

Effect of Curing Time on Behaviour and Engineering Properties of Cement Treated Soils

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ABSTRACT: In the new age ground improvement techniques, pertaining to strengthen the weaker soils and to improve the strength characteristics and stiffness of these types of soils, cement stabilization is proved to be more effective. In the cement stabilization, the “curing time” is the key factor in the context of strength gain of the soil-cement mixture. Limited literature shows the importance of the curing conditions, mainly time. Also, it has been found that in nature, where the ground water is deeper, the use of such mixtures, especially during grouting are never considered for curing. Keeping this in view, an attempt is made to study the effect of curing time on the strength characteristics of cement treated soil and also to show the engineering behavior in various properties which includes the compaction, compressibility and the shear strength parameters. To achieve this, laboratory tests have been conducted for various types of soils treated with different types of cements, varying the percentages were performed. The results show that the curing time has a significant effect on the unconfined compressive strength and it is found that on the addition of cement content, the engineering properties are also affected.

KEYWORDS: Cement treated soils, Curing time, Engineering Properties, unconfined compressive strength.

I. INTRODUCTION

In general, partially saturated clayey soils having high plasticity are very sensitive to the variations in water content. These type of soils are classified as an expansive soils, which exhibits the increase in the volume when comes in contact with water. These soils, during drying, can create cracks and cause to damage to the paved roads, embankments for highways and retaining slopes, foundations for buildings, railway lines, water structures and irrigation systems [1]. The method Cement stabilization has been picked over the other treatment methods due to its capability to provide faster development of strength. This Cement Stabilization has been used widely all over world to improve the engineering properties of the soils [2]. It is well established that two major chemical reactions were takes place, which are induced by the addition of cement to soil and governs the soil cement stabilization process: the primary is hydration reaction between cement & water and the secondary is pozzolonic reaction between the lime released by the cement and the soil minerals [3].

The role of hydraulic cement such as Portland or slag cement are to bind the soil particles together, revamp compaction properties, and reduce void spacing, improve the engineering properties of available soil such as, unconfined compressive strength, compressibility, modulus of elasticity, permeability, workability and swelling characteristics to changes in moisture content[4]. Based on [5] to stabilize any type of soil cement material can be used without those having organic content greater than 2% or having pH lower than 5.3. Due to addition of cement in the soil-cement treatment, significant reduction in plasticity index and significant increment in the strength characteristics can be observed. It is concluded that, reduction in plasticity index is due to an increasing in the PL of soil, which is highly affected by cement content and curing time [5]. By treating the soil with cement, it will be increase optimum water content and reduces the maximum dry density [6]. However according to [5], it is stated that the cement treatment leads to changes in maximum dry density and optimum moisture content, but the varying direction is unreliable.

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II. LITERATURE REVIEW

The additives such as lime, cement, fly ash, lime-cement-fly ash admixture, cement kiln dust, and polymer stabilizers are used to improve their engineering properties. Study shows a comprehensive examination on the effectiveness of cement treatment on geotechnical properties of soils. The addition of cement was found to improve the drying rate, workability and compaction characteristics of the soils (Balasingam Muhunthan, 2008). The addition of cement was found to improve the engineering properties of available soil in stabilized forms specifically strength, workability, and compaction and compressibility characteristics (Ajanta Sachan, 2007). The laboratory tests such as compaction, Atterberg limits, unconfined compressive strength, direct shear and consolidation tests for different percentages of cement content and original soil samples were performed. The test results show that decrease in dry density and increase in moisture content and reduced compressibility due to the addition of cement with the soil. Besides that the unconfined compressive strength and shear strength of soil can be optimized with the addition of 7.5% of cement content (Grytan sarkar, 2008).

Limited literature shows the importance of the curing time. Also, it has been found that in nature, where the ground water is deeper, the use of such mixtures, especially during grouting are never considered for curing. Hence, an attempt is made in the present study to ascertain the direction of omc & mdd curve due to the addition of hydrophilic material such as cement and changes due to the variation in the cements.

