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Subgrade Soil Stabilization Using Cigarette Butt as a Reinforcing Material

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ABSTRACT
Cigarette butts are the one of the most common garbage worldwide; over a million tonnes of cigarette butts (CBs) are produced worldwide annually. These CBs accumulate in the environment due to the poor biodegradability of the cellulose acetate filters and pose a serious environmental risk. The stability of any pavement depends upon the stability of its subgrade soil. Subgrade governs the performance, life span and effectiveness of the pavement. The entire load coming over the pavement is ultimately borne by the subgrade. Thus, the subgrade plays a very important role in the pavement design. Now-a-days, many techniques are used to stabilize the subgrade soil, this paper an attempt was made on recycled CBs into soil stabilization. In order to stabilize the subgrade soil, CBs proportions of 0%, 0.5%, 1%, 1.5% and 2% were used as the reinforcing agents and tested for California Bearing Ratio (CBR). The study reveals that the CBR value increases with the increase in cigarette butts reaches to a desirable CBR value for subgrade of pavement.The results shown marked improvement in CBR values of the CBs mixed soils in comparison with that of the original soil.

Key words: Cigarette butts, Soil subgrade, Soil stabilisation

INTRODUCTION

It is an eminent fact that thousands of chemicals are found in cigarette smoke with dozens of these chemicals being identified as human and animal carcinogens (United States Department of Health and Human Services [USDHHS], 2010). However, it is not known if cigarette butts, which have become a huge litter problem in recent decades, can be a toxic risk and become a health risk to marine as well as freshwater habitats. One of effective ways to reduce pollution is introduced by recycling the cigarette butts. But, there are few reports on reusing cigarette butts. CBs accumulate in the environment mainly due to the poor biodegradability of the cellulose acetate filters. CB filters release a range of toxic chemicals as they deteriorate [9], [10]. CBs are carried by storm water into watercourses and ultimately the ocean where the chemicals they contain pose a risk to the organisms of both freshwater and marine environments [7], [11]. Landfilling and incineration of CB waste are not, universally, neither environmentally sustainable nor economically feasible disposal methods. Even when correctly binned and sent to landfill far from natural waterways, CBs remain an environmental hazard [12]. Also, landfilling of waste with high organic content and toxic substances is in general becoming increasingly costly and difficult [13]-[15]. Incineration of CBs is also a seemingly unsustainable solution as emissions from the burning waste contain various hazardous substances

[16]. Recycling CBs is problematic because there are no easy mechanisms or procedures to assure efficient and economical separation and recycling of the entrapped chemicals. An alternative could be to incorporate CBs in a sustainable soil stabilizing material in subgrade of flexible pavement.

Subgrade is the lowest layer of the pavement. It takes all the loads of the pavement as well as the loads coming on the pavement. So, it should possess sufficient stability under adverse climatic and loading conditions. The defects in black top pavement surface like rutting, corrugation, etc. are generally attributed to poor subgrade. Thus the stability of the pavement depends upon the stability of the subgrade. In order to enhance the engineering properties, soil can be reinforced using Cigarette butts.

EXPERIMENTAL METHODOLOGY

All the tests of soil before the stabilization and with different mixtures of CBs were carried out as per the Indian standard. For laboratory tests specimens of soil with and without admixtures has to be prepared by thoroughly mixing the required quantity of soil and stabilizers in pre-selected proportions in dry state and then required quantity of water was added and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures. To maintain the homogeneity and uniformity of mix proportions, the California Bearing Ratio tests has to be performed under soaked conditions, so as to ensure uniformity in proportion of materials and water content. The 0%, 0.5%, 1%, 1.5%, and 2% proportion of CBs are mixed with original soil individually and laboratory results has to be analysed according Indian standardization of design criteria.

