

REVIEW OF IMPROVING PROPERTIES OF SOIL USING FLY-ASH AND TERRA-ZYME

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Abstract – Now days as there is lots of development work going on and lots of construction work is going on today. It is not possible to find which is completely fit for the construction purpose. So to make the soil fit for construction we need to stabilize the site for which different stabilizers are available in the market. As the cost of construction is huge cost of stabilizers make it even more. So to overcome this we need stabilizers which are cheap and easily available. This problem of stabilizers can be overcome by Terra-zyme and Fly-ash. These both are the waste products of industries so basically they are very cheap and easily available. Thus their effect on soil with poor bearing capacity is studied.

Key words: California bearing ratio, Fly-ash, Maximum Dry Density, Soil Stabilization Optimum Moisture Content, Terra-zyme.

1.1 Introduction

Soil is a heterogeneous mixture which consists of hard rocks, coarse soil, organic matter, and different minerals which occurs naturally. Depending on various types of soil they possess different physical, chemical and strength characteristics. Different types of soil have different bearing capacities. During the selection of site for the construction purpose bearing capacity is taken as one of the important property. If bearing capacity of soil is found to be poor, the following options are considered:

- i. Modifying design so that it suits site condition.
- ii. Modifying the in situ soil with strong soil.
- iii. Rejecting site.

Following options in order to get perfect condition for construction can increase cost of project. And also as we have got limited land resources it is very unlikely to abandon the selected site. However, in most geotechnical projects, it is not possible to obtain a construction site that will meet the design requirements without ground modification. So to overcome these problems and to make soil suitable for the construction it is very important to improve the properties of soil so that the required for the project can be achieved and the construction is safe. Soils which have poor engineering properties and which are not suitable for not even small and less important construction are required to improve. Loose, expansive and organic soil must be improved to the requirement of the civil engineering projects. Method of artificially improving the quality of soil is called as soil stabilization. In soil stabilization various methods such as Mechanical, chemical etc. are used to improve the bearing capacity of soil and make soil fit for use in construction.

1.1 Soil stabilization

Soil stabilization is the process in which properties of natural soil is improved in order to meet requirement of the engineering project. Various methods such as mechanical or chemical are used for soil stabilization.

Stabilization of soil includes various processes such as compaction soil, pre-consolidation of the soil surface, drainage of water and many other such processes such as adding the cementing material or a chemical to the natural soil. In stabilization of soil our aim is to reduce permeability of soil, compressibility of soil and to increase shear strength and bearing capacity of soil. The properties of soil vary a great deal according to different places, or in certain cases it may vary at a single place; the success of such soil stabilization depends on the testing. The methods employed to stabilize the soil, should be verified in the lab with the soil material before applying it on the field.

2. Literature review

Lacuoture and Gonzalez (1995) conducted study on the results of Terra-Zyme on sub-base and sub-grade. Soil with Terra-Zyme and soil without Terra-Zyme were observed and compared with one another. Final conclusion they made was that soil with Terra-Zyme had shown improvement in strength in small duration of time as compared to the soil without Terra-Zyme and also cohesive soil showed successive improvement.

Bergmann (2000) conducted his research on the different types of soil using bio-enzymes. In his studies he conducted various experiments on samples of different soils. In his research work he found that the effect of bio-enzymes was quite good in the initial phases but gain in strength during later phases were even better. Experiments conducted by him was CBR test which he conducted on the different soil samples for up to 14 weeks and the results obtained went from 28% for the plain untreated soil to as high as 100% for soil with bio-enzyme on the 14 week. In his studies he also found that the bio-enzyme is only effective on the soils which have at least 2% of clay content. And best results were obtained when clay content varies from 10% to 15%. Bio-enzymes is less effective in the sandy soils or soil with low water content. And the results obtained are good on the later stage after addition of bio-enzyme as bio-enzyme require some time to show its actual strength.

Andrew et al (2003) conducted experiment in laboratory to evaluate the effect of treatment of soil with Bio-Enzyme on sub-grade soil. Various experiments were conducted on soil to determine change in properties. Results of assorted experiments such as CBR, strength, soil stiffness and soil modulus were compared against soil without enzymes. The CBR test appears to be a comparatively poor indicator of direct soil strength for testing conditions.

