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Original Article

Experimental Study of an Effective Utilization of Industrial By Products in Bituminous Paving Mixes

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Abstract - *In the present study, an attempt is made to find the usage and utilization of by-products or recycledmaterials in bituminous paving mixes. The experiment started with the conduction of basic tests for various materials like Coarse aggregate, Fine aggregate, Bitumen, and by-product or recycled materials like copper slag, foundry sand, and brickbats. These materials were tested for their suitability in carrying out the work or as a prediction to know an alternative to these materials. The basic tests are also carried out for Bitumen like ductility, softening point, penetration, flash and fire, specific gravity & viscosity. Marshall stability test is done for both conventional mix and alternativemixes.*

Keywords - *Bitumen, Brickbats, By-product materials, Copper slag, Foundry sand, Marshall stability test.*

1. Introduction

Roads are the largest network means of transport communication in our country and across the world. India ranks second due to its multidimensional expansion throughout. Due to many road vehicles, it becomes necessary to look after the stability of the roads where they have to be designed for future increases in traffic loads. The pavements are designed for a design period of about 10 - 15 years, depending on the huge increase in traffic. Due to industrialization, many industries have found it difficult to recycle their by-product and waste products produced in large quantities.

Some materials like copper slag, foundry sand, etc., are facing the disposal problem. The present study focuses on using by-products or recycled materials in the different layers of pavements. About 2 million tonnes of by-products are remaining. Hence, an attempt is made to utilize these recycled materials and make the environment greener. As per the recent studies on copper slag, foundry slag, and brickbats, a huge quantity of recycled materials was utilized in different ways in different layers of pavement.

Mei-zhu Chen etal. (2011) conducteda comparative study on the performance of two mixtures using recycled brick powder and limestone filler. The results show that the mixtures prepared with recycled brick powder have better mechanical properties than those with limestone filler. Shiva Prasad etal. (2012) study has proved that modifying asphalt binder with polymer additives offers several benefits.Yazoghli-Marzouk etal.(2014) study has proved that the foundry sand, treated witha 5.5% hydraulic binder, displays acceptable mechanical performances and doesn't show environmental impacts. They concluded that the foundry sand could be used as road materials.Chetan, and Dr.Sowmya (2015), investigated that copper slag is used as a fine aggregate by varying the percentage with stone dust and fly ash as filler material. After obtaining from roasting copper, they concluded that the Copper slag is free from sulphur and can be used as filler or fine aggregate material in the pavements.DipuSutradharetal. (2015) compared the effects of fillers like waste concrete and brick dust with the conventional bituminous mixes. They concluded that it is possible to use waste concrete and brick dust as filler in bituminous mixes.DipankarSarkaretal. (2016) carried out a study on over-burnt brick aggregate (OBBA) and stone aggregate (S.A.) mixed in different ratios (by weight) such as 20: 80, 40: 60, 60: 40, and 80: 20, respectively. They concluded that the bituminous concrete mix prepared with 20% brick aggregate and 80% stone aggregate shows considerable improvement in various mechanical properties compared to other mixes.DipankarSarkaretal. (2016) investigated plastic-coated OBBA as an alternative material for bituminous road construction.They concluded that the plastic-coated OBBA is suitable for constructing bituminous concrete roads.Dr. HasanHamodi Joni and Hussein Hamel Zghair's (2016) studies have proved that using foundry sand as a filler and fine aggregate in hot asphalt mixture aims to minimize the environmental effect. Also, it can be used in the production of asphalt mixture.

Jayashree etal. (2016) investigated the use of copper slag to replace bitumen mix partially. They have concluded that Copper slag is considered one of the waste materials which will have a promising future in the construction industry as a partial substitute for natural aggregates in the bituminous mix. IvicaAndrojicandGordanaKaluder (2017) have concluded that various recycled materials are used as replacements for stone filler in asphalt mixes. Prof.

