Laboratory studies on cigarette butts with bituminous concrete

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ABSTRACT

Cigarette consumption is on the rise globally, the amount of littered cigarette butts is also increasing the environment According to estimations from Euromonitor International over 5.7 trillion cigarettes were consumed worldwide in 2013; and, each year, an estimated 4.5 trillion butts from the annual cigarette consumption are deposited somewhere in the environment. The objective of our project was to incorporate these cigarette butts in bituminous concrete (sma) in varying percentages of 2%, 4% and 6% to carry out lab tests as per mort&h specification and know whether it satisfies the standards. In this project only the coarse aggregates were partially replaced by cigarette butts (CBs) and the quantity of fine aggregates was maintained constant. Bitumen of class 60/70, OPC 43grade were used. Preliminary tests were conducted on aggregates and bitumen and Marshall stability test was conducted to study the strength parameters after incorporation of cigarette butts.

Keywords: *cigarette butts, Bituminous concrete, Marshall stability test, SMA,*

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1. INTRODUCTION

1.1 GENERAL

Bituminous concrete is a type of construction material used for paving roads, driveways, and parking lots. It's made from a blend of stone and other forms of aggregate materials joined together by a binding agent. This binding agent is called "bitumen" and is a by-product of petroleum refining. It has a thick, sticky texture like tar when heated, then forms a dense solid surface once it dries. Bituminous concrete is also widely known as asphalt in many parts of the world. Despite its name, this material is quite different from standard concrete, and contains no cement. While most cement-based surfaces are white or grey, bituminous concrete is known for its distinctive black appearance. It is often laid right over a gravel base layer to form new roads and parking lots, but may also be poured over existing concrete to repair or smooth out bumps and voids. Once the bituminous concrete has been poured onto the roadway, installers use large paving machines to smooth and compact the surface.

There are three major types of asphalt surfacing, characterized by a mixture of bitumen and stone aggregate.

- Dense Graded asphalt (DGA)
- Open Graded Asphalt (OGA)
- Stone Mastic Asphalt (SMA)

Dense Graded asphalt (DGA)

A dense-graded asphalt mix is a well-graded HMA intended for general use. When properly designed and constructed, a DGA mix is relatively impermeable & Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse-graded. Fine-graded mixes have finer and sand sized particles than coarse-graded mixes.

Open Graded Asphalt (OGA)

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are

Stone Mastic Asphalt

Stone mastic asphalt (SMA) is a stone-on-stone like skeletal structure of gap graded aggregate, bonded together by mastic, which actually is higher binder content, filler and fibre to reduce the binder drain. This structure improves the strength and the performance of SMA even higher than the dense graded and open graded asphalt mixtures. High percentage of binder content is important to ensure the durability and laying characteristics of SMA. SMA is best explained as two-component hot mix asphalt HMA which comprises a coarse aggregate skeleton derived from a gap-graded gradation and a high bitumen content mortar.

Composition of SMA

- Asphalt (Binder): SMA contains very high content of bitumen as compared to conventional mixes ≥6.5 %. It is used to bind the aggregates, fillers and stabilizing additives. Different studies on SMA have been conducted by using different bitumen grades namely bitumen of grade 60/70.
- Aggregate: The strength and rut resistance of SMA mostly depends upon whether the aggregate mix is 100% crushed and with good shape (cubical) and strength limits for abrasion resistance and crushing strength. The sand used must be crushed sand as the internal friction contributes into the overall strength.
- Fibres: Fibres are being used in SMA as a stabilizing agent and to reduce the drain down significantly
- Mineral filler: The term mineral filler is typically referred to the mineral fine particle with particle size passing the 200-mesh sieve (smaller than 75 micron) in this project cement is used as mineral filler.

In this project the lab test was conducted on stone mastic asphalt as per Mirth specification in which the aggregates were partially replaced by cigarette butts because the CBs consists of un-smoked tobacco, the filter of a cigarette, and a paper wrap which have various impact on environment The filters are made of cellulose acetate, sourced from plastic, are photodegradable – can be broken down by UV light, but still, take an extended period to break down. The ingredients in the filter, therefore, remain in the soil for a long period of time, up to 10 years, as estimated by researchers. As long as they are present in the soil, the soil remains polluted. Since cigarette butts have fibrous properties there may be a way to incorporate them as a fibre material in the preparation of SMA without compromising the strength Hence in this project we replace the coarse aggregates by varying percentages by weight with cigarette butts and conduct experiments to find out stability and flow values.

2. OBJECTIVES

The main objective of this project is to incorporate cigarette butts (CBs) by partially replacing coarse aggregates in varying percentages (2% 4% 6 %) by weight of coarse aggregates.

- To carry out preliminary tests on aggregates and bitumen by conducting various lab experiments namely impact test, specific gravity test, crushing test for aggregates and specific gravity test, penetration test, softening point test, flash and fire point test.
- To prepare test specimens and to carry out Marshall stability test as per MORTH specifications by partially replacing 2% 4% 6% of coarse aggregates
- To analyse the data obtained and calculate and compare the values by plotting graphs.

