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Stabilization Of Contaminated Dump Yard Soil By Bio-Enzymes

[1],*Megha Mayuri B G and [2]Anil Kumar

[1],[2]Dept. of Civil Engineering, NMAMIT, Nitte,
*Corresponding author. Email: meghamayuri23@gmail.com

Abstract— *the occurrence or detection of the construction project is often problematic because of the associated time constraints in correctly determining and classifying the contaminant region and the costs involved with maintaining the safe and effective handling of the contaminated material. The present research work aims to provide a solution to that problem with the help of a newly developed non-conventional stabilizer known as DZ-2x bio enzymes.*

Contaminated soil from a dump yard is tested with the bio enzymes to determine possible changes in its strength and usability as a construction material. The experiments showed a positive results in terms of its unconfined compression strength, maximum dry density and optimum moisture content with compressive strength increased up to 164% at the end of 28 days.

Index Terms— *soil contamination, stabilization, bio-enzymes,compaction, unconfined compression test*

I. INTRODUCTION

Many a time's engineers are faced with challenge of working with soils which do not possess sufficient engineering properties to support the imposing loads or the building activities on them. For the better performance of the structures built on poor soils, the performance characteristics of such soils must be improved. When a poor quality soil is present at the working site the best way to handle the construction environment is to modify the properties of that soil until it meets the requirements. This need has resulted in variety of soil stabilizing techniques depending upon the types & properties of the soils [1].

Table 1. Trace elements in the samples compared with Effluent Standards (Ojoawo et. al, 2015)

Elements (ppm)	Obtained	EPA standard
Cu	26.7	3.0
Pb	25.9	1.0
Mg	417.4	-
Cr	0	2.0
Ni	0.9	1.0
Zn	11.6	5.0
Mn	0	2.0
Cd	1856.4	0.03

Soil pollution and land degradation by various human activities involving the xenobiotic elements reduce, alter and change the properties of soils. Soil contamination by hazardous materials is an issue of concern worldwide. Various studies have been undertaken to find the effective way of treating, stabilizing and utilizing this naturally available soil for the construction activities. Table 1 and 2 depicts the chemical properties of the leachate and elements found in the soil of the area under study. It clearly shows the excess of chemical present in the soil. It is impractical to remove and replace the entire soil layer of a building site. Therefore using stabilizing methods to increase the workability and constructability is a better and economical option. The recent advancement in using enzymes as a stabilizing agent has proved to increase the soil stability and other engineering property necessary for a building quality soil. Enzymes are environmental friendly, organic compounds which used in right way can provide a great stabilization of soils which are especially good for the construction of sub grade for highway, road beds [2].

Table 2: Chemical parameters as compared with the Effluent Standards (Ojoawo et. al, 2015)

Properties	Obtained	EPA standard
pH	8.37	6.0
Electrical conductivity (Ms/cm)	76000	-
Chloride (mg/l)	11700	-
COD (mg/l)	44800	160
Sulphate (mg/l)	48.0	-
Nitrate (mg/l)	160.0	50.0
Phenol (mg/l)	1010.0	1.0
Phosphate (mg/l)	85.4	4.0

Combined with rising relocation to urban centers, the growing global population means that vacant land sites are being redeveloped to satisfy demand. Absence of appropriate due diligence to adequately determine the possibility of polluted soil on a site at the early stages of pre-planning and construction can run the risk of significant budget overruns or potentially may have severe safety consequences for all workers and future residents. Open dumping of the city wastes has been extensively practiced in India. The resulting leachate produced from the landfill pose a serious environmental threat to the surrounding area by contaminating the soil and ground water sources [3].

The area under this experimental study is a large open dump site in Mangaluru city. Around 250 MT of solid urban waste is being dumped without shredding and sorting at the dumping yards (Ravi Shankar et al., 2004). The dump yard receives carcasses of animals, chemical, industrial, and bio-medical waste. (Sitaram et al., 2007). Table 3 shows an estimation of growing amount of wastes disposed in the city, thereby prompting a thorough study of soil in the area to mitigate the problems raised due to leachate and low strength.

Scope of the problem

An initial survey of the area reveals an extensive contamination of the soil due to the heavy leakage of the leachate. The ground water sources of the nearby village such as Mandara is found to be polluted.

The basic test of the dump yard soil indicates very low geotechnical proprieties suggesting any possible future infrastructure development is impossible without proper ground improvement. The present experimental program is an attempt to come up with solutions to these problems [4].