Chaudhari etal. (2017) have concluded that the foundry sand replacement has improved the bituminous mix's properties. Sankarlaletal. (2017) have concluded that Copper slag is used as a fine aggregate with stone dust and fly ash as a filler material and with waste plastic, provides good interlocking and eventually improves volumetric and mechanical properties of bituminous mixes.Premlathaetal. (2018) concluded that using municipal waste and foundry sand avoids the depletion of regular materials and results in economically feasible pavements.Suvarna et al. (2018) evaluated the fatigue life of bituminous concrete mixtures using stone, ceramic, and brick dust as filler materials. They concluded that the B.C. mix with ceramic dust had shown higher value than the B.C. mix with stone and brick dust as filler materials.HassanZiarietal. (2019) experimentedwith the influence of replacing limestone aggregates with copper slag on the performance of warm mix asphalt. They concluded that the 20% copper slag in warm mix asphalt enhances resilient modulus, Marshall stability, rutting, and cracking resistance the most and has a substantial positive effect on moisture susceptibility.

2. Objectives

The main objectives of bituminous mix design are to check the suitability of Binders (VG-30) in various bituminous mixes and to compare the B.C. mixes prepared from Industrial by-product materials and Conventional materials in terms of stability, flow value, etc.

3. Methodology of work

Industrial by-product materials like broken brickbats, copper slag, foundry sand, and conventional materials like coarse aggregate and M-sand are selected for this project. Before starting the experiment, the materials are tested for their basic properties, and their values are compared with that of BIS codes. The sizes of coarse aggregate used are 20 mm and 12.5mm and are kept as a basic material in the mix. The fine aggregate used is M sand and copper slag, as they give good ease of mixing.

The filler materials used are copper slag, foundry sand, and brick bats, which are excellent industrial by-product materials. The basic tests for conventional materials are Specific gravity, fineness modulus, water absorption, silt content, crushing strength, impact strength, etc.

The tests on Bitumen are done for VG-30 like ductility, softening point, penetration, flash and fire, specific gravity, etc., which satisfied the requirement of IS:73-2006. Samples are prepared for Marshall Mix design, and Optimum bitumen content for VG30 is determined by using 5%, 5.5%, and 6% binder content. After determining OBC for various mix samples at a different percentage binder content, the most suitable mix is selected as an alternative material for flexible pavement.

4. Experimental Program

4.1. General

The experiment started with the conduction of basic tests for various materials like Coarse aggregate, Fine aggregate, Industrial by-product materials, and Bitumen. These materials were tested for their suitability in carrying out the work or as a prediction to know an alternative to these materials.

The basic tests for materials like Coarse aggregate, Fine aggregate, and Industrial by-product materials like copper slag and foundry sand were conducted. Table 1 & Table 2 shows the values of the test results.

4.2. Bituminous Mix Design

The Marshall Test specimens were prepared with conventional and industrial waste by-product materials. The following are the various types of bituminous mixes:

(i) Mix-1: The conventional mix consists of coarse aggregate (20mm and 12.5mm down size), M- sand as fine aggregate, and M-sand dust as filler material.

(ii) Mix-2: The bituminous mix consists of M-sand as fine aggregate and Foundry sand as filler material.

(iii) Mix-3: The bituminous mix consists of M-sand as fine aggregate and Brickbats as filler material.

(iv) Mix-4: The bituminous mix consists of Copper slag as fine aggregate and Foundry sand as filler material.

After the materials are decided for the mix and the percentage of Bitumen is added to the mix, theweight of materials to be taken is decided through Rothfutch's method.

4.2.1 Rothfutch's Method:

Itis a graphical method where the proportioning of materials can be adopted for design mixes of two, three, or more materials without making several trials. The results of the grain size distribution are tabulated, giving the different sieves and the cumulative percentages passing each sieve, ranging from zero to 100%.

Figure 1 represents proportioning of materials by Rothfutch's method.

