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PERFORMANCE TEST OF DIFFERENT TYPES OF WASTE AS PARTIAL REPLACEMENT OF CEMENT IN HOT ASPHALT MIX

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Abstract : One of the major fillers used in HMA is cement. With the extensive use of cement in mortars/concrete, there have been some environmental concerns in terms of damage caused by the extraction of raw material and Carbon dioxide (CO2) emission during cement manufacture. This has brought pressures to reduce the cement consumption in the industry. This journal outlines the ongoing research on different waste materials partial replacement of cement as filler used in hot mix asphalt mixes. Many studies regarding their effects on bituminous mixes were also analysed in combination with cement filler mastic. This project summarizes the interaction of Waste materials partial replacement of cement with different percentages 0%, 25%, 50%, 75%, 100% and finding out the optimun percenetage of waste material i.e: GGBS, Flyash, Concrete dust, Metakaolin and Marble powder as partial replacment of cement in bituminous mixes. Marshall properties such as stability, flow value, unit weight, air voids, are used to determine optimum waste material content for the used grade of bitumen (100/120).

Keywords – Filler, Metakaolin, Marble powder, concrete dust, GGBS, Flyash, Marshall stability, Flow value, Optimum waste material Content, unit weight, air voids.

1.INTRODUCTION

India has a road network of over5,603,293kilometres(3,481,725 mi) as on 31 March 2016, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of total road network. Being a vast country, India has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors are such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved.

The importance of using mineral filler in bituminous mixtures has been well recognised. The intention of using fillers in asphalt mixes can be traced back to 1890, but until as late as 1893 there was still a question as to whether or not it was beneficial to add filler in the paving mixture. In early practices, only carbonate of lime was used, they thought that there will be some chemical reaction between the bitumen and carbonate, later they believed that pulverized silica was used. Later in 1913 richardson stated “filler was defined as a part of the mineral filler with at least 75 percent passing 75mic sieve. Later several experiments have been conducted on different fillers and their properties.

A filler defined as that fraction of an inert mineral dust having particle size less than 75µ in a bituminous mixture can perform several functions. One function is that of filling voids in coarser aggregates, which increases the density, stability, and toughness of a conventional bituminous paving mixture. another, is the creation of a filler-asphalt mastic in which the particles of dust either may be individually coated with asphalt or are incorporated into the asphalt in mechanical and colloidal suspension. these forms of mastic are produced by special processes, such as cooking, atomized asphalt, and foamed asphalt. in paving mixtures the mastic serves as the cementing agent. the effect of fillers in conventional-type mixes is pronounced. excess quantity of filler tends to increase stability, brittleness, and proclivity to cracking. deficiency of filler tends to increase void content, lower stability, and soften the mix. in mastic mixes the quantity of filler used is not critical. when filler particles are individually coated with thin films of asphalt, strong, stable, tough mixes may be prepared composed of 100 percent filler with 20 to 25 percent of asphalt.

In recent years, many countries have experienced an increase in truck tyre pressures, axle loads and traffic volumes. If the tyre pressure and axle load increases then the top layer of the pavement surface is exposed to higher stresses. High density of traffic in terms of commercial vehicles, overloading of trucks and significant variations in daily and seasonal temperature of pavements have been responsible for development of distress like raveling, undulations, rutting, cracking, bleeding, shoving and potholing of bituminous surfaces. Suitable material combinations with bituminous binders have been found to result in longer life for wearing courses depending upon the aggregates used (Mladen Fistri 2010). Bituminous concrete is strong enough to handle the traffic with higher axle loads as compared to other mixes and is easy to repair or refinish.

The type of Hot Mix Asphalt (HMA) most frequently used in tropical countries are manufactured in an asphalt plant by hot-mixing of appropriate proportion of Coarse aggregate, fine aggregate, filler material and bitumen.

The filler material serves as void fillers which increase the densification of aggregates and also helps to determine the Optimum Bitumen Content (OBC) of the mixture. In selecting the filler present in the quantity to be added depends on the amount of filler present in the aggregate, desired reduction in voids, the extent to which additional increment will decrease the OBC in the mix .