OBJECTIVES

1. To use recycled Cigarette butts as a stabilizing material and to solve the litter problem.
2. To evaluate the Compaction and strength characteristics of soil by replacing
   0%, 0.5%, 1 %, 1.5 % and 2% proportions of Cigarette butts

MATERIALS USED

The materials used in the present investigation were, Cigarette butts and locally available soil.

a. **Soil:** The soil used in the study was obtained locally collected at a depth of 1.5m from ground level and has been collected from an excavation site near Uttarahalli, Bangalore, Karnataka State, India. On visual inspection it was found to be reddish brown soil and from HRB classification it is found to be of category A-4(Silty soil with moderately plastic in nature). Evaluated properties of the soil are shown in table 1. Based on Liquid Limit, Plasticity Index and Unified Soil Classification system the soil may be classified as SM (Sandy Silt and Silty sand mixtures).

b. **Cigarette butts**

A method was developed to collect the CBs is keeping prepared CBs bins near smoking zones, municipal solid waste and streets, road sides in and around RR Nagar, Bangalore. Cigarette butts were collected from any receptacle in the area, and from the ground in an approximate 6-foot radius where the concentration of cigarette butts was heaviest. At each site, collection proceeded until a 2-litre collection container for that site was full, or all discarded butts within the defined area had been collected.

Table 1: characteristics of soil

Sl. No	Characteristics	Value
1	Specific Gravity	2.5
2	Liquid Limit (%)	31
3	Plastic limit (%)	22
4	Plasticity Index (%)	9
5	Classification of soil	A-4
6	Maximum Dry Density MDD(gm/cc)	1.82
7	Optimum Moisture Content OMC (%)	7
8	Soaked CBR (%)	1.53

The CBs collected in two different methods:
1) CBs collected in bins, 2) Municipal solid waste and streets, road sides.

Fig 1: Collection of CBs from different places

EXPERIMENTAL WORK : Detailed experimental study was under taken to investigate the characteristics and behaviour of typical locally available soil mixed with CBs (Top surface of the butt paper layer is removed and only CBs Cellulose fibre was used for experimental process) in different percentage and in several combinations from the view point of applicability of such materials in road subgrade. Even experimental works have been done to investigate the behaviour of soils with and without adding admixtures. Routine tests were carried out for characterization such as Liquid Limit, Plastic Limit and strength properties for unstabilized soil and the relevant IS code followed for experimental work have been listed in table 2.

Table 2: Relevant IS Code followed for Experimental Work

Sl. No	Name of Tests	Relevant IS code followed
1	Specific Gravity	IS : 2720, Part-3, 1980
2	Atterberg Limits	IS : 2720, Part -5,1985
3	Classification and Identification of soil	IS : 2720, Part-1498,1970
4	Water content determination	IS : 2720, Part -2, 1973
5	Laboratory CBR	IS :2720, Part-16,1979

All the tests of original soil were carried out as per the standard practice as laid out in the relevant IS code of practice. For tests of specimens of mixed/stabilized soils, specimens were prepared by thoroughly mixing the required quantity of soil and stabilizers in preselected proportion in dry state and then required quantity of water was sprinkled and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures.

For laboratory CBR tests, specimens were prepared in the CBR mould as per the standard practice and then it was submerged for four days for soaked tests.

For *Atterberg's limit* test on mixed soils, specimens were prepared by mixing soil and stabilizers in dry state as per the preselected proportions thoroughly and then water was added as per the standard practice. To investigate the effect of mixing CBs with the original soil to be used for construction of road subgrade, CBs was mixed in various proportions of 0%, 0.5%, 1%, 1.5, %, 2%. To determine the moisture content dry density relationship, CBR of stabilized soil, Standard Proctor Test (IS 2720, Part-7, 1980) was carried out. Specimens for CBR tests were compacted at moisture content equal to Optimum Moisture Content and the results are tabulated in table 3.

Table 3: Consistency limits for soil with varying percentage of CBs

SOIL (%)	CBs (%)	L.L (%)	P.L (%)	P.I (%)
100	0	31	22	9
99.5	0.5	31.26	14.36	16.9
99	1	38.43	25.57	12.86
98.5	1.5	41.12	30.72	10.4
98	2.0	46.01	32.81	13.2

Standard Proctor Test

Standard proctor test have been conducted to determine the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. Thus, the routine laboratory tests with different mix proportions involves conducting Standard Proctor Test as per IS: 2700(Part-VII), 1980/87 on both unstabilized and stabilized soil mixes to determine their individual OMC and MDD and the results are tabulated in table 4.

The Optimal moisture content and Maximum dry density for normal soil were:

- Optimum moisture content 7%
- Maximum dry density of soil is 1.82g/cc.

