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A Review on Effects of Stabilizing Agents for Stabilization of Weak Soil

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Abstract

Soil stabilization is a process to treat a soil to maintain, alter or improve the performance of the soil as a construction material and very important to minimize the cost of earth work in case of unavailability of good earth at nearby source. The use of Stabilizing agent, for sub-grade with weak soil, improves strength parameter such as cohesion and improvement in cohesion leads to strengthening of embankment. This will ultimately lower down the road construction cost. This paper specifically addresses about soil stabilizing agent which are used to stabilize weaker soil to improve subgrade quality. In this paper review on use of different stabilizing agents such as lime, fly ash, cement, rice husk, geo-grid, chemical stabilizing agents etc.is done to analyze effect of stabilizing agent for application for stabilization of soil of Gujarat region.

1. Introduction

Geotechnical properties of problematic soils such as soft fine-grained and expansive soils are improved by various methods. The problematic soil is removed and replaced by a good quality material or treated using mechanical and/or chemical stabilization. Different methods can be used to improve and treat the geotechnical properties of the problematic soils (such as strength and the stiffness) by treating it in situ. These methods include densifying treatments (such as compaction or preloading), pore water pressure reduction techniques (such as dewatering or electro-osmosis), the bonding of soil particles (by ground freezing, grouting, and chemical stabilization), and use of reinforcing elements (such as geotextiles and stone columns) (William Powrie, 1997).

In Germany, Vosteen (1998 & 1999) reported that the use of cement or lime for the stabilization of pavement bases (during the past few decades) was investigated and developed into practical construction procedures. These practical procedures have been improved and covered periodically by the technical standards for road and traffic. Fly ash-soil stabilization for road construction is applied in USA, Japan, Scandinavian countries, and some other countries like India. In Germany, fly ash-soil stabilization for road construction is not applied and there are no German recommendations and regulations for soil stabilization using fly ash. The Engineers are often faced with the problem of constructing roadbeds on or with soils (especially soft clayey and expansive soils).These problematic soils do not possess enough strength to support the wheel loads upon them either in construction or during the service life of the pavement. These soils must be, therefore, treated to provide a stable sub-grade or a working platform for the construction of the pavement. One of the strategies to achieve this is soil stabilization. The soil stabilization includes both physical stabilization [such as dynamic compaction] and chemical stabilization [such as mixing with cement, fly ash, lime, and lime by-Products, etc] (Materials& Tests Division, Geotechnical Section, Indiana, 2002).

Chemical stabilization involves mixing chemical additives (binding agents) with natural soils to remove moisture and improve strength properties of the soil (sub-grade). Generally, the role of the stabilizing (binding) agent in the treatment process is either reinforcing of the bounds between the particles or filling of the pore spaces. Most of these chemical stabilizing agents are not available in Egypt, except cement and lime which are well- known. The chemical stabilizing agents are relatively expensive compared with other methods of stabilization, so that the soil stabilization technique is an open-field of research with the potential for its use in the near future (Egyptian Code, 1995).

The quality of the sub-grade soil used in pavement applications is classified into 5-types (soft, medium, stiff, very stiff, and hard sub-grade) depending on unconfined compressive strength values (Das, 1994). The quality of the sub-grade soil used in pavement applications is classified into 5-types (very poor, poor to fair, fair, good, and excellent) depending on the CBR values (Bowles, 1992). The sub-grades having CBR–values of 0 – 7% are very poor and poor to fair and the sub-grades having unconfined compressive strength values of (25 – 100 KN/m^2) are soft and medium. These types are considered as unstable sub-grades and need to be stabilized, especially, in terms of pavement applications.

2. Benefits Of Soil Stabilization

2.1 Substantial Savings

By choosing to stabilize the existing subgrade, the costs associated with excavating the existing soil, removing it from the site, and replacing it with suitable materials are eliminated. This can result in substantial savings to the owner.

2.2 Reduces Weather Related Delays

In areas where the climate and weather conditions prevent site work during certain times of the year, soil stabilization may be utilized to treat unstable soils in order to continue site work. This can impact construction schedules in a positive way and translate in a cost savings for an owner who does not have to wait for good weather to continue work on the project.

2.3 Eliminates Supply Problems

In areas where suitable materials to replace existing materials is in short supply or if the site is in a remote area where aggregate supply is cost prohibitive to import, soil stabilization becomes a cost effective alternative.

