International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 4, April - 2014

Study on Strength Characteristics of River Sand in Combination with Cement and Waste Tire Rubber Chips

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Abstract— **In the present study, an attempt has been made to determine the utility of industrial wastes in the stabilization of river sand. Cement and waste tire rubber has been considered to investigate their potential in stabilizing sand. They were mixed in sand in varying percentages so as to find their optimum proportions needed for the effective stabilization of sand with the help of standard proctor test. California bearing ratio tests and unconfined compressive strength tests were performed on the optimum mixes. Results indicate that the peak strength value has been obtained at 8% cement and 2% waste tire rubber chips by weight of river sand.**

Keywords— River sand stabilization, cement, waste tire rubber chips, California bearing ratio tests and unconfined compressive strength.

I. INTRODUCTION

Industrialization and urbanization has increased at great pace in India in recent year's which results in the production of many industrial wastes which are hazardous to our environment. Waste tire is one of them which are found abundantly in India. Waste tire has several advantageous applications in civil engineering as it possesses properties such as strength, resiliency, flexibility and high frictional resistance. Thus it can be reused usefully for the purpose of construction instead of burring or dumping. Rao and Dutta reported that the total amount of discarded tire in India were of the order of 112millions per year. (Humphrey et.al 1992) stated that tire chips could be used as light weight land fill material. (Eldin et.al 1993) stated that tire chips could be used for low strength ductile concrete. (Bernal et.al 1996) stated that the uses of tire rubber chips are useful for construction of pavement as they provide beneficial utility in economical, technical and environmental terms. Use of tire rubber chips provides good settlements and drainage which avoids the increment of pore water pressure. (Bosscher et.al 1997) stated about the possibility of using waste tire chips in civil engineering application such as in road construction. (Brooms et.al 1999) concluded that tire chips could be used as a light weight backfill materials in retaining structures. (Ghani et al 2002) stated that scrap tires constitutes approximately 26% carbon black, 47 % natural rubber, 30 % synthetic rubber and its use depends upon the shredding process. (Akbulut et.al 2007) investigated that improvement in the behavior of clayey soil by the usage of scrap tire rubber and synthetic fibers. He tested the reinforced and unreinforced samples for unconfined compression, shear box and resonant frequency test and found positive results for their usage as reinforced material for the modification of clayey soil. (R. Ayothiraman et.al 2011) stated that soil stabilized with waste tire is found to have the CBR value of about 22% higher than that of the CBR value of un-stabilized soil. As seen from the above literature review there are limited information about the combined use of river sand, cement and tire rubber chips. In this paper an attempt has been made to study the strength characteristics of this composite as a sub-base material through laboratory investigation.

II. EXPERIMENTAL PROGRAM

A. *Materials:*

Beas river sand has been used in the present study. According to ASTM classification system (ASTM D2487-11), this sand was put into the category of poorly graded nature and its basic physical properties are given in Table 1. Cement used in this study was Ordinary Portland cement of grade 43 while the tire rubber chips were procured from Jalandhar and cut in to size range of 10 mm×10 mm for the use in experiments.

Table 1: Physical properties of sand

Property tested	Values
Specific gravity	2.63
Coefficient of uniformity (Cu)	1.69
Coefficient of curvature (Cc)	1.04
Optimum moisture content (%)	6.44
Maximum dry density(gm/cc)	1.5094
Permeability(cm/s)	2.46×10^{-3}
Soaked CBR (%)	8.9

Table 2: Physical properties of cement:

Property tested	Values
Type of cement used	OPC grade 43
Optimum moisture content (%)	30.71
Maximum dry density (gm/cc)	1.445