II. LITERATURE STUDY

Mohd. Yosuf et al., (2016) a laboratory investigation was conducted in this study to analyses TerraZyme's quality on various types of soil. Using 2 % & 5% TerraZyme, laterite and kaolin are treated to assess improvements in the geotechnical properties of the soil. In terms of compaction, unconfined compressive strength and bearing ratio, the results obtained are evaluated and investigated. Modifications in the geotechnical properties of stabilized and unstable soils have been controlled for 0, 7, 15, 21 and 30 days. Laterite with 5% TerraZyme was found to have increased maximum density and decreased optimum moisture content. It is concluded that TerraZyme is not ideal for Kaolin stabilization; to achieve better efficiency, TerraZyme needs soil.

Carvalho et al., (2017) this research aims to show how the use of enzymes in the construction industry could be beneficial. It thus discusses the chemical and biological functioning of enzymes; it examines their advantages and uses in the field of construction and measures the addition of two different types of enzymes in different concentrations to a soil: Alpha soil as well as DZ-2X. In the flexural and compressive tests the soil without treatment and the addition of enzymes are based. The results thus allow the study of the interferences of these enzymes in soil resistance and the comparison of the improvements caused by both substance additions. Finally the results of the study show that adding enzymes to the soil will significantly improve its flexural and compressive behaviour.

Kushwaha et al., (2018) conducted a study on stabilization of red mud with different content of Eko Soil Enzymes (ES). ES variability in the samples was rendered by volume of water 1 to 7 per cent. 7 Samples of varying red mud content of ES were prepared and index and engineering properties tested. The CBR experiments were conducted on unsoaked and soaked samples to understand the role of ES as stabilizing material. Depending on the experimental findings, the application of ES (up to 4%) to red mud improves the average dry density and reduces the optimal content of moisture. The optimal mix was RM+ 4 percent and it improved the soaked CBR by 580.9 percent and UCS by 578 percent for 45-day healing period. The properties of permeability and leachate was evaluated for different flow cycles from 1 to 7 days of mixture RM+4 per cent ES [5].

Shankar et al., (2009) Carried out a laboratory investigation to study the properties of laterite soil of Udupi and Dakshina Kannada district with and without blending the soil with sand, in addition to the commercially available enzyme namely Terrazyme. The investigation showed a medium enhancement in the physical properties of soil. Hence the paper suggest that prior experiments with bio-enzymes have to be made before applying it in the field. By using a higher dosage of 200mml per 2m3 of soil, it was possible to get 300% increase in CBR value, 450% rise in unconfined compressive strength. Permeability was reduced by 42% for a curing period of four weeks. The experiment noted that the enzymes are not effective for cohesion less soils [6]

III. METHODOLOGY

The research work is carried out at the NMAM institute of technology, Nitte. During the initial work the main focus of the study is to understand the geotechnical properties of the heavily contaminated soil of the dump yard. Later part consist of finding an economical solution to improve the soil condition as well as to reduce the percolation of leachate into the soil.[7]

Selection of soil from 4 different location of the dump yard as a representative of the contaminated soil and

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studying their physical and geotechnical properties.
Selection of soil in its natural condition from the near by location to study the comparison between the contaminated and non contaminated soil.
Study the basic engineering properties of soil.
Applying a non conventional enzymatic solution to contamiated soil to study any improvements in its geotechnical characteristics.[8]

Table 3 Estimation of waste generation in MCC area (City Corporation, Mangalore)

Year	Population	Waste in tons/day
2001	398745	140
2005	440247	162
2010	486068	189
2015	536658	219

Soil

The representative soils were collected from the selected locations at a depth of 1.0-1.2 m. The soil samples were oven dried before conducting the laboratory tests.

Table 4 Nomenclature of the soil samples

Samples	Abbreviation
Natural soil sample	N.S
Contaminated soil sample 1	C.S I
Contaminated soil sample 2	C.S II
Contaminated soil sample 3	C.S III
Contaminated soil sample 4	CS IV

Fig 1 Collection of soil samples

DZ-2x

It is a naturally occurring biodegradable substance. It changes and improves physical and chemical properties of soils through its behavior, resulting in considerably less mechanical effort to achieve higher compaction densities. Soil adsorbs the proteins, which initially allows it to stretch and then contract. The enzymes also help the soil bacteria release hydrogen ions, resulting in pH gradients at the soil particle surfaces, which help break up the soil structure. An enzyme is by definition an organic catalyst that accelerates a chemical reaction, which would otherwise occur at a slower rate, without being a part of the final product. The enzyme interacts with the complex organic molecules to form a reactant intermediate that exchange ions with the surface of the soil, breaking down the lattice and inducing the cover-up reaction, which avoids further water absorption and density loss. The reaction regenerates the enzyme and goes on to react again. The compaction of aggregates by construction machines close to the maximum moisture content provides the desired high densities typical of the shale. The resulting surface has permanent "shale" properties created in a fraction of the time (millions of years) needed by nature.[9]

The enzymes increase the wetting and bonding capacity of the soil particles when applied to a soil. The enzyme makes it possible for soil particles to get moist and densely compacted. It also strengthens the chemical bonding which helps to bind the soil particles together, making a more permanent structure which is more immune to weathering, wear and water penetration. (Dhara Biotech manual)

A. Basic tests

Primary tests were conducted on the soil sample in accordance with the standard code book. The basic tests included specific gravity as per IS 2720: Part III, moisture content as per IS 2720: Part II, Sieve analysis as per IS 2720: Part IV. Modified proctor test was performed to determine the maximum dry density at optimum moisture content in accordance with IS 2720: Part VIII. Other test like unconfined compression test as per IS 2720: Part X, soaked and unsoaked California bearing ratio as per the code of IS 2720: Part XVI.

