International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 06, June-2015

A Study on use of Carbon Black Powder in Bituminous Road Construction

Saritha N
PG student (HT)
Dept. of civil engineering
GOV.SKSJTI, BANGALORE, INDIA

Dr. Kiran Kumar B V
Associate professor
Dept. of civil engineering
GOV.SKSJTI, BANGLORE, INDIA

***Abstract*— In this research deals with the effective usage of carbon black powder as a additive in bitumen grade VG-10. For identification of basic properties changes in bitumen after addition of carbon black powder in various percentages like 0.25%, 0.5%, 0.75, 1.0%, 1.25%, 1.5%, 1.75% and 2.0% for all the different percentage addition of carbon black to the bitumen, tests were conducted to identify the basic properties changes and optimum addition of carbon black powder for the Marshall mix design to calculate OBC. Here the changes found related to softening point temperature and the viscosity. Also calculated OBC from the Marshall method of mix design.**

Keywords— OBC-optimum binder content, CB- carbon black, BC- bituminous concrete,VFB- voids filled with bitumen,Vb- voids in bitumen .

I INTRODUCTION

The increasing of human population increases the needs for them to travel from one place to other place. Due to this, the use of vehicles increase which also increases the loading on the flexible pavement. Due to that the demand for the better pavement to withstand all the harsh condition also increased. Effective, timely and speedy maintenance is the only way to protect the huge capital investments which are linked to the road system. The proper strengthening and maintenance of the road network is required. Where deteriorating of roads increase with the steady traffic. Overlaying the distressed pavements with virgin courses had been adopted and continuous application of overlays increases the pavement thickness and approaches the curb line. To decrease and overcome the above problems here I selected carbon black powder as additive in bituminous mix to change its properties.

II NEED FOR THE STUDY

The study is focused on VG10 bitumen. The engineering properties of the VG10 bitumen added with carbon black additives are determined. The scope of the study focuses on obtaining a mixture that contains a good proportion of the mixture by laboratory test Marshall Method of mix design to obtain optimum binder content of bitumen.

A. Carbon black powder or carbon soot:

The fine powdery 'soot' or carbon black formed by the burning of hydrocarbons under oxygen-depleted conditions. And also carbon black defined as, "virtually pure elemental carbon in the form of Colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions". Carbon black is produced in two ways which are the furnace black and the thermal black processes. In the furnace black process, it uses the heavy aromatic oils as the feedstock. It uses a closed reactor to atomize the heavy aromatic oils under carefully controlled conditions such as temperature and pressure.

B. Objectives:

- To investigate the viability of using carbon black and latex as additives in flexible pavement.
- To determine the performance characteristics of asphalt mixture such as (Indirect Tensile Test-Rutting).
- Produce combination of aggregate into asphalt mixture which will result in the better performance of flexible pavement.
- The main objective for this study is to specify the engineering properties of VG-10 bitumen by adding additives of carbon black, which is different than the current binder used in Malaysia's roads.
- Addition of carbon black increases the resistance against rutting and cracking.
- Carbon black improves the properties of the bitumen.

III LITRATURE REVIEW

civil engineering university tun Hussein onn Malaysia PhD students in civil engineering faculty M B S alfergani and abdalla Ab sinusi saiah presented international journal of civil engineering and advanced technology (IJEAT) ISSN:2249-8958, VOLUME-2, ISSUE-3 February 2013 on topic "pavement performance with carbon black and natural rubber (latex)", from the journal it is concluded that the use of carbon black in that research project was identified to have the potential to becoming a modifier in HMA mixes due to elastic behavior and in reducing the rutting potential. This study presents the viability of carbon black as an additive in bitumen as binder and hot mix asphalt concrete with different ratios of 10, 15, 20% CB blended with each other. It was observed that the creep values are also lowest with 10% addition of carbon black powder. Thus, this shows carbon black may contribute towards better flex6ible roads in the future.

