



OPTIMIZATION OF ASPHALT-CONCRETE USING MARSHALL MIX-DESIGN HAVING DIFFERENT PERCENTAGE OF BITUMEN CONTENT

¹Upasana Mishra, ²Anil suman

¹PG Scholar, ²Assistant Professor

^{1,2}Department of Civil Engineering

^{1,2}Shri Shankaracharya Technical Campus -SSGI, Bhilai

Abstract - This works implies that the optimization of asphalt concrete mix having different bitumen content having filler as cement and natural fine sand. Marshall Mix-Design shall be used for the making of this asphalt concrete. The test conducted for optimization is Density, Stability, Deformation, Voids in Total Mix, Total Air voids, Voids in Mineral Aggregate. The result shows that the bitumen content having 4.5 % are showing better performance as compared to other bitumen content. This optimized mix can be applied in heavy traffic flows.

Keywords - Asphalt, Natural Sand, Density, Stability, Deformation

1. Introduction

The asphalt is used as a binder agent in the Marshall mix. The filler agent is cement and sand. The use of Marshall mix-design, the mix will perform better as compared to some random trial and experience method. With the help of Marshall mix-design the engineer in the construction areas, can easily predict or detect how well asphalt mixture would perform and the mix can carry how much amount of load as support. The optimized mix-design will lead to high stability or strength to the asphalt mixture. The asphalt mixture has property of permeability as they are used in highway construction but to a certain limit. If the mixture is made little bit Harsh then the mixture will tend to separate all the ingredient or segregate resulting in poor workability in handling and transporting. Tender mixes are very unsteady to compact and transport properly. This instability is due to less amount of mineral filler, large amount of coarser sand and round aggregate particles and high amount of moisture present in the mix. The basic concepts of the Marshall mix design method were developed around 1939 by Bruce Marshall of the Mississippi Highway Department and then refined by the United States Army. The Marshall method seeks to select the asphalt binder content at a desired density that meets minimum stability and flow range requirements. (White, 1985).

2. Materials Used

The raw materials used in this research work are collected from different parts of Raipur, Chhattisgarh. Each materials have such physical properties which is to be studied to produce concrete blocks for engineering applications such as VG40 Grade Bitumen, PPC Grade 43, Natural Fine Sand and Coarse Aggregate.

3. Case Trials for the Considered Study

In this study, total no. of 12 specimens were utilized out of which 3 specimens of each trial case is been evaluated. The design is been carried by Marshall Mix-design in which four basic requirement is evaluated for Stability, Density, Voids in Mineral Aggregate, Voids Filled with Asphalt to obtain optimized Asphalt content from the mix-design. The cases to be utilized in this research work for the optimized Asphalt Content by using cement as filler material is described below in terms of percentage.

Table 1 Case Trails for the Study (All Values are in percentage)

Test Specimen Case Id	Coarse Aggregate	Fine Aggregate	Filler (Cement)	WFS (Waste Foundry Sand)	Bitumen Asphalt
BFS1	33	57	10	-	3
BFS2	33	57	11	-	4
BFS3	33	57	12	-	5
BFS4	33	57	13	-	6

4. Mix-proportion for the Making of Asphalt-Pavement

The mix-proportion for all the cases is such that the material which were discussed above is mixed based on trial-and-error proportion are as follows-

Table 2 Quantity of Ingredients Required for Mix-Proportion of Trial Cases (in gram)

Test Specimen Case Id	Coarse Aggregate	Natural Sand	Filler (Cement)	WFS (Waste Foundry Sand)	Bitumen Asphalt
BFS1	695	1200	210	-	63
BFS2	695	1200	232	-	84
BFS3	695	1200	252	-	105
BFS4	695	1200	274	-	126



