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Improvement of sub-grade material using additives

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ABSTRACT

Conventional construction material like aggregates is becoming scarce due to increase in rapid construction and thus leading to ecological imbalance. This has shifted focus from use of large scale conventional aggregates to use of locally available and stabilized soil for construction. In recent years there is an increase usage of bio enzymes as soil stabilization chemical, which is a natural material, non-corrosive, non-flammable, non-toxic liquid enzyme fermented from vegetable extracts that improves the engineering properties of soil, which allows higher soil compaction, reduces permeability and increase strength. A bio enzyme known as TerraZyme is used in this study to improve sub-grade. The aim of the study is to stabilize the sub-grade and design and evaluate the fatigue and rutting parameters of flexible pavement for stabilized and un-stabilized sub-grade material for different composition of pavement materials mentioned in code book IRC: 37-2012 are subjected to analysis using the software IITPAVE. In this study a urban road at Hyderabad having heavy volume traffic movement which is supposed to be widened due to on-going METRO rail construction is considered.

Keywords: Bio-enzymes, Fatigue, Rutting,Sub-grade, Terrazyme

1. INTRODUCTION

Stabilization provides an alternate method to improve the structural support of the foundation for many of the sub-grade conditions presented. In all cases, the provision for a uniform soil relative to textural classification, moisture, and density in the upper portion of the sub-grade cannot be over-emphasized. This uniformity can be achieved by soil stabilization techniques. Stabilization may also be used to improve soil workability, provide a weather resistant platform improves soil strength in terms of California bearing ratio(CBR). Fatigue cracking is conventionally considered as a 'bottom-up cracking' phenomenon, the fatigue cracking of the bottom of asphaltic concrete due to heavy axle loads. .Rutting is the permanent deformation in pavement usually occurring longitudinally along the wheel path. The rutting may partly be caused by deformation in the sub-grade and other non-bituminous layers which would reflect to the overlying layers to take a deformed shape.

II. OBJECTIVE AND SCOPE OF THE WORK

The broad objective of this investigation is to evaluate the soil strength in terms of California Bearing Ratio (CBR) using bioenzymes over a period of time and to design the thickness of flexible pavement also to evaluate the rutting and fatigue performance of flexible pavements for different composition of pavement materials like cementitious base, cementitious sub base, crack relief layer of aggregates, treated RAP and SAMI as per IRC provisions and mechanistic empirical software IITPAVE.

The Scope of the work includes the following:

- To determine the variation of California bearing ratio values using bio enzyme named as terrazyme..
- To find out the optimum dosage of terrazyme to be used for the selected soil samples for the study.
- To design the pavement thickness design using IRC:37-2012 using with and without bioenzyme.
- To design and evaluate the rutting and fatigue performance of flexible pavements for different composition of pavement materials

III. REVIEW OF LITERATURE

Lacuoture and Gonzalez (1995) conducted study on the effects of TerraZyme on sub-base and subgrade. The reaction of the soil treated with Bio Enzyme was observed and compared with soil without Bio Enzyme. It was concluded that soil showed improvement in short duration of time but the cohesive soils showed improvement successively. Bergmann (2000) concluded from his study on bio enzyme that for imparting strength to the soil, bio enzyme requires some clay content. He stated that for successful stabilization of soil minimum 2% clay content is required and 10 to 15 % of clay content gives good results. Compared to 28 % of untreated soil CBR after 1, 2, 3, 14 week was found as 37, 62, 66 and 100 respectively. Dhinakaran (2011) performed test on 3 different soils with different properties. These soils were tested with different dosage of enzyme. The liquid limit and plasticity index of soil were reported as 28, 30, 46 % and 6, 5 and 6 % respectively. An increase of 157 to 673 % is seen in CBR after 4 weeks of curing and 152 to 200 % in UCS.]. Komershetty Goutami Dr. KSR Murthy D. Sandhya Rani(2017) Based on the pavement thickness analysis and design carried out using IIT Pave software and IRC 37:2012, the alternate pavements with less total pavement thickness can cater the same traffic as that of conventional pavement except the alternate pavement with CTB and GSB. Harish gr (2017)Out of all the different compositions the cemented base and cemented sub base with SAMI interface at the interface of cemented base and the bituminous layer provides good serviceability when compared to other compositions. This is because of presence of SAMI (Stress absorbing membrane interface) in the structure which acts as stress relieving interlayer.