ALLIOTTI first introduced the concept of using carbon black as a reinforcing agent in 1962 published a paper on "The use of carbon black as a reinforcing agent" in that paper he described the characteristics of carbon black and identified its potential advantages as an asphalt additive.

yao monismith (1986), vallerga and gridley (1980) published a technical paper on "carbon black as a reinforcing agent for hot mixed asphalt" in that they included it has been reported that carbon black is also used to reinforce asphalt cement pavements. And also reported that the use of carbon black increased the rutting resistance at high temperature and the durability of the asphalt. They found that the temperature susceptibility and the cracking propagation potential of asphalt of low temperature decreased. In spite of its effectiveness as a modifier, however, the use of carbon black has been somewhat limited due to its relatively high material cost.
Statement by CONG, CHEN and CHEN (2011) agreed that by adding additives, the bitumen either may strengthen, which proven that that carbon black added in the asphalt binder improves the resistance against deformation at high temperature and even against the thermal cracking at low temperature.

Besides that, proved by ZHANG, Xi, ZHANG (2008) after the addition of carbon black, asphalt has decreased the softening point temperature and viscosity remains same which helps in enhancing the resistance to rutting at high temperature.

INTERNATIONAL CARBON BLACK ASSOCIATION (ICBA) in 1985 defined carbon black as "virtually pure elemental in the form of elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions".

According to Hjelm, Wampler and Gerspacher published a paper on "production of carbon black powder" in 1986, they defined carbon black as " the fine powdery soot formed by the burning of hydrocarbons under oxygen-depleted conditions". IARC monographs defined "carbon black as a form of elemental carbon manufactured by the controlled vapour-phase pyrolysis and partial combustion of hydrocarbons". As a conclusion they said, carbon black is literally a black colored pure carbon of colloidal particles that are produced by burning under insufficient oxygen of hydrocarbons.

According to WANG he published a paper on "The primary carbon black particles size and molecular structures" in 2003. He explained in this paper about the detailed particle size and also about the structural properties.

Explanation about particle size as follows, the primary carbon black particles, also known as the nodule, is approximately 10 to 500 nm in diameter. The significant area of difference between a carbon black from furnace black and thermal black process are particle size and structure. Carbon black from thermal black process has the larger particle or nodule size that has mean diameter of 240 to 320 nm hence have lower surface area at 7-11 m2/g. whereas nodule size from furnace black process three to twenty times smaller which has mean diameter of 15-80 nm providing surface area from 27-145 m2/g. below figure shows the visual comparison of particle.
About carbon black particles molecular arrangement he explained as follows, the nodule is the primary particle. It is made up of condensed aromatic ring system of carbon atoms arranged in large sheets of variable size and alignment. These sheets are randomly stacked around an axis, held together by "VAN DER WAALS FORCES", and overlaid to form structures called nodule.

III MATERIALS AND METHODOLY

A. Aggregates:

For the present studies aggregates are obtained from Hosur Bande quarry Bangalore. The basic properties tests results of the aggregates are as shown below in table 1.

Table 1 basic properties of aggregates

SL NO	**TESTS**	**VG-10**
1	Penetration at 25°C, 5sec	100
2	Softening point,°C	44.5
3	Flash point, °C	250.00
4	Ductility at 25°C,	77.00
5	Specific gravity	0.962

B. Bitumen binder:

In the present study VG-10 binder is used to ascertain the characteristic of bituminous mixes containing carbon black powder. Table 2 shows test results of virgin bitumen.

Table 2: basic properties of bitumen binder

SL NO	TESTS	AGGREGATES
1	Crushing Value (%)	21.5
2	Impact Value (%)	20.01
3	Abrasion Value (%)	14.15
4	Combined Index (%)	26.19
5	Specific gravity	2.52
6	Water Absorption (%)	1.2

C. Carbon black powder:

Carbon black powder which is produced from source of burnt plastic waste. Source obtained from M/S K K Waste plastic management Pvt. Ltd. Bengaluru. As shown in figure 1

Figure 1: shows carbon black powder

D. Mix design of BC :

The present investigation aimed at the laboratory evaluation of bituminous mix containing carbon black material which is added in various percentages. Virgin bitumen and about carbon black powder described in chapter-II are subjected to standard laboratory investigations to know its physical and engineering properties.