Table 4: Compaction characteristics of soil with varying percentage of CBs

Soil	CBs (%)	O M C	M D D(g/cc)
100	0	7	1.82
99.5	0.5	8	1.62
99	1	10	1.78
98.5	1.5	11	1.75
98	2.0	12	1.71

CBR Test *for soil and soil mixed with admixtures*

California Bearing ratio is a penetration test used for evaluation of mechanical strength of road subgrades and base courses. California Bearing Ratio test was conducted on the soil reinforced with different percentages of CBs for soaked condition. It is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm /min, and the test results are tabulated in table 5.

Table 5: CBR Test Data of Reinforced Soil Sample

Penetration (mm)	Load (kg)				
	0 % of CBs	0.5% of CBs	1 % of CBs	1.5 % CBs	2.0 % CBs
0.5	0	0	8.4	0	0
1	8.4	0	42	0	8.4
1.5	16.8	8.4	50.4	8.4	8.4
2	16.8	20.5	67.2	23.6	16.8
2.5	21	41.2	75.6	34.4	29.8
3	25.2	48.6	92.4	39.8	34.2
4	33.6	51.4	117.6	48.4	38.3
5	37.8	58.8	119.1	56.6	42.1
7.5	58.8	84.6	149.2	72.2	60.2
10	67.2	93.6	162.1	98.8	71.5
12.5	75.6	111.1	173.6	132.3	112.3

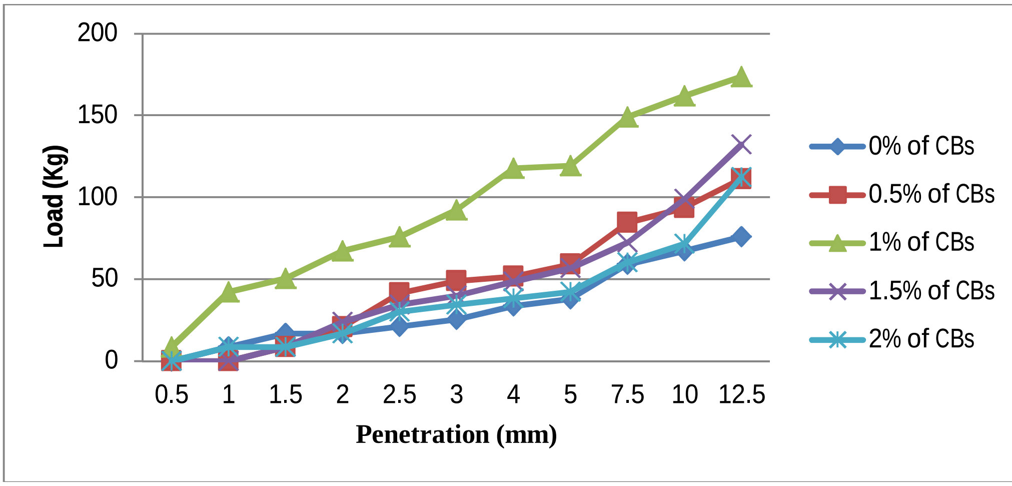

Fig 2: CBR curve for soil sample with different CBs content

Table 6: CBR values at different CBs content

CBs Content	CBR at 2.5mm penetration	CBR at 5mm penetration
0 %	1.53	1.83
0.5 %	3.0	2.86
1.0 %	5.51	5.79
1.5 %	2.51	2.75
2.0%	2.17	2.04