The desired gradation is to be decided either based on recommended grain size distribution tables or by using a theoretical equation

$$P= 100(d/D)^n$$

Where P = percent finer than diameter d (mm) in the material.

d = diameter of the smaller particle, mm

D = diameter of the largest particle, mm

n = gradation index, which has values ranging from 0.5 to 0.3 depending upon the shape factor of the coarser fraction of the materials.

On a plain graph paper, the cumulative percentage passing through various sieves ranging from 0 to 100 % are plotted on Y- the axis and different particle sizes ranging from 0 to 26 mm are plotted on X-axis. The locally available materials A, B, and C are to be mixed, and the grain size curves of these materials are plotted on the graph.

After drawing the gradation line from Rothfutch's method, the materials' final weight percentage was fixed. Therefore the percentages of the weight of materials obtained from the graph are as follows:

Desired percentage of Coarse aggregate by weight of materials= is 47 %

Desired percentage of Fine aggregate by weight of materials= 29 %

Desired percentage of filler by weight of materials = 24 %

Table 3 shows the total weight of the mix and percentage of Bitumen

Table 4 shows the various types of mixes with different percentages by weight

Figure 2, 3&4 shows the conventional M- sand with Foundry sand & Copper Slag with Foundry sand mix specimen for 5, 5.5 & 6% of bindercontent.

5. Analysis of Test Results and Discussions

Testing is done on prepared Marshall Samples of various bituminous mixes, and the calculation work is carried out to determine the desired parameters. The Marshall properties of each specimen, such as air voids (Vv), bulk density, stability, flow value, voids in mineral aggregate (VMA), and voids filled with Bitumen (VFB), are tabulated in Tables 5 through 8.The graphical representations are also shown in Figures 5(a) to 5(e).

Table5. shows Marshall properties forconventional mixes.

Table 6. shows Marshall properties for M- sand & Foundry sand.

Table 7. shows Marshall properties for M- sand & Brickbats.

Table 8. shows Marshall properties for Copper slag & Foundry sand.

Figure 5. (a),(b),(c),(d) & (e) Shows the Experimental Results of Air voids, Bulk Density, Stability, Flow Value & Voids Filled with Bitumen (VFB) of 4 different types of mixes.

Air voids: Figure 5.(a) shows the experimental results of Air-voids. The conventional mix has 2.89% to 5% air voids with bitumen content of 5% to 6%. M-sand with Foundry sand has air voids of 5.83% to 3.37%, with a bitumen content of 5% to 6%. M-sand with Brickbats has air voids of 5.34% to 4.60%, with the bitumen content of 5% to 6%.Copper slag with Foundry sand has air voids of 4.31% to 3.58%, with a bitumen content of 5% to 6%.

Density: Figure 5.(b) shows the experimental results of densities. The conventional mix has a 2.32g/cc density to 2.27g/cc with bitumen content of 5% to 6%. M-sand with Foundry sand has a 2.32g/cc density to 2.29g/cc with bitumen content of 5% to 6%. M-sand with Brickbats has a density of 2.30g/cc to 2.28g/cc with bitumen content of 5% to 6%. Copper slag with Foundry sand has a density of 2.44g/cc to 2.42g/cc with a bitumen content of 5% to 6%.

Stability: Figure 5.(c) shows the experimental results of stability values. The conventional mix has a stability value of 1461.89kgs to 1820.57kgs with bitumen content of 5% to 6%. M-sand with Foundry sand has a stability value of 1116.84kgs to 1375.63kgs with bitumen content of 5% to 6%. M-sand with Brickbats has a stability value of 1502.75kgs to 1675.28kgs with bitumen content of 5% to 6%. Copper slag with Foundry sand has a stability value of 956.23kgs to 1107.76kgs with bitumen content of 5% to 6%.