This study investigates the effect of utilization of materials on Marshall Stability of bituminous course mixes. BC grading II of MORTH (IV revision) was considered for the study.

The aggregates are collected from the crusher at hosur bande about 45km from Bangalore. Aggregates, virgin bitumen and carbon black powder as described in the section A, B and C are tested for basic properties check for their suitability. The most common and convenient method to determine optimum binder content of bituminous mixes is marshal method. Standard Marshall Specimens were prepared with trial percentages of bitumen to determine optimum binder content. The parameters viz., stability, density, voids in mineral aggregate, voids filled with bitumen and air voids etc. will be evaluated to arrive at optimum bitumen content. The test results so obtained for VG-10 binder for optimum percentage addition of carbon black powder were compared to deduce the present work

E. Gradation:

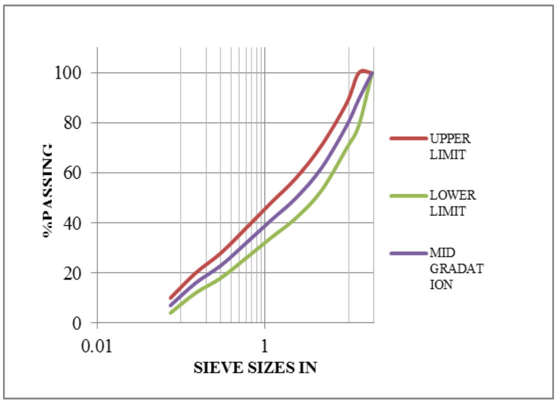
Gradation of aggregate or arriving at suitable JMF (job mix formula) is the most crucial in bituminous mix design. The gradation affects almost all the key property of a bituminous hot mix. A proper selection of aggregate during the primary stage of mix design plays very significant role in the durability and stability of road surface.

the virgin aggregates as per MORTH-IV revision BC grade two values referred to achieve the desired gradation as specified in the table are adopted. Gradation table- 3 and gradation curves graph -1 as shown below.

Table 3: gradation of aggregates for BC grade-II

MORTH SPECIFICATION FOR BC LAYER				
Sieve sizes (mm)	*Grade II*	*Upper limit*	*Lower limit*	*Mid Gradation*
19	100	100	100	100
13.2	79-100	100	79	89.5
9.5	70-88	88	70	79
4.75	53-71	71	53	62
2.36	42-58	58	42	50
1.18	34-48	48	34	41
0.6	26-38	38	26	32
0.3	18-28	28	18	23
0.15	12-20	20	12	16
0.075	4-10	10	4	7

Graph 1: showing gradation curves for BC grade-II



F. Preparation of Marshall mould or test specimens :

The coarse aggregates, fine aggregates and the filler material are proportioned and mixed in such a way that final gradation of the mixture is within the range of bituminous course (BC) mix. The aggregates and filler are mixed together in the desired proportion to fulfill the design requirements and the specified gradation. The required quantity of the mineral aggregate mix is weighed and taken so as to produce a compacted bituminous mix specimen of thickness 63.5mm approximately. The compaction level chosen is 75 blows on either side of the Marshall specimens for bituminous mix. Marshall Tests were conducted according to ASTM-D1559-96.