One of the major fillers used in HMA is cement. With the extensive use of cement in mortars/concrete, there have been some environmental concerns in terms of damage caused by the extraction of raw material and Carbon dioxide (CO_2) emission during cement manufacture. This has brought pressures to reduce the cement consumption in the industry.

Pozzalanas such as fly ash, limestone dust, blast furnace slag, rice husk ash, incinerator ash, billet scales, siliceous and ionic materials most of which are waste from farms and milling industries across the globe or those that require relatively less energy to manufacture are now used in construction because of their cementitious properties.

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The sources of good quality mineral aggregate are depleting due to large-scale road infrastructure projects in India. Therefore, there is a need to explore the use of various types of fillers partial replacement like Fly ash, GGBS, lime, marble powder, metakaolin etc. which can be used in road construction. Among all the civil engineering sectors, it is found that the highway sector has a great potential to use sufficient quantities of these, however the laboratory and field performance studies should be carried out to check the suitability of these materials in road construction. Different types and quantity of filler have an effect on the performance of asphalt-concrete mixture. Filler provides better resistance to micro cracking so that it can increase the fatigue life of asphalt-concrete mixture.

A) Waste Materials

In thisproject we are partially replacing the waste materials in filler. Mineral filler consists of very fine, inert mineral matter that is added to the hot mix asphalt, to increase the density and enhance strength of the mixture. These fillers should pass through 75μm IS Sieve. Conventional filler materials (pass through 75μm IS Sieve) such as cement, lime, granite powder.Non conventional filler materials such as fly ash, metakaolin, marble powder, ggbs and concrete dust are finer than 0.075 mm size sieve were used as partial replacement of cement as filler in the bituminous mixes for comparison and economical point of view.

The waste materials used in this research Flyash, Metakaolin, Marble powder, GGBS, Concrete dust.

2. OBJECTIVE

The objectives of the work are stated below:

i) To findout the optimum binder content with respective percentages 5%, 5.5%, 6%.
ii) To study the effect of partial replacement of waste materials of cement in hot mix asphalt with the respective percnetages 0%, 25%, 50%, 75%, 100%.
iii) To determine Marshall Values, namely Marshall Stability Value, Marshall Flow Value, Voids present in air, Voids in Aggregates and Voids in Bitumen (determined from Marshall Stability Test).
iv) To findout the optimum waste material content in HMA by using marshall values.

3.MATERIALS USED

The grades of aggregates and their quantities to be used for preparing Marshall samples were graded as per Ministry of Road Transport and Highways (2001) given in Table.2.

BC mix with smaller aggregate in the other way having relatively higher bitumen contents, which not only impart high flexibility but also increase their durability.

A.Coarse Aggregates

The Coarse aggregates consisted of stone chips, up to 4.75 mm IS sieve size. Its specific gravity was found as 2.67. Standard tests were conducted to determine their physical properties as summarized in Table.3.

B. Fine Aggregates

The Fine aggregates, consisting of stone crusher dusts with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found to be 2.61.

C. Filler

The Aggregate passing through 0.075 mm IS sieve is called as filler. Here partial replacement of Portland cement (Grade 43) with waste material i.e: Metakaolin, Marble powder, GGBS, Concrete dust and flyash was used as filler material.

Material Sample	Total Weight of Sample (gms)	Weight of sample Retained on 90micron Sieve (gms)	Fineness Modulus (%)
Cement	100	6	6
GGBS	100	5	5
Metakaolin	100	4	4
Marble powder	100	5	5
Flyash	100	4	4
Concrete Dust	100	5	5

Table.1 Fineness modulus of waste material

IS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
19	100	100
13.2	90-100	95
9.5	70-88	75
4.75	53-71	60
2.36	42-58	50
1.18	34-48	40
0.600	26-38	32
0.300	18-28	20
0.150	12-20	15
0.075	4-10	5
Binder Content % by weight	5-7	5.0 to 6.0

Table.2 MORTH gradation for BC (NMAS 13 mm)

Property	Method of Test	Specification
Aggregate Impact Value (%)	IS: 2386 (Part-IV)	Max 24%
Aggregate Crushing Value (%)		Max 35%
Coating And Stripping of Bitumen Aggregate Mix	(IS:6241)	Minimum Retained Coating 95%
Water Absorption (%)	(IS:2386 Part III)	Max 2%

Table.3 Tests on aggregates

D. Binder

The Bitumen used in preparing Marshall samples was of 80/100 penetration grade. The Specific gravity was 1.01. It's important properties is given in table.4.

