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MACRO AND MICRO INVESTIGATION OF CHANGE IN CURING PERIOD ON SOIL STABILIZED WITH LIME AND CEMENT USING STONE DUST AND RHA AS ADDITIVES

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ABSTRACT

Subgrade performance depend on its ability to support load which is often affected by optimum moisture content, and amount of compaction and the other most important factor is volume changes in subgrade when it is subjected to adverse conditions of environment for ex., extreme heating, excessive moisture and freezing temperatures. These changes are very well noticed in expansive soils generally termed as black cotton soils, contain montromillinite making the subgrade highly non workable. During the years it has been seen that with the growth of infrastructure has also led to the problem of disposal of waste materials such as Stone Dust and Rice husk ash. Most of the times in developing countries these waste materials are disposed in open and they mix with water land and air there by polluting the environment. But when observed carefully it has been seen that these materials are highly siliceous and prove to be cheaper material while used as additives together with cement and lime in subgrade soil stabilization for problematic expansive soils. This paper presents a study of effect of various curing periods on Soil-Lime-Rice Husk Ash, Soil-Lime-Stone Dust, Cement-Rice Husk Ash and Cement- Rice Husk Ash separately. It was seen from the results in all the mixes curing period has a considerable effect on strength of various mixes. This change was clearly visible when curing period of 7 days were compared with 28 days. All the analysis are well supported by scanning electron microscopy analysis.

Keywords: waste material, soil stabilization, curing period, UCS, SEM.

1. INTRODUCTION

In developing countries like India the main stay of country's development lie in the development of rural sector. When development of rural sector is considered, connectivity of rural sector to urban by proper pavement is a major important concern. Many initiatives such as Pradhan Mantri Gram Sadak Yojana and vision Rural Roads 2020 etc. have been launched by Indian Government with main aim of connecting every village by at least a paved road. But due to poor workmanship and since most of these roads are maintained by village panchayats, the quality of pavements such developed are not good either in terms of quality or quantity.

This problem is more worsened if the subgrade stratum contains expansive soil. These soils contain montmorillonite which is subjected to alternate swell and shrinkage due to moisture variations. Soil Stabilization either with lime or cement till date proved to be one of the effective methods to treat expansive soils. Since there is enormous rise in cost of cement and lime during the recent years the need of a low cost technology need to be founded. Alternatively waste materials such as rice husk ash and stone dust when observed possess pozzzolonic properties. Hence cement and lime when separately mixed with stone dust and rice husk ash were found to be more economical mixes.

It is well known phenomenon that the strength of cement mixes increases as there is increase in curing period.In this particular paper an attempt has been to study the effect of curing period (7, 14, 28, 56 days) on Soil-Lime-Rice Husk Ash, Soil-Lime-Stone Dust, Cement-Rice Husk Ash and Cement- Rice Husk Ash separately by fixing optimum lime and cement from earlier studies and different percentages of stone dust and rice husk ash in increments of 2%.

2. LITERATURE REVIEW

Lack of funds is certainly a major obstacle in many places. However, recent studies show that the ineffective use of available funds can also be a major contributor to the deterioration of the road network. Rather than repairing roads which have been left unattended at the time of construction it would more cost effective if better construction practices are used at the time of construction.
Mr. Jairam Ramesh, in a recent press conference he described the roads as being constructed in one monsoon only to be washed out by the next. Especially in case of expansive soils possessing montrimorillnite. This paper deals with two waste materials viz. rice husk ash and stone dust mixed with lime and cement separately to stabilize sub grade of these expansive soils. Since Gain in strength of stabilized compound depends mainly on curing period. Hence study of strength gain and microscopic analysis of Soil-Lime-Rice Husk Ash, Soil-Lime-Stone Dust, Cement-Rice Husk Ash and Cement- Rice Husk Ash mixes as stated above was done. Many researchers have studied the effect of rice husk ash and stone dust on lime and cement stabilized soils as admixtures. Some of the findings of the researchers is presented below.

Bhasin et al. (1988) [4] studied black cotton soil using RHA, fly ash, bagasse ash, and lime sludge, black sulphite liquor independently with and without lime. And noticed that RHA causes greater improvement due to excessive percentage of reactive silica in RHA.

A.A. Amadi et al (2016) [1] has studied the effect of curing time on strength development in black cotton

soil - Quarry fines composite stabilized with cement kiln dust (CKD) and observed that there is a slow rate of increase in strength between the 7th day and 14th day which is followed by a steeper increase that extends to the 28th day. And also stated that the seeming delay in strength development at the initial stage of curing may be probably due to induction period necessary for pozzolanic reaction between soil particles and the chemical stabilizer in the mixtures resulting in the formation of cementation products.