Isaac et al (2003) a full analysis of Terra-eficacy Zyme's on the clayey form of soil and lateritic soil was carried out, which he obtained from kerala. The soil effect of Terra-Zyme has been observed, documented and compared with the results of different experiments conducted on untreated soil. For a period of 8 weeks, study work was carried out. The results obtained from the study were very good, increased by the addition of CBR's Terra-Zyme value, which proves that it can be used as a good stabilizing agent. The rise in CBR ranged from 136 to 180 times the initial value. Terra-Zyme was very helpful for sandy soil and clayey soil, but is less essential for silty soils and CBR increased by 700 percent for clayey and sandy soil.

Manoj Shukla (2003) performed his research work on the effect of bio-enzyme on the soil samples. In his research work he chooses five different types of soil whose clay proportion varied from low to high. To compare the effect of bio-enzyme on the soil samples he first conducted different experiments on the untreated soil. The experimental work includes liquid limit experiment, plastic limit experiment, proctor test, CBR test and UCS test. Then he conducted same test on the soil treated with bio-enzymes and then comparison was made of the various results obtained by him. From the comparison it was clear that there was increase in value of CBR as well as UCS from that obtained from untreated soil samples. But though the results obtained were good there was variation in the results obtained. Soil with low clay content showed lesser improvement and soil samples with high clay content showed much better results. Reason behind this kind of variation was that soils with low clay content are less reactive with bio-enzymes as compared to the soils with high clay content. With the increase in the value of CBR and UCS it was observed that the thickness of pavement was reduced from 24% in soil with low clay content to 48% of that type of soil with high clay contents.

Sharma (2006) performed his research work on the study of bio-enzymes on different types of soils. the soils considered by him for his research work was mainly clayey soils with varying proportion of clay content, which were clay with high plasticity (CH), clay with low plasticity (CL) and silt with low plasticity (ML). He conducted different laboratory experiments on the different soil samples to find the properties of the plain soil. Then bio-enzymes were added to the different samples of soil in different proportion and the results obtained were compared with to the results obtained from the experiments performed on the parent soil. And from comparison it was found that there was improvement in the value of CBR and the best results obtained were from the soil with high clay content. It was found that the result of CBR increased form 21% to 40% on the 28th day of stabilization. Increase of 100% was found in the value of unconfined compression test.

Shankar (2009) researched on the impact of bio-enzyme on the stabilization of soil. For his research work he selected lateritic soil which he collected from Indian district of Dakshina Kannad. He performed different laboratory test on the soil which he collected and find out that the liquid limit of soil was 25% and plastic limit of soil was 6%. Soil of that region was very weak and it does not satisfy the sub-base requirement. To obtain sub-base requirement of soil sand in different proportion was added and mixed so that required values were achieved. Effect of enzyme on the various properties of soil such as permeability, unconfined compression test and CBR was studied for the period of 28 days. With 10% sand and high

dosage of enzyme of 200ml/2m³ CBR value increased by 300% after 4 week of curing. A 450 percent increase in the unconfined compressive strength value, a 300 percent increase in the CBR value and a 42 percent decrease in soil permeability was seen after 28 days of healing with a high dose of 200 ml/2 m³ of enzyme. From the CBR results of untreated and treated soil, it was concluded that enzyme addition has no effect on the cohesion of less soil. It has also been recognized that the bioenzyme used in the laboratory must be tested for its effect on the form of soil prior to field application. Tests were carried out on the National Highway to check the field efficiency of Bio Enzyme, which shows that soil mixed with enzymes has a high CBR value compared to ordinary soil, indicating that the enzyme is not successful for cohesion less soil.