Property	Method of Test	Test Result
Specific gravity	IS : 1202-1978	1.01
Penetration at 25°C (mm)	IS : 1203-1978	85
Softening Point (°C)	IS : 1205-1978	48

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Ductility (cm)	IS : 1208-1978	80
Flash Point (°C)	IS : 1209-1978	248
Fire Point (°C)	IS : 1209-1978	291

Table.4 Properties of Binder

4. MARSHALL STABILITY

A. Mixing Procedure

The mixing of ingredients was done as per the following procedure (STP 204-8).

Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan.This was kept in an oven at temperature 160^0c for 10min. This is because the aggregate and bitumen are to be mixed in heated state so preheating is required. The bitumen was also heated up to its melting point prior to the mixing.

- Select the aggregate proportion to meet the specification requirements
- Measure out 1200g of aggregates, are blended in desired proportions
- Heat the aggregates in the oven to the mixing temperature i.e. 155-160ºC
- The temperature to which the asphalt must be heated to produce viscosities of 170 ± 20 centi stokes as the mixing temperature.
- Mix the materials in a heated pan with heated mixing tool until a uniform color is obtained.
- Place the mixture in a heated Marshall mould with a color and base. Spade the mixture around the sides of the mould. Place filter papers under the sample and on top of the sample.
- The dimensions of Marshall mould to be 100mm diameter and 64mm high. Place the mould in the Marshall Compaction pedestal.
- Apply 75 blows with the automatic compactor using a free fall of 457mm. Remove the base plate and collar, and reverse and reassemble the mould. Apply the same number of compaction blows to the face of the reversed specimen.
- Normally specimens are allowed to cool over 24 hours.
- The specimens to be immersed in water bath kept at a constant temperature 60ºC for 30 minutes.
- The point of failure is defined by the maximum load reading obtained. The total number of Newtons required to produce failure of the specimen shall be recorded as its Marshall Stability value.

Figure.1 Uniform colour throughout the mix

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Figure.2 Closer view of Marshall sample

6. MARSHALL TESTING AND RESULTS

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm/min. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. In India, it is a very popular method of characterization of bituminous mixes due to its simplicity and low cost. In the present study the Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and then compare mixes to check addition of which of the additive mentioned gives more stability.

Figure.3 Marshall stability test setup

In the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.
a. Bulk specific gravity (Gb) determination
b. Stability and Flow test
c. Density and Void analysis

A. Bulk specific gravity (Gmb) determination

Bulk specific gravities of saturated surface dry specimens are determined.

B.Stability and flow tests

After determining the bulk specific gravity of the test specimens, the stability and flow tests are performed. Immerse specimen in water bath kept at 60˚C ±1˚C for 30 to 40 minutes before testing. When the testing apparatus is ready, remove the specimen from water bath and carefully dry the surface. Place it centrally on the lower testing head and fit upper head carefully. Fix the flow meter with zero as initial reading. The load is applied at a constant rate of deformation of 51 mm (2 inches) per minute. The total load at failure is recorded as its Marshall Stability Value. The reading of flow meter in units of 0.25 mm gives the Marshall Flow value of the specimen. The

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entire testing process starting with the removal of specimen from bath up to measurement of flow and stability shall not take more 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide road and record.

C.Density and voids analysis

After completion of the stability and flow test, a density and voids analysis is done for each set of specimens.Average the bulk density determinations, for each asphalt content. Values obviously in error need not be considered. This average value of Gb is used for further computations in void analysis.