In past many researchers have carried out the design and analysis of flexible pavement for different material components. The results from these studies encourage the use of different composition of pavement materials which not only improves the life and performance of the pavement, but also the economic consideration.

IV. METHODOLOGY

Bio-Enzyme is a natural, non-toxic, non-flammable, non-corrosive liquid enzyme formulation fermented from vegetable extracts that improves the engineering properties of soil, facilitates higher soil compaction and increases strength.TerraZyme is specially formulated to modify the engineering properties of the soil .They require dilution in water before application. TerraZyme acts to reduce the voids between soil particles and minimize absorbed water in the soil for maximum compaction. This decreases the swelling capacity of soil particles and reduces permeability. The application of TerraZyme enhances the increases load bearing capacity of soils.

The method used in data analysis is mechanistic-empirical method which considered the design life of pavement to last till the fatigue cracking in bituminous surface extended to 20 per cent of the pavement surface area or rutting in the pavement reached the terminal rutting of 20 mm, whichever happened earlier.. The mechanistic empirical software called IIT-PAVE is used to analyze the pavement responses. The structural analysis of flexible pavement for IIT-PAVE is based on the multi-layer theory

A flexible pavement is modelled as an elastic multilayer structure. Stresses and strains at critical locations (Fig.1) are computed using a linear layered elastic model. The Stress analysis software IITPAVE has been used for the computation of stresses and strains in flexible pavements. Tensile strain, ϵt, at the bottom of the bituminous layer and the vertical subgrade strain, ϵv, on the top of the sub-grade are conventionally considered as critical parameters for pavement design to limit cracking and rutting in the bituminous layers and non-bituminous layers respectively. The computation also indicates that tensile strain near the surface close to the edge of a wheel can be sufficiently large to initiate longitudinal surface cracking followed by transverse cracking much before the flexural cracking of the bottom layer if the mix tensile strength is not adequate at higher temperatures. (IRC: 37-2012)

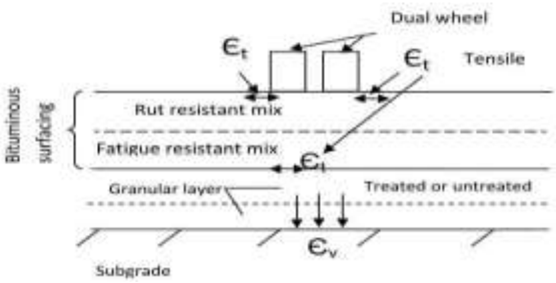

Figure 1 Critical strain locations in flexible pavement(IRC 37:2012)

In this study a urban road at RTC X roads at Hyderabad having heavy volume traffic movement which was meant to be extend the width of pavement due on-going METRO rail construction. Traffic survey data of the year 2017 was collected through traffic video recordings from traffic police station at Basherbagh and was calculated as per IRC guidelines. Soil sample was collected near shoulders at sub-grade level for investigation of index and engineering properties of soil.

V. RESULTS

The results of various tests performed on soil are discussed in this section. With the aim to understand the changes in the CBR values of the soil with the introduction ofbio enzyme, the CBR test has been conducted on the soil , with different dosages and at 7 days curing period. The soil in the CBR mould has been divided into 5 layers with equal weights (considering constant density and Volume per layer) treated with terrazyme .The soil has been mixed thoroughly and the CBR tests have been performed for each dosage. The results obtained in all the tests have been analysed and the discussion has been included herein.