2.4 Additional Material Reduction

In roadway sections or parking areas, the sections of base material and asphalt paving may be reduced if the existing subgrade is stabilized in order to create sufficient strengths. This reduction in the sections of base material and asphalt paving can also create cost savings to the owner.

3. Materials

3.1 Lime stabilization

Qubain et al. (2000) incorporated the benefits of sub-grade lime stabilization, for the first time, into the design of a major interstate highway pavement in Pennsylvania. The project comprised widening and complete reconstruction of 21 Km of the Pennsylvania turnpike in somerset-county. Field explorations indicated that the sub-grade is fairly homogeneous and consists primarily of medium to stiff clayey soils. To safeguard against potential softening due to rain, lime modification has been traditionally utilized as a construction expedience for highway project with clayey sub-grade. Lime improves the strength of clay by three mechanisms: hydration, flocculation, and cementation. The first and second mechanisms occur almost immediately upon introducing the lime, while the third isa prolonged effect. Qubain et al. (2000) investigated the first and second mechanisms. Laboratory tests were performed to accurately capture the immediate benefits of lime stabilization for design. Both treated and natural clayey samples were subjected to resilient modulus and California bearing ratio testing. To prevent cementation, the lime-treated specimens were not allowed to cure. Nevertheless, they showed significant increase in strength, which, when incorporated into design, reduced the pavement thickness and resulted in substantial savings.

Witt (2002) mentioned (Geotechnik Seminar Weimar 2002) that Weber (2001)investigated the effect of both curing (storage) and degree of compaction on the loss loam stabilized using different additives. He obtained the best results under condition of moisture atmosphere storage. At the water storage condition, the tempering of the stabilized specimens delayed due to the changing of pH-value in the pores water. The reactivity of lime stabilized specimens was continuing under this water storage condition. He noticed that the variation of compaction degree of the stabilized specimens affected on the behavior of the stabilized specimens and the compaction (at the highest densities) led to brittle failure behavior.

Ismail (2004) studied materials and soils derived from the Feuerletten (Keuper) and Amaltheenton (Jura) formations along the new Nuernberg-Ingolstadt railway line (Germany). His work included petrological, mineralogical studies and scanning electron microscope-analysis. Ismail (2004) treated and stabilized these materials related to road construction using lime (10%), cement (10%), and lime/cement (2.5%/7.5%). He determined consistency limits, compaction properties, and shear- and uniaxial-strength. Ismail (2004) concluded that by increasing the optimum moisture content (%) of the treated-materials (soils mixtures), the maximum dry density (g/cm3) decreased. The cohesion and the friction angle of the improved materials increased for all the treated mixtures. In case of the lime-treated materials, the cohesion decreased by curing time. ForFeuerletten materials, uniaxial strength increased strongly using lime and cement together. For Amaltheenton, uniaxial strength increased strongly with cement alone. He also noticed that the loss of weight during freezing and thawing test was low and depended on the material type.

Ampera&Aydogmust (2005) treated Chemnitz clayey soil (A-7-6 Group) [according to American Association of State Highway and Transportation Officials (AASHTO)] using lime (2, 4, and 6%) and cement (3, 6, and 9%). They conducted compaction-, unconfined compressive strength-, and direct shear- tests on untreated and treated specimens. They concluded that the strength of cement-treated soil was generally greater than the strength of lime-treated-soil. They also reported that lime-stabilization is (in general, more tolerant of construction delay than cement-stabilization) more suitable for the clayey soils. The relationships determined from direct shear tests were similar to those determined from unconfined compressive strength tests. Thus, the results of shear strength tests showed a similar trend to that of the unconfined compressive strength tests.

3.2Fly ash stabilization

Various studies were carried out in several countries like USA, Japan, etc to verify the soil stabilization process using fly ash (by-product)either class F or class C and other off-specification types of fly ash (Lee & Fishman 1992, Ferguson 1993, Turner 1997, Sahu 2001, Acosta et al. 2002, Edil et al. 2002, Şenol et al. 2002, and Thomas & White 2003).

