ER) and 1 % styrene butadiene rubber latex were added to the soil sample. Mechanical analysis of polymer treated soil was done to measure the improvement in soil aggregation and atterbergs limit was tested to get information concerning cohesion properties of the soil. For mechanical analysis and atterbergs limit test, chemicals were added to 4.75 mm and 425 micron passing soil samples, respectively. To compare the effect of polymer with conventional soil stablizer 1.0% of sodium aluminate, calcium aluminate and calcium hydroxide were added to the dispersive soil sample and mechanical analysis was done and index properties were evaluated.

From the above result it is clear that on adding polymer aggregate size of soil is increasing thus the polymer used for above study are effective in binding soil particles. Lowering of LL, PL and PI indicate that on wetting of soil by rain water it will soften to a lesser extent thus making it more suitable for construction of road or lining of dam.

2.4. N.Sohaib el.al (2018) studies use of acrylic polymer for stabilisation of clayey soil.in this studies acrylic polymer is used as a stabilizer .which mixed with clayey soil for preparation of soil-acrylic polymer was mixed with chloroform to prepare the acrylic paste and the added to the soil. The chloroform was evaporated later on. Each sample was sealed in plastic sheet to make it air tight sample were then placed in an oven at 40^0C for the desired curing period.

From the studies and experiment conclusion can be made:

- The use of non-traditional chemical agents (acrylic polymers) can significantly enhance the engineering characteristics of soft soil. The soil is reactive with acrylic solution. Optimum percentage of acrylic solution required for stabilization of the soil is 6% by weight of the soil. It can be used as stabilizing agent in conjunction with acrylic is technically and financially feasible as it increases both the strength and durability parameters of soil.
- Compaction effort quickly after mixing acrylic solution is likely to yield maximum strength in the field. The maximum dry density from untreated soil increases to 5.92% with addition of 6% acrylic polymers. Beyond this MDD starts decreasing.
- Unconfined compressive strength increases from un-treated soil to 57% (for 3, 7 and 14-days curing) with addition of 6% of acrylic polymer, further addition of acrylic polymer causes decrease in compressive strength.
- In California Bearing Ratio test, maximum increment obtained from treated soil was 102% at 6% addition of stabilizer in comparison with untreated soil.

2.5.Lariso.chaindris et.al (2017) studies expansive soil stabilisation (general consideration) which is the paper revive The paper reviews the phenomena of active clays from a mineralogical, mechanical and especially a geotechnical point of view.

Clay soils exhibit, sometimes, a significant volume change due to the variation of water content in the mass of the soil, in response to climatic conditions and the action of vegetation. These volume changes affect the function of the constructions and foundations in contact with the soil and they represent the causes of damage, especially intense, during periods of drought.

We conclude that in general, all lime treated fine-grained soils exhibit decreased plasticity, improve workability and reduced volume change characteristics. We need to take into consideration that final aim improving also the strength characteristics of the soil. It should be emphasized that the properties of soil-lime mixtures are dependent on many factors such as soil type, lime type, lime percentage and curing conditions. .

2.6. Anjaneyappa et.al (2015) studies character action of polymer stabilized. The construction of pavements is becoming costlier due to very high cost of quality construction materials and transportation cost from long distances. Highway engineers are forced to look for ways to reduce the cost of construction and sustainable construction materials and methods. Soil stabilization techniques are important in constructing economical and sustainable roads. Nontraditional stabilizer additives are being marketed as cost effective, environmental friendly potential solutions by manufacturers for stabilization of pavement layers with very high claims. Various types of nontraditional stabilizers available in the market include chemical, polymer, enzyme based stabilizers.

Conclusion made by this paper was reduction of about 41 to 47% in radial strains below bituminous layers and 38 to 47 % in vertical compressive strain on subgrade were observed for soil stabilized with polymer.

