

# Experimental Study on the Effect of Bio-Enzyme Stabilization on Black Cotton Soils and Red Soil

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**ABSTRACT:**The present paper describes the study carried out for checking the improvements in the properties of Black cotton soils and red soil treated with Terra-Zyme stabilizer. The locally available soil samples were treated with a commercially available Terra-Zyme and the treated soils were cured at different curing period 7, 14 and 21 days. The different mix proportions of enzyme used for stabilization on the geotechnical properties of soils are studied. The geotechnical properties like the Liquid limit (LL) and Unconfined compression strength (UCS) are studied and discussed. These tests were conducted to understand the optimum proportion of the Terra-Zyme at different curing period.

**KEYWORDS:** Soil stabilization, Terra-Zyme, Liquid limit (LL) and Unconfined compression strength (UCS).

## I. INTRODUCTION

The soil is the only material which supports the structural foundation of buildings, dams and roads. About one third of Indian areas are covered with black cotton soil, which occurs in western and central parts of India and many areas are covered with silt and clay soils as these possess poor bearing capacity problems during the construction or during the life service of structures. For the poor engineering properties of these soils it has forced Engineers to improve the bearing capacity problem by improving the engineering properties of soil by using different soil stabilization methods. These methods of soil stabilization involves of replacing of soil or using complex methods of chemical stabilization [5]. The clay of medium to high compressibility characterised by high swelling and shrinkage properties which covers the area of north Karnataka regions has become a challenge to the engineers in construction. This soil when becomes dry is very hard but loses its strength properties completely when it is in wet condition [7]. Therefore, it is very important to know various properties of soil such as physical and engineering properties. Soil can be stabilized by chemically or mechanically. The chemical stabilizers are the substances that can enter in the natural reactions of the soil and control the moisture which is getting into the clay particles. Chemical stabilizers are divided into three groups they are as follows;

- Traditional stabilizers (hydrated lime, Portland cement and fly ash),
- Non-Traditional stabilizers (sulfonated oils, ammonium chloride, enzymes, polymers and potassium compounds) and
- By-product stabilizers (lime kiln dust, cement kiln dust) [10].

The compaction is the most basic form of mechanical stabilization, which increases the performance of a natural material. Soil stabilization is the process of improving engineering properties of soil. The enzyme stabilizer is a natural organic compound, similar to properties of soil. The enzyme stabilizer is a natural organic compound, similar to proteins, which acts as a catalyst and wide variety of soils can be stabilized using Terra-Zyme. When enzyme is added to soil, bearing capacity and the strength behaviour of soil can be improved and it makes the soil wet which can be more densely compacted [10]. Several field study were conducted on the effect of bio-enzyme in enhancing properties of soil have been presented by many investigators as (Hitam, A et al. 1998) [1]. The durability tests such as free- thaw,

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wet dry and leaching test were conducted on the effective dosage of lime, cement, class C fly ash, and Perrma-Zyme 11-X (Milburn, J.P et al. 2004) [4]. The properties of changes in fibre of soil particles were also studied, however many experimental studies were conducted at laboratory on the physical and engineering properties of different type of clayey soils mixed with different type of dosages of Terra-Zyme and was tested at different curing periods (A. U. Ravi Shankar et al. 2009) [6]. The mineralogical properties like Cat-ion exchange capacity for exchangeable Cat-ion properties were studied under X-Ray diffraction (SurekaNaagesh et al. 2011) [7]. The durability tests of soil by using enzyme as Terra-Zyme (Lekha B. M et al. 2013) [9]. Many tests were carried out to study the effect of enzyme on lateritic soil and blended with sand in terms of permeability, compaction, UCS, CBR characteristics. It has been observed that the enzyme treated soil showed significant improvement in UCS, CBR for longer curing period, but it is not much effective on cohesionless soil.

The main object of this work is to study

- To study the changes in the physical and strength properties when stabilized with Terra-Zyme and to evaluate the influence of various parameters such as curing period on stabilized soil.

## II. EXPERIMENTAL INVESTIGATIONS AND METHODOLOGY

### 2.1 Materials used

**Soil:** The locally available four different types of soils from four different places were procured and used for the present study i.e. three black soils and red soil and they as follows.