III. EXPERIMENTAL PROGRAM

Materials

For the purpose of stabilization, the three types of soil samples and two types of cements were chosen namely Black cotton Soil (BC), Murrum (M) & Sand (S) and Ordinary Portland Cement (OPC) & White Cement (WC). **Black Cotton Soil, Murrum and sand** has been used in this study available in Hyderabad. The soil samples were air dried and grounded to determine the various properties, discussed herewith. Also, two types of **cements** (OPC and White cement) have been considered for the study.

To evaluate the index properties of the materials, index tests viz., Atterberg limits, Specific gravity, Proctor and Engineering Properties i.e. standard proctor test and unconfined compressive strength test were performed for the comparative study. The Test Procedures performed were presented in following.

Laboratory Mix Design

In order to stabilize the soils, the chosen dry soils were mixed with the various percentages (3%, 5%, 7.5%, and 10%) of cements and the following tests have been conducted. The details of the methodologies and the results obtained have been included in the further sections.

Specific Gravity

The Specific gravity (G) of the soil has been determined by exploited some density bottle and pycnometer as per the guidelines provided by [7]. The average value has been taken from the three trials was obtained and the result as shown in the table.

Standard Proctor Compaction Test

The soil sample was oven dried at 110°C for about 24 hours. Later, as per [8] standards, the soil is mixed with the various percentages (3%, 5%, 7.5%, 10%) of cement in weight and then this mix has been compacted in three equal layers with each set of experiments with increasing the water content. Later, based on the compaction curves plotted for the different mix, optimum moisture content (OMC) and maximum dry density (MDD) for each test specimens were obtained.

Direct Shear Test

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The shear parameters of the sand and murrum have been determined with shear box 60mm x 60mm was employed as per the guidelines of [9]. The results obtained have been discussed in the further sections.

Unconfined Compression test

Specimen Preparation

The UCC specimens were prepared by using the Harvard miniature apparatus mould. The soil sample which is sieved through 425mic sieve was treated with the various cement percentages (0, 3, 5, 7.5, 10% cement content in weight) and the water is added at the corresponding Optimum moisture Content value and maximum dry density for that mix design. The soil quantity was quantified as per the density gained for that soil according to the volume of mould. After mixing the soil and cement, this mix has been placed into the mould and the mould was fixed under the compression machine and given the 10 tamping blows per 15sec [10] up to standard compaction for the specimen. After ejection of the specimen from the split mould, checked for dimensions as per standards [11]. For Each Cement Content with one soil the 3 set of specimens has been prepared, in them one for 7 days curing, second one for 14 days is curing and last one for 28 days curing. The specimens were wrapped in a polythene cover for one day and later immersed into portable water (pH=7) for curing. The sample weights are measured before and after immersion in water to determine any intake in the moisture.

Test Procedure

The unconfined compressive strength of the cylindrical shaped specimens (38 mm diameter and 76 mm length) was determined according to IS: 2720-Part 10, (1991). The cylindrical specimen was placed on the base plate and the load frame has been fixed without any stress application upon the specimen. Set the dial gauge reading and proving ring to zero. Axial load increment was applied at a strain rate of 1.5 mm/min. Noted the proving reading value at regular intervals of the dial gauge reading.

Table 01: Properties of the selected materials

| Property | BC | M | S | |
|-------------------------------------|--------|------|------|----|
| Specific Gravity (G) | 2.58 | 2.63 | 2.68 | |
| Sieve Analysis | | | | |
| Sand | Coarse | - | 3 | 3 |
| | Medium | - | 15 | 65 |
| | Fine | 13 | 12 | 32 |
| Silt | 30 | 61.5 | - | |
| Clay | 57 | 8 | - | |
| Atterberg Limits | | | | |
| LL | 66 | 28 | - | |
| PL | 37 | 16 | - | |
| PI | 28 | 12 | - | |
| Soil Classification | CH | ML | SP | |
| Optimum Moisture Content (OMC), (%) | 16.2 | 10 | 8 | |
| Maximum Dry Density (MDD) (g/cc) | 1.98 | 1.94 | 1.80 | |
| Cohesion (kg/cm ²) | 0.56 | - | - | |
| Angle of Internal Friction (°) | - | 31 | 30 | |
| UCC in (kg/cm ²) | 1.12 | 1.4 | | |

