Utilization Of Carbon Black Waste For Subgrades In Flexible Pavements

S. Naveen Kumar, A. Vijaya Kumar, P. Abhinaya Sai Teja Reddy

Abstract: Characteristics of soil subgrade play a prominent role in pavements. As an essential concern, weakly sub graded soil enhanced by adopting the most efficient stabilization techniques. The principle point of the present investigation is to validate that the by-products from scrap tyres like carbon black can be utilized as stabilizing the material. In this study trail tests have been conducted to find out the improvement in CBR by adding 2% to 10% of the carbon black and observed that the addition of carbon black proportions in soil results in a definite increase in CBR. The carbon black stabilized soil can be used in low volume road construction where there is less movement of traffic like HCV's, leading to significant cost advantages. Besides rendering the safe disposal of scrap tyres in to an environment as a recycled product for various constructions purposes in the modern era where they have a massive importance.

Index Terms: Carbon black, CBR test, Soil Subgrade, Stabilization, Waste Material.

1 INTRODUCTION

Discarding of waste rubber tires is gradually becoming a problem in most developing countries all over the world (Piskorz et al.1999). Especially in India, where urbanization and industrialization are in tremendous growth, the need and demand of vehicles for personal and commercial purposes have rapidly increased, besides where the disposal of the warn out tyres from these on to the landfills in the form of waste was a mounting issue. Every so often, many researchers have carried out many studies and methodologies in the technology from time to time to recover higher value recycled materials and energy from scrap tyres is moving forward. As per a report by End-of-Life tyre report in 2018, the total amount of ELTs recovered among various countries and the European (ETRMA) region volumes to nearly 17,158kilotons per year and 17,712kilotons per year if civil engineering and back filling as a recovery path is considered. The overall amount of ELT generated in these countries is estimated to be25,676kilotons by the end of 2020.Besides India has the second highest recovery rate of scrap tyres (98% in 2015) with around 60% of the recovery done on unceremonious secondary markets such as artisanal products, use on fishing boats, roofs-tops or swings. According to ATMA (Automotive Tyre Manufacturers Association), ELT are seen as a treasured material in India. For the reason that the deathtraps allied with scrap tyres in landfills, nearly all technologically advanced countries legalize their disposal for reuse. As a part of it, many recycling plants have recognized these days where these scrap tyres pulverized, and the products extracted from these same crumb rubber in powder form, fuel, fibres, and carbon black utilized for many purposes in daily life. Among them, carbon black is found to be the most common chemical component of tire crumb. It is a nano-particulate powder formed by the incomplete incineration of heavy petroleum products and hydrocarbons (OEHHA,2016).

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End to end with rapid change in field of technology contamination over a large extent, the characteristics of soil is being improvised, where in natural conditions its richness is lowered due to which the process of formation of soil is occurring in a reasonably slow manner. Keeping this point in view further improvement of stability or bearing capacity of a sub-grade of the soil in pavement layers by use of precise compaction, proportioning, and the addition of appropriate admixtures or stabilizers is essential (Anas,2011).Further with the process of stabilizers in the process of stabilization in the subgrade layers of pavement a wide range of subgrade materials can be treated. Previous studies conducted earlier recommend that preventative measures once if the content of halite and sulfate doesn't exist in between 0.2%, and 0.05%. Quite a few reviewers yet claim that there will be change in properties of soil from place to place (Fookes et al.1989, Booth et al.1984). In order to increase the utilization of locally available materials and decrease the use of natural resources when they are available in a very low volume, various measures have been proposed. The most efficient common methodology adopted for treating these soils is chemical stabilization by means of various admixtures or superplasticizers like lime, cement, foamed asphalt (Al-Amoudi et al. 2006,1995, Reza et al. 2011). Besides the increase in cost of these as an additive, during these days, the doors for the development of new additives such as recycled plastic waste, bamboo fibre, carbon black, etc. This new technique of soil stabilization can be effectually instigated in reducing the wastes deposited on the landfills, in turn producing an ecofriendly material from non-useful waste materials. The furthermost communal improvements attained by the new technique of stabilization comprise better soil gradation, reduction of plasticity index or swelling potential, increases in durability, and strength (Anas 2011). Use of carbon black, a byproduct of pulverized scrap tyres is creating a huge demand in form of recycled material for various civil engineering purposes. In the present paper a brief overview of the results of a series of CBR tests carried out with specimens of soil mixed with varying percentages of carbon black.