3. LITERATURE REVIEW

General

An attempt is made with cigarette butts as a partial replacement of coarse aggregate in the bituminous concrete mix. The main aim of this section is to present an overview of research work carried out by various researchers in the field of cigarette butts and replacement of coarse aggregates.

- Gazia Khurshid khan and others (2017) researched the use of natural fibre and binder quality in SMA. Where natural fibre was bamboo fibre and cellulose fibre with varying bitumen content, they tested Marshall stability it is observed and concluded that addition of fibre favourably affects the properties of bituminous mixtures and it will sustain on various climatic conditions in India.

- Narayan panda (2010) carried out a laboratory study and compared the strength of pavement wearing coats made with SMA mix with fibre and without fibre. This research was done to evaluate viability of sisal fibres as stabilizing agent in laboratory tests in [7]which mechanical properties was analysed with varying binder content 4-7% and fibre used was 0.3% by weight of aggregate and 60/70 was grade of bitumen.

- Abbas Mohajerani and others (2017) studied mechanical and physical properties of asphalt concrete by marshall stability with use of encapsulated cigarette butts' samples of asphalt concrete were manufactured with 10,20,30 kg/m³ of encapsulated CBs. Different bitumen classes (C1700, C320 andC600) were used to encapsulate the CBs in order to determine how the use of higher-class bitumen would affect the properties of AC. several tests were conducted in relevance to Australian standards.

- Md Tareq Rahman (2020) studied SMA with use of encapsulated CBs with different percentages of bitumen content using Marshall stability test and where flow results showed significant improvement in the strength. And discussed some of the results from a comprehensive study on recycling cigarette butts in asphalt.

- Yu Chen (2020) carried a Marshall stability test based on role of mineral filler in an asphalt mixture, types of mineral filler and to get know about low temperature performance and fatigue cracking resistance and moisture damage resistance of asphalt mixture by using them.

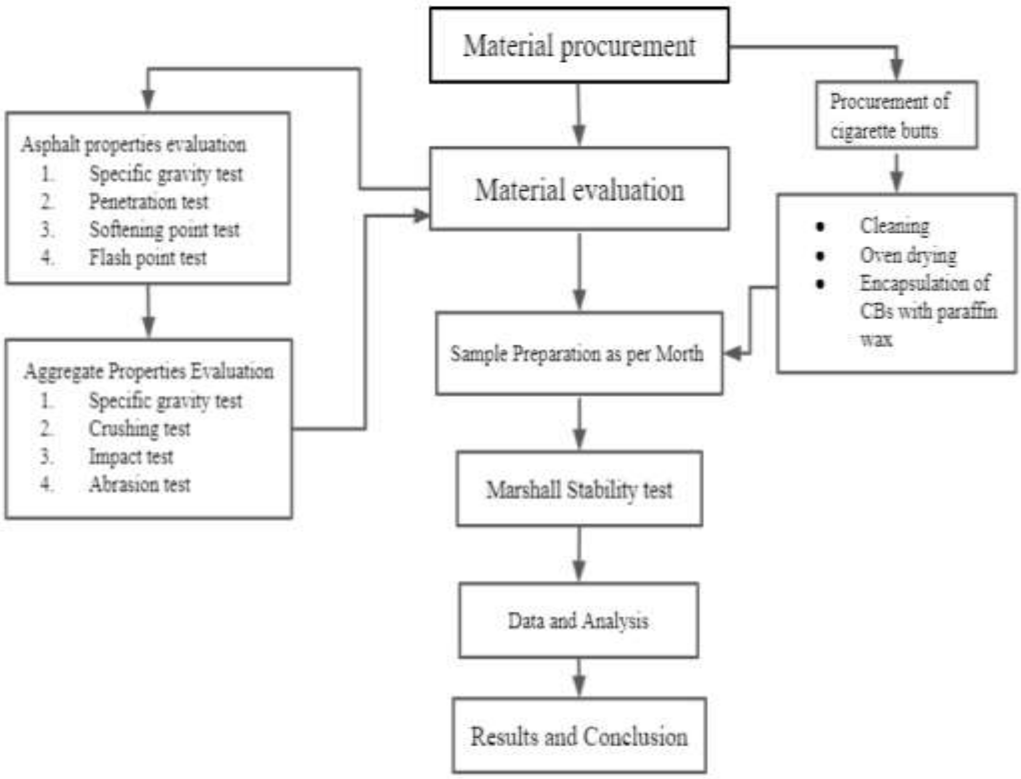
- E R Brown and others (1997) evaluated design mixture for stone matrix asphalt for materials and mixture criteria and with these other factors also evaluated were Los Angeles abrasion loss, flat and elongated particle content.