Shyam Prakash Koganti et al (2016) [12] studied strength Characteristics of Expansive Soil and Murrum using Quarry Dust and observed that as the percentage of stone dust increases; there is a marked reduction in liquid limit and plastic limit of expansive soil and murrum tested. Since the flow and plastic characteristics of the soil sample are gradually decreasing with increase in the percentage of stone dust. This reduced plasticity of clay is very much required to avoid the failure patterns in the road construction over the expansive sub grade soils and murrum.

Musa Alhassan et al (2007) [11] studied the effect of rice husk ash on Cement Stabilized Laterite. They stated that the increase in MDD with cement content is attributed to the relative higher specific gravity of cement to that of the soil, increase in OMC with cement content was as a result of water needed for the hydration of cement and more affinity of rice husk ash towards water, initial decrease in the MDD of soil-cement –rice husk ash mixes may be due to the replacement of soil by relatively lower specific gravity particles of RHA as they coat soil cement by RHA with larger voids and hence less density and after optimum the increase in density from minimum at 6% RHA content to 8% Ash content could be due to molecular rearrangement in the formation of "transitional Compounds" and also due to reaction between the lime liberated from the hydration reaction of cement and the pozzolanic RHA, which contributed to inter-particle bonding.

Manikantha, et al (2016) [13] studied the effect of effect of Rice Husk Ash and Lime Admixtures on OMC, MDD and curing period of highly expansive black Cotton Soil. Their findings are as follows, as on percentage of RHA & lime increases OMC values are increasing & MDD values are decreasing. Increase in OMC and decrease in MDD values are due to increase in lime concentration in pore water makes the solid particle which needed more pore water to mobilize the particle against compaction effort. It is also seen as the percentage of RHA and Lime increases CBR and UCS values are also increasing with curing period of 28 days. Increase may be due to availability of free calcium ions to react with silica and alumina from the RHA and soil particles for formation C-S-H & C-A-H gel compounds, and they become more crystalline and strengthen as on curing period increases.

Koteswara Rao. D et al (2011) [10] conducted experimental studies on expansive soil stabilized with lime using rice husk and stone dust as additives. The findings of the study are as follows. They found that as on percentage of rice husk ash increases with 5% of lime till 20 % increase in ash the UCS and CBR of soil increase and there after decreases. This may be due to the percentage increase of silica in rice husk ash, which Leads to the cementitious action between clay, rice husk ash and lime. They also found that unconfined compressive strength and CBR values were higher for 28 days than 7 days. The higher increase in 28 day strength is due to further development of pozzolonic action. And more pronounced in soaked conditions due to inter-reaction between silica, lime, Rice husk ash.

Sabat (2012) [3], [14] had studied the effects of polypropylene fiber on engineering properties of RHA-lime stabilized expansive soil. He observed that UCS of expansive soil increases as on rice husk ash percentage increases till 10 % on addition of rice husk ash after which the strength slightly decreases, this may be due the increase in strength due to frictional resistance offered by rice husk and after that decrease in strength due to formation of lumps due to excessive rice husk ash.

Akanbi, D.O. et al [2] studied the suitability of stabilized black cotton soils obtained from Dadin-kowa , Nigeria which was classified as A-6 with cement and quarry dust .black cotton soil with 6% cement and 20% QD results in savings of approximately 20% cost compared with the only cement stabilized soil.

Thirumalai, S. et al (2017) [15] studied various research works done by eminent researchers by using rice husk ash and other solid wastes like ceramic dust, GGBS, Stone dust etc .

Indiramma P. et al. (2018) [9] conducted Scanning electron microscopy analysis on soil stabilized with stone dust and fly ash using different combinations of fly ash and stone dust separately and observed that The texture of soil with addition of Quarry Dust where rough surfaces with sharp edges and presence of Quarry Dust particles on surfaces was clearly observed.

3. MATERIALS AND METHODS

3.1 Materials

Soil: In the present study soil was collected from Nurukullapu Village, Amravathi Mandal, and fast growing capital of divided Andhra Pradesh.

Lime and cement: Lime used for the present study was collected from Piduguralla, Andhra Pradesh. Cement used for the study is OPC 53 grade cement from Sree Shakthi Cement suppliers in Guntur.

Rice husk ash: Rice husk ash was collected from open dump site after using roce husk ash as cooking furl from Narulullapadu village, Andhra Pradesh

Stone dust: Stone dust was collected from Srinivasa crushers.

4. METHODOLOGY

a) Compaction test is conducted by conducting compaction test by adding stone dust to virgin soil with optimum lime varying stone dust and Rice husk ash separately in increments of 2%.

b) Then UCS samples are made at OMC and MDD for soil –lime-Rice husk ash and soil- lime-stone dust mix by varying rice husk ash and stone dust in increments of 2% separately as per IS 2720-10: Methods of test for soils [7] & [8].
c) Then UCS samples are cured for 7, 14, 28 and 56 days. UCS test is conducted on these samples after 7, 14, 28 and 56 days. The same methodology is adopted for soil - Cement-Rice husk ash and soil- Cement-stone dust mixes.
d) SEM analysis is conducted for the mixes stated below after 7, 14, 28, 56 days of curing are given in Table-1.