(a) Determine the theoretical maximum specific gravity (Gmm) by equipment

(b)The BSG's(Gsb) of the individual coarse aggregate fractions, the fine aggregate and mineral filler fractions are used.

(c) Vv, VMA and VFB are then computed using the standard equations

Determination of Optimum Bitumen Content

Determine the optimum binder content for the mix design by taking average value of the following three is as follows: binder content corresponding to maximum stability, binder content corresponding to maximum bulk specific gravity, and binder content corresponding to the median of percent air voids in the total mix. The methodology used for determination of OBC is explained below,

1. A collection of 3 samples each bitumen content are to be obtained
2. OBC is to be conducted at same filler content, filler used as cement
3. Samples are to be prepared using different bitumen content of 5.0, 5.5, 6.0 respectively.

% Binder	**Unit weight (Kg/m^3)**	**Stability (KN)**	**Flow value (mm)**	**Va(%)**	**VMA(%)**	**VFB(%)**
5	2.303	13	3.2	4.75	15.44	70.32
5.5	2.346	14.38	3.4	4.59	15.82	73.92
6.0	2.322	12.6	3.7	4.32	16.26	74.69

Table.5 Marshall Properties of specimens with filler Cement

From the above tablated values 5.5% of bitumen was optimum value. For finding of Partial replacment of cement with waste material as filler in hot mix ashphalt to used optimun binder content that is 5.5% of bitumen of whole marshall sample.

Determination of Optimum waste material Content:

GGBS(%)	Unit weight (Kg/m^3)	Stability (KN)	Flow value (mm)	Va(%)	VMA(%)	VFB(%)
0	2.346	14.38	3.4	4.82	16.53	72.45
25	2.388	15.8	3.3	4.75	15.44	70.32
50	2.352	15.5	3.2	4.59	15.82	73.92

75	2.342	14	3.1	4.32	16.26	74.69
100	2.339	14.28	2.6	4.06	15.97	75.08

Table.6 Marshall Properties of specimens with partial replacment of cement withGGBS

GGBS(%)	Unit weight (Kg/m^3)	Stability (KN)	Flow value (mm)	Va(%)	VMA(%)	VFB(%)
0	2.346	14.38	3.4	4.82	16.53	72.45
25	2.301	15.5	3.2	4.81	16.13	69.56
50	2.336	16.8	3.1	4.54	17.02	73.92
75	2.332	16.3	2.9	4.08	16.06	74.55
100	2.329	14.5	2.8	4.18	15.66	73.3

Table.7 Marshall Properties of specimens with partial replacment of cement withFlyash

GGBS(%)	Unit weight (Kg/m^3)	Stability (KN)	Flow value (mm)	Va(%)	VMA(%)	VFB(%)
0	2.346	14.38	3.4	4.82	16.53	72.45
25	2.306	16.3	3.3	4.59	15.82	73.92
50	2.356	15.9	3.1	4.52	15.31	71.09
75	2.325	15.3	2.7	4.48	15.69	74.96
100	2.319	14.38	2.5	4.06	15.97	75.08

Table.8 Marshall Properties of specimens with partial replacment of cement withMetakaolin

GGBS(%)	Unit weight (Kg/m^3)	Stability (KN)	Flow value (mm)	Va(%)	VMA(%)	VFB(%)
0	2.346	14.38	3.4	4.82	16.53	72.45
25	2.303	15	3.0	4.28	14.23	69.93
50	2.346	14.8	2.9	4.77	14.56	67.23
75	2.322	14.5	2.7	4.9	14.74	66.75
100	2.331	14.1	2.5	4.087	16.06	74.55

Table.9 Marshall Properties of specimens with partial replacment of cement with Marble powder

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GGBS(%)	Unit weight (Kg/m^3)	Stability (KN)	Flow value (mm)	Va(%)	VMA(%)	VFB(%)
0	2.346	14.38	3.4	4.82	16.53	72.45
25	2.348	16.4	3	4.26	15.11	71.8
50	2.337	17	2.9	4.49	14.93	69.92
75	2.334	15.8	2.7	4.32	16.26	74.69
100	2.326	13.8	2.6	4.06	15.97	75.08

Table.10 Marshall Properties of specimens with partial replacement of cement withConcrete dust

7. MARSHALL GRAPHS

A. Plotting Curves for finding optimum bitumen content

These samples prepared by cement as filler. By the reference of Table.5.

