Quarry Dust as a filler material in bituminous concrete: Sustainable construction

Praveen kumar P

Department of Civil Engineering, MIT, Manipal, INDIA

Abstract: Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment; as well as enhance the performance of highway in service. Two things are major considerations in this regard: Pavement design and mix design. This paper emphasizes on the mix design considerations. Right mixtures of ingredients for bituminous mix would result in a mix which is adequately strong, durable and resistive to fatigue and permanent deformation and at the same time environment friendly and economical. In order to achieve this, we have to try different proportions of material combinations through a number of tests on the mix and identify the mix with satisfies the requirements. For a given aggregate gradation the optimum bitumen content is estimated by satisfying a number of mix design parameters. Fillers play an important role in engineering properties of bituminous paving mixes. Conventionally cement and lime are used as fillers. An attempt has been made in this investigation to assess the influence of non-conventional and cheaper filler such as quarry dust in bitumen paving mixes. It has been observed as a result of this project that bituminous mixes with these non-conventional fillers result in satisfactory *Marshall Properties* though requiring a bit higher bitumen content, thus substantiating the need for its use. The fillers used in this investigation are likely to partly solve the solid waste disposal of the environment and Sustainable construction.

1. Introduction

Determining the right blend of aggregates, fillers and bitumen which gives adequate strength as well as economical is the main objective of the mix design. This mix should satisfy strength requirements for the adhering traffic and it should be durable for the design period. Marshall Stability test is used for this purpose. Test determines the maximum stability value (load taken by specimen) at optimum bitumen content by varying percentages of filler material and aggregates. Also determines its flow value (deformation rate). Sufficient voids in total compaction mix is also important parameter in bituminous mix as it would allow additional compaction and traffic loading without flushing, bleeding and loss of stability yet low enough to keep out harmful air and moisture.

2. Literature Review

The properties of fillers has noticeable effect on the durability of bituminous mix, it was also confirmed by the Craus et al. (1981) study on mixes consisting of one type of aggregate, one gradation and six types of filler. Among the fillers Lime and Stone dust/Quarry Dust are predominantly used in the mix. Their influence on fatigue performance was studied by Chari and Jacob (1984) and they found lime to have some effect on the fatigue properties, although static strength remained unaltered for the both. Many waste materials can be used in bituminous mix as filler material which would reduce the problem of disposal. The lab and field evaluation of such materials was discussed by Kandhal (1993).Fwa and Aziz (1995) partial replaced aggregates used in bituminous mix with incinerator residue. Baig and Wahhab (1998) compared rock wool natural fibers – hematite, as filler material and compared with conventional crused stone filler. Katamine (2000) studied the strength of bituminous mix with oil shale fillers. From the results of Marshal Stability tests, it was found that Optimum Binder content was not altered, also stability was more. Taha et al. (2002) studied cement Bypass Dust (CBPD) and Karasahin and Terzi (2007) studied marble dust as filler. Both filler material gave required strength to bituminous mix. Sharma et al. (2010) showed that use of flyash in bituminous mix would increase the strength of mix as it contains high calcium oxide which is important strength governing parameter.

3. Experimental investigation

3.1. Tests of Materials Used In Paving Mixes

Materials used are Aggregates, Bitumen and aggregates as filler material. Basic property test were conducted on Bitumen and Aggregates before using for bituminous mix. Quarry dust which was obtained from nearby quarry retained on 0.07mm and 0.15mm sieve was used.