Table-1. Details of mixes on which SEM analysis has been done.

S. No	Name of the mix	S. No	Name of the mix
1	soil-lime-rice husk ash mixes	3	soil-cement-rice husk ash mixes
1a	soil-8%lime-2%rice husk ash	3a	soil-8%cement-2%rice husk ash
1b	soil-8%lime-10%rice husk ash	3b	soil-8%cement-8%rice husk ash
1c	soil-8%lime-12%rice husk ash	3c	soil-8%cement-12%rice husk ash
2	soil-lime-Stone dust mixes	4	soil-cement-Stone dust mixes
2a	soil-8%lime-2%stone dust	4a	soil-8%cement-2%stone dust
2b	soil-8%lime-10%stone dust	4b	soil-8%cement-10%stone dust
2c	soil-8%lime-12%stone dust	4c	soil-8%cement-12%stone dust

5. RESULTS AND DISCUSSIONS

5.1 Properties of materials

The soil taken for the study is highly expansive having a liquid limit of 86.27% and a free Swell Index of 140% having a clay content of 72% and soaked CBR of 0.85%.The higher value of differential free swell index and liquid limit makes the soil highly non workable. The properties of natural soil are summarized in Table-2. The SEM image of soil is given in Figure-1.

Table-2. Properties of natural soil.

Property	Value	Property	Value
Specific gravity	**2.5**	**IS Classification of soil**	**CH**
Particle size distribution a) Sand (%) b) Silt (%) c) Clay (%)	 24 3.2 72.8	Maximum Dry Density (kN/ m^3)	14.4
Liquid limit (%)	86.27	Optimum Moisture Content	23
Plastic limit (%)	36	Soaked CBR value (%)	0.85
Plasticity Index (%)	50.27	Differential free swell index (%)	140

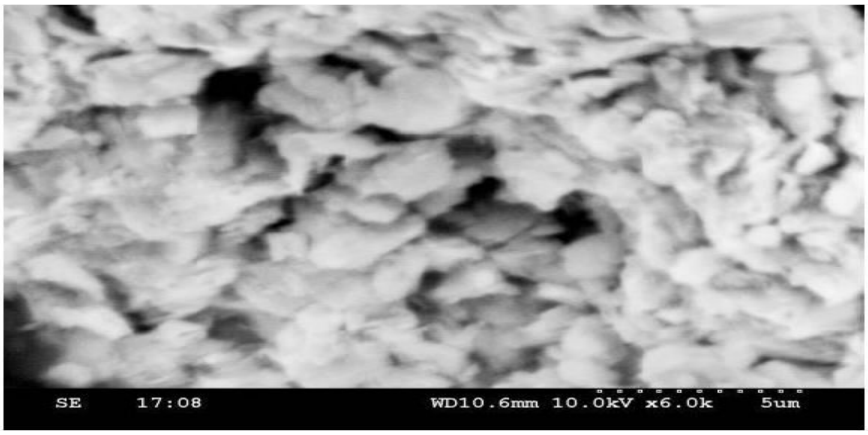


Figure-1. SEM image of expansive soil without treatment.

The chemical composition and physical properties of stone dust are summarized in Table-3 & Table-4. The SEM image of Stone dust is given in Figures 2a & 2b

Table-3. Chemical Composition of Stone Dust.

S. No	Constituents	(%)
1	Silica - SiO_2	95
2	Alumina - Al_2O_3	1.59
3	Carbon	1.45
4	Calcium Oxide - CaO	1.2
5	Magnesium Oxide - MgO	0.4
6	Potassium Oxide - KaO	0.2
7	Ferric Oxide -Fe_2O_3	0.16

Table-4. Physical Properties of Stone Dust.

Property	Value
Specific gravity	2.77
Maximum Dry Density (kN/ m^3)	20.1
Optimum Moisture Content (%)	9.4
Particle size distribution Gravel size Sand size Silt size	 3%, 81% 16%
IS Classification	SM

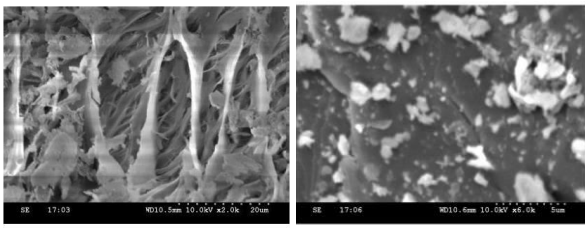


Figure-2a & 2b. Scanning Electron Microscopy Images of Stone Dust under different magnifications.