- Umer Qureshi (2014) researches about the impact of cigarette butts on environment, interpreting environmental risks of cigarette butts towards environment and relevant about impact of interrepublic attitudes towards litter, and other impact like toxicity and metals leach from cigarette litter and moral responsibility for environment towards cigarette butts.

4. METHODOLOGY

General

In this chapter we will study about the experimental procedures involved and also about the materials which are used to accomplish the objectives of the project.



Flow Chart 4.1: Methodology

This chapter discusses the methodology which was adopted to prepare stone mix asphalt (SMA) as per MORTH specification and also about the materials used in the experiment i.e., aggregates (coarse and fine), asphalt binder-bitumen, mineral filler-cement, fibres-cigarette butts. And also gives detailed information about the incorporation of CBs at varying percentages.

4.1 AGGREGATES:

In SMA consists of high percent about 70-80 percent of coarse aggregate and 8-10 percent of fine aggregates in the mix. The aggregates used in this project consists of both coarse and fine aggregates passing from IS sieve size starting from 19mm to 0.3mm and the least size of the aggregate particle used is of size which is retained at 0.075mm sieve.

The tests conducted on aggregate are specific gravity test, aggregate crushing test, aggregate impact test, abrasion test to check the physical properties of the aggregates. The test results are tabulated in the table 3.1 The aggregates were collected from the quarry near Bengaluru(mittganhalli).

Sl.No	TEST	Specification as per MORT&H	Obtained value	Test method
1	Specific gravity	>2.5	2.62	IS 383-1970
2	Aggregate crushing test	Max 30%	25.30%	IS:2368 part 4-1963
3	Aggregate impact test	Max 27%	20.89%	IS:2368 part 4-1963
4	Los Angeles abrasion test	Max 2 %	0.35%	IS:2368 part 4-1963

Table 4.1.1: Physical properties of aggregates

4.2 ASPHALT BINDER:

In this project the asphalt binder used is straight run/plain bitumen of penetration grade 60/70 equivalent to viscosity grade VG-30. To assess the physical properties of the bitumen specific gravity test, penetration test, softening point and flash point tests were conducted and the results are tabulated in the table 3.2.1

Sl.No	TEST	Specification as per MORT&H	Obtained value	Test method
1	Specific gravity	-	1.01	IS:1202
2	Penetration	50-70	61	IS:1203-1925
3	Softening Point	Min 47	54	IS:1205-1978
4	Flash Point	Min 220	302	IS:1209-1978

Table 4.2.1: Physical properties of bitumen

4.3 FIBRES (CIGARETTE BUTTS CBS):

Fibres are used in SMA as a stabilizing agent and to reduce the drain down significantly. Various fibres have been used in various studies showing different results, in this project cigarette butts were chosen as fibres since the filter material in the cigarette butts have fibrous quality.

The required quantity of CBs was collected from various places around stores and near vacant sites. The Cbs were cleaned to remove unwanted soil particles, leaf particles etc and other dust particles, later the CBs were oven dried for 1 hour at a temperature of 100^{o}-$103^{o}C$ to remove any moisture content. And then they were encapsulated with paraffin wax, the purpose of encapsulation of cbs with paraffin wax was to increase the performance of bitumen at high temperatures because studies showed that bituminous concrete showed improvement under the influence of paraffin wax, resulting in the asphalt mixture having increased resistance to permanent deformation. As paraffin wax is a flow improver, the viscosity of bitumen at high temperatures is reduced. Also, the mixing and compaction temperature of the asphalt mixture decreases, resulting in lower energy consumption. Hence the cigarette butts were dipped in paraffin wax for 2 to 3 seconds to provide a thin layer of complete encapsulation.

4.4 MINERAL FILLER:

Mineral filler used in asphalt mixtures consists of fine-grained mineral particles either naturally present in or separately added to the aggregate system., mineral fillers are generally treated as being suspended in the asphalt binder without particle–particle contact and contributed to the toughening and stiffening of the asphalt binder, it has also been viewed as part of the aggregate skeleton and provides contact points between particles or assumes a dual role. Mineral fillers are defined as the portion of aggregates passing through a 0.075 mm sieve and also referred as mineral dust or rock dust. The physical and chemical properties of mineral fillers are also strongly involved in the determination of pavement performances of asphalt mixture, including rutting, fatigue cracking, low-temperature cracking and stripping or moisture damage.

There are 3 categories in mineral fillers:

1. Mineral powders directly manufactured through screening and crushing of original rocks.
2. Industrial products or by-products, such as hydrated lime.
3. Ashes or fine particles derived from waste materials like steel slag powder, rice husk ash, glass powder etc

In this project category 2 i.e., cement was used as mineral filler.

4.5 MARSHALL STABILITY TEST AND MIX DESIGN:

Marshall stability test:

Objective of Marshall Mix Design:

- To determine the density – voids analysis for the given bituminous mixture;
- To determine the strength (Marshall's stability value) and flexibility (flow value) for the given bituminous mixture.
- To determine the suitability of the bituminous mixture to meet the specified criteria for the surface course.