Similarly reduction in thickness of granular layers in the order of about of 50% was observed. It is necessary to study the field performance using the polymer stabilizer for both low and high volume roads. The use of polymer for stabilization pavement layers cans be considered for low volume roads

2.7. Athulya P.V. et.al (2015) studies stabilization of sub grade soil using additives – a case study. The objective of the present study is to conduct experimental study and analyze the strength properties of plain soil, soil with terrasil and soil with cement kiln dust separately by conducting consistency limit test, CBR test, Triaxle test and permeability test and then to compare the effectiveness of these additives on stabilizing the weak soil

Conclusion made by this paper the behavior of soil varies largely with introduction of stabilizer. It is observed that increment in dosages resulted in decrement of consistency limits. So it is clear that the chemical makes the soil stiff. It is noted that CBR value increases with increase in dosage of stabilizer and an optimum value is obtained. Cement kiln dust being a waste product is economical and the CBR value also showed a considerable increase. The water proofing property of soil had a significant effect of adding Terrasil compared to cement kiln dust. The elastic modulus value for soil with additives showed a considerable increase compared to unsterilized soil.

2.8.Bibha mahtr et.al (2015) studies a review paper on improvement of sub grade by rbi grade 81 and pond ash The objective of the study is to find out the impact of RBI Grade 81 at 2%,3% and 4% mixed along with pond ash 3%, 6% and 9% on silty and clayey soil and the change in California Bearing Ratio (CBR), Dynamic cone penetration (DCP) Maximum Dry Density (MDD), Optimum Moisture Content (OMC) has been observed through different mixes of RBI Grade 81 and pond ash on soils. . The outcome helps in looking at the change in CBR, DCPT, OMC, MDD value when soils were stabilized by RBI grade 81 and soils stabilized by both RBI Grade 81 and Pond ash.

Conclusion made by this paper.is the RBI Grade 81 is successful in adjustment of most sorts of soils. The increment in CBR esteem fluctuates w.r.t sort of soil. For some soils, the augmentation is substantial with little expansion of the chemicals like fly ash, Sodium Silicate, pond ash, morum and stone dust. Since RBI Grade 81 assistance to use by regional standards accessible soil for road construction, consequently the expense of construction can be diminished by maintaining a strategic distance from substitution of soil. The splashed CBR qualities increment with expansion in RBI 81 expansion recommend its suitability as great stabilizer to enhance execution of delicate soils. The utilization of fly ash alongside RBI Grade 81 essentially enhances the geotechnical properties of soil.

2.9. Basantadhakal et.al (2016) studies effect of liquid acrylic polymer on geotechnical properties of fine graned soil. This paper investigation the effect of liquid polymer on the geotechnical properties of fine grained soil. Commercially available liquid polymer (acrylic polymer) was used to stabilize natural Carbondale soil (Soil A) and commercially available soil (Soil B). The polymer was mixed at various percentages (i.e., 2, 3, 4, and 5 %) of the dry weight of both soils. Tap water was added corresponding to its OMC (optimum moisture content) for a particular soil-polymer mixture and compacted to achieve its maximum dry unit weight. The compacted samples were allowed to cure for 7, 14, and 28 days under confined and open air environment. Unconfined compressive strength (UCS) test was performed to evaluate the strength of polymer stabilized soil. The results show that with the addition of polymer; UCS value for Soil B samples prepared at OMC increases from 30 to 75 % in open air environment and the UCS value increases from 12 to 14 % in confined air environment. Soil A samples prepared at OMC (i.e., 23.50%) show cracks while curing in open air environment and there is no significant change (i.e., 1.2–13.8%) of strength in confined air environment. For the Soil A samples prepared with reduced moisture contents (less than OMC i.e., 12.50%) and cured in open air environment shows increase in UCS strength from 7 to 10%. Also, California bearing ratio (CBR) test was performed for both soils and there was marginal increase (i.e., 14%) in CBR value for Soil A but a significant increase (i.e., 340%) in CBR value for Soil B.