Flow value: Figure 5.(d) shows the experimental results of flow values. The conventional mix has a flow value of 2.43mm to 2.63mm with bitumen content of 5% to 6%. M-sand with Foundry sand has a flow value of 2.13mm to 2.37mm with bitumen content of 5% to 6%. M-sand with Brickbats has a flow value of 2.40mm to 2.70mm with bitumen content of 5% to 6%. Copper slag with Foundry sand has a flow value of 2.14mm to 3.04mm with bitumen content of 5% to 6%.

Voids filled with Bitumen (VFB): Figure 5.(e) shows the experimental results of VFB values. The conventional mix has a VFB value of 72.64% to 76.67%, with bitumen content of 5% to 6%. M-sand with Foundry sand has a VFB value of 65.27% to 74.82%, with a bitumen content of 5% to 6%. M-sand with Brickbats has a VFB value of 67.61% to 74.27%, with bitumen content of 5% to 6%. Copper slag with Foundry sand has a VFB value of 73.29% to 79.73%, with a bitumen content of 5% to 6%.

Table 1. Properties of Conventional and Industrial by-product Materials

Sl. No.	Specific Gravity	Water Absorption (%)	Fineness Modulus	Silt Content (%)	Crushing test (%)	Impact Test (%)
1.	Coarse aggregate (< 12.5mm)					
	2.61	-	2.62	-	27.5	28.82
2.	Coarse aggregate (< 20 mm)					
	2.58	-	2.07	-	22.64	27.64
3.	Foundry sand					
	2.52	5	4.33	4.8	-	-
4.	M- Sand					
	2.61	1	4.82	16.8	-	-
5.	Brickbats					
	2.63	2.5	3.24	-	-	-

Table 2. Bitumen Test Summary Results

Sl No	Name of Tests	Values	Values as per code	I.S. Codes
1	Specific gravity	1.03	Min 0.99	1202- 1978
2	Penetration (mm)	75	Min 45	1203- 1978

3	Flash Point (°C)	284	Min 220	1209- 1978
4	Softening Point (°C)	54	Min 47	1205- 1978
5	Viscosity (Poise)	2483	Min 2400	1206 (P-II)-1978
6	Ductility (cm)	87	Min 40	1208- 1978

Table 3. Total weight of the mix and percentage of Bitumen

Total weight of mix, gms	1200	1200	1200
Weight of Bitumen to the total weight of mix, %	5%	5.5%	6%
Weight of bitumen, gms	60	66	72
Weight of aggregate (without Bitumen), gms	1140	1134	1128

Table 4.Types of mixes with different percentages by weight

Mix type	**Percentage of bitumen (%)**	**C.A., gms**	**F.A., gms**	**Filler, gms**
Conventional	5	0.47 * 1140 = 536	0.29 * 1140 = 331	0.24 * 1140 = 274
	5.5	0.47 * 1134 = 533	0.29 * 1134 = 329	0.24 * 1134 = 272
	6	0.47 * 1128 = 530	0.29 * 1128 = 327	024 * 1128 = 271
M- sand + Foundry sand	5	0.47 * 1140 = 536	0.29 * 1140 = 331	0.24 * 1140 = 274
	5.5	0.47 * 1134 = 533	0.29 * 1134 = 329	0.24 * 1134 = 272
	6	0.47 * 1128 = 530	0.29 * 1128 = 327	024 * 1128 = 271
M- sand + Brick bats	5	0.47 * 1140 = 536	0.29 * 1140 = 331	0.24 * 1140 = 274
	5.5	0.47 * 1134 = 533	0.29 * 1134 = 329	0.24 * 1134 = 272
	6	0.47 * 1128 = 530	0.29 * 1128 = 327	024 * 1128 = 271
Copper slag + Foundry sand	5	0.47 * 1140 = 536	0.29 * 1140 = 331	0.24 * 1140 = 274
	5.5	0.47 * 1134 = 533	0.29 * 1134 = 329	0.24 * 1134 = 272
	6	0.47 * 1128 = 530	0.29 * 1128 = 327	024 * 1128 = 271