Edil et al. (2002) conducted a field evaluation of several alternatives for construction over soft sub-grade soils. The field evaluation was performed along a 1.4 Km segment of Wisconsin state highway 60 and consisted of several test sections. By products such as fly ash, bottom ash, foundry slag, and foundry sand wereused. A class C fly ash was used for one test section. Unconfined compression testing showed that 10% fly ash (on the basis of drweight) was sufficient to providethe strength necessary for the construction on the sub-grade. Data were obtained before and after fly ash placement by testing undisturbed samples in the laboratory and by using a soil stiffness gauge (SSG) and a dynamic cone penetrometer (DCP) in the field. Unconfined compressive strength, soil stiffness, and dynamic cone penetration of the native soil before fly ash placement ranged between 100 - 150 KPa, 4 - 8 MN/m², and 30 - 90 mm/blow, respectively. After fly ash addition, the unconfined compressive strength reached as high as 540 KPa, the stiffness ranged from 10 to 18 MN/m2, and the Dynamic Penetration Index (DPI) was less variable and ranged between 10 and 20 mm/blow. CBR of 32% was reported for the stabilized sub-grade, which is rated as “good” for sub-base highway construction. CBR of the untreated sub-grade was 3%, which is rated as “very poor” according to Bowles, 1992.

Acosta et al. (2002) estimate the self-cementing fly ashes as a sub-grade stabilizer for Wisconsin soils. A laboratory-testing programwas conducted to evaluate the mechanical properties of fly ash alone, and also to evaluate how different fly ashes can improve the engineering properties of a range of soft sub-grade soil from different parts of Wisconsin. Seven soils and four fly ashes were considered for the study. Soil samples were prepared with different fly ash contents (i.e., 0, 10, 18, and 30%), and compacted at different soil water contents (optimum water content, 7% wet of optimum water content “approximate natural water content of the soil”, and a very wet conditions “9 to 18% wet of optimum water content”). Three types of tests were performed: California bearing ratio test, resilient modulus test, and unconfined compressive strength test. The soils selected represented poor sub-grade conditions with CBR ranging between 0 and 5 in their natural condition. A substantial increase in the CBR was achieved when soils were mixed with fly ash. Specimens prepared with 18% fly ash content and compacted at the optimum water content show the best improvement, with CBR ranging from 20 to 56. Specimens prepared with 18% fly ash and compacted at 7% wet of optimum water content showed significant improvement compared to the untreated soils, with CBR ranging from 15 to 31 (approximately an average CBR gain of 8 times). On the other hand, less improvement was noticed when the specimens were prepared with 18% fly ash and compacted in verywet condition (CBR ranging from 8 to 15).

Soil-fly ash mixtures prepared with 18% fly ash content and compacted at 7% wet of optimum water content had similar or higher modulus than untreated specimens compacted at optimum water content. Resilient modulus of specimens compacted in significantly wet conditions, in general, had lower module compared to the specimen compacted at optimum water content. The resilient modulus increased with increasing the curing time. The resilient modulus of specimens prepared at 18% fly ash content and compacted at 7% wet of optimum water content was 10 to 40% higher after 28 daysof curing, relative to that at 14 days of curing. Unconfined compressive strength of the soil-fly ash mixtures increased with increasing fly ash content. Soil-fly ash specimens prepared with 10 and 18% fly ash content and compacted 7% wet of optimum water content had unconfined compressive strength that were 3 and 4 times higher than the original untreated soil specimen compacted at 7% wet of optimum water content. CBR and resilient modulus data was used for a flexible pavement design. Data developed from stabilized soils showed that a reduction of approximately 40% in the base thickness could be achieved when 18% fly ash is used to stabilize a soft sub-grade.

Şenol et al. (2002) studied the use of self-cementing class C fly ash for the stabilization of soft sub-grade of a city street in cross plains, Wisconsin, USA. Both strength and modulus-based approaches were applied to estimate the optimum mix design and to determine the thickness of the stabilized layer. Stabilized soil samples were prepared by mixing fly ash at three different contents (12, 16, and 20%) with varying water contents. The samples were subjected to unconfined compression test after 7 days of curing to develop water content-strength relationship. The study showed that the engineering properties, such as unconfined compressive strength, CBR, and resilient modulus increase substantially after fly ash stabilization. The stabilization process is construction sensitive and requires strict control of moisture content. The impact of compaction delay that commonly occurs in field construction, was evaluated, one set of the samples was compacted just after mixing with water, while the other set after two hours. The results showed that the strength loss due to compaction delay is significant and, therefore, must be considered in design and construction. CBR and resilient modulus tests were conducted and used to determine the thickness of the stabilized layer in pavement design.