5.1 properties of the soil

Table 1: properties of soil

Property	Symbol	Values
Specific Gravity	G	2.51
Gravel (%)		2.9
Sand (%)		79.68
Fines(%)		16.3
Liquid Limit	LL	30
Plastic Limit	PL	17.10
Plasticity Index	PI	12.9
Classification	SC	Claye sand
OMC (%)		9
MDD (g/cc)		2.16
CBR unsoaked		7.37%
CBR soaked for 4 days		4.89%

5.2 Effect of terrazyme on soil type

California bearing ratio test was done for soaked conditions. The test was performed by taking different dosages of TerraZyme i.e. (3.0m3 /200ml), (2.5m3 /200ml), (2.0m3 /200ml). Before performing test the sample of soil with different enzyme content are cured for one week. This section represents that the results obtained from CBR test conducted by mixing Terrazyme with soil at different dosages. It can be observed that the mixing of Terrazyme at different dosages at D1, D2, D3 have CBR Value increased from 4.89% up-to 8.2%, 8.51%, 11.2% respectively.

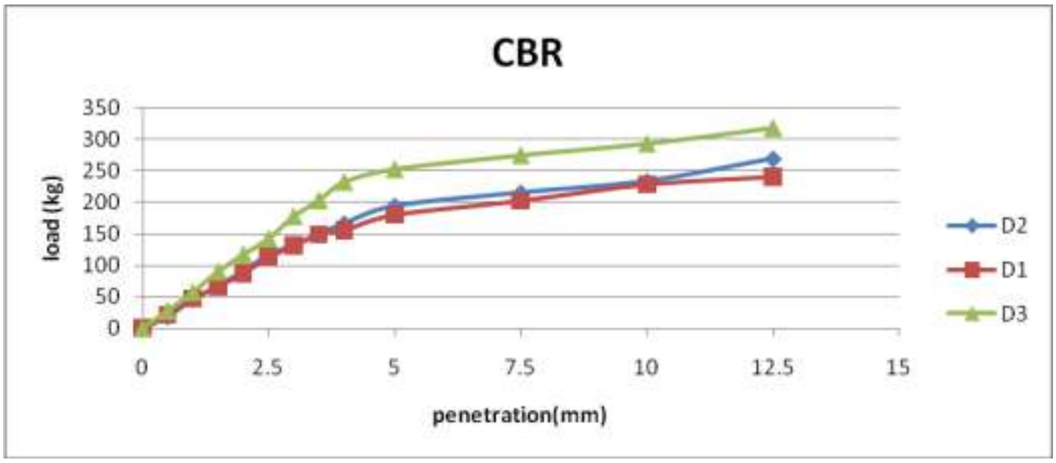

Figure2: CBR of soil at three dosages at 7days curing

Fig3 represents that the results obtained for CBR test conducted using with and without terrazyme at soaked and unsoaked conditions. From the below graph, it can be observed that using terrazyme the CBR value is highest at D3 as 11.3% as shown below figure

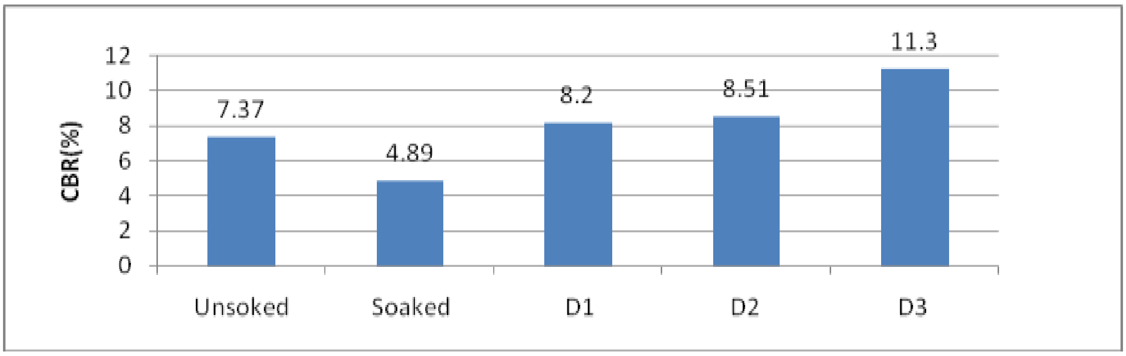

Figure3: CBR of soil at different conditions

5.3 Design and Analysis

The traffic data collected through traffic video recordings from traffic police station at Basherbagh from traffic survey data of the year 2017 and was calculated as per IRC guidelines. The pavement design and analysis has been carried out for different pavement components materials as per IRC 37-2012.