2 MATERIALS

An ephemeral explanation of the material used for the study and various method adopted (as per IS-2720-Part-V (1987)) were discussed below.

2.1 Soil

For the purpose of laboratory investigation locally available soil sample was segregated from an unmodified Coarse-grained subgrade soil near Boddam village, Srikakulam District, Andhra Pradesh, India, having mean particle diameter (D_{30}) 0.82mm, coefficient of uniformity (C_u) 4.42 and coefficient of curvature (C_c) 0.82. Based on the Unified Classification System (IS-1498-1970) chart the soil was termed as 'SP'. Laboratory tests were carried out on unmodified soil for Atterberg Limits, Dry Density, Moisture Content, Grain size analysis, and tabulated below.

***TABLE 1**. ATTERBERG LIMITS, MDD & OMC RESULTS*

Properties	Code Specification	Result	Limitations
Liquid Limit (W_L)	*IS-2720(V)-1985*	*38%*	*< 40 % (as per MoRTH)*
Plastic Limit (W_P)	*IS-2720(V)-1985*	*21.36%*	*-*
Plasticity Index (I_P)	*IS-2720(V)-1985*	*16.64%*	*< 18 (as per MoRTH)*
Dry Density	*IS-2720(VIII)-1983*	*1.63 g/m^3*	*Not less than 1.75 g/cm^3*
Moisture Content	*IS-2720(II)-1973*	*11.4%*	*-*
CBR	*IS-2720(XVI)-1983*	*7.09*	*Not less than 5% (as per IRC-37-2018)*

2.2 Carbon Black

Carbon black which is used as a stabilizer admixture to soil is collected from a pyrolysis plant located in Bobbili, Vizianagaram Dist. (18° 34' 24.6180"N 83° 21' 30.1248" E). Further the carbon black is sieved to remove any kind of organic matter, scrap trye granules dust. The main reason for considering Carbon black is that on pyrolysis of the scrap tyres, the carbon black exhibits very low grade in terms of purity which in return cannot be utilized for further utilization in manufacture of rubber products or tyres. So, this aspect has created a thought-provoking question for the researchers to recycle the leftover which is very challenging, and this has provoked to make utilization of its usage in engineering applications (Clark et al.1993). From the reports of International Carbon Black Association (2018), the fundamental particles of carbon black are merged together, making the aforementioned particle size distribution not appropriate. Besides, the spheroidal particles bond together to form isolated units called aggregates, which can show a strong structure and can withstand shear forces. From the studies of various researchers, it was evident that carbon black was found to have non plastic nature and thus it can replace the fines in gravel with clay. The chemical constituents of the obtained carbon black tested from Centurion University, Department of Civil Engineering, Bhubaneswar, Odisha. The compositions like Oxygen (O_2), Iron (Fe), Zinc (Zn), Carbon (C), and Sulphur (S) were analyzed by means of XRD. It was studied that pyrolyzed carbon black includes 75% carbon, 9% ash, 4% sulfur, and 12% of butadiene copolymer (Roy et al.1990).