Thomas & White (2003) used self-cementing fly ashes (from eight different fly ash sources) to treat and stabilize five different soil types (ranging from ML to CH) in Iowa for road construction applications. They investigated various geotechnical properties (under different curing-conditions) such as compaction, qu-value, wet/dry and freeze/thaw durability, curing time effect, and others. They reported that Iowa self-cementing fly ashes can be an effective means of stabilizing Iowa soil. Unconfined compressive strength, strength gain, and CBR-value of stabilized soils increased especially with curing time. Soil-fly ash mixtures cured under freezing condition and soaked in water slaked and were unable to be tested for strength. They also noticed that stabilized paleosol exhibited an increase in the freeze/thaw durability when tested according to ASTM C593, but stabilized Turin loess failed in the test.

3.3Lime/fly ash stabilization

Several works were done to treated stabilize various types ofthe problematic soils using lime and fly ash together (Nicholson &Kashyap 1993, Nicholson et al. 1994, Indraratna et al. 1995, Virendra&Narendra 1997, Shirazi 1999, Muntuhar&Hantoro 2000, Lav A. &Lav M. 2000, Cokca 2001, Consoli et al. 2001, Nalbantoglu 2001, Nalbantoglu&Tuncer 2001, Yesiller et al. 2001, Nalbantoglu&Gucbilmez 2002, Zhang & Cao 2002, Beeghly 2003, and Parson & Milburn 2003).

Nalbantoglu&Gucbilmez (2002) studied the utilization ofan industrial waste in calcareous expansive clay stabilization, where the calcareous expansive soil in Cyprus had caused serious damage to structures. High-quality Somafly ash admixture has been shown to have a tremendous potential as an economical method for the stabilization of the soil. Fly ash and lime-fly ash admixtures reduce the water absorption capacity and the compressibility of the treated soils. Unlike some of the previously published research, an increase in hydraulic conductivity of the treated soils was obtained with an increase in percent fly ash and curing time. X-ray diffract grams indicate that pozzolanic reactions cause an alteration in the mineralogy of the treated soils, and new mineral formations with more stable silt-sand-like structures are produced. The study showed that, by using cation exchange capacity (CEC) values, with increasing percentage of fly ash and curing time, soils become more granular in nature and show higher hydraulic conductivity values.

Zhang & Cao (2002) conducted an experimental program to study the individual and admixed effects of lime and fly ash on the geotechnical characteristics of expansive soil. Lime and fly ash were added to the expansive soil at 4 - 6% and 40 - 50% by dry weight of soil, respectively. Testing specimens were determined and examined in chemical composition, grain size distribution, consistency limits, compaction, CBR, free swell and swell capacity. The effect of lime and fly ash addition on a reduction of the swelling potential of an expansive soil texture was reported. It was revealed that a change of expansive soil texture takes place when lime and fly ash are mixed with expansive soil. Plastic limit increases by mixing lime and liquid limit decreases by mixing fly ash, and this decreased plasticity index. As the amount of lime and fly ash is increased, there is an apparent reduction of maximum dry density, free swell, and of swelling capacity under 50 KPa pressure and a corresponding increase in the percentage of coarse particles, optimum moisture content, and in the CBR value. They concluded that the expansive soil can be successfully stabilized by lime and fly ash.

Beeghly (2003) evaluated the use of lime together with fly ash in stabilization of soil sub-grade (silty and clayey soils) and granular aggregate base course beneath the flexible asphalt layer or rigid concrete layer. Hereported that lime alone works well to stabilize clay soils but a combination of lime and fly ash is beneficial for lower plasticity (higher silt content) soils. He noticed that both unconfined compressive strength- and CBR-values of treated stabilized soils (moderate plasticity "PI < 20" and high silt content "i.e. >50%") with lime and fly ash together are higher than the values with lime alone. Beeghly (2003) also concluded that the capillary soak of the stabilized specimens led to a loss of unconfined compressive strength (15 - 25%). Finally, lime/fly ash admixtures resulted in cost savings by increment material cost by up to 50% as compared to Portland cement stabilization.