$$N = \frac{365 * [(1+r)^n - 1]}{r} * A * D * F \qquad (1)(IRC37\text{-}2012)$$

N =the cumulative number of standard axles to be catered for in the design in terms of msa.

A = Initial traffic in the year of completion of construction in terms of the No. of the commercial vehicles per day

D= Lane distribution factor

F = Vehicle damage factor

n= Design life in years

r = Annual growth rate of commercial

The traffic in the year of completion is estimated using the following formula

$A= P(1 + r)^X$

Where,

P= Number of commercial vehicles as per last count.

x=Numberofyearsbetweenthelastcountandtheyearofcompletionofconstruction=2.5years

Average 7-day-24 hour traffic in terms of commercial vehicles per day is calculated as 5800. Traffic growth rate is assumed to be 5% and design life of 20years for urban road. Vehicle damage factor is considered to be 4.5 and Lane distribution factor as 0.75 from the traffic survey it is known to have traffic split of 55:45. From this data The cumulative number of standard axles is calculated as 133MSA

5.4 Pavement thickness composition

The design thickness for different composition of materials has been found out using design catalogue given in code IRC:37-2012. The different compositions are mentioned below,

- Granular base and granular sub base (C- 1)
- Cemented base and cemented sub base with SAMI (C-2)
- Foamed bitumen/ bitumen emulsion treated RAP/ aggregate over cemented base (C-3)

Table 2: Pavement thickness composition

Composition	Total thickness in mm for untreated soil (CBR-4.89%)	Total thickness in mm for treated soil (CBR-11.3%)
C-1	745 (plate-3)	625 (plate-7)
C-2	520 (plate-14)	510 (plate-15)
C-3	550 (plate-18)	510 (plate-19)

Resilient Modulus ($M_{R)}$: The performance of thesub -grade is mainly elastic in nature under the transient traffic loading with negligible permanent deformation in a single pass. M_R is the measure of its elastic nature performance which evaluated from recoverable deformation from the laboratory tests. The modulus is an important parameter for design and the performance of a pavement. The relation between resilient modulus and the effective CBR is given as shown below

M_R (MPa) = 10 * CBR for CBR< 5 (2)(IRC37-2012)

M_R (MPa) = 17.6 * (CBR)0.64 for CBR > 5 (3)(IRC37-2012)

Where, M_R = Resilient modulus of sub-grade soil

$M_R$granular= 0.2* $h^{0.45}$* M_R sub-grade (4)(IRC37-2012)

Where, h = thickness of granular sub-base and base, mm.

Fatigue model: Two fatigue equations were fitted, one in which the computed strains in 80 per cent of the actual data in the scatter plot were higher than the limiting strains predicted by the model (and termed as 80 per cent reliability level in these guidelines) and the other corresponding to 90 per cent reliability level. The two equations for the conventional bituminous mixes designed by Marshall method are given below:

$$N_f= 2.21 * 10^{-04} x\ [1/\varepsilon t]^{3.89} * [1/M_R]^{0.854} \quad (5)(IRC37-2012))$$

$$N_f= 0.711 * 10^{-04} x\ [1/\varepsilon t]^{3.89} * [1/M_R]^{0.854} \quad (6)(IRC37-2012)$$

Where, N_f = fatigue life in number of standard axles,

εt = Maximum Tensile strain at the bottom of the bituminous layer,

M_R = resilient modulus of the bituminous layer.