Fig. 1 Marshall Bitumen-Aggregate Mix

5. Result

5.1 Density

The density of mixture of bitumen with waste foundry sand is previously done by Hakan Koyuncu (2006) in which the percentage of foundry sand were from range five to twenty percentage. The result values according to the test are given in table and graph below in which the densities are calculated as per equation-

$$G_{mb} = \frac{W_{air}}{W_{SSD} - W_{water}} \dots\dots\dots(1)$$

Table 3 Density values of Asphalt Bitumen Mix

Test Specimen Case Id	WFS (%)	Bitumen Content (%)	Average Density (gm/cm ³)
BFS1	-	3	2.42
BFS2	-	4	2.48
BFS3	-	5	2.58
BFS4	-	6	2.36

5.2 Stability Test

The result values according to the test are given in table and graph below in which the stability is calculated as per equation-

$$G_{mm} = \frac{W_f + W_b + W_{ca} + W_{fa} + W_{fs}}{\frac{W_f}{G_f} + \frac{W_b}{G_b} + \frac{W_{ca}}{G_{ca}} + \frac{W_{fa}}{G_{fa}} + \frac{W_{fs}}{G_{fs}}} \dots\dots\dots(2)$$

Table 4 Marshall Stability values of Foundry Sand–Asphalt Bitumen Mixtures

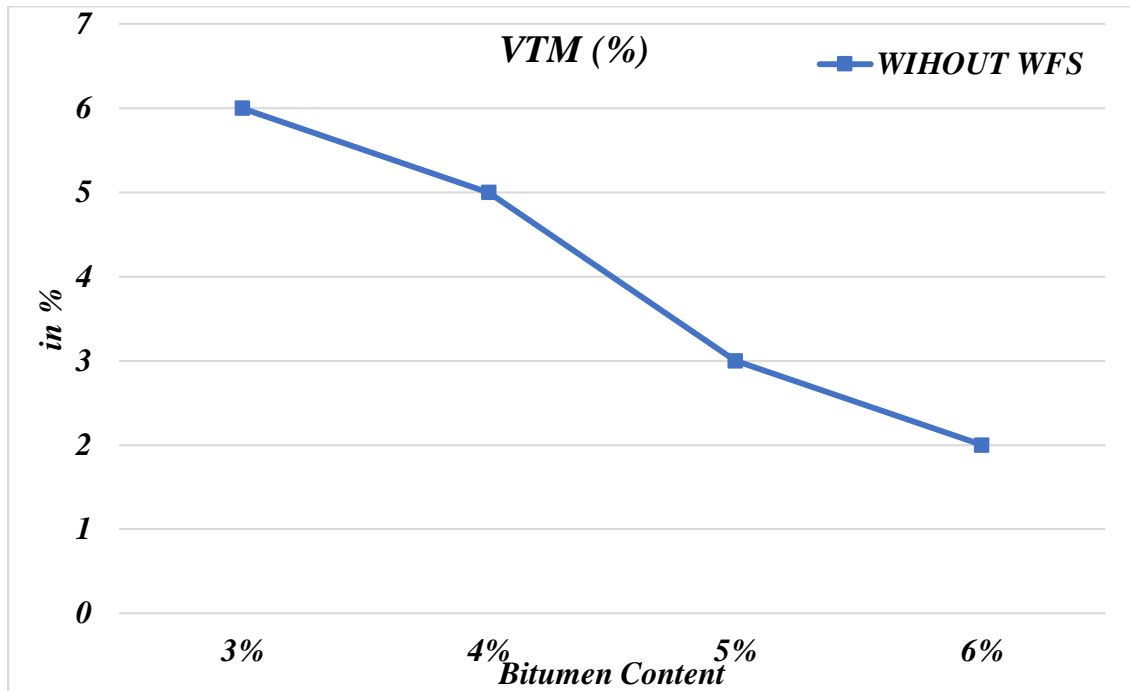
Test Specimen Case Id	WFS (%)	Bitumen Content (%)	Load (KN)
BFS1 (0 % WFS, 3% BT)	No	3	10.62
BFS2 (0 % WFS, 4% BT)	No	4	10.84
BFS3 (0 % WFS, 5% BT)	No	5	11.12
BFS4 (0 % WFS, 6% BT)	No	6	10.27