- Navalgundtaluk (Anigerechanammanakeri), Dharwad district (S1).
- Navalgundtaluk (Benihala), Dharwad district (S2).
- Nargundtaluk (Kalikere) Gadag district (S3), and
- Red soil Badamitaluk (Mutulgere), Bagalkot district (S4).

**Terra-Zyme:** A commercially available Enzyme is used. The cementious property is obtained when the enzyme is mixed with predetermined quantity of water and applied. This enzyme solution combines the organic and inorganic material present in the soil through catalytic bonding process [9]. Enzyme promotes the development of cementious compounds using the following reaction. The properties of Terra-Zyme are studied in the present study is and is given in Table I.

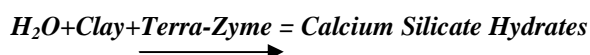


Table I Properties of Terra-Zyme (supplied by manufacturer)

Identity (As It Appears On Label)	N-Zyme
Hazardous Components	None
Boiling Point	100 Degree Celsius
Specific Gravity	1.05
Melting Point	Liquid
Evaporating Rate	Same as Water
Solubility in Water	Complete
Appearance/Odour	Brown liquid, Non obnoxious

### 2.2 Terra-Zyme Dosage

The Enzyme dosage used in the present study is as recommended by the supplier and dosage of Terra-Zyme varies from 200ml/0.25m<sup>3</sup> m<sup>3</sup> to 200ml/3m<sup>3</sup> of the soil and it depends on the soil properties. In this experimental study the Table II below represent enzyme dosages and curing periods.

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**Table II Dosage of Terra-Zyme and curing period in days**

Dosage	200ml/m <sup>3</sup> of soil	Curing period in days
1.	200ml/0.5m <sup>3</sup>	7, 14 and 21days
2.	200ml/0.75m <sup>3</sup>	
3.	200ml/1m <sup>3</sup>	

As in the present study the above dosages are preferred.

The dosage 200ml/0.5m<sup>3</sup> of soil sample *S1* calculation is presented as below.

**Soil sample S1**

Bulk density soil= 1.944gm/cc or 19.07kN/m<sup>3</sup>

Bulk density = Weight/Volume

Weight = Bulk density X Volume

**For Dosage 1**

200ml for 0.5 m<sup>3</sup> of soil = 1.944X0.5X1000= 972kg of soil

For 1kg of soil = 0.205ml quantity of Enzyme.

### III. RESULTS AND DISCUSSIONS

The tests conducted at laboratory to know the various Geotechnical properties of Black cotton soils and Red soil is given below in Table III.

**Table III Geotechnical properties (Black cotton soils and Red soil)**

Laboratory tests	Soil sample name			
	(S1)	(S2)	(S3)	(S4)
Sp. Gravity	2.61	2.73	2.78	2.85
Sand (%)	4	6	2	60.1
Silt (%)	18	10	6	39.9
Clay (%)	78	84	92	
Liquid limit(LL)	55.80	70.50	84.35	27.50
Plastic limit(PL)	36.57	37.90	48.61	21.15
Shrinkage limit	12.43	8.59	7.30	18.08
IS soil classification	CH	CH	CH	ML
Free swell index (%)	75	81.82	90.5	25
Maximum dry density (MDD) kN/m <sup>3</sup>	16.08	14.32	14.32	18.54
OMC (%)	20	22	24	14
CBR Soaked(%)	1.21	1.01	0.66	2.42
UCS kN/m <sup>2</sup>	180	196	205	60

### IV. LIQUID LIMIT TEST RESULTS

The liquid limit test results of untreated soil samples are tabulated in Table III, this test was conducted by using various dosages of Terra-Zyme 200/0.5m<sup>3</sup>, 200/0.75m<sup>3</sup>, 200/1m<sup>3</sup> and cured for 7,14 and 21 days of curing period. The liquid limit test results of enzyme treated soil samples are tabulated in Table IV, V and VI.