3 EXPERIMENTAL WORK

The laboratory studies involved a sequence of preliminary tests and a series of CBR tests on undisturbed soil sample and a soil sample of arbitrarily preoccupied with carbon black. Besides the samples were prepared by compacting soil in a dry state by placing it equally in three layers with a dry density of 1.63g/m^3, in CBR mould having 150mm diameter and a height of 175mm. Carbon black proportioned soil sample is also prepared at the same dry density of 1.63g/m^3. The amount of carbon black estimated to mix with soil for each layer as weighed separately and mixed thoroughly with soil to form a uniform mix. After mixing the soil sample was then transferred to the mould and a surcharge base plate with 148mm in diameter, and 25 N weight was placed onto it to avoid any ill effects like segregation during vibration. After completion of compaction the soil in the mould it is placed on a vibrating table for 2 min to avoid any honeycombs or airgaps in the sample. The similar procedure is developed for other two years as well. Further the test was carried out in the laboratory as per the guidelines specified in IS2720-Part 16(1987). Before start of the test a surcharge plate of 2.44kPa was placed on the soil specimen and the reading of the load and penetration were recorded carefully up to a total penetration of 12.5mm. To conclude the study a series of load-penetration curves were drawn with respect to each proportion of carbon black, and corrections were applied by means of standard procedure if any. From the so obtained CBR values at the penetration of 2.5mm to 5.0 mm were determined. On repetition of experiment for all the cases, CBR value at 5mm penetration was found to be higher than that of 2.5. Therefore, CBR value considered in the present study are of 5mm penetration. It was further aimed to perform additional tests if the test results have a significant change in value more than 4%. A design of flexible pavement with granular base course and sub-base course based on subgrade CBR (%) value was proposed for comparative study of pavement.

4 RESULTS AND DISCUSSIONS

The effect of carbon black on Atterberg limits and compaction characteristics of soil sample was tabulated in Figure 1 and Figure 2. It is evident that there is a decrease of 30% in Atterberg limit of untreated soil to soil treated with carbon black. Besides, OMC is reduced by 9% to 11% and MDD is increased from 20% to 22%. The load-penetration curves attained from the soaked CBR tests for soil proportioned with varying proportions (2% to 10%) are shown through Figure 2.It is apparent from figure1 and figure 2 that in general, adding of carbon black in the soil increased the load at a certain deformation significantly as related to that of unproportioned soil sample, e.g. load of the unmodified soil corresponding to 2.5mm and 5.0mm penetration was found to be 952.22N and 1292.51N respectively but when the soil was mixed with 6% carbon black, the load increased to 1329.78N and 1768.72N respectively. The difference in CBR value for unmodified soil with carbon black at various proportions is given in Figure 3. From Figure 3 it can be seen that for a given soil sample, the CBR values was found to be increased by increase in content of carbon black (2% to 6%) and decrease in CBR value (8% to 10%). The level of enhancement in the CBR values is due to the addition of carbon black has been expressed by a dimensionless term namely; Carbon black bearing ratio index, defined as the ratio of CBR value of modified soil (CBR_c) to the CBR value of unmodified soil (CBR_u) [CBBRI=CBR_c/CBR_u]. The variation of CBBRI with carbon black content for various proportions has been shown in Figure 5. The increase in CBRI is noticeably attributed by addition of carbon black in the soil and the extent of improvement is observed to be governed by the parameters. At 2% to 6% carbon black content, the range of improvement in CBBRI is from 70-80% depending on proportion when compared with unmodified soil. When the carbon black content is increased from 8% to 10%, then the range of enhancement in CBBRI is from by 50-60% only if compared with unmodified soil. But once the strip content reaches to 6%, the enhancement in CBBRI is significant and is approximately 1.2 to 1.5 times to that of undisturbed soil for different proportions. This can be due to the fact that the proportion required for developing the bond between carbon black and soil may not be adequate at less proportion in the range of 2% - 4%, thus resulting less perfection in CBBRI. But once the carbon black content becomes 6% in the mix, sufficient bonding is produced between carbon black and soil causing noteworthy enhancement in CBBRI.