Parson & Milburn (2003) conducted a series of tests to evaluate the stabilization process of seven different soils (CH, CH, CH, CL, CL, ML, and SM) using lime, cement, class C fly ash, and an enzymatic stabilizer. They determined Atterberg limits and unconfined compressive strengths of the stabilized soils before and after carrying out of durability tests (freeze/thaw, wet/dry, and leach testing). They reported that lime- and cement-stabilized soils showed better improvement compared to fly ash-treated soils. In addition, the enzymatic stabilizer did not strongly improve the soils compared to the other stabilizing agents (cement, lime, and fly ash).

3.4 Clay stabilization for sandy soil

Dioufet. al. (1990) has done extensive research to evaluate the effectiveness of adding clay to very sandy soil to reduce wind erosion susceptibility. In this research they found that The aggregates' resistance to crushing increased greatly with increasing clay content. Because the bentonite was several times more effective than kaolinite, bentonite was used in the second part of the study. Wind erosion susceptibility of sandy soil was reduced greatly by adding small amounts of bentonite clay in this laboratory study.

3.5 Cement Stabilization

Strength gain in soils using cement stabilization occurs through the same type of pozzolanic reactions found using lime stabilization. Both lime and cement contain the calcium required for the pozzolanic reactions to occur; however, the origin of the silica required for the pozzolanic reactions to occur differs. With lime stabilization, the silica is provided when the clay particle is broken down. With cement stabilization, the cement already contains the silica without needing to break down the clay mineral. Thus, unlike lime stabilization, cement stabilization is fairly independent of the soil properties; the only requirement is that the soil contains some water for the hydration process to begin.

Saad Ali Aiban (1994) has donean attempt to assess the strength properties of stabilized granular soils and to evaluate the behavior of cement- treated ands. Two types of cementing agent were used: Portland cement and calcium carbonate. The effects of some of the variables encountered in the field such as curing type and time, confining pressure, cementing agent content, density, saturation and reconstitution on the behavior of stabilized soils, were studied. Test results show that the addition of a cementing agent to a wind-blown sand (cohesion less material) with uniform size distribution produces a material with two strength components, that due to cementation or "true" cohesion and that due to friction. The angle of internal friction for the treated sands is not much different from that of the untreated sand. The results also show that the drying process is essential in the development of cementation, especially when calcium carbonate is used as the cementing agent. Peak strength as well as initial tangent modulus values, increase with an increase in curing period, confining pressure, cement content and density. Residual strength values seem to be independent of all parameters other than the confinement and density; a behavior commonly observed for uncemented sands.

3.6 Rice Husk Stabilization

Musa Alhassan (2008) conducted an extensive research to know potential of rice husk for lateritic soil stabilization. This soil which is clay of high plasticity (CH) was stabilized with 2-12% rice husk ash (RHA) by weight of the dry soil. Using British standard light (BSL) compaction energy level, performance of the soil-RHA was investigated with respect to compaction characteristics, California bearing ratio (CBR) and unconfined compressive strength (UCS) tests. The results obtained, indicates a general decrease in the maximum dry density (MDD) and increase in optimum moisture content (OMC) with increase in RHA content. There was also slight improvement in the CBR and UCS with increase in the RHA content. The peak UCS values were recorded at between 6-8% RHA, indicating a little potential of using 6-8% RHA for strength improvement of A-7-6 lateritic soil.

3.7 Polymer stabilization

EvangelinRamaniSujathaet. al. (2012) has done research in which geo -grids are used to improve the strength of the sub-grade (soft murrum) and reduce the pavement thickness. The results show that the strength of the sub-grade is considerably increased by introducing geo-grid reinforcement in the soil. It is found that geo-grids placed at 2/3 the distance from the base showed higher CBR than when placed at 1/2 and 1/3 distances from the base. CBR values two layers of geo-grid are significantly higher than a single layer. CBR of three layers of geo-grid show lesser CBR than two layers, but higher than single layer. The use of three layers of geo -grid confines the soil, improving the soaked CBR of the sub-grade. The differences in the behavior of the soil under unsoaked and soaked conditions improve on increasing the number of layers of geo-grid. The increase in water content for unsoaked CBR test shows significant decrease in strength.