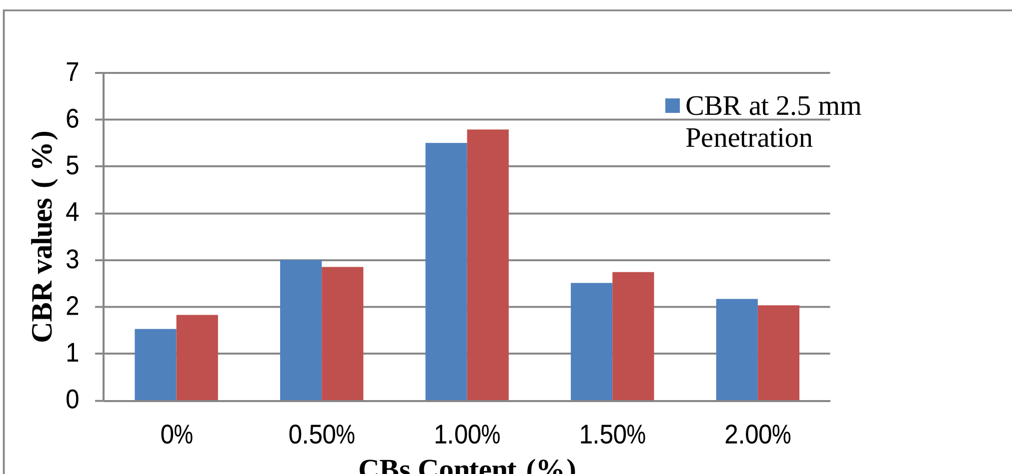

Fig 3: CBR at different CBs composition

RESULTS AND DISCUSSION

Effects of CBs on Compaction Characteristics of soil

The results indicated in Table 4 with increase in CBs content, OMC of the soil lime mix increases gradually with same compactive effort. While the natural soil has an OMC of 7% and addition of 0.5 % of CBs with soil raise the OMC to 8% and an addition of 1% CBs raise the OMC of mixed soil up to 10%. The increase in OMC with increased CBs content is due to its cellulose acetate content present in the CBs.

It can be seen from the results of table 4 with the increase in CBs contents MDD decreases gradually. While the normal soil has the MDD of 1.82 gm/cc an addition of 0.5% of CBs reduces the MDD to 1.62 gm/cc and addition of 1 % CBs further reduces the MDD of mixed soil to 1.78 gm/cc. The decrease results from the cellulose acetate and fibre content present in the CBs corresponding decrease in dry density. The decrease in the MDD of the CBs treated soil is reflective of the increased resistance offered by the CBs soil structure to the compactive effort. This agrees with the findings of the other investigators of this area.

Effect of CBs addition on strength characteristics of soil

From table 6 the variation of CBR of soil-CBs combination for soaked condition shows that for 0.5 % of CBs addition, the CBR value for soaked conditions increase gradually to a value more than those of 0% CBs content .But at 1% of CBs content for soaked CBR reach to a peak value of 5.51% and thereafter CBR value continue to drop with further addition of CBs. This enhances the cellulose acetate fibre combined with soil and as a result CBR value increases. But further addition of CBs occupies the space in between the soil particles in the specimen and thus reduces the bond and CBR value of the soil CBs mixture.

From the above discussion an inference may be drawn that with the increase in admixtures content CBR values for soaked conditions increases .Out of the above discussed four cases, we seen that the 1% of CBs gives the highest value of CBR of 5.51 % for soaked condition, so it is increased compared to that of original soil.

CONCLUSION

General increase in OMC and decrease in MDD was found when CBs was added with soil. Addition of CBS found to improve the soil strength characteristics substantially. Based on the present investigation, it is concluded that CBR value of soil increases with the inclusion of CBs. When the CBs content is increased, the CBR value of soil further increases and this increase is remarkable at CBs content of 1%. The maximum increase in CBR value was found to be more than 360 % over that of plain soil. It has been concluded that reinforcement of soil using CBs is economically advantageous as it is cheap and locally available material. Compared to existing methods of soil reinforcement which have practical difficulties in the field, the application of CBs-Soil is easier. The recycled CBs reinforcement is a superior solution for the construction of low volume roads on weak subgrades. The results found so far shows that cigarette butts can be regarded as a potential addition to subgrade of soil stabilization.

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Biography:

Naveen Kumar A.B was born in Hassan, India, in 1988. He received the B.E. degree in Civil Engineering from the Visvesvaraya Technological University, India, in 2009, and the M.Tech. Degrees in Highway Technology from the R.V College of Engineering(RVCE) Bangalore, India, in 2012 and pursuing his Ph.D. Degree from the Visvesvaraya Technological University, India,

In 2009, he joined the Department of Civil Engineering, in KS Polytechnic, India as a Lecturer, and he was an Assistant Professor, in Yellamma Dasappa Institute of Technology from 2012 to 2014, later he joined as an Assistant Professor in S.J.B Institute of Technology (SJBIT), Bangalore, India from 2014 to 2016. Currently he is working as a Faculty Member in Civil Engineering Department, Mettu University, Mettu, Ethiopia. He taught and guided number of Undergraduate and Post Graduate students in his carrier. His current research interests include stabilization of flexible pavement layers, Transportation Engineering, Traffic Engineering, Railway Engineering, utilization of recycled materials for road construction. He has published research articles in reputed national and international journals and also presented research papers in various conferences. He is a Life Member for reputed journals like IJMER and International association of Engineers IAENG etc. He got the best Academic and Performer Awards also.