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IV. RESULTS AND DISCUSSIONS

Effect of Cement

Engineering Properties

In order to study the effect of cement content on the various properties of different soils, ordinary Portland cement and white cement has been considered for this study. The Atterberg limits for untreated and treated soils were determined by performing the Casagrande apparatus in the laboratory. Fig.01 shows the variation of liquid limit and plastic limit for Black cotton soil which is treated with Ordinary Portland cement. It has been observed that when the cement content increases the liquid limit increases and the plastic limit also increases as well as the decrement was observed in the plasticity index.

As it is clear from the Fig.02, that the black cotton soil was treated with white cement, the LL & PL of the soil is increases with increasing in the cement content. But at cement percentages 3% & 5% the LL of BC+OPC less than BC + WC and next for 7.5% & 10% the LL is increased for BC + OPC when compared to BC + WC. On the other side the plastic limit also increases with increase in cement content.

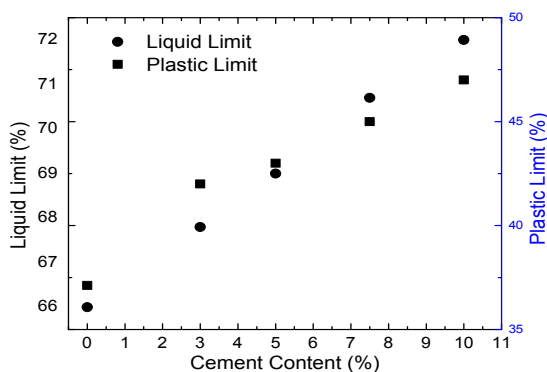


Fig.01 Effect of OPC cement on LL & PL of black cotton soil

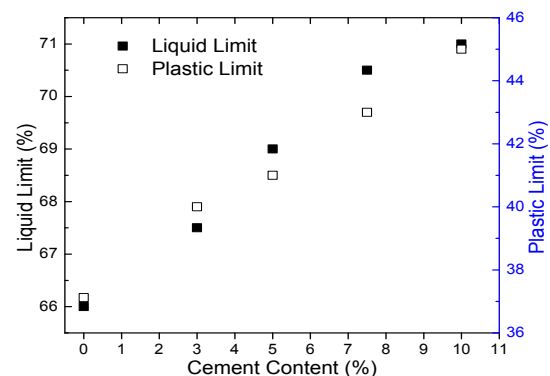


Fig.02 Effect of white cement on LL & PL of black cotton soil

According to Fig.03, it has been showed that LL is increased gradually for Murrum soil when it is treated with opc content but PL is increased up to the cement content of 5% and gradually decreases. This LL improvement clearly says that there is a requirement for more water to get fluid state. On the other hand The PL is increased up to cement content 5% and then decreases. This decrement showing that the soil is in the plastic state up to 5% cement content and for 7.5% & 10% it was gradually transformed into semisolid state.