Preparation of test specimen

- Measure out 1200 g of aggregates blended in the desired proportions.
- Heat the aggregates in the oven at the mixing temperature (150^o-160^{o}C)
- Add bitumen at the mixing temperature to produce viscosity of 170± centistokes at various percentages both above and below the expected optimum content.
- Mix the materials in a heated pan with heated mixing tools.
- Return the mixture to the oven and reheat it to the compacting temperature (to produce viscosity of 280 ± 30 centistokes).
- Place the mixture in a heated Marshall mould with a collar and base. Spade the mixture around the sides of the mould. Place filter papers under the sample and on top of the sample.
- Place the mould in the Marshall compaction pedestal.
- Compact the material with 75 blows of the hammer (or as specified), invert the sample, and compact the other face with the same number of blows.
- After compaction, invert the mould. With the collar on the bottom, remove the base and extract the sample by pushing it out the extractor.
- Allow the sample to stand for a few hours to cool.
- Obtain the sample's mass in air and submerged, to measure density of specimen, so as to allow calculation of the void's properties.

Test procedure

- Specimens are heated to 60^o ±1^{o}C, either in a water bath for 30-40 minutes.
- Remove the specimen from the water bath and place it in the lower segment of the breaking head. Then place the upper segment of the breaking head on the specimen and place the complete assembly in position on the testing machine.
- Place the flow meter over one of the posts and adjust it to read zero.
- Apply a load at a rate of 50 mm per minute until the maximum load reading is obtained.
- Record the maximum load reading in Newtons (N). At the same instant obtain the flow as recorded on

the flow meter in units of mm.

Recorded observations:
Mass of aggregates in mixing pan=1200 g
Mass of bitumen added= 78g
Bitumen content = 6.5 %
Mixing temperature-aggregate= 150^{o}-$160^{o}C$
Compacting temperature= $135^{o}C$
Number of blows with hammer per face=75
Mass of specimen in air W_a = g
Mass of specimen Submerged in water W_w= g

Formulae:

1. Bulk density (kg/m³) = $\frac{Wa}{Wa-Ww} \times 1000$
2. Percent Air Voids, Va(%) = $\frac{(100-Bitumen\ content) \times Density}{Specific\ gravity\ of\ Agg}$
3. Volume of Asphalt Vb(%) = $\frac{(Bitumen\ content) \times Density}{Specific\ gravity\ of\ Agg}$
4. Percent voids in Mineral Agg. VMA (%) = 100-Va
5. Percent voids in Asphalt VFA (%) = $\frac{100 \times Vb}{VMA}$

4.6 MIX DESIGN:

The SMA mix design was done as per Marshall Mix design. The gradation adopted for coarse aggregate, fine aggregate and bitumen content is shown in **Table:**4.6.1. Also, the partial replacement of encapsulated CBs at varying percentages i.e., 2%, 4% and 6% by weight of coarse aggregates is shown in **Table:**4.6.2.

IS Sieve Size(mm)	Cumulative % by Weight of total agg. passing
19	100
13.2	90-100
9.5	50-75
4.75	20-28
2.36	16-24
1.18	13-21
0.6	12-18
0.3	10-20
0.075	8-12
Bitumen content	6.5

Table 4.6.1: Gradation Adopted for bituminous concrete (SMA) mixes as per MORT&H

Sieve Size	Requirements	% Passing	% Retained	Weight of agg (g)	Weight of CBs 2% (g)	Weight Of Agg. after 2% Replacement (g)	Weight of CBs 4% (g)	Weight Of Agg. after 4% Replacement (g)	Weight of CBs 6% (g)	Weight Of Agg. after 6% Replacement (g)
19	100	100	0	0	0	0	0	0	0	0
13.2	90-100	95	5	60	1.2	58.8	2.4	57.6	3.6	56.4
9.5	50-75	60	35	420	8.4	411.6	16.8	403.2	25.2	394.8
4.75	20-28	21	39	468	9.36	458.67	18.72	449.28	28.08	439.92
2.36	16-24	16	5	60	0	60	0	60	0	60
1.18	13-21	14	2	24	0	24	0	24	0	24
0.6	12-18	12	2	24	0	24	0	24	0	24
0.3	10-20	10	2	24	0	24	0	24	0	24
0.075	8-12	8	2	24	0	24	0	24	0	24
			92	1104						
		Cement	8	96						
		Total	100	1200						
		Binder Content	6.50%	78 g						

Cigarette Butts %	Sample No.	Bitumen Content	Weight Of sample (g)	Volume (cm^3)	Bulk density	Theoretical density	Percent Air	Volume of Asphalt	Percent voids in	Percent voids in	Stability Value	Flow (mm)

Table 4.6.2: Gradation of aggregates and mix design

5. COMPILATION OF TEST RESULTS:

5.1 INTRODUCTION

The Marshall method of mix design has been carried out for the SMA of varying percentage of cigarette butts which were encapsulated with paraffin wax. For this the experimental results are shown in the **Table**:5.1.1. The graphs have been drawn between CBs content and density, CBs content and stability, CBs content and flow, CBs content and VMA, CBs content and VFB, CBS content and percentage of ai voids.