Figure 2: shows casted BC moulds

G. *Testing of specimen:*

- The aggregates were proportioned and mixed as given in the Table 3. The aggregates were heated to a temperature of 1600-1800C.
- Required quantity of bitumen i.e., 4,4.5, 5.0, 5.5, and 6.0 and percent by weight of aggregate. It is heated to a temperature 120-1450C for both the mixes.
- The heated bitumen is added to the heated aggregates and thoroughly mixed at a desired mixing temperature of 165-1750C.
- The mix is placed in a preheated mould of 10.16cm diameter and 6.35cm height with base plate and collar.
- After leveling the top surface, the mix is compacted by means of rammer of 4.54kg weight with 457mm height of free fall with 75 blows. The process is repeated on the other face also.
- After the compaction the specimen with the mould is allowed to cool down to the room temperature.
- Three specimens are prepared for bitumen contents of 4, 4.5, 5.0, 5.5and 6.0 percent by weight of aggregates for designed aggregate gradation.
- The same test procedure was adopted for Marshall Test on BC.
- The compacted specimens are removed after 24 hours curing in air. Later the specimen is extracted using specimen extractor.
- The mean height, weight in air, weight in water of the specimens was noted and bulk density is calculated.
- The specimens are kept in a thermostatically controlled water bath and maintained at 60±1 for 30-40 minutes. The specimens are taken out, placed in Marshall Test head and tested to determine Marshall Stability value, which is the maximum load before failure, and the flow value, which is the deformation of the specimen in "mm" up to the maximum load. The equipment used is strain controlled with strain rate of 50mm/minute.
- The corrected Marshall Stability value of each specimen is determined by applying appropriate correction factor, if the average height of the specimen was not exactly 63.5mm.

Figure 3: Marshall testing machine.

Figure 4: placing a mould inside the breaking head for testing.

Figure 5: failed or bulged mould after testing.

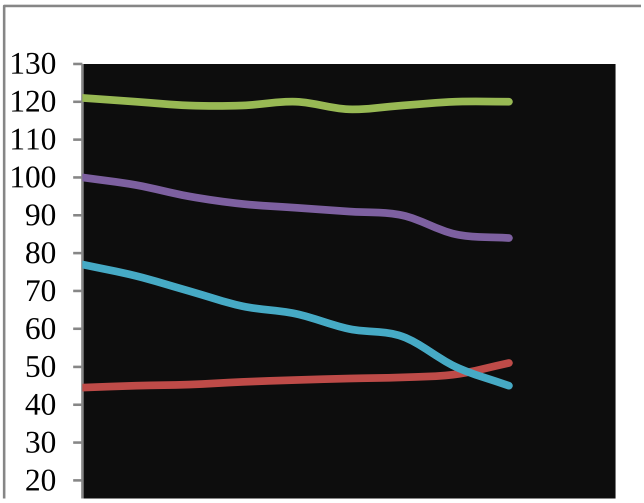
IV RESULTS AND DISCUSSIONS

A. *Basic properties changes after addition of CB powder:*

Table 4: basic test results after addition of CB

[1] Test's / % of CB	Specific gravity	Softening point in °C	Viscosity in sec	Penetration in MM	Ductility in CM
Virgin bitumen	0.962	44.5	101.66	100	77
0.25	0.964	45	101	98	74
0.5	0.972	45.3	100	95	70
0.75	0.978	46	99	93	66
1	0.980	46.5	98	94	64
1.25	0.982	46.83	97	93	60
1.5	0.997	47.16	96	90	58
1.75	0.999	48	94	85	50
2	1.12	51	85	84	45

Graph 2: showing variation in basic properties after addition of CB



By observing basic properties test results of bitumen after addition of carbon black powder in varying percentages from 0.25% to 2.0% as shown in table 4. After observing the graph 2 the softening point temperature goes on increasing.

B. Marshall stability test results:

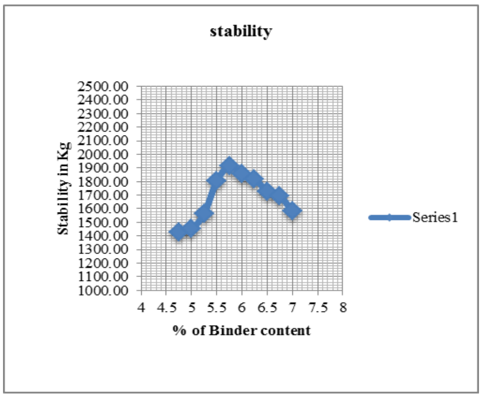
Below graphs show test results of Marshall stability, flow, void ratio, voids filled with bitumen and unit weight graphs drawn from average values respective readings as shown in table number 5 below.