3.1.1. Characteristics of Bitumen: Bitumen obtained from the plant was tested for its physical properties and which adhered to MORTH specification was used for the study. The results are given in the following table:

Table 1. Characteristics of Bitumen

Properties	Result	Standard	Specification
Penetration Test, mm	92	IS 1203-1925	50-70
Softening point,°C	52	IS 1205-1978	Min 47
Ductility, cm	98	IS1208-1978	Min 75
Specific gravity at 25°C	1.05	IS 1202	0.98-1.02
Flash point, °C	270	IS 1209-1978	Min 220
Viscosity, sec	110	IS 1206	Min 2400

3.1.2. Characteristics of Aggregates: The following results were obtained when lab tests are conducted on aggregates.

Table 2. Characteristics of Aggregates

Parameters	Value
Specific gravity of Coarse aggregate	2.7
Specific gravity of Fine aggregate	2.65
Impact strength (%)	27 %
Water absorption (%)	2.9
Crushing strength (%)	25 %

3.2. Marshall Method of mix design for determination of Optimum Bitumen Content
For each specimen, a total of 1200gm of dry blended aggregates was measured. The proportions of ingredients by weight for varying percentage of bitumen were taken as per IRC – 29 (grading-2 of Table 3) specification. The aggregate mixture was heated to a temperature of 154°C to 160°C and was thoroughly mixed. Heated Bitumen of 80/100 penetration grade was added and mixed until all the aggregates were coated by bitumen.

Table 3. Aggregates gradation for determination OBC

Sieves (mm)	Percentage retained	4% Bitumen	4.50% Bitumen	5% Bitumen	5.50% Bitumen	6% Bitumen
20	0					
12.5	10.4	130	130	129	127	127
10	9.6	120	119	117.5	115.5	114.5
4.75	16.4	205	204	202	154	153
2.36	11.6	145	144	142	140	139
0.6	17.2	215	214	212	209	208
0.3	8.6	107.5	107	106	104	103.5
0.15	6.8	85	84.5	83.5	82	81.5
0.075	8.6	107.5	107	106	104	103.5
Pan	6.8	85	84.5	83.5	82	81.5
Total aggregate		**1200**	**1194**	**1187.5**	**1181**	**1175**
Bitumen		**50**	**56**	**62.5**	**69**	**75**

Bituminous mix was placed in Marshall Mould with collar and base and was compacted with 75 blows on each face to compact the specimen to 100mm dia and 64mm height approximately. After compaction, the base plate was removed and the mould containing the specimen was immersed in cool water for 2 minutes. The specimen was allowed to cool at room temperature.

3.2.1. Stability Determination: Specimen were placed under Marshall loading frame and load was applied vertically at the rate of 50mm per minute. The maximum load at sample fails is recorded as the Marshall Stability value.

3.2.2. Stability curve and Flow curve: Fig 1 and Fig 2 shows the variation of Marshall Stability curve and flow value for varying percentage of bitumen content. From the curve, it can be observed that the stability (i.e., load taking capacity) was higher at bituminous mixture with 5.5% bitumen content, after which it started decreasing. From this we can say, 5.5% is the optimum bitumen content for good bituminous mixture. Flow curve usually follows a linear trend with increase in bitumen content.
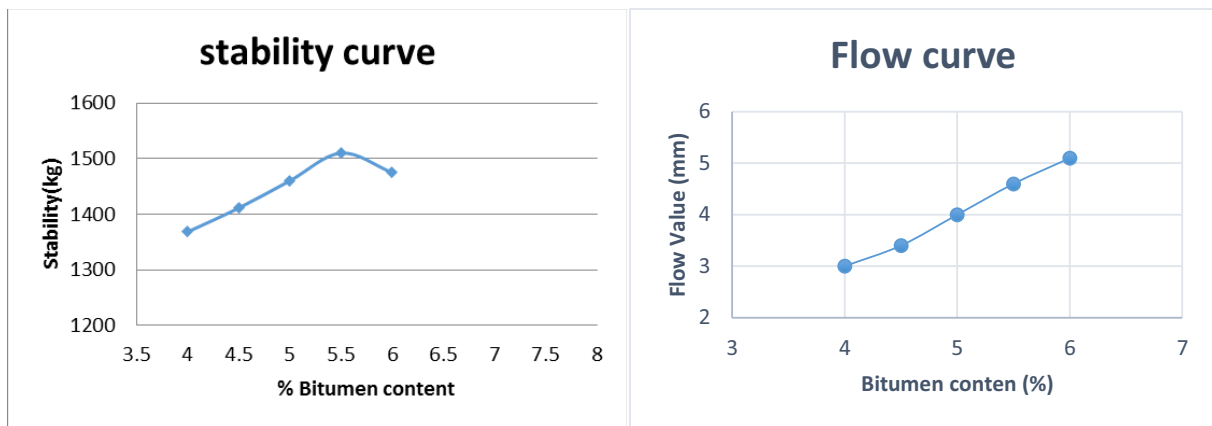