B. Method of Testing

All the laboratory tests were conducted in accordance with ASTM standards. The specific gravity tests and the standard proctor tests were conducted in accordance with ASTM D854-10 and ASTM D698-07e1 respectively for sand and cement as presented in Table 1 and Table 2. The particle size distribution of sand was done as per ASTM D6913-04 (2009) and its respective gradation curve is given in Figure 1. The sizes of the compaction molds used were of 101 mm diameter and 125 mm height. From the compaction test OMC and MDD of different mixes were obtained. The California bearing ratio tests were performed in laboratory in accordance with ASTM D1883-05. The sizes of samples were of 150mm diameter and 125mm height. To prepare CBR test samples, they were compacted statically at maximum dry density and optimum moisture content. Surcharge weight of 50N was used during the testing. A metal penetration plunger of diameter 50 mm and 100 mm long was used to penetrate the samples at the rate of 1.25 mm/minute using computerized CBR testing machine. Unconfined compressive strength test has been performed on all the optimum mixes according to ASTM D2166-13. The samples were prepared in the UCS mold at optimum moisture content and maximum dry density by compacting the sample with a temping rod so as to obtain the final sample of aspect ratio of 2 i.e. 38mm diameter and 76mm length.

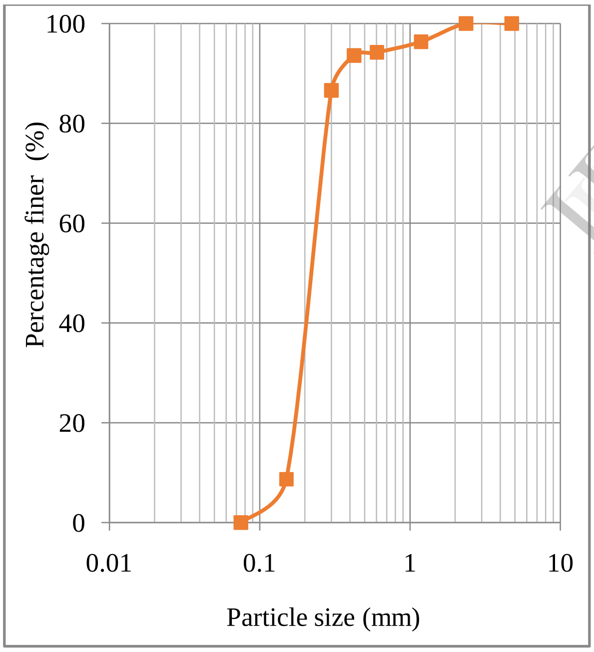

Figure 1: Particle size distribution of river sand

III. RESULTS AND DISCUSSIONS

A. Compaction Tests:

The sand used in this study has maximum dry density of 1.50gm/cm^3 with the optimum moisture content of 6.44%. On mixing cement in sand in the varying percentages from 4% to12% the maximum dry density of the mix increases from 1.50g/cm^3 to 1.68g/cm^3 up to 8% cement content while it decreases to a value of 1.623g/cm^{3}for 12% of cement content as shown in "fig. (**2**) and fig. (**3**)".

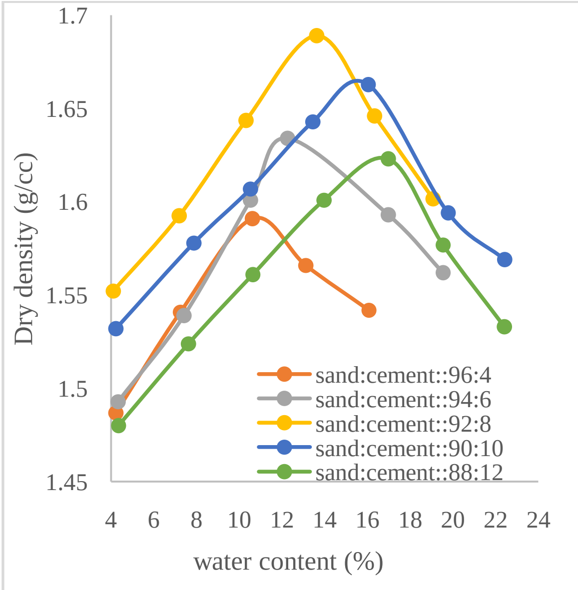

Figure 2: Compaction characteristics of river sand and cement mixes.