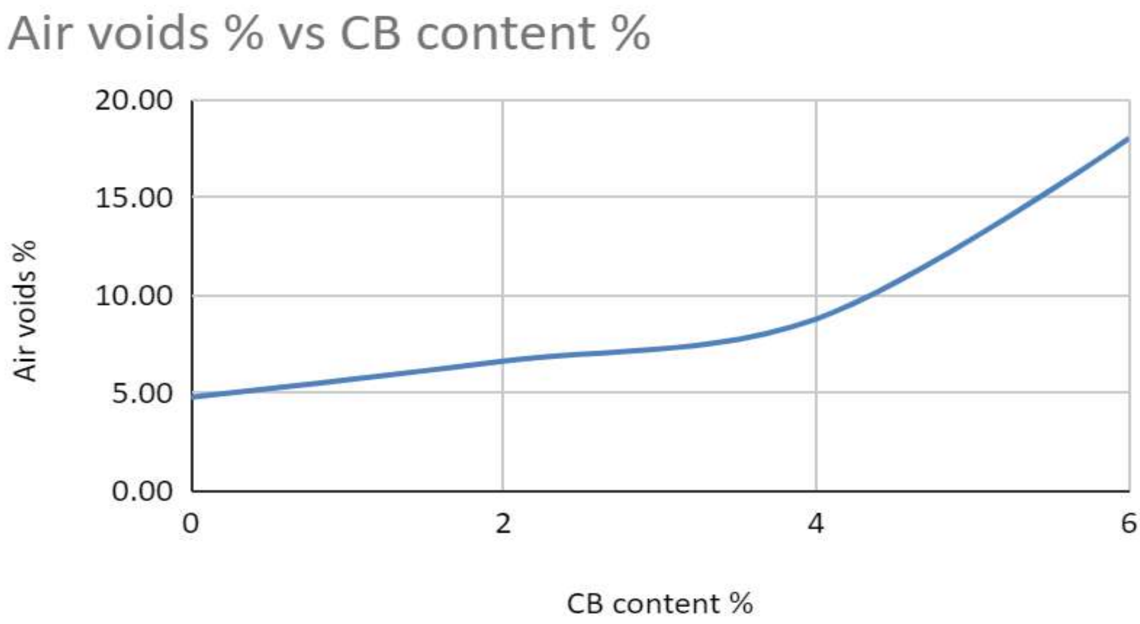
Marshall properties for stone mastic asphalt.

The Marshall stability test specimens were prepared with plain bitumen as binder content 6.5%, constant for all experimental specimens. In the conventional Marshall mix design 1.2 kg of aggregates were used to prepare the specimen. And only coarse aggregates were partially replaced by cigarette butts at 2% 4% and 6% of the weight of coarse aggregates.

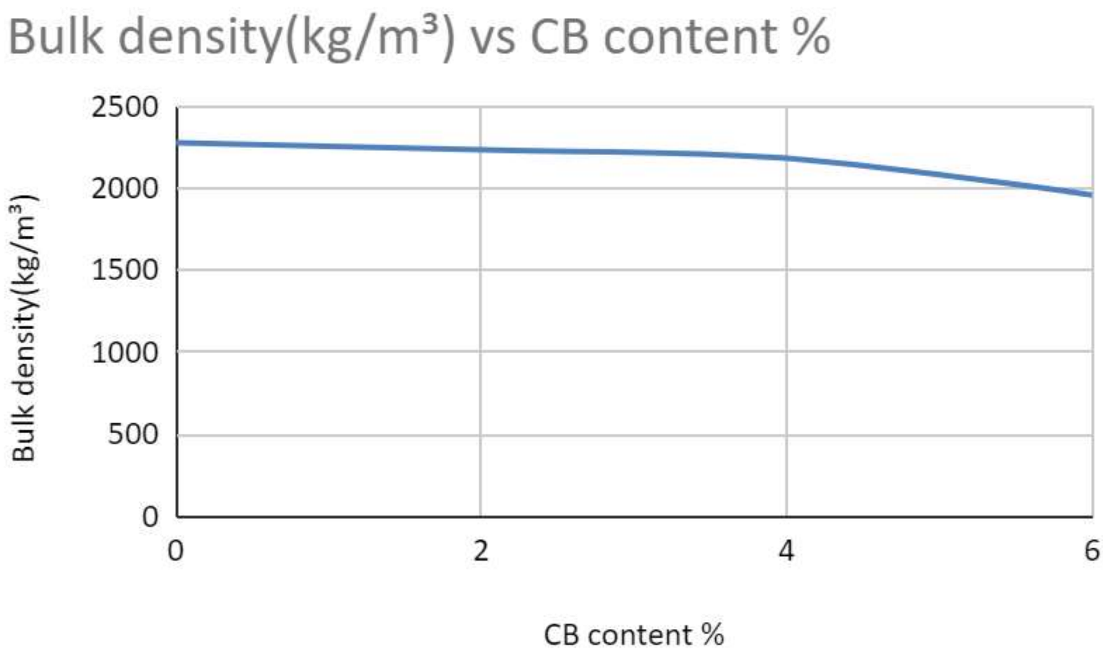
The Experimental results of the Marshall test carried out are represented in the **Table**:5.1.1 and the corresponding graphs are also plotted.