Figure 1. Stability curve-Marshall test to determine OBC

Figure 2. Flow curve-Marshall test to determine OBC

3.3. Marshall Stability test to determine Optimum Quarry Dust (%) in bituminous mix

After determination of optimum bitumen content for good mix, percentage of Quarry dust as a filler material was tested. The quantity of Quarry dust obtained from nearest site added to the bituminous mix, it was varied from 9% to 25% of the total weight. For Density determination, the specimen was weighed in air and in clean water at room temperature. The difference between the two weights in grams was used to determine the volume. Bulk density of specimen (G_b) is given by $G_b = \frac{Weight\ of\ specimen\ in\ air}{Volume\ of\ specimen}$

3.3.1. Marshall Stability curves: Fig 4.3 displays the graphical representation of stability curve for variation in % of quarry dust at optimum bitumen content for Marshall Specimens In quarry dust specimens maximum stability is obtained at 1598 kg at 21% quarry dust. The decrease in stability value by further increase of quarry dust percentage may be due to decrease in the % air voids of specimen which is necessary for bituminous mix design.

3.3.2. Marshall Flow value curves (mm: Fig 3 displays the graphical representation of flow value curve for variation in % of quarry dust at optimum bitumen content for Marshall Specimens
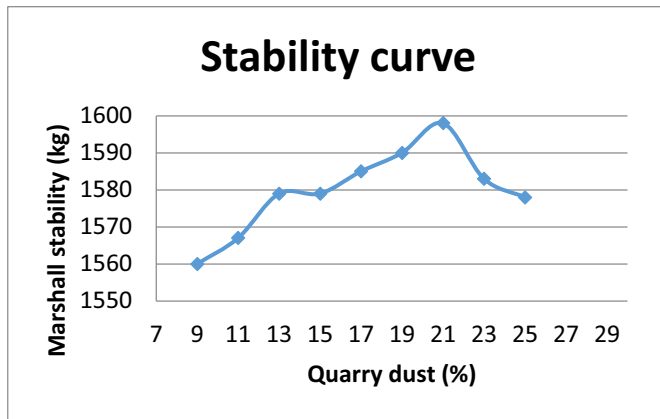
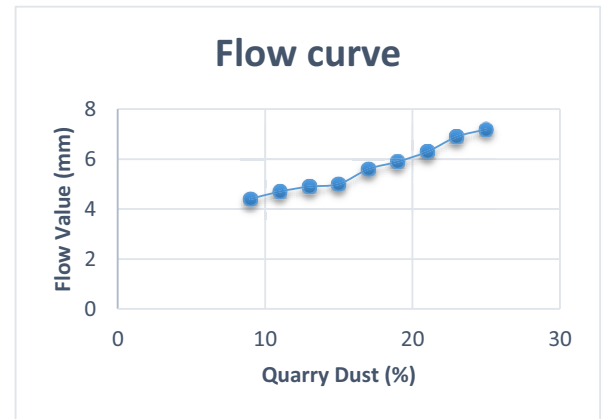**Figure 3.** Stability curve-Marshall test to determine OQD