5.3 VTM (Voids in total mixture)

The results based on void of total mixture are given below which is calculated as per equation (3)

$$\text{Voids in Total Mix (VTM)} = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \times 100 \dots\dots\dots (3)$$

where G_{mb} = bulk specific gravity of mixture and G_{mm} = maximum specific gravity of mixture



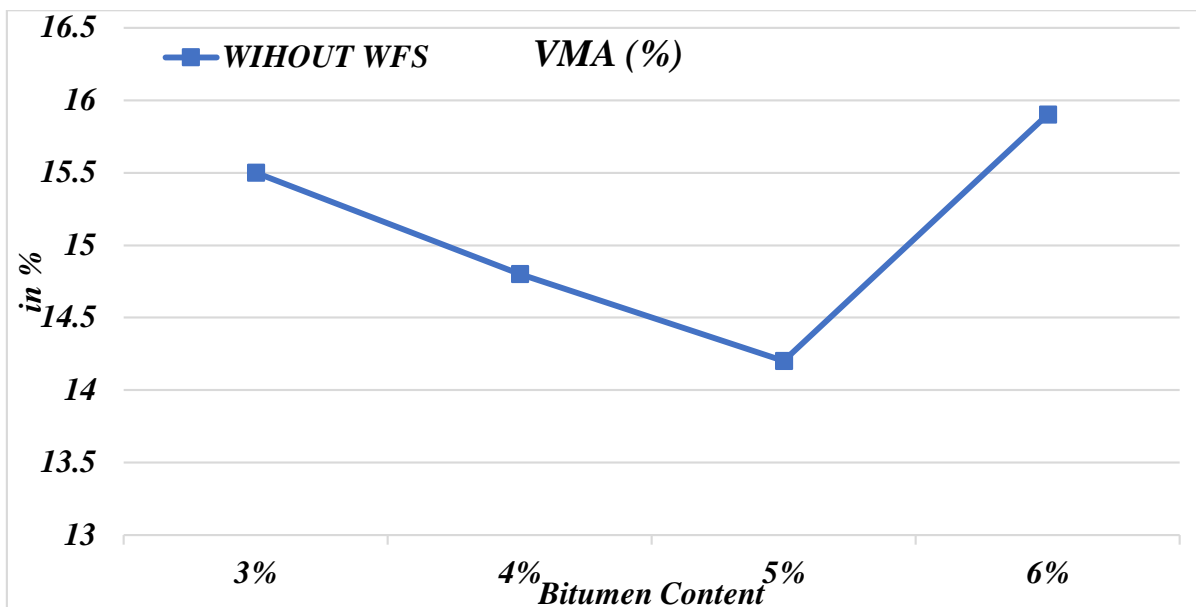
Graph 1 Total Voids in Foundry Sand–Asphalt Bitumen Mixtures

5.4 VMA (Voids in Mineral Aggregate)

The results based on mineral aggregate are given in table and graph below which is calculated as per equation (4)

$$\text{Voids in Mineral Aggregate (VMA)} = \left(1 - \frac{G_{mb} \times (1 - P_b)}{G_{sb}}\right) \times 100 \dots\dots\dots (4)$$

Where P_b = asphalt binder content of mixture



Graph 2 Voids in Mineral Aggregate of Foundry Sand–Asphalt Bitumen Mixtures

5.5 VFA (Voids Filled with Asphalt)

The results based on filled asphalt are given in table and graph below which is calculated as per equation (5)

$$\text{Voids Filled with Asphalt (VFA)} = \left(1 - \frac{VTM}{VMA}\right) \times 100 \dots\dots\dots(5)$$

Table 5 Voids in Asphalt of Foundry Sand–Asphalt Bitumen Mixtures

Test Specimen Case Id	WFS (%)	Bitumen Content (%)	VFA (%)
BFS1 (0 % WFS, 3% BT)	No	3	52
BFS2 (0 % WFS, 4% BT)	No	4	65
BFS3 (0 % WFS, 5% BT)	No	5	80
BFS4 (0 % WFS, 6% BT)	No	6	88

5.6 Optimum Asphalt Content

From the above result, we must evaluate the optimum asphalt content. The procedure is such that addition of the asphalt content carries maximum density, maximum stability, and the produces exactly 4% air voids (VTM) divided by 3. The mathematical approach is given below-

Optimum Asphalt Content (OAC) = (Max Density + Max Stability + 4% air voids) /3 = (4 + 5 + 4.5) /3 = 4.5 % bitumen content.