It can be seen from SEM image 2a & 2b that Stone Dust particles were spherical in shape. The particles had shiny surfaces without any dust over them. Figures (3, 4, 5, 6) given in the following paragraphs shows the variation of UCS for four mixes viz., Soil-Lime - RHA mixes, Soil-Lime - stone dust mixes, Soil-Cement–RHA mixes, Soil-Cement–stone dust mixes

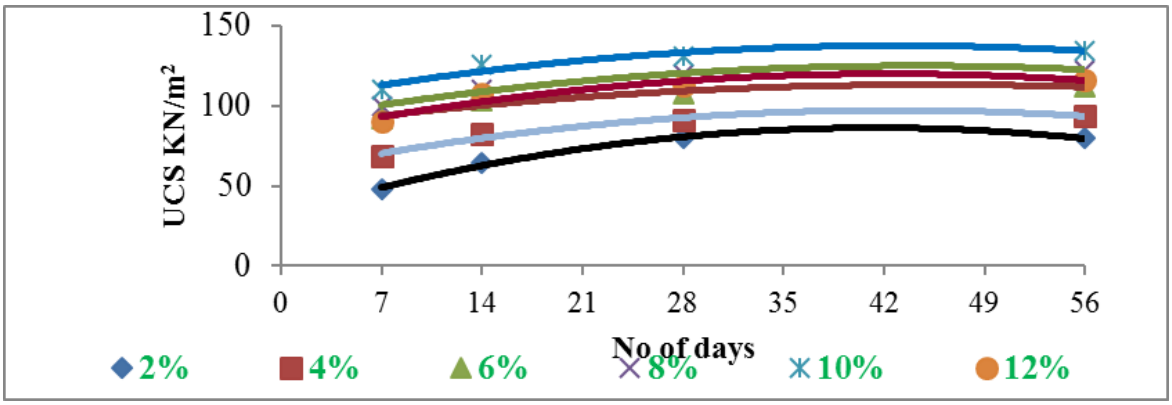


Figure-3. Variation of UCS with different curing periods for different percentages of RHA of Soil-Lime - RHA mixes.

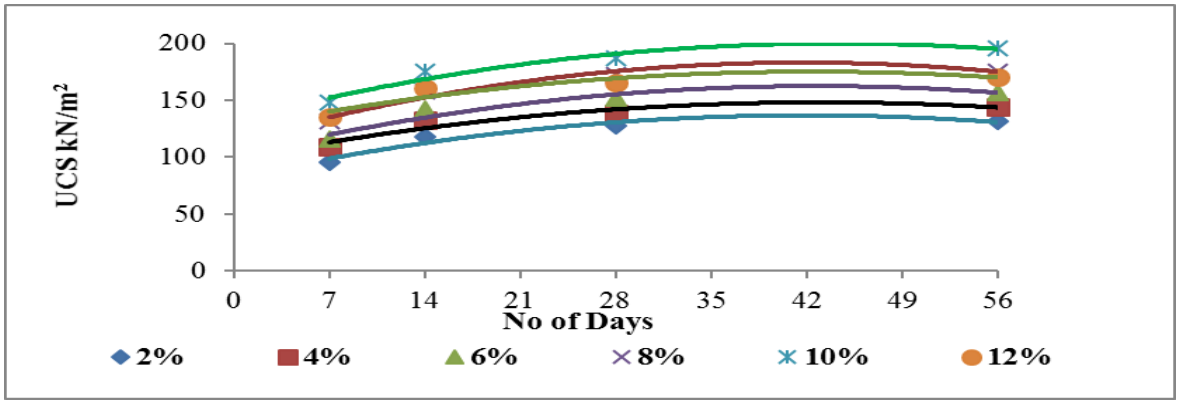


Figure-4. Variation of UCS with different curing periods for different percentages of RHA of Soil-Lime - stone dust mixes.