Figure 4. Flow curve-Marshall test to determine OQD

3.3.3. Air Voids And VMA: After completion of stability and flow test a density and void analysis was made for each series of test specimen. The percentage of air voids of the specimen is given by

$$V_v = \frac{G_t - G_b}{G_b} * 100$$

Where, G_b = Bulk Density

G_t = Theoretical specific gravity of mixture = $\dfrac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}}$

Where

W_1 = Percentage weight of coarse aggregates in total mix; W_2 = Percentage weight of fine aggregates in total mix; W_3 = Percentage weight of filler in total mix; W_4 = Percentage weight of bitumen in total mix
G_1 = Apparent specific gravity of coarse aggregate; G_2 = Apparent specific gravity of fine aggregate; G_3 = Apparent specific gravity of filler; G_4 = Apparent specific gravity of bitumen

The percent **voids in mineral aggregate (VMA)** were determined using formula given below.

$$VMA = V_v + V_b$$

Where, V_v = Volume of air voids;
V_b = Volume of bitumen = $G_b * \left(\frac{W_4}{G_4}\right)$

Table 4. Marshall Test results of bituminous mix for varying size

Quarry dust (%)	Wt. in air(gm)	Wt. in water(gm)	Stability Value(kg)	Flow value(mm)	G_t	G_b	% air voids	VMA %
9	1220	622	1560	4.4	2.43	2.04	16	21.55
11	1219	621.5	1567	4.7	2.42	2.04	15.9	21.4
13	1217.5	620.5	1579	4.9	2.42	2.03	15.44	20.94
15	1215	619.5	1579	5	2.41	2.02	15.8	21.3
17	1205	614.5	1585	5.6	2.41	2.04	15.43	20.9
19	1198.5	611	1590	5.9	2.4	2.04	15.3	20.8
21	1191	607	1598	6.3	2.4	2.05	15.13	20.63
23	1185.5	604.5	1583	6.9	2.38	2.04	14.9	20.4
25	1179.5	601.5	1578	7.2	2.38	2.04	14.68	20.18

4. Results and Discussion

- Optimum Bitumen Content for a bituminous concrete was found to be 5.5% which showed high value of stability and then gradually decreasing. This could be attributed to reduction of minimum Air voids which is necessary for further densification of mix.
- Bituminous mixes with varying percentage of quarry dust as filler at optimum content of bitumen showed maximum stability of 1598 kg at 21% displaying an ascending trend up till 21% and then decreasing.
- The flow value showed an increasing trend, the percentage of air voids obtained were seen to be decreasing with increase in quarry dust.

5. Conclusions

From the study it can be concluded that the waste dust generated from Quarry can be effectively used in bituminous mixes as a filler material without reducing its strength characteristics. But further tests has to be carried out in order to understand the characteristics of filler and their influence on fatigue and rutting performance. Further modification in design mixes can result in utilization of quarry dust as fillers in bituminous pavement thus partially solving the disposal of industrial and construction wastes respectively. The cost effectiveness of these unconventional filler materials can be realized after performing a cost analysis.

6. References

[1]　IRC: 29-1988 *Specification for Bituminous Concrete for Road Pavement*.
[2]　D.Larson Thomas., *Portland cement and Bitumen Concrete*, Mc Graw Hill Publication 1963
[3]　Das Animesh and Pandey,B B (2000) *Economical design of bituminous pavements with two grades of bitumen in the surfacing* seminar on Road Financing, Design, Construction and Operation of Highways in 21st Century, 24th and 25th September, IRC, pp.II-35-II-42.
[4]　Kadeyali: *Principles and practice of Highway Engineering*.3rd edition (1997).
[5]　Katamine NM: *Phosphate waste in mixtures to improve their deformation*. J Transport Eng 2000; 126:382–9

[6]   Kandhal P. S., Lynn C. Y. and Parker F. 1998. *Characterization tests for mineral fillers related to performance of asphalt paving mixtures* Transportation Research Record: Journal of the Transportation Research Board. 1638(1): 101-110.