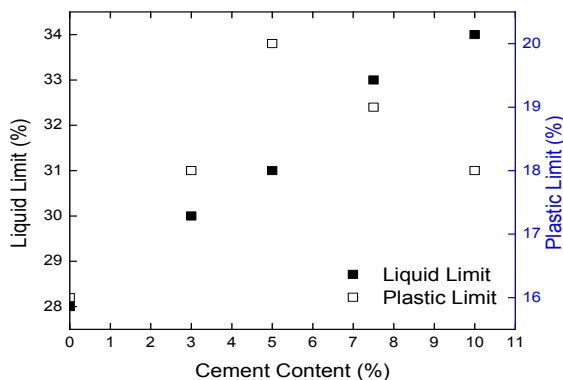


Fig.03 Effect of OPC cement on LL & PL of murrum soil

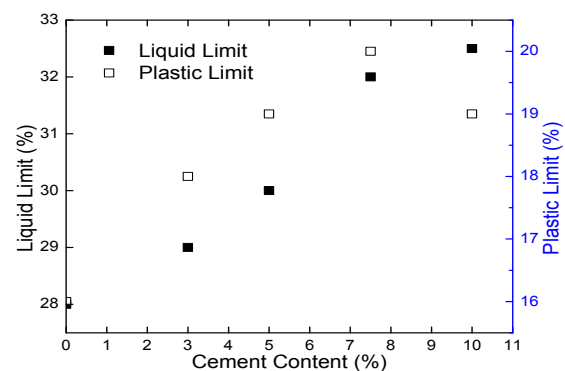


Fig.04 Effect of white cement on LL & PL of murrum soil

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The Fig.04 illustrates that when the cement increases, the LL is increases gradually, and when compared to black cotton soil LL is low for Murrum soil. Coming to PL of Murrum it is increased for cement content 7.5% and then fallen. It is clear that the amount of water is required to lubricate the soil due to the cause of cement content needs more water for binding the soil into uniform mix, in this process the hydration of cement will occur. Due to this hydration, the water need is necessary. This represents the LL variation for BC & M soil treated with cements opc & white cement varying in their proportions. It has been observed that, when the opc was treated with BC soil, LL is greater than the same soil treated with white cement. So the low amount of water required to lubricate the BC soil with white cement over opc. At the lower levels of LL of Murrum soil showing slightly variation between treated with opc and white cement.

Compaction Characteristics

The contrast of optimum moisture content and maximum dry density of untreated and treated Soil was clearly shown in the following figures. According to the Fig.05 (a), the BC soil is treated with ordinary Portland cement represents the maximum dry density of the black cotton soil decreases gradually increases with the increase in the cement content because of the phenomenon of flocculation. This phenomenon will occur due to the cement reacted with the clay minerals. Due to that flocculation, the excess amount of water required for fine grained soils, resulting to there is a drop in the value of maximum dry density.

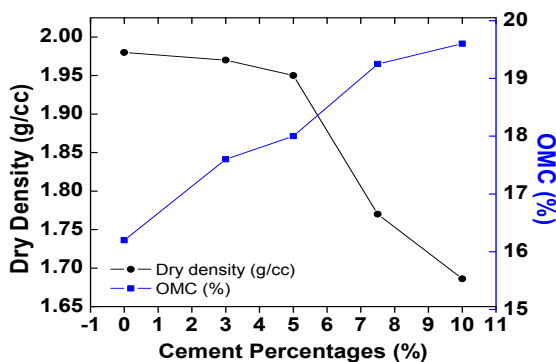


Fig.05 (a) BC + OPC MDD & OMC Variations

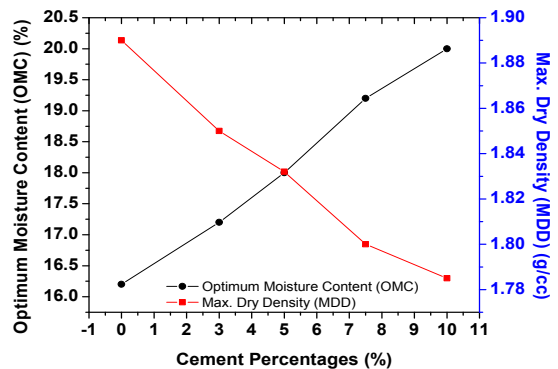


Fig.05 (b) BC+ WC OMC & MDD Variations

On the other hand, optimum moisture content of the BC soil increases with an increase in the cement content according to that fig. This should be due to the cause of cement also consists of fine particles. With the fines increment the more water is required to obtain well lubrication. From The Fig.05 (b), when the black cotton soil was treated with the white cement, the omc of black cotton soil increases than the BC + OPC and the max. Dry density decreases.