Mithanthaya.I.R, Harsha Kumar Rai and Ravishankar.A.U (2009) carried out there research work on what will be the effect of use of TERRA-ZYME on the lateritic type of soil. They first performed all the laboratory experiments on the untreated soil and found different properties of soil and from the experimental results it was clear that bearing capacity of soil was very weak and required some stabilization to make it suitable for the use of construction purpose. For the stabilization purpose they selected TERRA-ZYME and they choose various quantity of TERRA-ZYME for the research purpose. The dose of TERRA-ZYME selected were 200ml for 3.5m³, 3m³, 2.5m³ and 2m³. Various tests were performed by them to study the effect of TERRA-ZYME on the soil. And from the different experimental studies and comparisons made from the results obtained from untreated soil and treated soil it was found that the value of CBR improved upto 400% of the value obtained on the plain untreated soil and the value form UCS went up to 450% of the value of original soil. And permeability of soil was also reduced greatly by upto 42%.

Sureka Naagesh and Gangadhara.S (2010) conducted experiment on clayey soil. Clayey soils are expansive soil therefore they used Terra-Zyme as stabilizer. Different percentage of Terra-Zyme was used in the experiment. Percent of Terra-Zyme varied from 0.2% to 1% results obtained were quite good. Investigation on swelling properties of Terra-Zyme treated expansive soil revealed that soil treated with Terra-Zyme showed less swelling pressure compared to original soil sample.

Venkatasubramanian & Dhinakaran (2011) Tests were performed on three soils with differences in their properties and varying percentages of Bio-Enzyme dosages. Soils with low medium and high plasticity were artichoke soils. Terra-Zyme dosages ranged from 3 m³ to 200 ml, 2.5 m³ to 200 ml, 2.0 m³ to 200 ml and 1.5 m³ to 200 ml. Based on various experiments carried out in the laboratory, the optimum dose of Terra-Zyme was found. Atterberg limit checks, accuracy index tests and CBR tests were distinct tests conducted. Positive findings were obtained based on subsequent studies. Three soils had liquid limits of 28, 30 and 46 percent, and 6, 5 and 6 percent plasticity indices. After 28 days of curing, 246 to 404 percent was recorded as a significant increase in unconfined compressive strength.

Lekha.B.M, Ravi Shankar.A.U and Goutham.S (2013) conducted laboratory tests on black cotton soil. Black cotton soil is most expansive soil and it must be stabilized before doing any construction so they used Terra-zyme as stabilizer in black cotton soil in their work. Terra-zyme was used in varying percentages, percent of stabilizer varied from 0.2% to 1% and the soil was cured for 7-28 days. It is noted that value of CBR increases with the increase in percentage of soil stabilizer upto certain limit after that limit if percent of stabilizer increased it decreased CBR value. Permeability showed most drastic change it was found to be nil for treated soil.

Vijay Rajorial, Suneet Kaur (2014) conducted a theoretical evaluation effect of bio-enzyme in the construction of roads. They conducted study of road constructed by public work department in Maharashtra. Studies concluded that the strength of road was more as compare to other roads. Roads constructed by using terra zyme as stabilizer require less maintenance as compared to other roads. Road served better in rainy season as compared to other roads. There was reduction of cost of about 18% to 26% in Terra-Zyme stabilized roads as compared to other roads. Finally they concluded those roads which are stabilized by Bio-Enzyme are more economical and have more strength as compared to other.

Ramesh.H.N and Sagar.S.R (2015) studied the effect of Terra-Zyme on expansive soil and non-expansive soil. According to the results obtained by the experiment there was some positive development in the swell index properties. Swell index of expansive and non-expansive soil decreased from 118% to 45% for desiccators and 27% to air dry conditions for third dosage of Terra-Zyme for at 30 days.

Venika Saini and Priyanka Vaishnava(2015) researched on the effect of TERRA-ZYME on clayey soils. Different tests were performed on the soil collected to determine the properties of soil. First sieve analysis was performed to find what type of soil it was and from the test results it was clear that soil was fine grade soil. And then consistency limit test were performed on the soil and from the test it was find out that the soil was clayey soil. Then standard proctor test, CBR test and UCS test were

performed to determine the γ_d and strength parameters of soil and from results it was clear that soil have very poor strength. Then they choose the different proportion of Terra-Zyme 200ml/3m³, 200ml/2.5m³, 200ml/2.0m³ and 200ml/1.5m³ and different tests were performed on it. And comparison was made between the test results of treated and untreated soil and from the comparison it was clear that there is considerable increase in the soil strength. And results obtained were good.