6 curves were plotted. i.e:

- Marshall Stability Value vs. bitumen Content
- Marshall Flow Value vs. bitumen Content
- VMA vs. bitumen Content
- VA vs. bitumen Content
- VFB vs. bitumen Content
- Bulk unit weight vs. bitumen Content

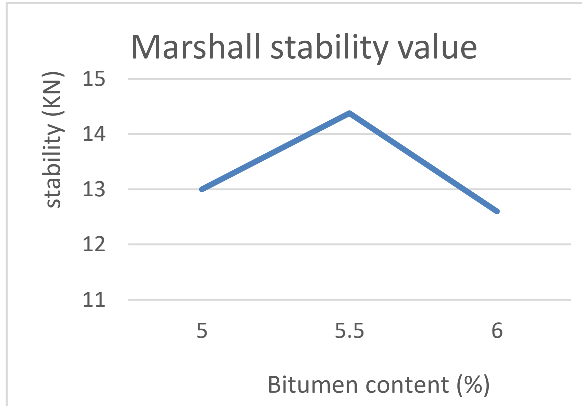

Figure.4Marshall Stability Value vs. Bitumen Content

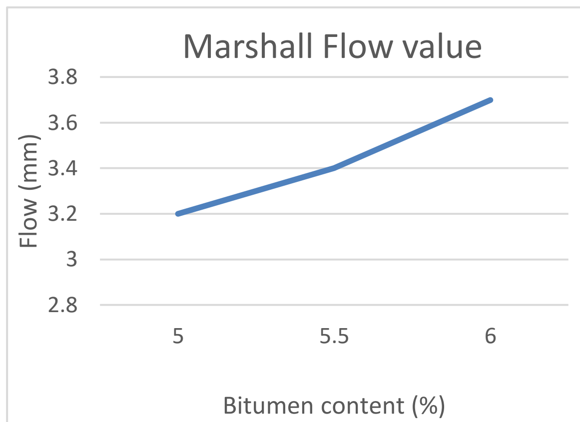

Figure.5 Marshall Flow Value vs. Bitumen Content

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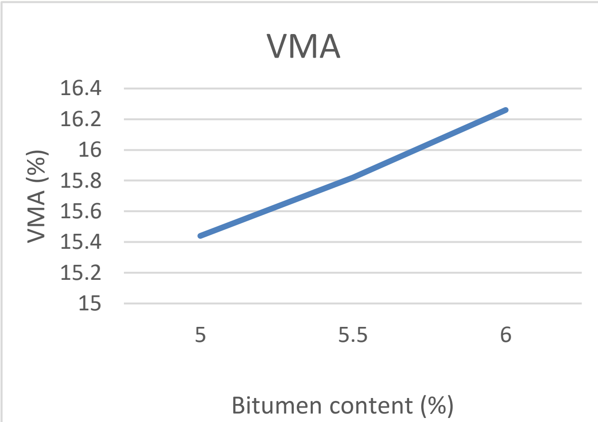