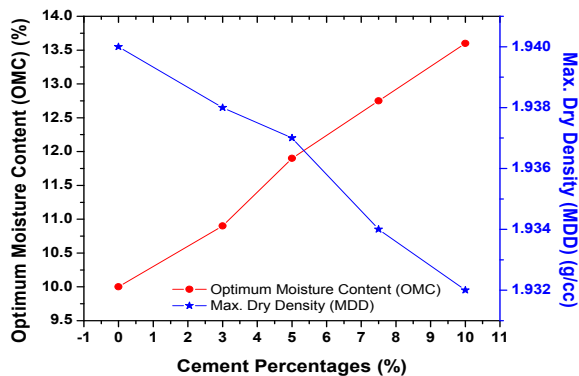


Fig.05 (c) M + OPC OMC & MDD Variations

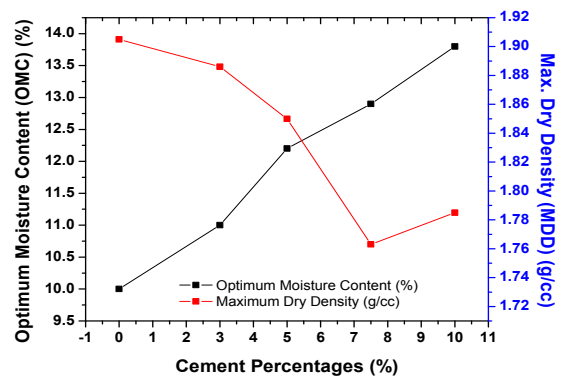


Fig.05 (d) M + WC OMC & MDD Variations

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It is depicted from the Fig.05 (c) & Fig.05 (d) The OMC of murrum soil is less than BC soil, and when it is treated with the cement contents omc is increased and the mdd decreased, but when the M+ WC 10% the mdd value is raised. The optimum moisture content values of different soils (BC soil, murrum & Sand) increased with the addition of cements because of the pozzolonic reaction of cement with the soil.

Besides the maximum dry density was decreased when the cement is added but in the murrum + WC the omc value is increased but coming to maximum dry density it is also increased from 7.5% 10% of cement content. The treated soil becomes coarser in particle size than origin soil sample because of the forming of agglomerations of soil-cement particles due to pozzolonic behavior of cement. The Effect of Cement content on OMC soils has been plotted in the Fig.06.

Effect of Cement on OMC of Soils

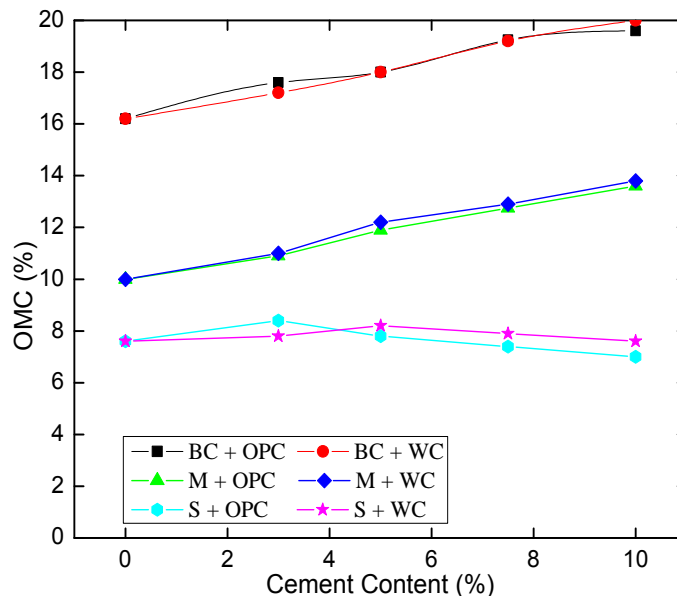


Fig.06 Effect of cement on OMC of Soil

According to Fig.06, Maximum omc is required to stabilize the soil with BC + WC compared to BC + OPC. Murrum needs low water to stabilize the soil for the "foundations" compared to the other soils rather than the sand has low omc but the sand will exist in the rare cases in the world like middle-east countries. In Sand + OPC, as fineness increases due to addition of cement the omc is increased gradually up to certain % and decreases, whereas the mdd is increased.