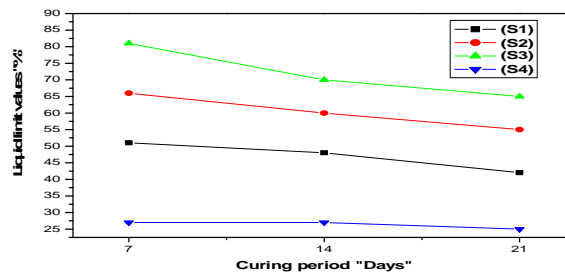
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**Table IV** Liquid limit of soil samples treated with Terra-Zymed dosage of 200ml/0.5 m<sup>3</sup> at different curing period

Curring Period in days	Soil Sample S1 (%)	Soil SampleS2 (%)	Soil Sample S3 (%)	Soil Sample S4(%)
Untreated	55.8	70.5	84.35	27.5
7	51	66	81	27
14	48	60	70	27
21	42	55	65	25



**Fig. 1** Liquid limit of soils treated with Terra-Zyme dosage of (200ml/0.5m<sup>3</sup>) at different curing period.

Above Fig. 1, shows the result of liquid limit of soil treated with Terra-Zyme200/0.5m<sup>3</sup>, at curing period of 7, 14 and 21 days.

**Soil sample S1:**

- The untreated soil sample liquid limit value is 55.8%, liquid limit test result values of Terra-Zyme treated soil are as 51% on 7days, 48% on 14days, 42% on 21days of curing.

**Soil sample S2:**

- The untreated soil sample liquid limit value is 70.5%, liquid limit test result values of Terra-Zyme treated soil was 66% on 7days, 60% on 14days, 55% on 21days of curing.

**Soil sample S3:**

- The untreated soil sample liquid limit value is 84.35%, liquid limit test result values of Terra-Zyme treated soil was 81% on 7days, 70% on 14days, 65% on 21 days of curing.

**Soil sample S4:**

- The untreated soil sample liquid limit value is 27.5%, liquid limit test result values of Terra-Zyme treated soil was 27% on 7days, 27% on 14days, 25% on 21days of curing.

**Table V** Liquid limit of soil samples treated with Terra-Zymed dosage of 200ml/0.75 m<sup>3</sup> at different curing period.

Curring Period in days	Soil Sample S1 (%)	Soil SampleS2 (%)	Soil Sample S3 (%)	Soil Sample S4(%)
Untreated	55.8	70.5	84.35	27.5
7	50	65	79	26
14	46	59	67	25
21	44	54	56	23

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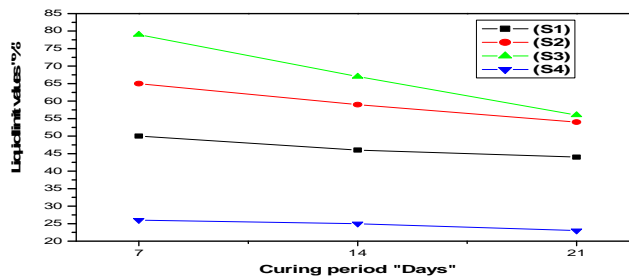


Fig. 2 Liquid limit of soils treated with Terra-Zyme dosage of (200ml/0.75m<sup>3</sup>) at different curing period

Above Fig. 2, shows the result of liquid limit of soil treated with Terra-Zyme200ml/0.75m<sup>3</sup>, at curing period of 7, 14 and 21 days.

**Soil sample S1:**

- The untreated soil sample liquid limit value is 55.8%, liquid limit test result values of Terra-Zyme treated soil is 50% on 7days, 46%on 14days, 44% on 21days of curing.

**Soil sample S2:**

- The untreated soil sample liquid limit value is 70.5%, liquid limit test result values of Terra-Zyme treated soil was 65% on 7days, 59% on 14days, 54% on 21days of curing.

**Soil sample S3:**

- The untreated soil sample liquid limit value is 84.35%, liquid limit test result values of Terra-Zyme treated soil was 79% on 7days, 67% on 14days, 56% on 21days of curing.

**Soil sample S4:**

- The untreated soil sample liquid limit value is 27.5%, liquid limit test result values of Terra-Zyme treated soil was 26% on 7days, 25% on 14days, 23% on 21days of curing.

Table V Liquid limit of soilsamples treated with Terra-Zymed dosage of 200ml/1 m<sup>3</sup> at different curing period.