Table 5: Marshall Test readings

BC							
Bitumen %	**Gb**	**Stability**	**Flow value**	**Air voids**	**VMA**	**VFB**	**unit wt g/cc**
4.75	2.24	1426.00	1.70	4.49	15.27	70.62	2.29
5.0	2.24	1453.60	1.73	4.32	15.64	72.39	2.30
5.25	2.23	1564.00	1.81	4.28	16.13	73.50	2.33
5.5	2.23	1803.20	1.93	3.99	16.20	75.36	2.33
5.75	2.24	1913.60	1.98	3.51	16.57	78.76	2.34
6.0	2.23	1857.25	2.17	3.32	16.87	80.34	2.33
6.25	2.23	1819.88	2.31	2.79	16.94	84.02	2.33
6.5	2.22	1728.45	2.47	2.60	17.29	85.11	2.32
6.75	2.23	1692.80	2.57	2.31	17.56	86.86	2.29
7	2.23	1582.98	2.78	2.25	18.02	87.53	2.28

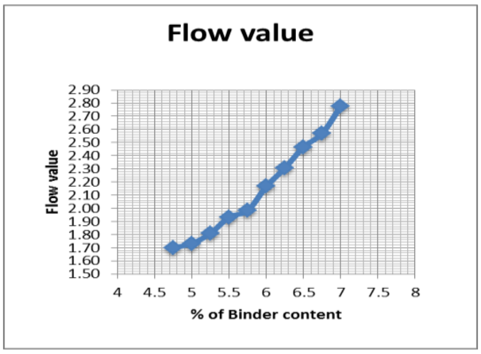
C. *Marshall test results graphs:*

Graph 3: showing stability values and OBC



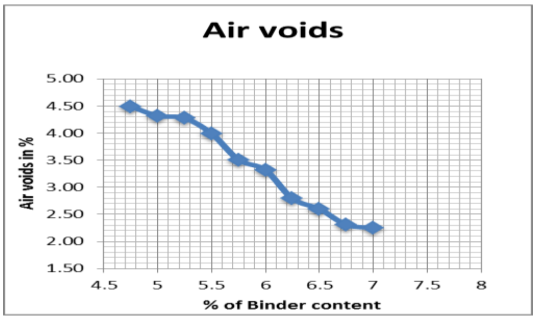
By referring graph 3, curve drawn between % of binder content versus stability in order to find OBC. From curve peak point the OBC value for the above mix is 5.75%.

Graph 4: shows flow value of the mix



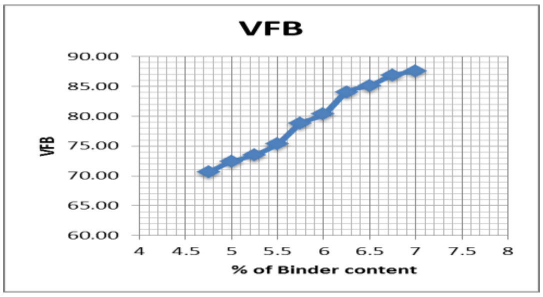
By referring graph 4, curve drawn between the % of binder and flow values. Curve shows that % of binder content increases flow value as goes on increases but flow value at OBC=1.98.