Table 5. Marshall properties for conventional mixes

Parameters	**5%**	**5.5%**	**6%**	**MoRTH Requirements**
Air voids (Vv) %	2.89	3.75	5	3- 6
Bulk Density (Kg/cm^3)	2.32	2.31	2.27	>2.2
Stability (kgs)	1461.89	2396.09	1820.57	> 900
Flow (mm)	2.43	2.53	2.63	2- 4
VMA (%)	15.01	16.08	18.28	12-15
VFB(%)	72.64	75.28	76.67	65-75

Table 6.Marshall properties for M- sand & Foundry sand

Parameters	**5%**	**5.5%**	**6%**	**MoRTH Requirements**
Air voids(Vv) %	5.83	4.20	3.37	3- 6
Bulk Density (Kg/cm^3)	2.32	2.30	2.29	>2.2
Stability (kgs)	1116.84	1439.19	1375.63	> 900
Flow (mm)	2.13	2.17	2.37	2- 4
VMA (%)	16.79	16.37	16.70	12-15
VFB(%)	65.27	74.34	74.82	65-75

Table 7. Marshall properties for M- sand & Brickbats

Parameters	**5%**	**5.5%**	**6%**	**MoRTH Requirements**
Air voids (Vv) %	5.34	3.73	4.60	3- 6
Bulk Density (Kg/cm^3)	2.30	2.32	2.28	>2.2
Stability (kgs)	1502.75	1952.23	1675.28	> 900
Flow (mm)	2.40	2.50	2.70	2- 4
VMA (%)	16.49	16.11	17.88	12-15
VFB(%)	67.61	74.84	74.27	65-75

Table 8. Marshall properties for Copper slag & Foundry sand

Parameters	**5%**	**5.5%**	**6%**	**MoRTH Requirements**
Air voids (Vv) %	4.31	4.74	3.58	3- 6
Bulk Density (Kg/cm^3)	2.44	2.41	2.42	>2.2
Stability (kgs)	956.23	1125.92	1107.76	> 900
Flow (mm)	2.14	2.37	3.04	2- 4
VMA (%)	16.14	17.60	17.67	12-15
VFB(%)	73.29	73.06	79.73	65-75