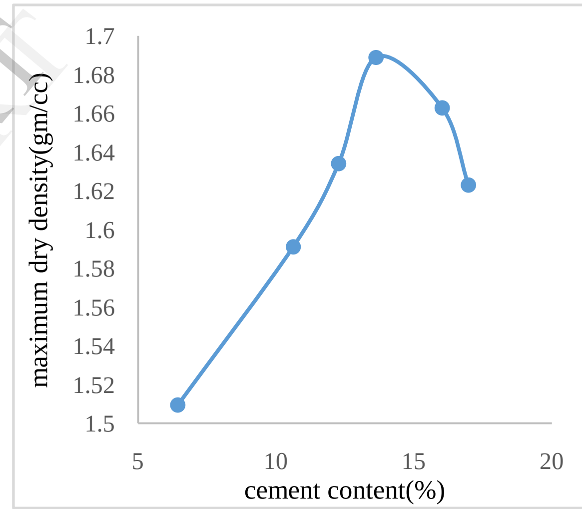

Figure 3: Maximum dry density variation of sand with cement content

The initial increase in the dry density of sand happened on the addition of fine grained cement particles due to its binding nature and filling up of the voids in the coarse grained sand particles. But after adding a certain percentage of cement the density decreases because of the segregation in the mix with the extra amount of cement.

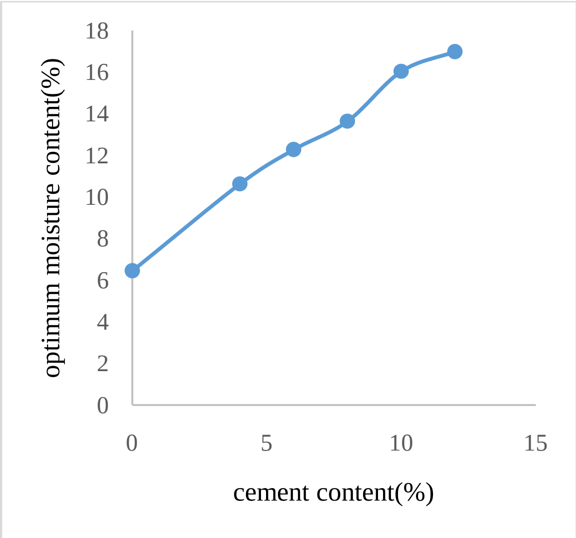

Figure 4: Optimum moisture content variation of sand with cement content

Also, on adding cement in the sand the optimum moisture content of the cement-sand mix increases because the cement particles are finer in nature i.e. they has larger specific surface area than that of pure sand and hence the mix consisting of cement and sand requires higher water content to attain the maximum dry density. The trend of variation of optimum moisture content with varying percentages of sand is shown in "fig. (**4**)".

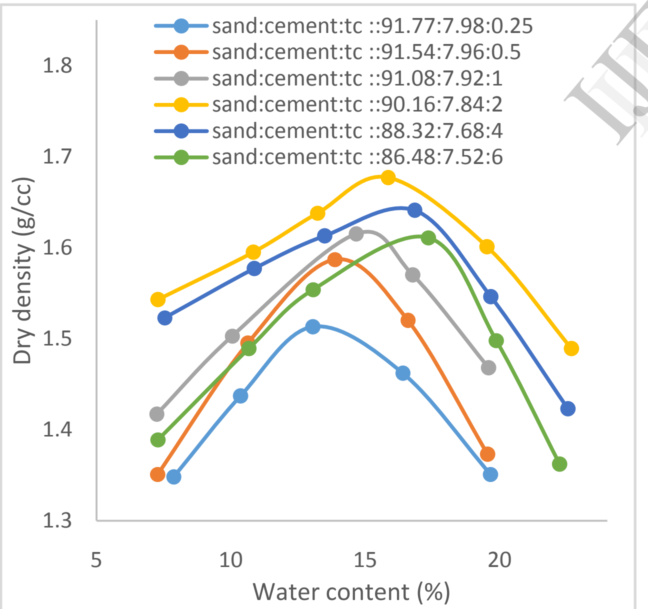

Figure 5: Compaction characteristics of river sand, cement and tire chips (tc).