It has been seen that the 4.5 % bitumen content is suitable enough for the application in heavy traffic load and in asphalt pavement.

6 Conclusions

- ❖ It been observed that when there is no WFS, there is increase in density with increase in bitumen content then decreases after 5% bitumen content.
- ❖ The flow value indicates that the maximum deformation obtained for the mixture having fine natural sand is 3.7 mm
- ❖ The presence of voids in mineral aggregate decreases reaches peak point till 5 % bitumen content then increase.
- ❖ The Optimum bitumen content obtained for asphalt mix is about 4.5 %.

REFERENCES

- 1) Akbulut, H. and Gurer, C., 2007. Use of aggregates produced from marble quarry waste in asphalt pavements. *Building and Environment*, 42 (5), 1921–1930.
- 2) Aramide, F. O, Aribo, S, and Folorunso, D. O (2011), Optimizing the Molding Properties of Recycled Ilaro Silica Sand, *Leonardo Journal of Sciences*, vol 19, pp. 93- 102.
- 3) Siddique, R., and Sandhu, R. K (2013). Properties of Self Compacting Concrete Incorporating Waste Foundry Sand. *Leonardo Journal of Sciences*, ISSN-1583-0233 , PP 105-124.
- 4) Joni, H. H., & Zghair, H. H. Effect of adding used-foundry sand on hot asphalt mixtures performance. *Eng. &Tech. Journal*, 34(6), (2016).
- 5) National Cooperative Highway Research Program, "Recycled Materials and Byproducts in Highway", Washington, D.C., 2013.
- 6) Federal Highway Administration," Foundry Sand Facts for Civil Engineers", Federal Highway Administration (FHWA), Report.
- 7) Goh, Boon Hoe, Pushan Sunnasee, Kok Hon Chin, Byung Gyoo Kang, and Sien Ti Kok. "Utilisation of Rice Husk Ash in Asphaltic Concrete Pavement." In *Advanced Materials Research*, vol. 1030, pp. 961-964. Trans Tech Publications Ltd, 2014.
- 8) Shuaibu, A. A., A. I. Mohammed, U. Hassan, B. H. S. Amartey, S. A. Wada, A. Mohammed, and A. M. Rimi. "An Experimental Study on the Performance of Bituminous Concrete Mixtures with Silica Sand as Filler Replacement." *Arid Zone Journal of Engineering, Technology and Environment* 17, no. 4 (2021): 453-468.
- 9) Shuaibu, A. A., H. S. Otuoze, H. A. Ahmed, and M. I. Umar. "Effect of Waste Foundry Sand as Partial Replacement of Fine Aggregate in Bituminous Concrete Mixture." *Nigerian Journal of Engineering* 28, no. 2 (2021): 73-73.
- 10) Alves, B. S.Q, Dungan, R. S. C, Raquel L. P. G, Rosa de Carvalho P, Catia R. S (2014), Metals in waste foundry sands and an evaluation of their leaching and transport to groundwater *Water, Air, and Soil Pollution* vol 225(5), pp 1-11 DOI – <http://10.1007/s11270-014-1963-4> .
- 11) Yazoghli-Marzouk, O. Vulcano-greullet, N. Cantegrit, L. Friteyre, L. Jullien, A. (2014), Recyclingfoundry sand in road construction–field assessment, *Construction and Building Materials*, vol. 61, pp 69-78, <https://doi.org/10.1016/j.conbuildmat.2014.02.055> .
- 12) Javed, S. & Lowell, C.W. (1994) Uses of Waste Foundry Sand in Civil Engineering. *Uses of Waste Foundry Sand in Highway Construction*; Final Report, pp. 109–113. Geotest Engineering, Inc., Houston, Texas, USA