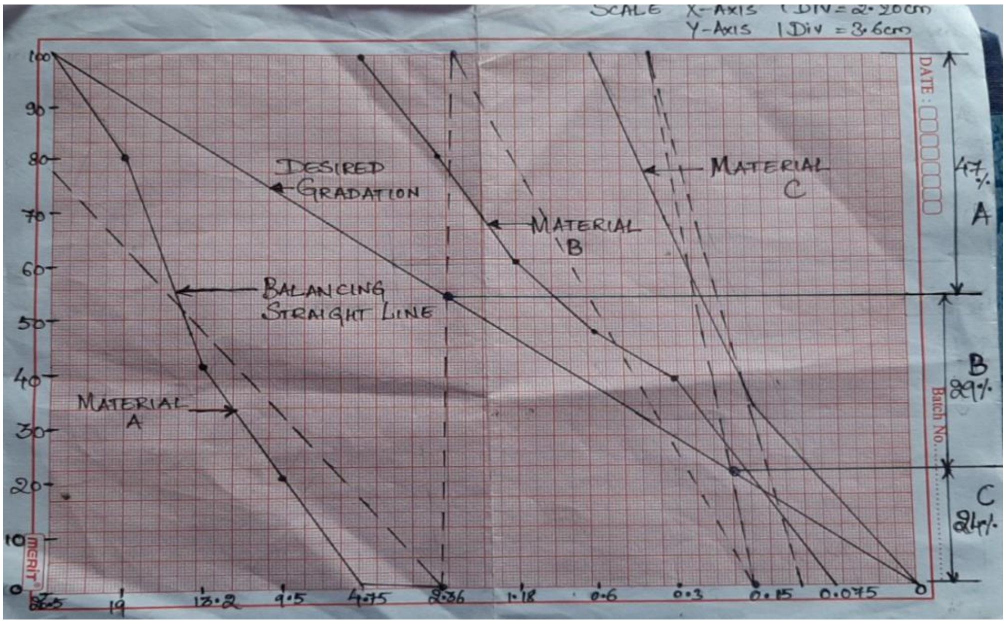

Fig. 1 Proportioning of materials by Rothfutch's method

a)with 5 % of Bitumen by weight

b) with 5.5 % of Bitumen by weight

c) with 6% of Bitumen by weight

Fig. 2 Conventional mix specimen

z

a)with 5 % of Bitumen by weight

b) with 5.5 % of Bitumen by weight

c) with 6% of Bitumen by weight

Fig.3 M- sand & Foundry sand mix specimen

Fig. 4 Copper Slag & Foundry sand mix specimen

(with 5 %, 5.5 % &6% of bitumen by weight)