Curring Period in days	Soil Sample S1 (%)	Soil SampleS2 (%)	Soil Sample S3 (%)	Soil Sample S4(%)
Untreated	55.8	70.5	84.35	27.5
7	54	68	83	27.5
14	50	63	74	27
21	48	58	60	26

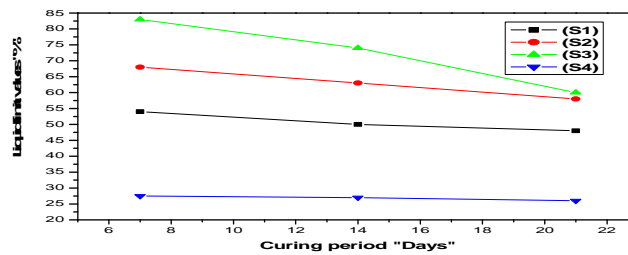


Fig.3 Liquid limit of soils treated with Terra-Zyme dosage of (200ml/1m<sup>3</sup>) at different curing period.

Above Fig.3, shows the result of liquid limit of soil treated with Terra-Zyme200ml/1m<sup>3</sup>, at curing period of 7, 14 and 21 days.

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**Soil sample S1:**

The untreated soil sample liquid limit value is 55.8%, liquid limit test result values of Terra-Zyme treated soil is 54% on 7days, 50% on 14days, 48% on 21days of curing.

**Soil sample S2:**

The untreated soil sample liquid limit value is 70.5%, liquid limit test result values of Terra-Zyme treated soil was 68% on 7days, 63% on 14days, 58% on 21days of curing.

**Soil sample S3:**

The untreated soil sample liquid limit value is 84.35%, liquid limit test result values of Terra-Zyme treated soil was 83% on 7days, 74% on 14days, 60% on 21days of curing.

**Soil sample S4:**

The untreated soil sample liquid limit value is 27.5%, liquid limit test result values of Terra-Zyme treated soil was 27.5% on 7days, 27% on 14days, 26% on 21days of curing.

Fig. 2 clearly shows the decrease in the Liquid limit for dosage of the enzyme 200ml/0.75m<sup>3</sup> at the 21days of curing. The percentage decrease in the values of soil samples S1 to S4 as 21.14%, 23.44%, 33.66% and 16.36%. Soil sample S3 shows maximum reduction in liquid limit as that of other three soils and soil sample S4 shows the marginal reduction in liquid limit. Terra-Zymestabilization has shown little to very high improvement in physical properties of soils. This little improvement may be due to chemical constituent of the soil, which has low reactivity with Terra-Zyme. The liquid limit decreases due to the reduction in the double layer due cat-ion exchange capacity there is marginal reduction. Amount of clay content plays a major role in the variation of LL.

## V. UNCONFINED COMPRESSION STRENGTH TEST RESULTS

This test was performed by mixing various dosages of enzyme such as with the local soils 200ml/0.5m<sup>3</sup>, 200ml/0.75m<sup>3</sup> and 200ml/1m<sup>3</sup> at curing period of 7, 14 and 21days at each dosage before testing. UCS of Black cotton soils and red soil was evaluated. The three specimens were prepared for each Terra-Zyme dosage and kept in desiccators for curing to retain the moisture of sample. The results obtained have been used to draw inferences under each category of mixes as follows.

Table VII Unconfined compression strength values for Black cotton soils and Red Soil for 200ml/0.5m<sup>3</sup> at different curing period.

Curring period in days	Soil Sample S1kN/m <sup>2</sup>	Soil Sample S2kN/m <sup>2</sup>	Soil Sample S3kN/m <sup>2</sup>	Soil Sample S4kN/m <sup>2</sup>
Untreated	180.00	196.00	205.00	60.00
7	186.86	270.02	286.52	67.00
14	220.90	339.912	381.43	76.23
21	320.97	380.67	439.22	84.00

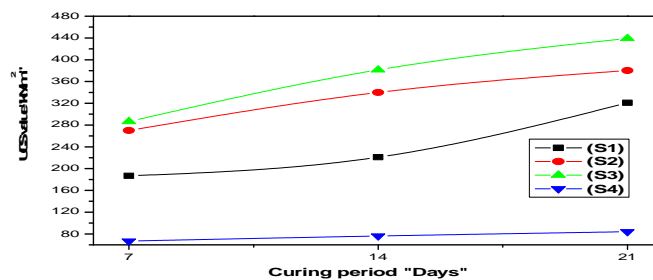


Fig. 4 UCS test results of soils treated with Terra-Zyme dosage of 200ml/0.5m<sup>3</sup> at different curing period

The graphical representation of Fig. 4, shows the results of UCS of soils treated with Terra-Zyme dosage of (200ml/0.5m<sup>3</sup>) at different curing period of 7, 14 and 21 days is summarized as below.