2.10. Qassun S Mohammad shafique, et.al (2018) studies on improvement on expansive soil using polymath-acrylate polymers. In paper investigation one of the worldwide problematic soils expansive clay accompanied by large volume change response when it is subjected to a change in the water content . a chemical method for enhancing the swelling og expansive clayey soil is provided using polymethacrylate (PMA) polymer material . The experiment programmer is conducted to estimate the effect of adding the(PMA) polymer on the properties of the prepared expansive soil. Modified clay specimen is characterized based on various experiment and soil sample prepared various percentage (i.e. 3%, 5% 7%) by weight of dry soil.

The result indicate that the induced of PMA polymers with in expansive soil caused decrease in liquid limit, plasticity index, free swell, and optimum moisture content and increase in plastic limit, unconfined compression test and CBR test.

The result of the indicated that the polymers significantly overcome the problem of expansive soil .in

adding higher UCS by 52.8% are observed by adding PMA with a percentage of 7% also adding same percentage of PMA polymer caused increasing in CBR value by 72.8% .

2.11 Relience private ltd. (2010) companies make the evaluation report of SoilTech treated soil stabilised base layer. The companies is about construction for the power generation, for the installation of machineries or tower. is on the constructed base layer which stabilised by SoilTech polymer. The company make case study on it all result carries out on basis of various test doing by sudhakarreddy from IIT Kharagpur.

Result is very positive and shows the SoilTech is good industries construction soil stabilizer.

2.12 Sepehr Rezaeimalek1,,et.al(2017) studies on Mixing Methods Evaluation of a Styrene-Acrylic Based Liquid Polymer for Sand and Clay Stabilization in this paper ,focused on applications andprovided promising results. This study focuses on the application of a lowviscosity liquid polymer for shallow soil improvement. The mixing method ofsoil specimens treated with the liquid polymer soil stabilizer, which belongs toStyrene Acrylic family, was studied through an experimental testing program.The tested soils included poorly graded sand and sulphate rich clay. The water, liquid polymer and dry soil were mixed with different sequence to assess theeffect on strength. The specimens were cured in controlled environment for upto 35 days before tested. It was found that the curing of the polymer stabilizer in sand and clay were time consuming and took to a month to reach their full strength.

2.13 J.Ranjitha et.al studies on experimental study on black cotton soil stabilised using SoilTech MK 3 polymer. This paper investigated on the pavement construction is becoming costlier because of very high cost of construction materials and transportation cost of such materials from long distances. The growing concern over environmental degradation due to borrowing of large quantity of soil and aggregates for construction of pavement has made the search for new techniques of stabilization. The subgrade soil should have high Maximum dry density (MDD) and low Optimum moisture content (OMC) so that it can take up the load of the overlying layers and the traffic. The high MDD and corresponding OMC can be achieved by stabilizing the soil using suitable stabilizer. In the present work the effect of using Nano Polymer called SoilTech MK III as a stabilizer to improve the properties of Black Cotton soil collected from Karnataka, India were determined. The laboratory experiments were conducted on the samples of BC soil and BC soil with stabilizer for Compaction test, UCS (Unconfined Compression Strength) and CBR (California Bearing Ratio) tests. Various samples were prepared by taking soil with different percentage of SoilTech MK III Polymer (0.2%, 0.4%, 0.6%, 0.8% and 1.0%). The comparison of the results with and without the use of SoilTech MK III has been done.

3. METHODOLOGY

Fig.1 indicates the methodology adopted in carrying out the various tests for the study