Nandini.D.N, Vinoda.A and Prathap Kumar.M.T (2015), performed experimental studies on red soil stabilized with Terra-Zyme. Different dosage of Terra-Zyme was used. Dosage of Terra-Zyme was respectively 3m³ per 200ml, 2.5 m³ per 200ml, 2.0m³ per 200ml and 1.5m³ per 200ml. They conducted experiment in three different levels. Experiment was conducted on 7 days, 14 days and 28 days. Different experiment performed were CBR, proctor test, atterberg limit test. Test result at the 3 level of dosage revealed that dosage showed better compaction in terms of maximum γ_d . There was increase in the value of CBR up to limit of 140% to 170%.

Srinivasa.G and Amith Kadaba Sheshadri (2016), conducted their soil stabilization experiment investigations using Terra-Zyme on black cotton soil. Results obtained by experimental studies were quite positive. Experimental studies revealed that liquid limit of soil decreased from 61.40% to 56.49% and plastic limit of soil decreased from 34.00% to 31.70% respectively. Also there was drastic improvement in value of CBR. CBR value increase of 387% compared to the untreated soil.

Sandeep Panchal, Md. Mohsin Khan, Anurag Sharma(2017) conducted their research work on the use of bio-enzyme as the stabilizing agent. They used Terra-Zyme as the stabilizing agent and they selected soil from district Amroha in Uttar Pradesh. Dosage of Terra-Zyme was taken as 500ml/m³, 700ml/m³, 900ml/m³, 1000ml/m³ and results were analyzed. Different test performed were standard proctor test, Atterberg's limit test and CBR test. Firstly tests were performed on untreated soil and results obtained were noted. Then test were performed on soil with different dosage of Terra-Zyme. Duration of test was for 28 days of curing period. Results showed increase in value of CBR with increase in dosage of Terra-Zyme and increase in curing period. Best results were obtained with the third dose in which value of CBR increased up to 131.49% after curing for 14 days.

Sanjeet Sahoo and G. Sridevi (2018) conducted the research work on effect of Terra-Zyme fine grained soil which they collected from Kausalya Ganga, Dhauli, Odisha. They used Terra-Zyme as stabilizing agent in there research work. Objective of their work was to study the behavior of soil when Terra-Zyme on different dosages is added to soil. Test was performed on different dosages of Terra-Zyme on black cotton soil. Dosage taken were 0.05% and 0.1% by weight and sample was cured in desiccators for 7 days. Results obtained showed improvement in UCS with increase curing period and increased dosage of Terra-Zyme. Value increased from 120kN/m² to 122.5kN/m² when curing is done for 7 days and increased to 151kN/m² when cured for 28 days with dose of 0.05% by weight. And with 0.1% dose value increased from 120kN/m² to 133.5kN/m² when cured for period of 7 days and increased to 173kN/m² when cured for 28 days. CBR value also increased by about 50% for treated soil.

Madhu G Banakar and Nandini D (2018) conducted there research work on the effect of Terra-Zyme and hypo-sludge on red soil. Research work was conducted for the period of 28 days taking different dosage of Terra-Zyme and hypo-sludge. Firstly the optimum dosage of Terra-Zyme was identified. Addition of Terra-Zyme in red soil gave the noteworthy outcomes. Depending on these results the optimum water content for the dosage was fixed. Then another additive hypo-sludge was added from 2% to 12%. Now different tests were performed on the mixture of soil, Terra-Zyme and hypo-sludge. Various test performed were proctor test, UCS, CBR. UCS and CBR were performed on samples on 0th day, 7th day, 14th day, 21st day and 28th day of curing. Results obtained were very good there was improvement in value of CBR and UCS with increase curing. Terra-Zyme alone also showed very good results and considerably improved value of CBR and UCS.