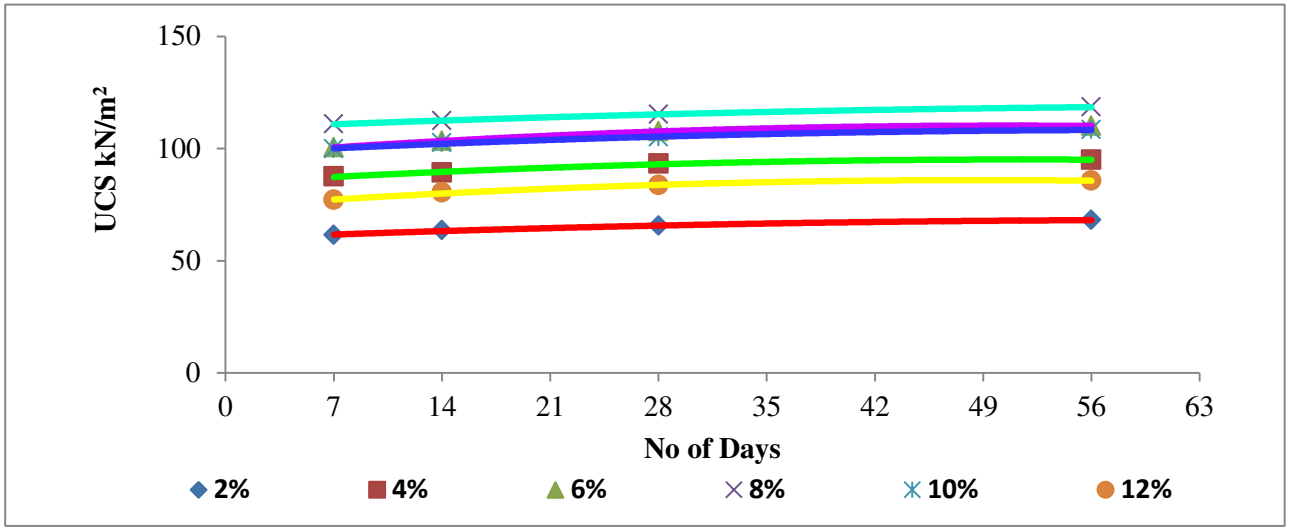


Figure-5. Variation of UCS with different curing periods for different percentages of RHA of Soil-Cement– RHA mixes.

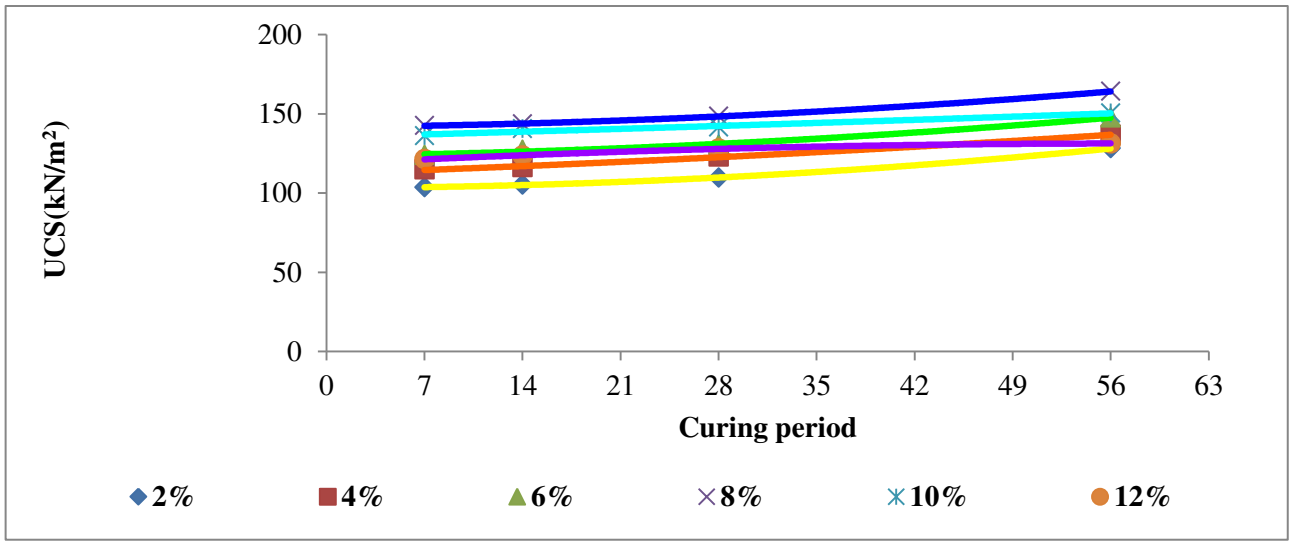


Figure-6. Variation of UCS with different curing periods for different percentages of Stone dust of Soil-Cement– Stone dust mixes.

It can be observed from Figures 3 & 4 it has been found that as on the curing time increases, the strength increases, and the gain in strength till 28 days may be attributed to the increased pozzolanic reactivity with time between the lime and the siliceous pozzolonic materials from both the RHA and Stone dust. The rise in strength may also attributed to increased bond action resulting in reduction of volume of pores which attribute to the development of strength as on curing time increases. During the curing period the volume of pores becomes smaller due to the hydration reaction resulting in strength gain.