Figure .6 VMA vs. Bitumen Content

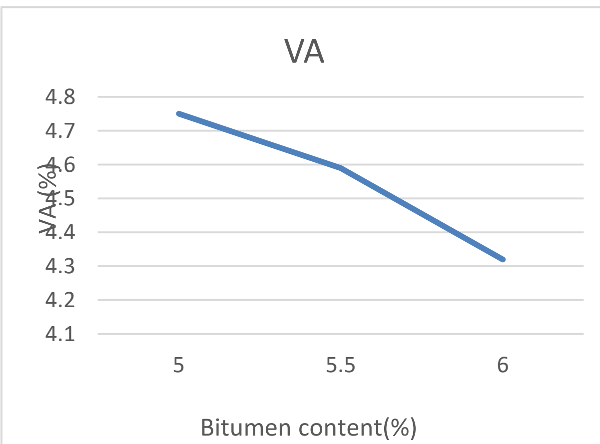

Figure.7 VA vs. Bitumen Content

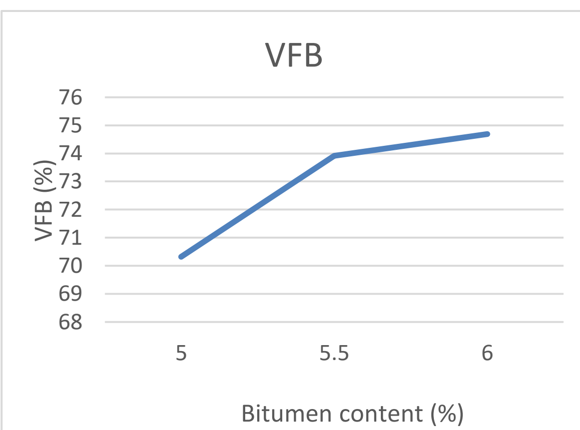

Figure.8 VFB vs. Bitumen Content

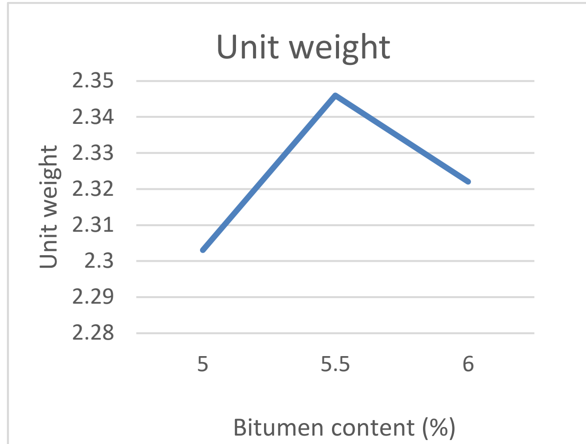

Figure.9 Bulk unit weight vs. Bitumen Content

B. Plotting Curves forOptimum waste material Content

These samples prepared by partial replacement of cement as filler with GGBS, Flyash, Metakaolin, Marble powder & Concrete dust. By the reference of Table 3.6 to 3.10.

6 curves were plotted. i.e:

- Marshall Stability Value vs. Waste material Content
- Marshall Flow Value vs. Waste material Content
- VMA vs. Waste material Content
- VA vs. Waste material Content
- VFB vs. Waste material Content
- Bulk unit weight vs.Waste material Content

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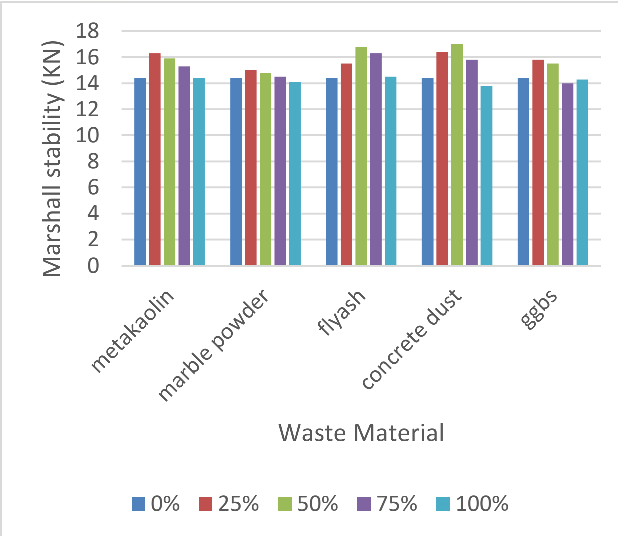