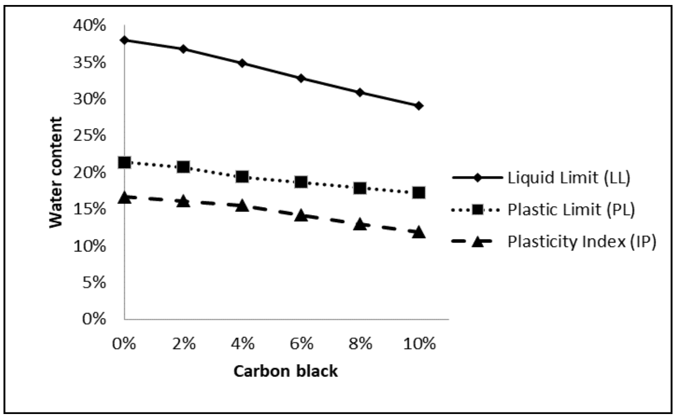

***FIG.1**. EFFECT OF CARBON BLACK ON ATTERBERG'S LIMIT*

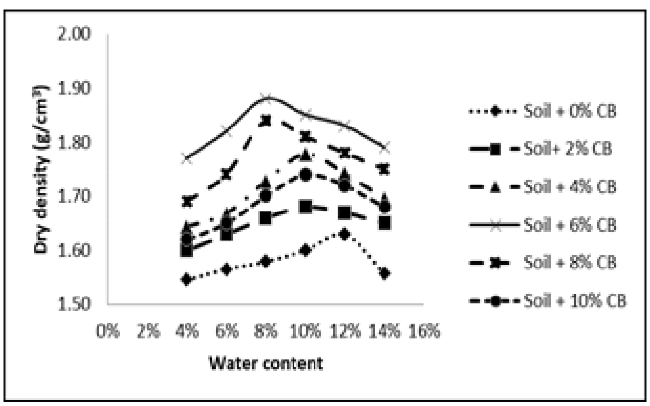

***FIG. 2**. EFFECT OF CARBON BLACK ON MDD & OMC*

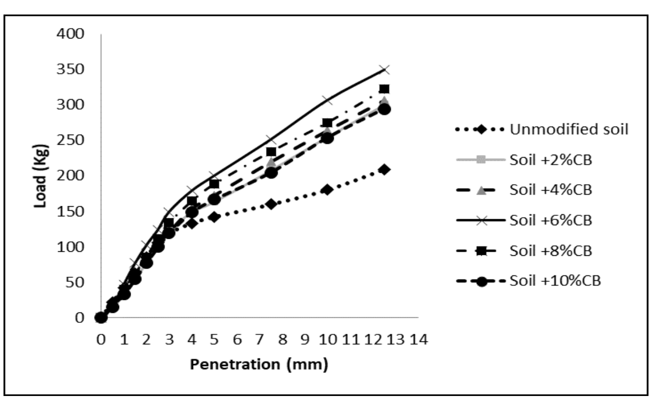

***FIG. 3**. LOAD PENETRATION CURVE FOR VARIOUS PROPORTIONS MM*

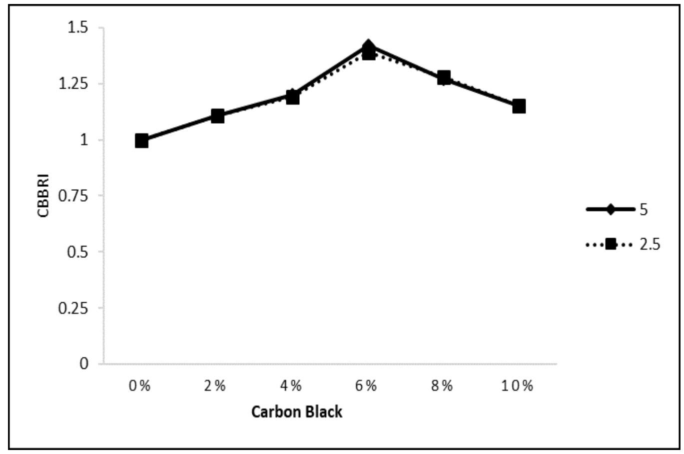

***FIG. 4**. VARIATION OF CBBRI WITH CARBON BLACK AT DIFFERENT PERCENTAGES*

5 CONCLUSIONS

Based on the outcomes of the current investigation subsequent conclusions can be drawn:

1) The adding of reclaimed carbon black from pyrolysis of scrap tyre as an admixture to soil results in a substantial rise in the CBR.

2) The benefit of increasing carbon black content in soil at various proportions the maximum value of CBR is around 20% that of an unmodified sample.

3) Though the maximum improvement in CBR is obtained when the carbon black is 6% but the enhancement in CBR is also substantial even at 8% to 10%.

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