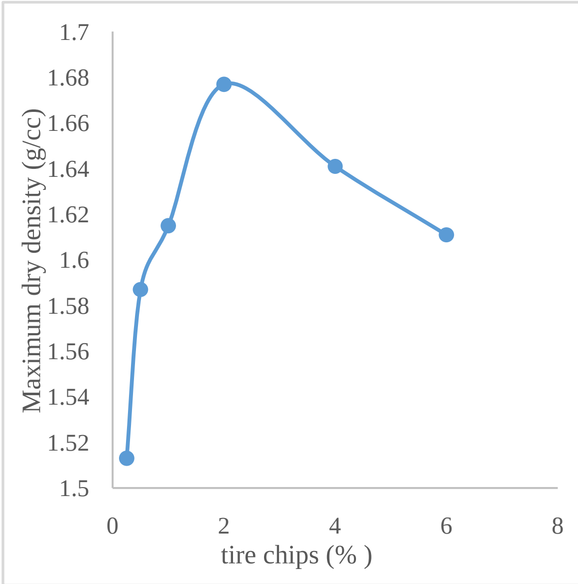

Figure 6: Maximum dry density variation of sand-cement composite with tire rubber chip content

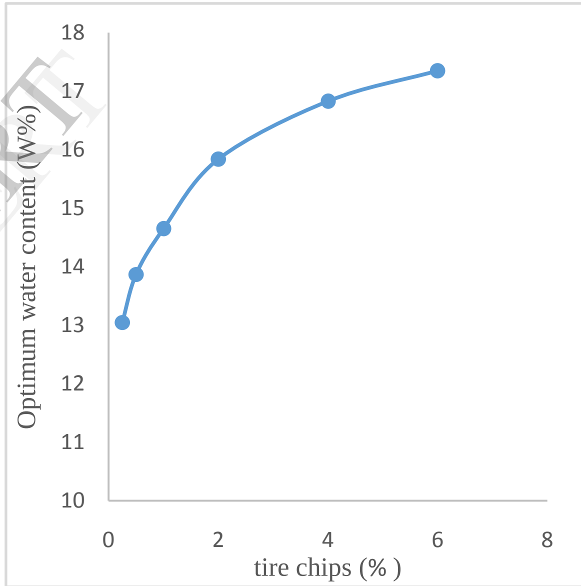

Figure 7: Optimum moisture content variation of sand–cement composite with tire rubber chip content

It was observed that maximum dry density (MDD) of the sand-cement optimum mix decreases with the inclusion of tire in that optimum mix i.e. sand: cement::92: 8 mix. When tire chips were further added in cement- sand optimum mix dry density increases up to 2% and thereafter it decreases. The initial decrease in density occurs due to the reason that tire rubber chips are light weight material and causes more voids and thus density decreases. Dry density increases up to 2% tire chips afterwards it decreases due to segregation.

The water content-dry density curves of optimum sand-cement composite with rubber tire chips is shown in figure 5.

The maximum dry density variation and optimum moisture content variation of sand-cement-tire chips mix with the varying percentages of tire chips content is shown in figure 6 and 7 respectively.

Thus the final reference mix obtained for testing the strength characteristics was sand: cement: tire chips:: 90.16:7.84:2.