Figure.10Marshall Stability Value vs. Waste material Content

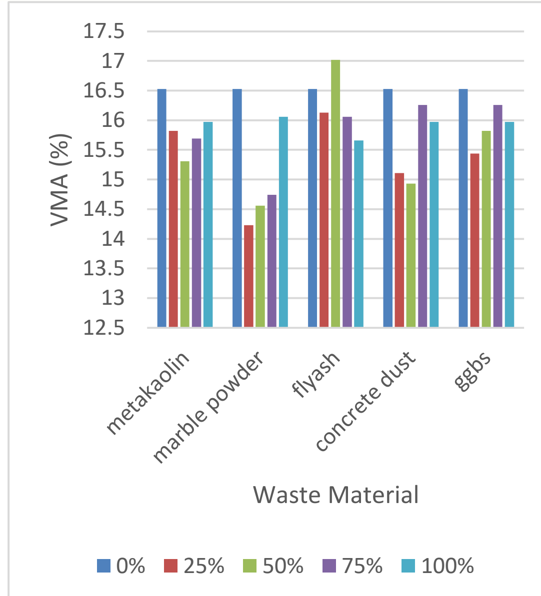

Figure.12 VMA vs. Waste Material

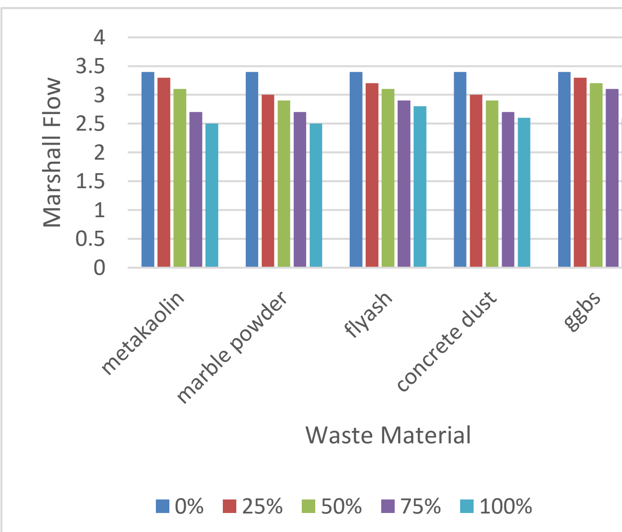

Figure.11 Marshall Flow Value vs. Waste Material

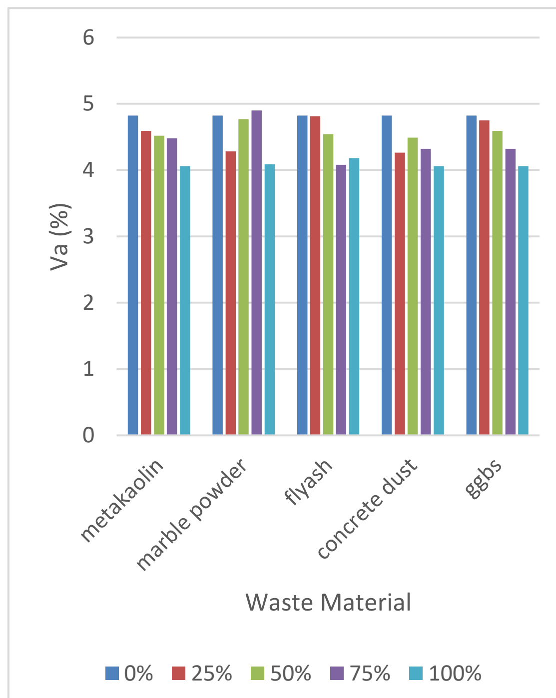

Figure.13 VA vs.Waste Material

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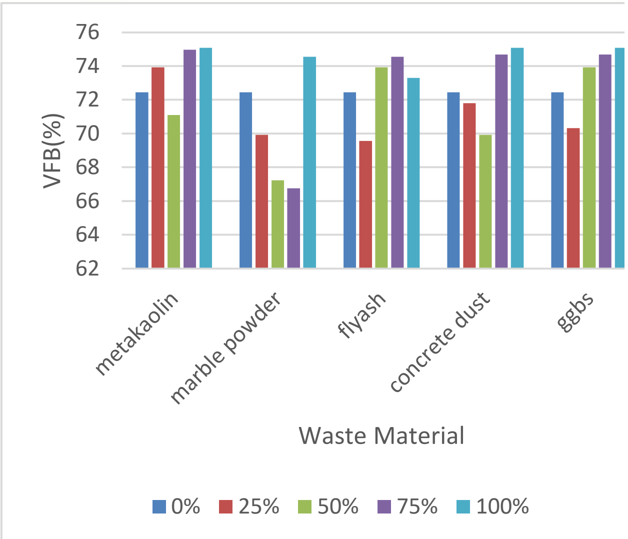