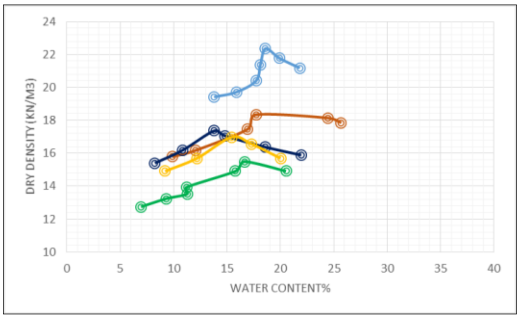

Fig 2 Compaction curves for the samples

The soil samples from the different parts of the dump yard region showed varied properties. The differences indicates the type and amount of the wastes being dumped over the course of the years. The sample CS-I is found be having more clay content in it resulting in more strength compared to the other soil samples.

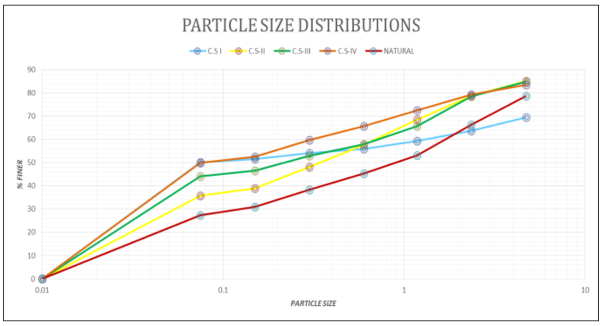

Fig 3 Particle distribution curves of the soil samples

The compaction characteristics of the soil reveal the presence of organic compounds that are accumulated over the course of time in terms of its dry density value which is lower compared to the naturally available soil from the same area. Fig 2 shows the graphical representation of the 5 soil samples and their variation with the moisture content. Table 5 summarizes the index and strength properties of the contaminated soil samples

Table 5: Physical & Geotechnical properties of untreated soil samples

Physical properties	NS	CS I	CS II	CS III	CS IV
Moisture content (%)	12.4	33.82	20.82	17.17	16.35
Specific gravity	2.728	2.394	2.41	2.462	2.321
Atterberg's limits and indices *Liquid limit* *Plastic limit* *Shrinkage limit* *Plasticity index* *Liquidity index* *Consistency index*	…. .. … 31 20.38 35.76 10.62 1.75 0.751	…. ….. 52 34.21 30.64 17.79 1.02 0.021	…. ….. - - - - - -	… ….. 39.29 26.07 32.41 13.22 1.67 0673	.. … … 36.1 20.06 33.86 15.5 1.27 0.274
Particle size distribution *Gravel (%)* *Sand (%)* *Silt & Clay (%)* C_U C_C	… 21.28 51.44 27.28 66.29 0.345	… … .. 30.56 19.28 50.16 91.06 0.098	.. … … 14.96 49.28 35.76 34.59 0.261	….. … 15.12 40.8 44.08 30.16 0.154	… …. 16.4 33.6 50 20.78 0.432
Compaction characteristics *Maximum dry density(kN/m³)* *Optimum moisture content (%)*	…. …. 18.33 16.63	… …. . 22.35 18.12	….. ….. 15.49 21.40	…… …… 17.35 13.79	…… …… 16.96 15.41
IS classification	SC	MI	SM	SC	CI
UCS (MPa)	146.3	157.57	105.7	127.4	133.5
Permeability *Constant head ($*10^{-3}$)* *Variable head ($*10^{-4}$)*	0.583 3.05	0.381 1.595	2.19 6.653	1.764 4.583	1.279 4.016

B. Dosage of DZ-2x stabilizer

It was stated (Tingle et al.) that enzymes remain actively engaged in the soil until no further catalyzing reactions occur. As the enzymes serve as a catalyst in soil inducing reactions, they are necessary for stabilization purposes in very limited dosages. Since no technical requirements have been developed, their applicability is dependent on

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empirical criteria laid down in previous studies. Because differing dosages of the enzyme have various effects on the same soil, this suggests that inadequate enzyme concentrations will not produce successful stabilization, whereas higher doses may have detrimental effects on soil. It would also be desirable to arrive at an optimum dose of DZ-2x to improve the effectiveness of enzyme stabilization. The subsequent dosages proposed for this analysis were considered as follows.