			Wt. in Air	Wt. in water		(kg/m³)	(kg/m³)	Voids, Va(%)	Vb(%)	Mineral Agg. VMA (%)	Asphalt VFA (%)	(kN)	
0	1 2 3	6.5	1178 1195 1220	668 673 674	580.90 573.05 565.20	2309.804 2289.272 2234.432	2391.083	3.399 4.258 6.551	14.719 11.222 10.953	18.119 15.480 17.505	81.239 72.494 62.573	5.219 5.494 6.318	6 6.5 6.8
		Average	1197.66	671.67	573.05	2276.933		4.774	12.298	17.072	72.036	5.677	6.43
2	1 2 3	6.5	1251 1246 1265	687 691 699	573.05 565.20 580.90	2218.085 2245.045 2234.982	2391.083	7.235 6.108 6.528	14.135 12.106 12.051	21.370 18.213 18.580	66.144 66.466 64.863	3.571 4.120 3.846	8 7.4 6.8
		Average	1254	692.33	573.05	2232.641		6.626	12.764	19.39	65.826	3.846	7.4
4	1 2 3	6.5	1219 1185 1221	662 636 665	573.05 549.50 588.75	2188.510 2158.470 2196.043	2391.083	8.472 9.728 8.157	13.946 12.697 12.918	22.418 22.425 21.075	62.210 56.619 61.295	1.923 2.472 2.197	7.5 6.8 6
		Average	1208.33	654.33	570.43	2181.107		8.782	13.187	21.969	60.027	2.197	6.77
6	1 2 3	6.5	1244 1208 1180	599 613 565	588.75 596.60 596.60	1928.682 2030.252 1918.699	2391.083	19.339 15.091 19.756	12.291 12.938 12.227	31.629 28.029 31.983	38.859 46.160 38.230	0.989 1.373 1.099	9 8.1 7.8
		Average	1210.67	592.33	593.98	1957.951		18.114	12.485	30.6	40.802	1.154	8.3

Table 5.1.1: Marshall Properties of SMA at varying Cigarette butts Percentages



Graph: 5.1.1



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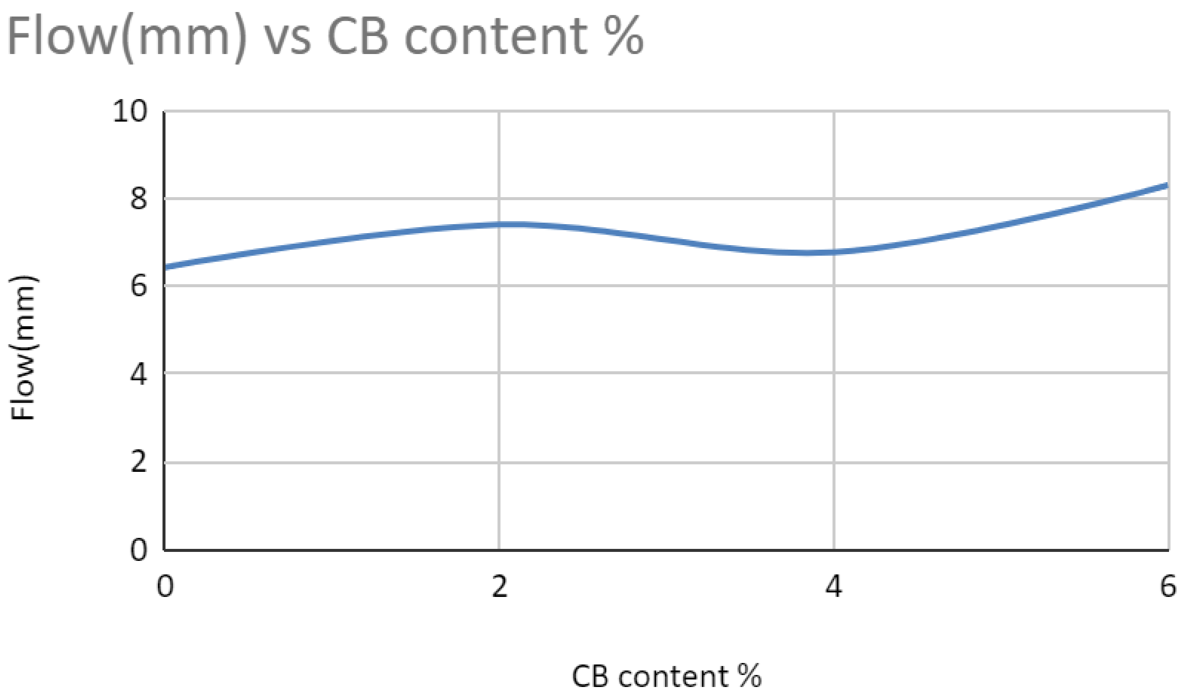