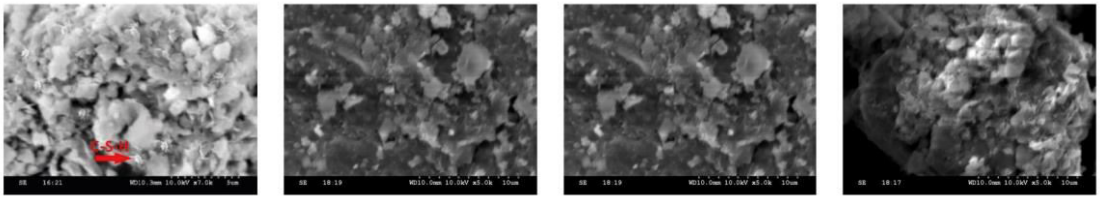
The considerable increase of UCS from 0 to 7 days may be attributed to the reason that cementitious products are formed at an early stage i.e. as soon as flocculation is completed due to lime-clay reaction notably during the first seven days of curing, and there after major increase in strength from 7 days to 28 days may be due to pozzolanic reaction due to addition of either Rice Husk ash or Stone dust, and thereafter minor increase from 28 to 56 days followed by a slow rate of reaction involving formation of long term cementious compounds.

It can be observed from above Tables Figures 5 & 6, that there is a slow rate of increase in strength till 7 days and 14 days, followed by a steeper increase that extends to the 28th day. The delay in strength development at earlier stages of curing probably represents the induction period which is necessary for pozzolanic reaction between soil particles, Cement and the additives (Rice husk ash & Stone dust) in the mixtures resulting in the formation of cementation products.

After that The increase in strength is probably due to fast pozzolanic reactions that resulted in the formation of various cementing compounds such as calcium silicate hydrates (CSH), calcium aluminates hydrates (CAH) and calcium aluminium silicate hydrates

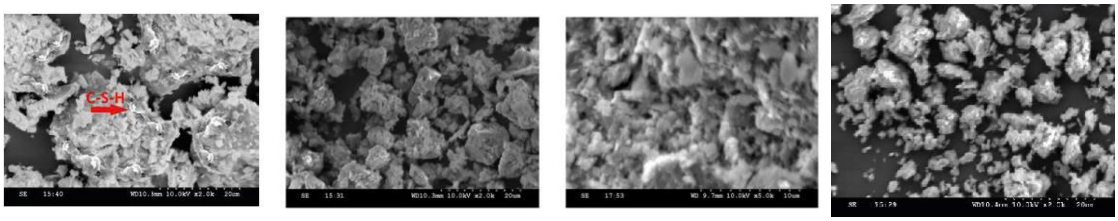
(CASH). And hence strength increases rapidly. There after till 56 days since 97 % of the strength is gained at the end of 28 days.

5.2 Scanning electron microscopy analysis results



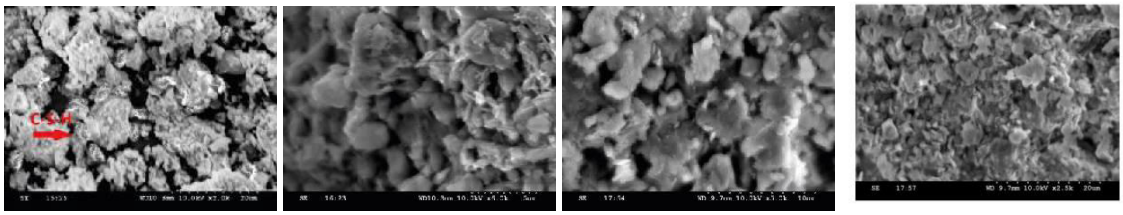
1a - 7 Day Curing 1a – 14 Day Curing 1a -28 Day Curing 1a – 56 Day Curing

Figure-7. SEM images of mix 1a for 7,14,28,56 days of Curing.



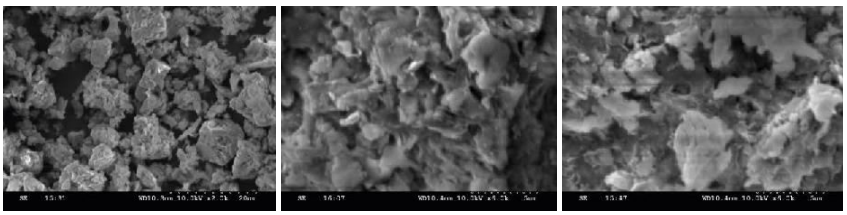
1b - 7 Day Curing 1b – 14 Day Curing 1b -28 Day Curing 1b – 56 Day Curing

Figure-8. SEM images of mix 1b for 7,14,28,56 days of Curing.



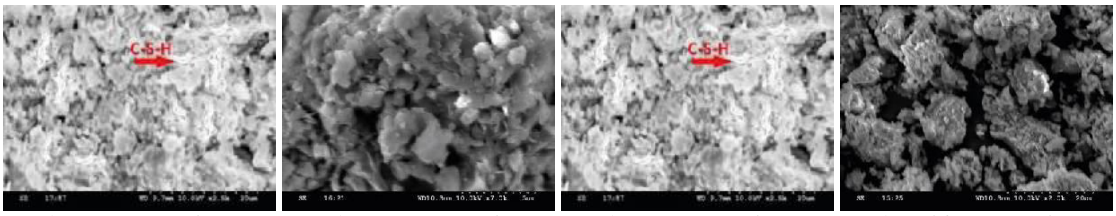
1c - 7 Day Curing 1c – 14 Day Curing 1c -28 Day Curing 1c – 56 Day Curing

Figure-9. SEM images of mix 1c for 7,14,28,56 days of Curing.