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**Soil sample S1:**

- The untreated soil sample UCS value is 180kN/m<sup>2</sup>, for soil was 186.86kN/m<sup>2</sup> on 7days, 220.90kN/m<sup>2</sup> on 14days and 320.97kN/m<sup>2</sup> on 21days of curing.

**Soil sample S2:**

- The untreated soil sample UCS value is 196.00kN/m<sup>2</sup>, for soil was 270.02kN/m<sup>2</sup> on 7days, 339.912kN/m<sup>2</sup> on 14days and 380.67kN/m<sup>2</sup> on 21days of curing.

**Soil sample S3:**

- The untreated soil sample UCS value is 205.00kN/m<sup>2</sup>, for soil was 286.52kN/m<sup>2</sup> on 7days, 381.43kN/m<sup>2</sup> on 14days, and 439.22kN/m<sup>2</sup> on 21days of curing.

**Soil sample S4:**

- The untreated soil sample UCS value is 60.00kN/m<sup>2</sup>, for soil was 67.00kN/m<sup>2</sup> on 7days, 76.23kN/m<sup>2</sup> on 14days and 84.00kN/m<sup>2</sup> on 21days of curing.

Table VIII Unconfined compression strength values for Black cotton soils and Red soil for 200ml/0.75m<sup>3</sup> at different curing period.

Curing Period in Days	Soil Sample S1kN/m <sup>2</sup>	Soil Sample S2kN/m <sup>2</sup>	Soil Sample S3kN/m <sup>2</sup>	Soil Sample S4kN/m <sup>2</sup>
Untreated	180.00	196.00	205.00	60.00
7	190.16	295.14	366.83	70.00
14	262.66	356.03	457.76	86.00
21	350.75	420.91	513.56	98.00

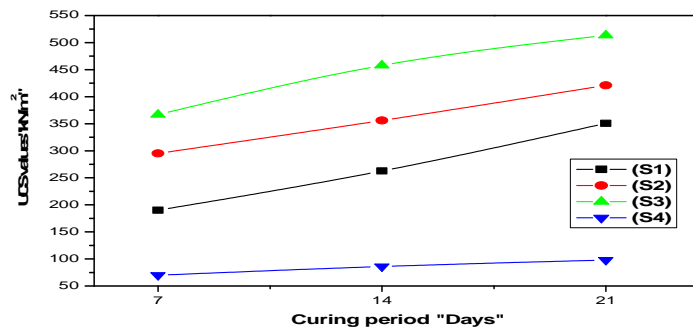


Fig. 5 UCS test results of soils treated with Terra-zyme dosage of 200ml/0.75m<sup>3</sup> at different curing period.

The graphical representation of Fig. 5 shows the results of UCS test results of soils treated with Terra-Zyme dosage of 200ml/0.75m<sup>3</sup> at different curing period is summarized as below.

**Soil sample S1:**

- The untreated soil sample UCS value is 180kN/m<sup>2</sup>, for soil was 190.16kN/m<sup>2</sup> on 7days, 262.66kN/m<sup>2</sup> on 14days and 350.75kN/m<sup>2</sup> on 21days of curing.

**Soil sample S2:**

- The untreated soil sample UCS value is 196.00kN/m<sup>2</sup>, for soil was 295.14kN/m<sup>2</sup> on 7days, 356.03kN/m<sup>2</sup> on 14days, 420.91kN/m<sup>2</sup> on 21days of curing

**Soil sample S3:**

- The untreated soil sample UCS value is 205kN/m<sup>2</sup>, for soil was 366.83kN/m<sup>2</sup> on 7days, 457.76kN/m<sup>2</sup> on 14days, 513.56kN/m<sup>2</sup> on 21days of curing.

**Soil sample S4:**

- The untreated soil sample UCS value is 60.00kN/m<sup>2</sup>, for soil was 70.00kN/m<sup>2</sup> on 7days, 86.00kN/m<sup>2</sup> on 14days and 98.00kN/m<sup>2</sup> on 21days of curing.