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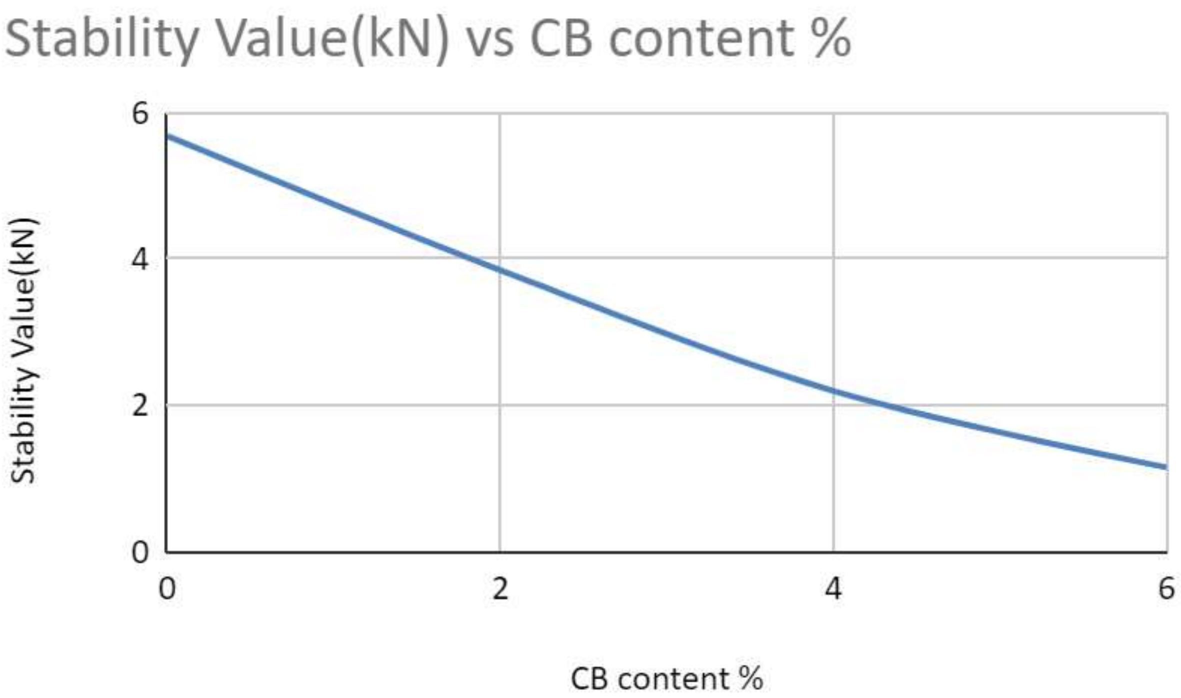

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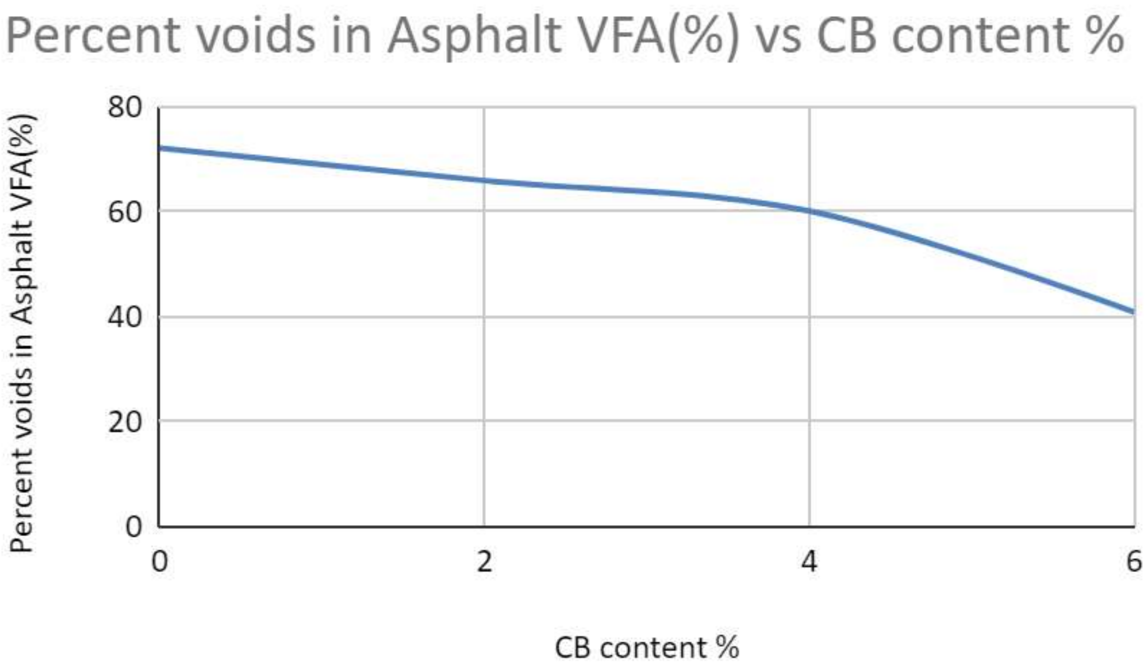