Graph 6: showing air voids



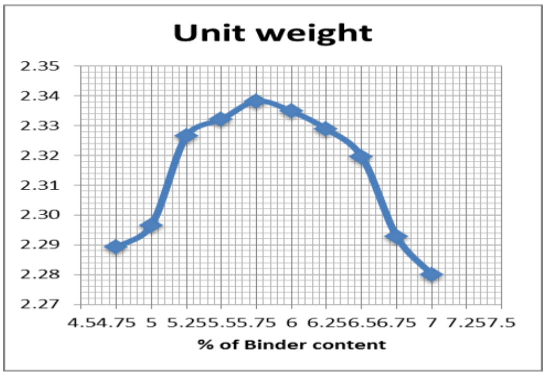
By referring graph 6, curve drawn between the percent of binder content versus void ratio values. From the curve air voids at OBC is evaluated i.e. air voids at OBC = 3.57.

Graph 7: shows voids filled with bitumen.



By referring graph 7, curve drawn between the percent of binder content versus VFB values. From the curve the value of VFB at OBC is 78.76.

Graph 8: shows unit weight.



By referring graph 8, curve drawn between the percent of binder content versus unit weight in kg/m2. From the curve unit weight value is 2.34 kg/m2.

V CONCLUSION

After doing experimental investigation, the following are concluded

- ✓ As the conclusion, the virgin bitumen is successfully added and mixed with carbon black with their respective percentages.
- ✓ The properties of the bitumen with carbon black additives are determined.
- ✓ The OBC is found at 5.75%.
- ✓ The stability at OBC is 1913.6 and flow value is 1.98 and air voids at OBC is 3.57, unit weight is 2.34 kg/m2 and VFB 78.76. all the values of the mix achieved absolutely within the standard limits.
- ✓ Both penetration and softening point test have proved that by adding carbon black additives, the values are improved better than the values obtained from the virgin bitumen. Thus, by using carbon black additives, bitumen's resistance upon rutting and cracking is improved.
- ✓ Lastly, due to difficulty in handling carbon black handling, the mixing process is disturbed. Besides that, bitumen's viscosity also contributed to the problem in handling mixing process. Thus, some precautions must be made in order to obtain result as accurate as possible.
- ✓ The addition of carbon black restricted to 5%, because addition of carbon black above 5% may causes brittleness of the pavement.
- ✓ Finally I conclude that use of carbon black reduces pollution as well as dumping plastic waste in landfills.
- ✓ Burnt plastic waste utilized in a very good manner.
- ✓ Air pollution get decreases in large quantities.

ANNEXURE

APPENDIX–I

MARSHALL MIX DESIGN CALCULATIONS

1. Theoretical Specific Gravity (G_t)

$$Gt = \frac{100}{(W1/G1) + (W2/G2) + (W3/G3) + (W4/G4) + (W5/G5)}$$

Where,

Gt	= Theoretical Specific Gravity of mixes.
Gb	= Bulk Density or Mass Density of Specimen.
W1	= Percent by weight of CA
W2	= Percent by weight of FA.
W3	= Percent by weight of Filler.
W4	= Percent by weight of Bitumen.
W5	= Percent by weight of Fines.
G1	= Apparent Specific Gravity of CA
G2	= Apparent Specific Gravity of FA
G3	= Apparent Specific Gravity of Filler.
G4	= Apparent Specific Gravity of Bitumen.
G5	= Apparent Specific Gravity of Fines.
VMA	= Percent Voids in Mineral Aggregate.
Vv	= Percent of Air Voids.
Vb	= Volume of Bitumen, %
VFB	= Percent voids filled by Bitumen.

2. Bulk Specific Gravity (Gb), gm/cc

$$Gb = \frac{\text{Weight in air}}{(\text{Weight in air} - \text{Weight in water})}$$

3. Volume of voids in mix (Vv), %

$$Vv = \frac{(Gt - Gb)}{Gb} \times 100$$

4. Volume of Bitumen (Vb), %

$$Vb = \frac{W4 \times Gb}{G4}$$

5. Voids in the Mineral Aggregate (VMA), %

$$VMA = Vv + Vb$$

6. Voids Filled with Bitumen (VFB), %

$$VFB = \frac{Vb}{VMA} \times 100$$

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