B. CBR Tests:

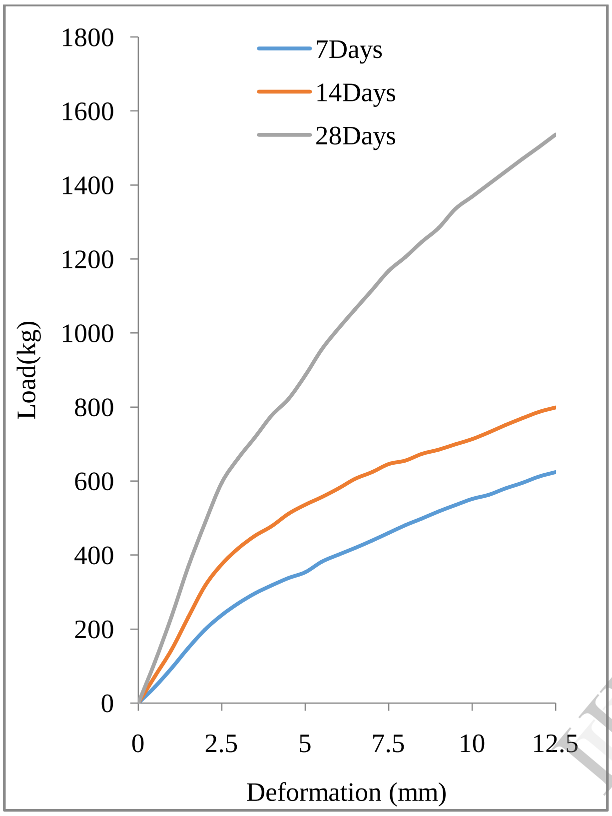

Figure 8: CBR values of the reference mixes with varying days of curing periods.

Number of days	CBR value of reference mix (%)
7	17.36
14	27.40
28	43.45

The improvement in CBR value may be attributed to better compaction and packing of the mix particles with addition of cement and tire waste. The California bearing ratio provides a basis of designing the sub-grades of flexible pavements. Usually, a value of CBR more than 30 is considered to be satisfactory for the design of flexible pavements with traffic intensity of 1 to 10 million standard axles (msa). Thus, the sand blended with cement and tire waste can be effectively used in the construction of sub-grades of roads with low traffic volume as it has achieved the CBR value more than 5 after treatment with cement and tire chips.

C. UCS Tests:

The unconfined compressive strength results with curing time were shown in figure 9. The UCS value of mix was improved because cement gains strength after the curing effect. The maximum strength i.e., 90% of cements strength is attained at 28 days curing only. The curing period thus increases the UCS value of the mix.

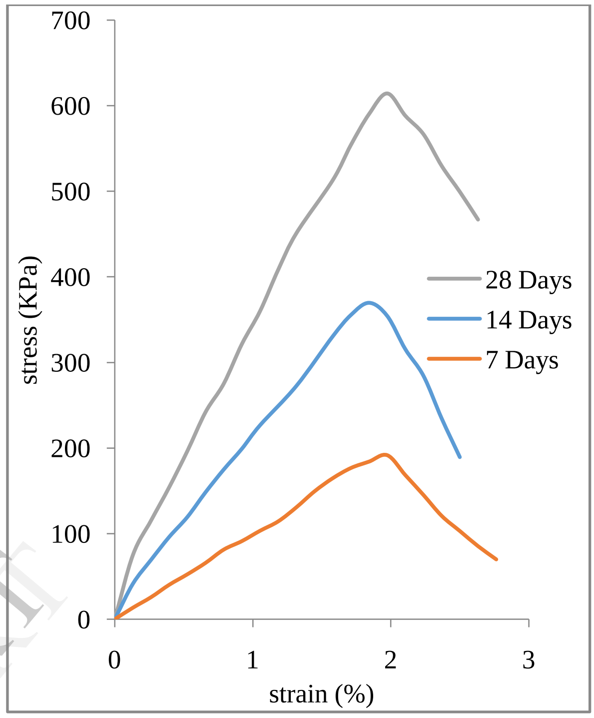

Figure 9: unconfined compressive strength of reference mix for varying days of curing period.

Number of days	UCS value of reference mix (kPa)
7	191.60
14	369.82
28	614.45

IV. CONCLUSION

This study examined the stress –strain and CBR response of river sand stabilized with cement and tire chips. The results obtained are concluded below:

1) The reference mix obtained on the basis of compaction tests contains 8% cement content and 2% of tire chips.
2) On mixing cement in different percentages in sand the value of optimum moisture content increases while that of maximum dry density initially increases up to 8% of cement content and then decreases.
3) On mixing tire chips in different percentages in the optimum sand-cement mix the value of optimum moisture content increases while that of maximum

dry density initially increases up to 2% tire chips and then decreases.

4) The unconfined compressive strength and CBR of river sand stabilized with cement and tire chips can be significantly improved.
5) The improvement in unconfined compressive strength and CBR value with the curing period was also observed.
6) After 28 days the UCS value of the final reference mix was 614.45 kPa and CBR value was 43.45% which were substantially larger than that for untreated sand.

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