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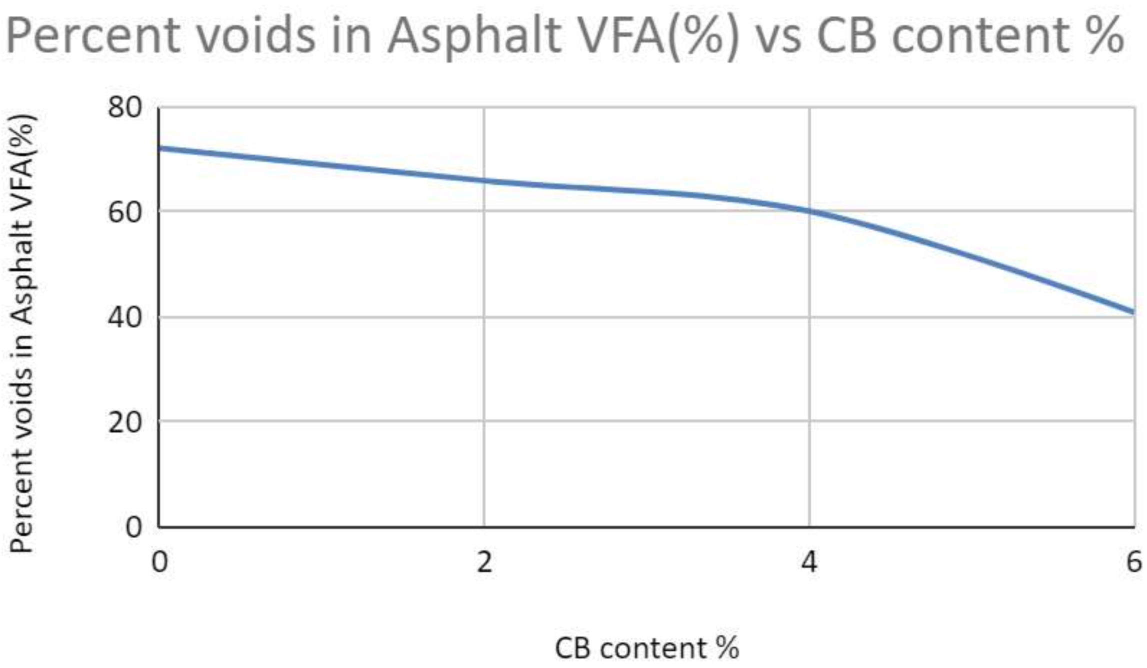

Graph: 5.1.6

6. RESULTS AND DISCUSSION:

Marshall Stability values

- The Marshall stability value for the SMA mix without CBs are found to be 5.67KN
- The Marshall stability value for the SMA mix with CBs of 2%,4% and 6% are found to be 3.846KN,2.197KN and 1.154KN respectively.
- The Marshall stability values are found to decrease as CBs percentage increases, but when CBs percentage was 2% and less than 2% the Marshall properties were found close to SMA mix without CBs.

Cigarette Butts %	Bitumen content	Percent Air Voids, Va(%)	Volume of Asphalt Vb(%)	Percent voids in Mineral Agg. VMA(%)	Percent voids in Asphalt VFA(%)	Bulk density (kg/m³)	Stability Value (kN)	Flow (mm)
0	6.5	4.774	12.298	17.072	72.036	2276.933	5.677	6.43
2	6.5	6.626	12.764	19.39	65.826	2232.641	3.846	7.4
4	6.5	8.782	13.187	21.969	60.027	2181.107	2.197	6.77
6	6.5	18.114	12.485	30.6	40.802	1957.951	1.154	8.3

Table 6.1.1: Marshall Properties of SMA with varying percentage of CBs

7. CONCLUSION:

1. The physical properties were conducted on the aggregates used in the present studies that satisfy the requirements as per the MORT&H specifications.

2.The physical properties were conducted on the 60/70(VG-30) grade bitumen and warm mix binder used for the present studies and satisfies the requirements as per MORT&H specifications.

3.The Marshall stability values are found to decrease as CBs percentage increases.

4. when CBs percentage was 2% and less than 2% the Marshall properties were found close to SMA mix without CBs.

5.with increase in the percentage of CBs above 2% there was gradual decrease of bulk density, VMA, VFA.

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