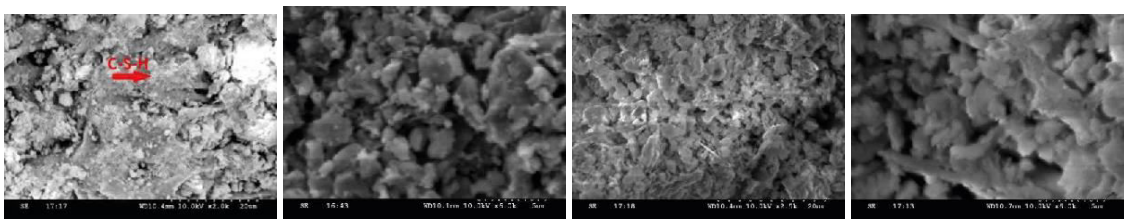
2a - 7 Day Curing 2a– 14 Day Curing 2a -28 Day Curing 2a – 56 Day Curing

Figure-10. SEM images of mix 2a for 7,14,28,56 days of Curing.



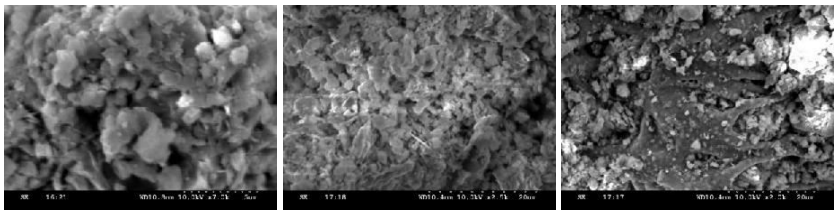
2b - 7 Day Curing 2b– 14 Day Curing 2b-28 Day Curing 2b – 56 Day Curing

Figure-11. SEM images of mix 2b for 7,14,28,56 days of Curing.



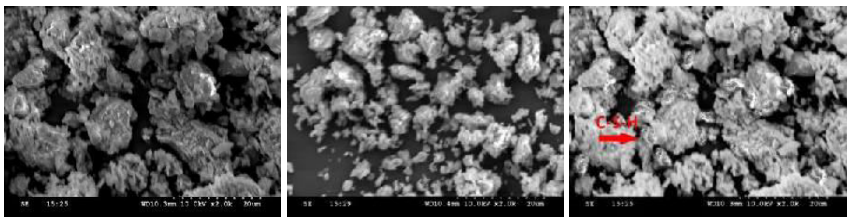
2c - 7 Day Curing 2c– 14 Day Curing 2c-28 Day Curing 2c-28 Day Curing

Figure-12. SEM images of mix 2c for 7,14,28,56 days of Curing.



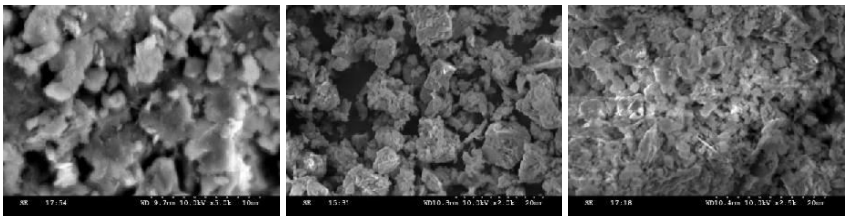
3a - 7 Day Curing 3a– 14 Day Curing 3a-28 Day Curing 3a– 56 Day Curing

Figure-13. SEM images of mix 3a for 7,14,28,56 days of Curing.



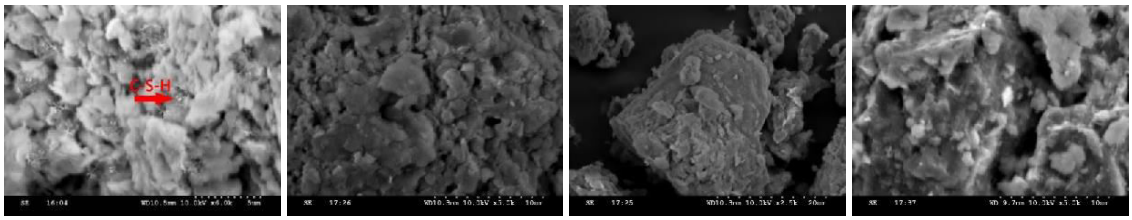
3b - 7 Day Curing 3b– 14 Day Curing 3b-28 Day Curing 3b– 56 Day Curing

Figure-14. SEM images of mix 3b for 7,14,28,56 days of Curing.