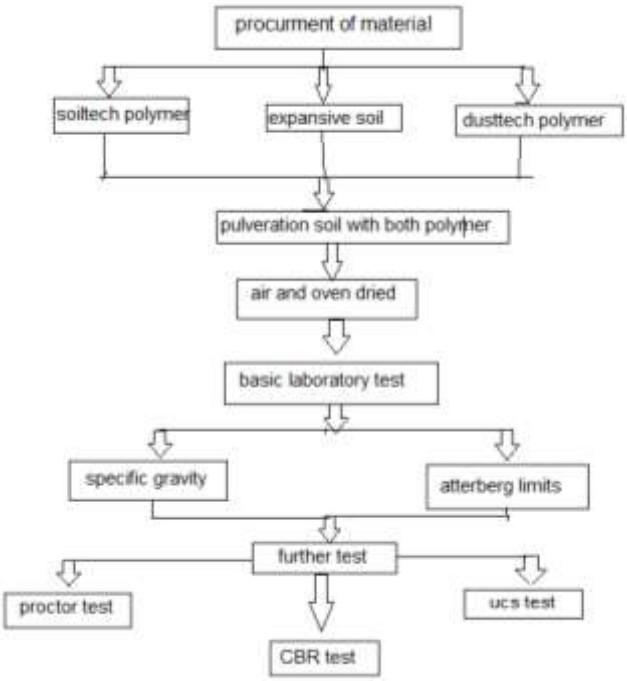

Fig -1: Layout plan of the experiments carried out

4. CONCLUSIONS

The review of literature indicate that polymers is a versatile material with attractive properties and advantages, as a result of this polymers is now being used widely all over the world. Waste fibers or plastics have durability, high strength, economic, and also they are non-biodegradable, therefore, may be used for the stabilization of soil. The use of polymer waste will results in increasing the solution against the disposal of wastes.

5. REFERENCES

[1] T.Raghvendra, B.Rohini, G.Divya,"Stabilization of black cotton soil using terrasil and zycobond" IJCRT 2018 , ISSN:2320-2882(PAPER) National Conference Proceeding NTSET feb 2018
[2] P.K.Kolay ,A.Pant ,V.K.Puri ,"Effect of liqyid polymer stabilizer on geotechnical properties of fine-grained soil", Indian Geotechnical Conference IGC 2016 IIT madras, Chennai.
[3] Samer Vyas, NeelamPhaugal , Pankaj Sharma , "stabilisation of dispersive soil by blending polymers", International Journal of earth science and Engineering ISSN:0974-5904, VOLUME 04, No. 06 SPL, PP 52-54, 2011
[4] N.Sohaib , M. SarfrazFaiz , G.Sana "Use of acrylic polymer for stabilisation of clayey soil" International Journal of Scientific and engineering research, Vol.9 ,Issue 11, ISSN 2229-5518, 2018
[5] LarisaChabdris , Dan Paul, LaelislauRandermanchere "Expansive soil stabilisation – genral consideration " Internatinal Multidisciplinary scientific Geo conference SGEM 2017
[6] Anjaneyappa, Dr. M.S. Amarnath and B.R. Shrinivasamurthy" Characterisation of polymer stabilised soil for [avment " Indian Road Congress Polymer Paper.
[7] AthulyaP.V. ,Dr. R.SathusChandran "stabilisation of subgrade soil using additives –a case study " ISSN:2278-0181 , NCRACE -2015 , International Journal of Engineering Research and Technology , IJERT.
[8] BibhaMahto, A.K.Duggal " Areveve paper on important of subgrade by RBI grade 81 and ash pond " e-ISSN:2395-0056 , P-ISSN:2395-0075 , IRJET 2015
[9] BasantaDhakal , Sanjeev Kumar , PrabirKolay " Effect of liquid acrylic polymer on geotechnical properties of fine grained soil" Springer International Publication Switzerland 2016.
[10] Qassun S. mohammadShafiqu and Safe H Bdan "improvement on expansive soil using polymethacrylate polymer " International Conference on material Engineering and Science 454 (2018) , 012138
[11] Case study – evaluation report of SoilTech treated soil stabilised base layer by reliance power limited
[12] SepehrRezaeimalek ,JieHuange, Sazzad Bin Shalique " mixing method evaluation of styrene , acrylic based liquid polymer for sand and clay stabilization " ISBN: 978-1-60595-442-4, ICTIM 2017.
[13] J.Ranjitha, Supriya D.K., Hitaishi.P, Pratik kumR , " Experimental Study On Black Cotton Soil Stabilised Using Soiltechmk 3 Polymer " e-ISSN :2319-1163 , p-ISSN :2321-7308 IJRET.