Figure.14 VFB vs. Waste Material

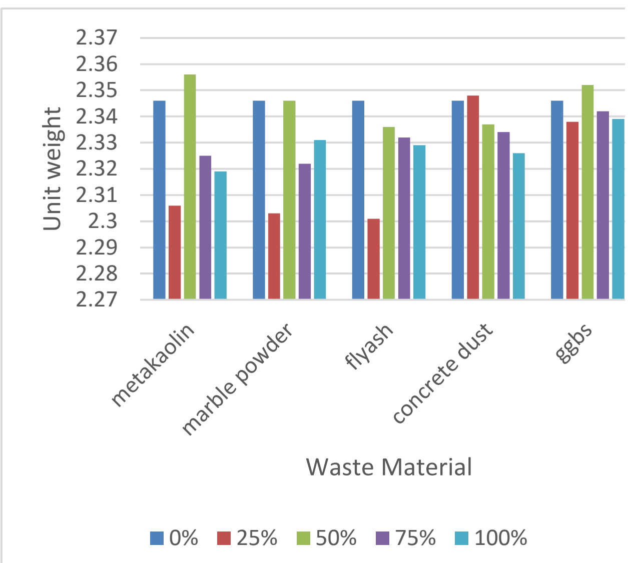

Figure.15 Bulk unit weight vs. Waste Material

8. ANALYSIS

A. Finding Optimum Bitumen Content

The value of Bitumen content at which the sample has maximum Marshall Stability Value and minimum Marshall Flow Value is called as Optimum Bitumen Content.

From the Figure 4&5 we get the Optimum Bitumen Content as 5.5% and also from Figures 6,7&8 we conclude thatthe voids present in the mix decreases.

B.Finding Optimum Waste material Content

The value of waste material at which the sample has maximum Marshall Stability Value and minimum Marshall Flow Value is called as Optimum waste material Content.

From the Figure 10&11 we get the Optimum waste material Content as varies with different waste material and also from Figures 12,13&14 we conclude thatthe voids present in the mix decreases.

9. CONCLUSION

The following conclusions were drawn from the study:

1. The Metakaolin, Marble powder, flyash, GGBS, Concrete dust used are a pozzolana and conforms to requirement which has great potential for use in concrete as well in hot mix asphalt filler.

2. The value for the required properties of bitumen as a binder as regards its penetration, viscosity, flash and fire point, ductility and solubility all conforms to those of the ASTM standard specification for the design of asphalt concrete.

3. The aggregate Crushing Value, aggregate Impact Value, Specific Gravity of coarse aggregate, Specific Gravity of fine aggregate was within specification.

4. The mix at varying percentages of bitumen content meets the standard specified in terms of

stability, flow and VMA and VIM and at an optimum bitumen content of 5.5%.

5. The Optimun waste material content with respect to bitumen 5.5% content the stability values. From the table 6 to 10 it can be observed that the BC (5.5% bitumen)sample prepared using 0%, 25%, 50%, 75%,100% of waste material partial replacment with cement as filler in HMA. The Optimum waste material content with respect to waste material tablulated below.

Waste material	Optimum Content of waste material(%)	Marshall stability(KN)
GGBS	25	15.8
Flyash	50	16.8
Concrete dust	25	16.4
Metakaolin	25	16.3
Marble powder	25	15

Table.16 Optimum waste material content and stability values

With some modification in design mixes, can result in utilization of GGBS, concrete dust, metakaolin, marble powder and flyash as partial replacement of cement as fillers in bituminous pavement, thus save considerable investment in construction and partially solving the disposal of wastes as recycling process.

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