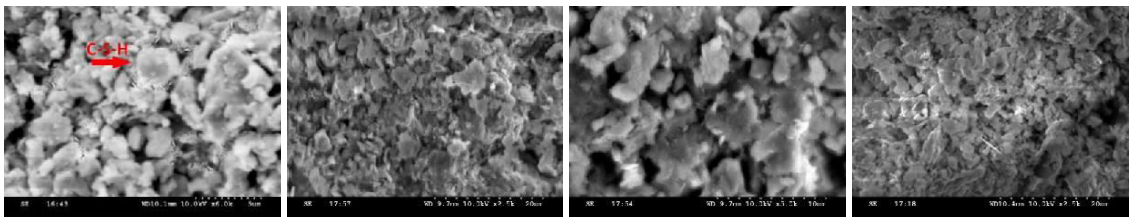
3c - 7 Day Curing 3c– 14 Day Curing 3c-28 Day Curing 3c– 56 Day Curing

Figure-15. SEM images of mix 3c for 7,14,28,56 days of Curing.



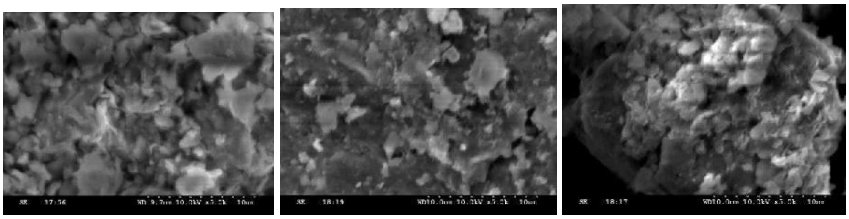
4a -28 Day Curing 4a – 56 Day Curing 4a - 7 Day Curing 4a – 14 Day Curing

Figure-16. SEM images of mix 4a for 7,14,28,56 days of Curing.



4b - 7 Day Curing 4b– 14 Day Curing 4b-28 Day Curing 4b– 56 Day Curing

Figure-17. SEM images of mix 4b for 7,14,28,56 days of Curing.



4c - 7 Day Curing 4c– 14 Day Curing 4c-28 Day Curing 4c– 56 Day Curing

Figure-18. SEM images of mix 3c for 7,14,28,56 days of Curing.

It can be seen that from SEM images (Figure-7, Figure-18) there is a slow rate of increase in strength till 7 days and 14 days, followed by a steeper increase that extends to the 28th day. The delay in strength development at earlier stages of curing probably represents the induction period which is necessary for pozzolanic reaction between soil particles, lime or Cement and the additives (Rice husk ash & Stone dust) in the mixtures resulting in the formation of cementation products. After that The increase in strength is probably due to fast pozzolanic reactions that resulted in the formation of various cementing compounds such as calcium silicate hydrates (CSH), calcium aluminates hydrates (CAH) and calcium aluminium silicate hydrates (CASH). And hence strength increases rapidly. There after till 56 days since 97 % of the strength is gained at the end of 28 days the strength development is less as on it reaches 56 days.

It can be also seen that from the above Scanning electron microscopic images (Figure-7, Figure-18) there was development of crystalline structure indication the gradual formation of calcium silicate hydrate gels. It can also been seen that for every mix as on the curing time approaches 28 days the growth in crystalline structure is more indicating more strength development. Not only that the considerable reduction in pores as on curing time reaches 28 days also indicate that the mix is more dense attributing more strength.

6. CONCLUSIONS

a) Results obtained for the above mixes indicated an increase in UCS values with increase in either stone dust or rice husk ash mixed separately with cement and stone dust.
b) UCS values also gradually increased as on curing time increases for all the four mixes viz, Soil-Lime–RHA mixes, Soil-Lime-stone dust mixes, Soil-Cement-RHA mixes, Soil-Cement-stone dust mixes.
c) The increase in UCS was very slow during initial 7 days since time was taken to develop cementitous bonds between Soil-Lime-stone dust - RHA, Soil-Lime–stone dust, Soil-Cement–RHA, Soil-Cement-stone dust and there was tremdous strength development after 28 days of curing. The strength gain was less pronounced between 28 to 56 days of curing since all the four mixes has almost reached 90% of their strength.
d) SEM analysis also supported the above discussions. From SEM analysis it can be clearly seen the predominant growth of microcrystals from 7 to 28 days of curing.
e) The study also revealed that the soil stabilized with lime and cement using Rice husk ash and stone dust as additives have the potential for a time-dependent increase in strength, hence additional curing period is necessary. Hence it is recommended at least 28 days of minimum curing period is required for stabilized subgrades using mineral admixtures such as rice husk ash and stone dust along with lime or cement separately or in combination.

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