Deepak Kumar Das and Dr. M. Maharana(2019) conducted research work in the soil stabilized by the mixture of Terra-Zyme and Fly-Ash for the construction of roads. Soil taken by them was clayey soil. They performed proctor test to find optimum moisture content. After fixing optimum moisture content they added Fly-Ash to the soil with different dosage varying from 10% to 40% and performed different tests on samples of soil and Fly-Ash mixture. CBR, UCS showed maximum improvement in strength when dosage of Fly-Ash is 30% so they fixed it as optimum dosage. After fixing Fly-Ash Terra-Zyme was added and the mixture of soil, Fly-Ash and terrezyme was prepared. Following dosages of Terra-Zyme were taken i.e. 200ml/5m³, 200ml/4m³, 200ml/3m³, and 200ml/2m³. Value of CBR increased to 183% of that of parent soil when dosage of Terra-Zyme was 200ml/5m³.

Table 1 literature Review Summary

Researcher name and year of research	Material used	Laboratory experiments	Conclusion
Lacuoture and Gonzalez (1995)	Terra-zyme	Proctor Test, CBR,UCS	Strength of soil improved in shorter duration with Terra-zyme as compared to soil without Terra-zyme.
Bergmann (2000)	Terra-zyme	Proctor test and CBR	Strength of soil increased to about 100%. And results was better when clay content was high
Andrew et al (2003)	Bio-enzymes	CBR	Results of soil with and without enzymes were compared and found that bioenzyme increases the strength to great extent.
Isaac et al (2003)	Terra-zyme And Lateritic Soil	CBR	The results obtained from the study were very good, increased by the addition of CBR's Terra-Zyme value, which proves that it can be used as a good stabilizing agent. The rise in CBR ranged from 136 to 180 times the initial value. Terra-Zyme was very helpful for sandy soil and clayey soil, but is less essential for silty soils and CBR increased by 700 percent for clayey and sandy soil.
Manoj Shukla (2003)	5 Different Types Of Soil ,Bio-enzyme	Proctor test, CBR test, UCS test	Soil with low clay content showed lesser improvement and soil samples with high clay content showed much better results. Reason behind this kind of variation was that soils with low clay content are less reactive with boi-enzymes as compared to the soils with high clay content. With the increase in the value of CBR and UCS it was observed that the thickness of pavement was reduced from 24% in soil with low clay content to 48% of that type of soil with high clay contents.
Sharma (2006)	Terra-zyme, Different Types Of Clay	Consistency limit test, proctor test,CBR and UCS	Improvement in the value of CBR and the best results obtained were from the soil with high clay content. It was found that the result of CBR increased form 21% to 40% on the 28th day of stabilization. Increase of 100% was found in the value of unconfined compression test.
Shankar (2009)	Lateritic Soil ,Sand, Terra-zyme	Consistency limit test, proctor test,CBR and UCS	Effect of enzyme on the various properties of soil such as permeability, unconfined compression test and CBR was studied for the period of 28 days. With 10% sand and high dosage of enzyme of 200ml/2m ³ CBR value increased by 300% after 4 week of curing. A 450 percent increase in the unconfined compressive strength value, a 300 percent increase in the CBR value and a 42 percent decrease in soil permeability was seen after 28 days of healing with a high dose of 200 ml/2 m ³ of enzyme
Mithanthaya.I.R, Harsha Kumar Rai and	Terra-zyme	CBR, UCS	From the different experimental studies and comparisons made from the results obtained