Tingle et al. (2003) performed unconfined compressive strength testing on lean clay and fat clay treated with various natural and synthetic polymers. For the lean clay, the greatest increase in strength compared to untreated samples was obtained from treatment with lignosulfonate. Treatment with synthetic polymer also showed an increase in strength for the lean clay, although not as great of an increase as encountered with lignosulfonate treatment. For the fat clay, treatment with synthetic polymer also showed increases in strength. Lignosulfonate treatment of the fat clay was not included in the testing program.

3.8 Bituminous Stabilization

ElifasBunga et.al. (2011) has done extensive research to improve the strength of highly eroded soil. In order to solve easily eroded sandy clay loam problem, a study was conducted by using emulsified asphalt as stabilization material. The emulsified asphalt concentrations were 1.5%, 3.0%, and 4.5%.The results of the study indicate that stabilization material for emulsified asphalt can improve physical, chemical, and mechanic characteristics of sandy clay loam. Chemical bindings occur among the soil minerals and emulsified asphalt. Plasticity and shear strength of soil increase in line with the increase of emulsified asphalt concentration.

3.9 Chemical Stabilization

According to the manufacturer, an enzymatic stabilizer is a natural organic compound, similar to proteins, which acts as a catalyst (Perma-Zyme 11X, 1998). Their large molecular structures contain active sites that assist molecular bonding and interaction. The organic formulation is designed to maximize compaction and increase the natural properties of soil to optimal conditions. The enzymatic stabilizer increases the wetting action of water to help achieve a higher density during compaction and the formulation accelerates cohesive bonding of soil particles, creating a tight permanent stratum (Perma-Zyme 11X, 1998).

Few peer- reviewed studies have been published on enzymatic stabilizers. Khan and Sarker reported increases in unconfined compressive strength with the addition of 5% enzymes and good performance in freeze-thaw testing (Khan L.I. and M. Sarker 1993). Rauch, et al reported no consistent, measurable improvement in soil properties with the addition of Permazyme in a more diluted form (Rauch et.al. 1998).

To achieve effective stabilization, the manufacturer recommends that it be used with soils containing approximately 20% cohesive fines. The soils are to contain a wide range of material sizes to provide shear strength and internal friction, which increases load- bearing capacity. Use of this material was limited to those soils meeting the manufacturer's recommendations (Perma-Zyme 11X, 1998).

4. Experience Of Soil Stabilization At GIDC, Sannad, Gujarat

Soil stabilization for clayey soil using lime/fly ash is done at GIDC, Sanand. Sanand is part of the dedicated Viramgam Special Investment Region of Gujarat. Located near the city of Ahmedabad, Sanand is about 70 kilometers (40 miles) from a recently rebuilt international airport. Sanand is linked to Ahmedabad and Kutch by state highway 17. The state highway 17 joins India's National Highway 8, part of the recently completed 4-lane Golden Quadrilateral highway linking Sanand to many of the major industrial, economic and cultural regions of India. Although sanand comes in Special Investment zone so it require better internal road connectivity but the problem is that it consist of clayey subgrade which makes road construction problematic. So to overcome form this problem subgrade soil is stabilized with lime/fly ash, which easily available material nearby this area. For soil stabilization lime and fly ash mixed with subgrade soil at standard proportion to get improved strength parameter. Mixing of fly ash and lime with soil is done by On-site mixing machine of L&T.

For On-site mixing following procedure is done:

I. Leveling the ground and homogenize subgrade soil.
II. Proportion of stabilizing agent (lime and fly ash) is made by considering dry density and moisture content.
III. Laying standard proportion of lime/fly ash on homogenized soil.


Fig. 1 Laying of fly ash/lime on subgrade soilFig. 2 Onsite mixing machine

IV. Automatic mixing is done by mixing machine for a standard time.

Fig. 3 Teeth's of mixing machine

V. Sprinkling of water on mixed surface.

VI. Compaction by roller.

5. Conclusion

The above study was carried out to analyze the effect of different stabilizing agent at different soil condition. This study shows that soil stabilization is beneficial for improving weak soil in a cost-effective way. For stabilizing weak soil, most waste material like fly ash, rice husk and egg shale is used which one of the waste utilization and also works as stabilizing agent which gives better results . The literature review done before application of stabilizing agent for application to stabilize the soil of Gujarat region. In Gujarat, black cotton soil is stabilized with fly ash & lime. The proportion of fly ash and lime is decided by considering moisture content and density. After soil stabilization by these stabilizing agents there is drastic improvement in strength parameter of subgrade.

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