Strength Characteristics

Effect of Curing Time and Cement on Unconfined Compressive Strength (UCS)

Cement treatment effect showed a significant improvement in unconfined compressive strength and besides in stiffness of treated soil. When the soil is treated with cement, the strength gained in the soil is fully dependent on the slow pozzolonic reactions, which are completed maximum in 28 days. The UCS test Results showed that when the cement content increases the unconfined compressive strength is increases gradually.

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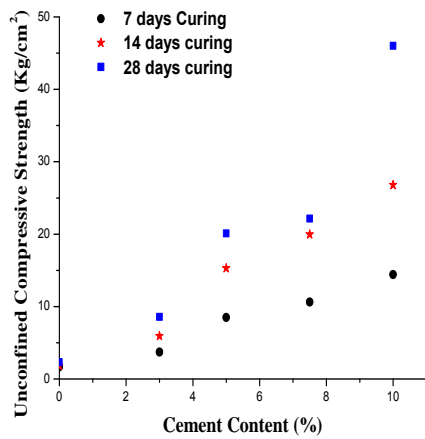


Fig.07 (a) Variation of UCS with OPC content for BC Soil

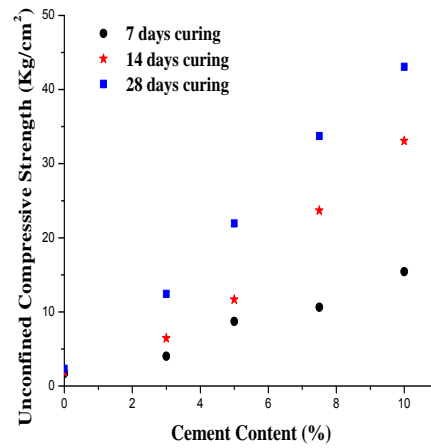


Fig.07 (b) Variation of UCS with WC content for BC Soil

The Fig.07 (a) depicted that the ucc strength value increases for Black cotton soil treated with ordinary Portland cement at various proportions with the curing period. At 3% opc for 7 days strength is 3.71kg/cm² is increased for 10% opc up to 14.41kg/cm² and for 28 days curing for 10% the value is significantly increased to 46 kg/cm². As also from Fig.07 (b)

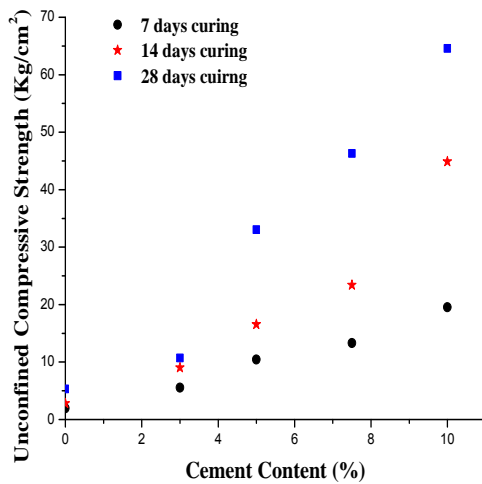


Fig.07(c) Variation of UCS with OPC content for murrum soil

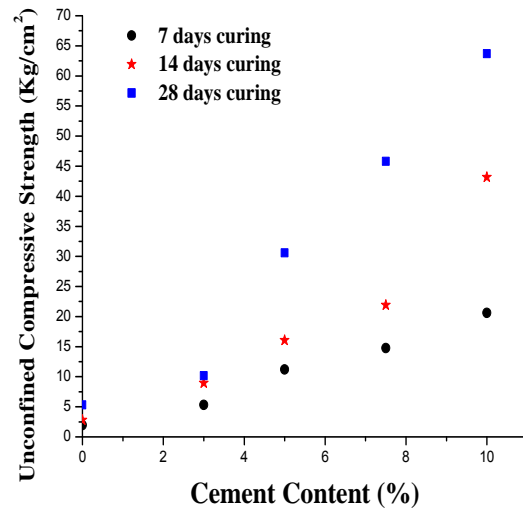


Fig.07 (d) Variation of UCS with WC content for murrum soil

Curing time has pretended effect on the increase in shear strength and stiffness of cement treated soil at low cement content according to Fig.07(c) & Fig.07 (d) Murrum soil with cement contents; however a significant increase in unconfined compressive strength and stiffness from 7 to 28 days curing time was noted at high cement contents. When the murrum soil was treated with Ordinary Portland cement, the UCS value is increased highly from 7 days curing to 28 days curing.