Ravishankar.A.U (2009)			from untreated soil and treated soil it was found that the value of CBR improved upto 400% of the value obtained on the plain untreated soil and the value form UCS went up to 450% of the value of original soil. And permeability of soil was also reduced greatly by up to 42%.
Venkatasubramanian & Dhinakaran (2011)	Terra-zyme		Positive findings were obtained based on subsequent studies. Three soils had liquid limits of 28, 30 and 46 percent, and 6, 5 and 6 percent plasticity indices. After 28 days of curing, 246 to 404 percent was recorded as a significant increase in unconfined compressive strength.
Vijay Rajorial, Suneet Kaur (2014)	Terra-zyme	CBR, UCS, Proctor Test	Reduction of cost of about 18% to 26% in Terra-Zyme stabilized roads as compared to other roads. Finally they concluded that road which is stabilized by Bio-Enzyme are more economical and have more strength as compared to other.
Venika Saini and Priyanka Vaishnava(2015)	Terra-zyme	Consistency limit, proctor test, CBR, UCS	They choose the different proportion of Terra-Zyme 200ml/3m ³ , 200ml/2.5m ³ , 200ml/2.0m ³ and 200ml/1.5m ³ and different tests were performed on it. And comparison was made between the test results of treated and untreated soil and from the comparison it was clear that there is considerable increase in the soil strength. And results obtained were good.
Srinivasa.G and Amith Kadaba Sheshadri (2016),	Terra-zyme	Consistency limit test , proctor test and CBR test	Experimental studies reviled that liquid limit of soil decreased from 61.40% to 56.49% and plastic limit of soil decreased from 34.00% to 31.70% respectively. Also there was drastic improvement in value of CBR. CBR value increase of 387% compared to the untreated soil.
Sandeep Panchal, Md. Mohsin Khan, Anurag Sharma(2017)	Terra-zyme	standard proctor test, Atterberg's Limit Test CBR Test	Test was performed on soil with different dosage of Terra-Zyme. Duration of test was for 28 days of curing period. Results showed increase in value of CBR with increase in dosage of Terra-Zyme and increase in curing period. Best results were obtained with the third dose in which value of CBR increased up to 131.49% after curing for 14 days.
Sanjeet Sahoo and G. Sridevi (2018)	Terra-Zyme, Black Cotton Soil	Consistency limit, proctor test, CBR, UCS	Test was performed on different dosages of Terra-Zyme on black cotton soil. Dosages taken were 0.05% and 0.1% by weight and sample was cured in desiccators for 7 days. Results obtained showed improvement in UCS with increase curing period and increased dosage of Terra-Zyme. Value increased form 120kN/m ² to 122.5kN/m ² when curing is done for 7 days and increased to 151kN/m ² when cured for 28 days with

			dose of 0.05% by weight. And with 0.1% dose value increased from 120kN/m ² to 133.5kN/m ² when cured for period of 7 days and increased to 173kN/m ² when cured for 28 days. CBR value also increased by about 50% for treated soil as compared to untreated soil.
Madhu G Banakar and Nandini D (2018)	Hypo Sludge And Terra-zyme	Consistency limit, proctor test, CBR, UCS	Different tests were performed on the mixture of soil, Terra-Zyme and hypo-sludge. Various test performed were proctor test, UCS, CBR. UCS and CBR were performed on samples on 0th day, 7th day, 14th day, 21st day and 28th day of curing. Results obtained were very good there was improvement in value of CBR and UCS with increase curing. Terra-Zyme alone also showed very good results and considerably improved value of CBR and UCS
Deepak Kumar Das and Dr. M. Maharana(2019)	Terra-Zyme And Fly-Ash	Consistency limit, proctor test, CBR, UCS	CBR, UCS showed maximum improvement in strength when dosage of Fly-Ash is 30% so they fixed it as optimum dosage. After fixing Fly-Ash Terra-Zyme was added and the mixture of soil, Fly-Ash and terrezyme was prepared. Following dosages of Terra-Zyme were taken i.e. 200ml/5m ³ , 200ml/4m ³ , 200ml/3m ³ , and 200ml/2m ³ . Value of CBR increased to 183% of that of parent soil when dosage of Terra-Zyme was 200ml/5m ³ .

3. Inferences drawn

After studying various research papers published by different researchers regarding various waste materials used for the stabilization following inferences can be drawn:-

- Materials such as Fly-ash, Ckd etc. which are waste products obtained from different industries can be used to improve the strength of soil and improve various properties.
- Natural enzymes or bio enzymes such as Terra-zyme improve strength of soil to very great extent and also reduce the maintenance cost of roads.
- Cost is reduced to a great extent when such waste materials are used for the construction purpose.
- Combination of Terra-zyme with Fly-ash improves the strength to great extent and also reduces the cost of construction.

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