Rutting model: Rutting model also has been calibrated in the studies using the pavement performance data collected during the studies at 80 per cent and 90 per cent reliability levels. The two equations are given below:

$$N= 4.1656\ x\ 10^{-08}\ [1/\varepsilon v]^{4.5337} \quad (7)(IRC37-2012)$$

$$N = 1.41x\ 10^{-8} x\ [1/\varepsilon v]^{4.5337} \quad (8)(IRC37-2012)$$

Allowable Horizontal tensile strain (εt) was evaluated for three pavement compositions C-1,C-2,C-3 by adopting 90% reliability equation and also by analysing through IITPAVE software and the corresponding values are given in TABLE 3 and 4 as shown belw

Table 3:Horizontal Tensile strain for untreated soil

COMPOSITION	IRC EQUATION	IITPAVE	REMARKS
C-1	145 $x10^{-6}$	79 $x10^{-6}$	Safe
C-2	145 $x10^{-6}$	72.8 $x10^{-6}$	Safe
C-4	145 $x10^{-6}$	102$x10^{-6}$	Safe

Table 4: Horizontal Tensile strain for treated soil

COMPOSITION	IRC EQUATION	IITPAVE	REMARKS
C-1	145×10^{-6}	103×10^{-6}	Safe
C-2	145×10^{-6}	76×10^{-6}	Safe
C-3	145×10^{-6}	116×10^{-6}	Safe

Allowable vertical compressive strain (εv) was evaluated for three pavement compositions C-1,C-2,C-3 by adopting 90% reliability equation and also by analysing through IITPAVE software and the corresponding values are given in TABLE 5 and 6 as shown below

Table 5: Vertical compressive strain for untreated soil

COMPOSITION	IRC EQUATION	IITPAVE	REMARKS
C-1	299×10^{-6}	149×10^{-6}	Safe
C-2	299×10^{-6}	128×10^{-6}	Safe
C-3	299×10^{-6}	113×10^{-6}	Safe

Table 6: Vertical compressive strain for treated soil

COMPOSITION	IRC EQUATION	IITPAVE	REMARKS
C-1	299×10^{-6}	151×10^{-6}	Safe
C-2	299×10^{-6}	143×10^{-6}	Safe
C-3	299×10^{-6}	100×10^{-6}	Safe

VI. DISCUSSIONS AND CONCLUSIONS.

- It is observed that the CBR values of SC soil with addition of stabilizing material have more CBR values compared with SC soil without addition of stabilizing material. As expected the thickness of pavement varied with the change in the value of CBR With higher value of CBR the lower will be the thickness of the pavement and vice versa
- Use of different composition materials in pavement structure, decreases the required design thickness for the same sub-grade properties and design traffic and also improves the serviceability.
- The soil stabilized with terrazyme with different dosages showed higher CBR values at D3.

- It is concluded that the thickness of pavement for unstabilized soil is highest for the composition of C-1 (745mm) and least for the composition of C-2 (520mm).It is also concluded that the thickness of the pavement for stabilized soil is highest for the composition of C-1 (625mm) and same for the composition of C-2 and C-3 (510mm).
- By increasing the CBR we can reduce the pavement thickness. By doing the modification we can reduce the excessive usage of the good quality earth materials thus avoiding the pollution
- It is observed that the horizontal tensile strain at the bottom of bituminous layer is $145\ x10^{-6}$and vertical strain of the sub-grade of soil computed manually is reported to be $299x10^{-6}$
- By the use of soil stabilizer there is considerable decrease in vertical compressive strain for stabilized soil, which in turn reduce the rutting parameter.
- For different pavement compositions the cemented base and cemented sub base with SAMI interface at the interface of cemented base and the bituminous layer provides good serviceability when compared to other compositions for un-stabilised soil .Out of all the different pavement compositions, the foamed bitumen/bitumen emulsion treated RAP/aggregate over cemented base provides good serviceability when compared to other compositions for stabilised soil.
- Based on the pavement thickness analysis and design carried out using IIT Pave software and IRC 37:2012, the alternate pavements are proposed for different soil conditions.

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