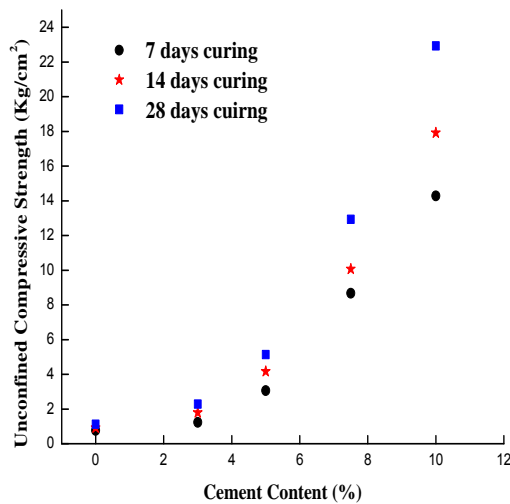


Fig. 7(e) Variation of UCS with OPC content for Sand

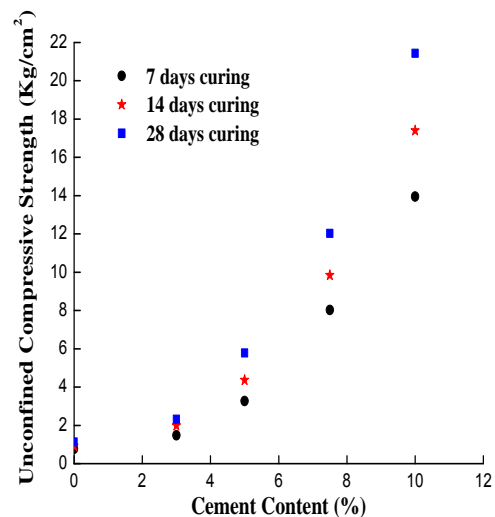


Fig.7 (f) Variation of UCS with WC content for Sand

Sand UCS values are graphed in Fig.07 (e) & Fig.07 (f). The Sand UCS values are low among BC and murrum Soil. Sand treated with Opc shows the maximum UCS value at 28 days curing.

By summarising of all UCS graphs as above shows the significant increase with increase in the cement content and curing time. Over them the M+OPC got the highest value which is 64.55 kg/cm². From Fig.07(c) it can show that most effective mix design for the construction of pavements and construction grounds. One thing has to say that the brittle-type failure occur at low strain levels was observed for treated soils (more brittle failure in Murrum (silt), Medium soft brittle failure in sand and more (compare to sand) brittle failure in black cotton (soft) soil) at 28 days curing as shown in the graph.

V. CONCLUSIONS

The Following Conclusions were made on the results obtained from the experiments performed:

1. A series of Liquid and plastic limit tests indicated that the value of liquid limit and plastic limits are increased for BC soil & murrum soil with the increasing of ordinary Portland cement & white cement percentage. But the BC soil has the greater liquid limit when the opc is treated than white cement treatment.
2. The compaction characteristics are improved upon the addition of Cement content.
3. The UCS values increased significantly with respect to curing time when the adding of cement contents in the proportions of 3%, 5%, 7.5% and 10%.
4. At 7.5% cement content and 28 days curing BC + WC was effective than BC + OPC. For BC soil, the white cement is the best suited cement material for gaining the strength in shorter time (14 days) but at 28 days BC + OPC is Effective. On the other hand Murrum soil with opc content got the highest compressive value at 28 days curing according to Fig.07(c) than any cement-soil mix. M + WC are effective at 7 days curing over M+OPC at lower compressive strength. But at 14 & 28 days of curing the values of M+OPC were maximum.
5. Based on the obtained UCC values, the optimum soil-cement mix "Murrum + 10% OPC" is better mix design for pavements and foundation. Cement treated geo - materials behave in a more brittle manner than non-treated materials.

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