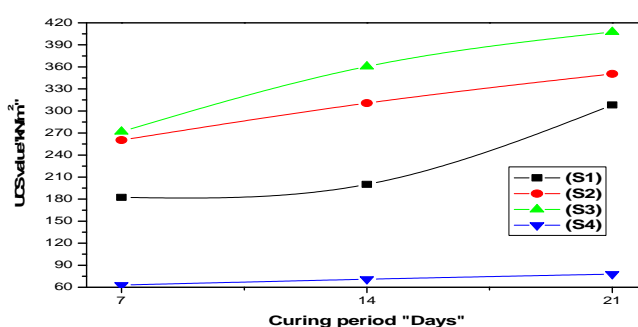
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**Table IX Unconfined Compression strength values for Black cotton soils and Red soil for 200ml/1m<sup>3</sup> at different curing period.**

Curring Period in Days	Soil Sample S1kN/m <sup>2</sup>	Soil Sample S2kN/m <sup>2</sup>	Soil Sample S3kN/m <sup>2</sup>	Soil Sample S4kN/m <sup>2</sup>
Untreated	180.00	196.00	205.00	60.00
7	182.30	260.42	238.58	63.00
14	200.41	310.67	360.62	71.00
21	308.82	350.55	407.54	78.00



**Fig. 6 UCS test results of soils treated with Terra-zyme dosage of 200ml/1m<sup>3</sup> at different curing period.**

The graphical representation of Fig. 6 shows the results of UCS test results of soils treated with Terra-Zyme dosage of (200ml/1m<sup>3</sup>) at different curing period is summarized as below.

**Soil sample S1:**

- The untreated soil sample UCS value is 180kN/m<sup>2</sup>, for soil was 182.8kN/m<sup>2</sup> on 7days, 200.41kN/m<sup>2</sup> on 14days and 308.82kN/m<sup>2</sup> on 21days of curing.

**Soil sample S2:**

- The untreated soil sample UCS value is 196.00kN/m<sup>2</sup>, for soil was 260.42kN/m<sup>2</sup> on 7days, 310.67 kN/m<sup>2</sup> on 14days and 350.55kN/m<sup>2</sup> on 21days of curing.

**Soil sample S3:**

- The untreated soil sample UCS value is 205.00kN/m<sup>2</sup>, for soil was 238.58kN/m<sup>2</sup> on 7days, 360.62kN/m<sup>2</sup> on 14days and 407.54kN/m<sup>2</sup> on 21 days of curing.

**Soil sample S4:**

- The untreated soil sample UCS value is 60.00kN/m<sup>2</sup>, for soil was 63.00kN/m<sup>2</sup> on 7days, 71.00kN/m<sup>2</sup> on 14days and 78.00 kN/m<sup>2</sup> on 21days of curing.

Fig. 5 clearly shows the UCS values increased when compared other two dosage of Terra-Zyme. The percentage increase in the value of UCS is around 94.86%, 114.69%, 150.28%, and 63.34% at 21 days of curing for the dosage of 200ml/0.75m<sup>3</sup>. This is due to the Enzyme reacts with the soil particles and water proofs the surfaces permanently and the load bearing capacity of soil gets improved. The main reason behind this increase in strength was due to destruction of clay particle structure, which developed from the original fermentation process, due to this reaction of enzyme with clay which results in cementation effect. However, when remoulded samples are held for some time, keeping the moisture content unchanged; they may gradually gain strength according to the curing period.

## VI. CONCLUSIONS

Based on the experiments conducted on the soils the following conclusions were drawn.

- With the application of Terra-Zyme best result for LL values was observed with the second dosage 200ml per 0.75m<sup>3</sup> of Terra-Zyme at curing period of twenty one days the value of LL was decreased for S1 as 21.14%, S2 as 23.44%, S3 as 33.66% and S4 as 16.36%



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- With the application of Terra-Zyme the UCS values increased around 94.86%, 114.69%, 150.28%, and 63.34% till twenty one days.
- Best result for UCS values was observed with third dosage 200ml per 0.75m<sup>3</sup> of Terra-Zyme at curing period of twenty one days.

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