Table 6: Dosage of DZ-2x stabilizer used in the study

Dosage (%)	ml/ 1 Lt of water
2	20
4	40
6	60
8	80
10	100

IV. RESULTS AND DISCUSSIONS

Out of the five samples collected from the dump yard the soil sample with least strength and density was chosen to carry out the further experimental investigation with the stabilizer. Only the sample C.S-II was used in all the tests with stabilizer.

C. Compaction characteristics

The compaction properties of the soil samples (B.I.S, 1987) were studied in the laboratory using standard proctor testing. The apparatus used in the test consists of a cylindrical mold with detachable base with an internal diameter of 100 mm and an effective height of 126 mm, with a total volume of 990 ml. The rammer weights 3.5 kilograms, with a 300 mm fall

Table 7 MDD vs OMC of the soil treated with enzymatic solution

Dosage	OMC (%)	MDD (kN/m^3)
0%	21.407	15.54
2%	20.844	15.69
4%	21.889	15.76
6%	19.703	16.17
8%	21.008	15.89
10%	21.27	15.79

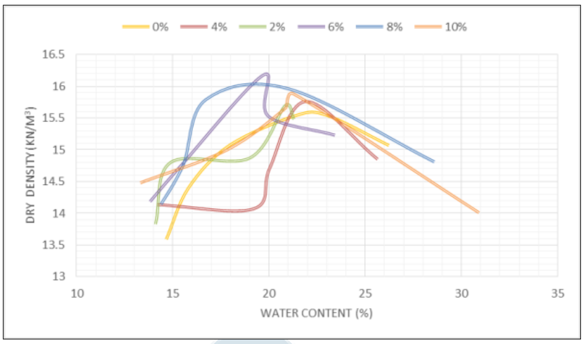

Fig 4 compaction curves for various dosages of stabilizers

The soil samples for the compaction tests were prepared such that the enzymatic solution is added and allowed to mellow for a minimum period of 12 hours as per the manufacturer's instruction in a sealed condition before the compaction procedure. This makes sure the reaction of enzymes with the soil. The result at the end of test yielded a linear increase in the maximum dry density of the soil with every 2% interval. The optimum solution for the maximum dry density is found to be at 6% of the solution.

D. Unconfined compression strength characteristics

Remolded samples prepared in the laboratory with an optimal moisture content and a maximum dry density using cylindrical molds. The height diameter ratio of each sample was 2:1 and the test was carried out as per IS: 2720 (part 10). Addition of stabilizer shows considerable improvement in the strength. Due to the enzymatic reaction in the soils, there is enhancement in the chemical bonding of the soil particles which helps in packing them closely.

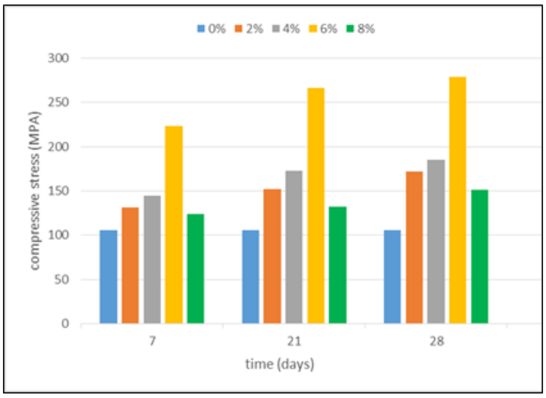

Fig 5 Graphical comparison of effect of stabilizer dosage on soil

The sample tested with 6% of the stabilizer showed almost double the value of the sample with 0% stabilizer. This mirrors the effect of the activities of enzymes in modifying arranging the structure of soil particles as highest at a particular dosage.

Table 8 The unconfined compression strength values

Days/ Dosage	0%	2%	4%	6%	8%
7	105.7	131.62	144.82	223.42	124.14
21	105.7	152.36	173.00	266.78	132.62
28	105.7	171.8	185.33	279.20	150.95

V. CONCLUSTION

This experimental study shows a considerable improvement in the maximum dry density. The contaminated samples have shown little to no negative impacts on the geotechnical properties of the soil in terms of strength. But upon the application of the stabilizer the soil sample has shown a significant improvement in the unconfined compression strength and dry density in comparison. The enzymes have combined with the large organic molecules to form an intermediary that exchange ions with the soil structure and break s down the lattice to produce a tight alignment of soil particles. Maximum dry density improved from 15.49 kN/m^3 to 16.17 kN/m^3. Compressive strength increased by 164% at the end of 28 days. It's imperative to conduct other tests in order to understand the effect of the enzyme on the contaminated soil before using it on a larger scale.

VI. ACKNOWLEDGEMENT

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