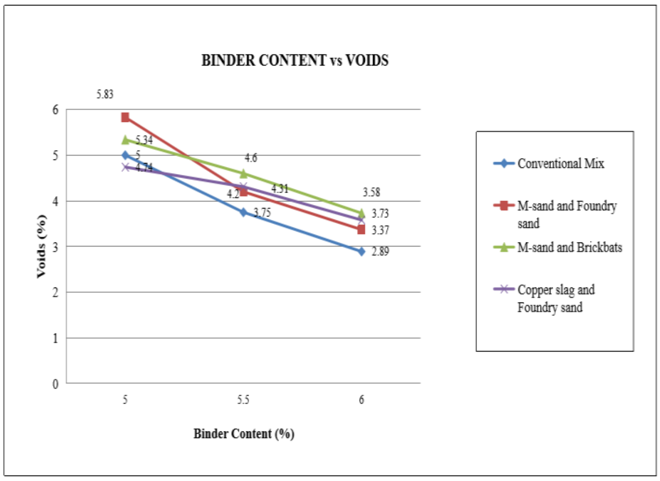

Fig. 5 (a)Binder Content vs. Air Voids

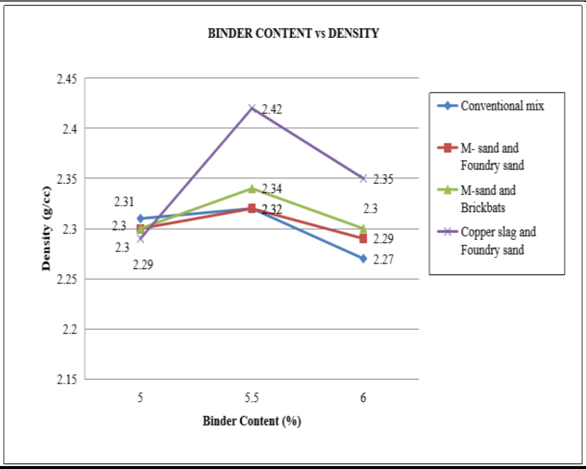

Fig. 5 (b)Binder Content vs. Density

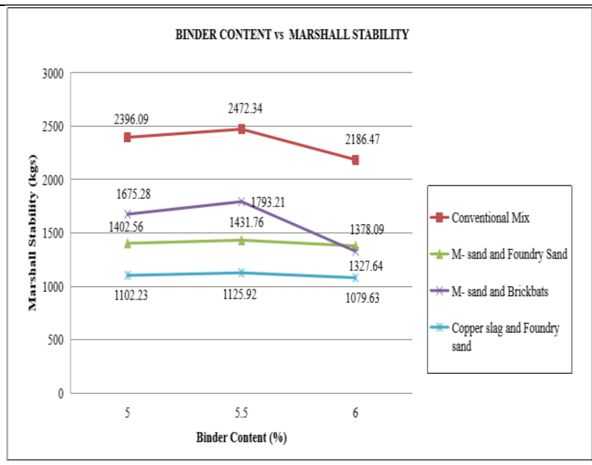

Fig. 5 (c)Binder Content vs. Marshall Stability

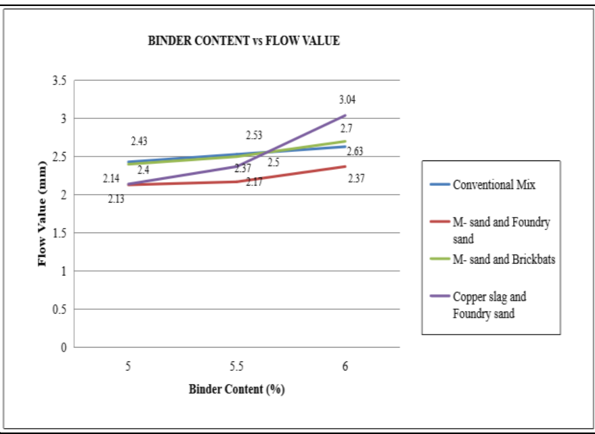

Fig. 5 (d)Binder Content vs. Flow Value

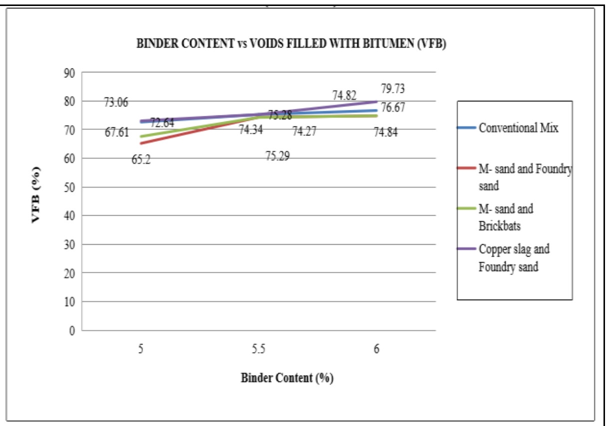

Fig. 5 (e)Binder Content vs. Voids Filled with Bitumen (VFB)

6. Conclusion

From the experimental investigations conducted, the following are the conclusions drawn.

The Optimum binder content (OBC) for various mixes such as Conventional,M-sand with Foundry-sand,M-sand with brickbats, and Copper slag with Foundry-sand is 5.5% in between the prescribed limits as per MORTH specifications.

Air voids: The MoRTH specifies air voids content in between 3 to 6%.From Figure 7.(a), it can be concluded that conventional, and other bituminous mixes give results of air void content within the range of MoRTH specifications.

Density: The MoRTH specifies density as greater than 2.2g/cc.From Figure 7.(b), it can be concluded that conventional and other bituminous mixes give results of densities within the range of MoRTH specifications.

Stability: As per MoRTH specifications, the stability value should be greater than 900 kgs.From Figure 7.(c), it can be concluded that conventional and other bituminous mixes give results of stability values within the range of MoRTH specifications.

Flow value: As per MoRTH specifications, the flow value (deformation) should be between 2 to 4 mm.From Figure 7.(d), it can be concluded that conventional and other bituminous mixes give results of flow values within the range of MoRTH specifications.

Voids filled with Bitumen (VFB): The MoRTH specifies VFB value should be between 65% to 75%.From Figure 7.(e), it can be concluded that conventional and other bituminous mixes give results of VFB values within the range of MoRTH specifications.

The results of this study suggest that utilization of industrial waste by-products can benefit the environment and, at the same time, reduce the amount of granite application in highway construction. With its excellent results in terms of the airvoids, bulkdensity, stability,flowvalue & voids filled with Bitumen, it is recommended that industrial waste by-products be used as an aggregate replacement for sustainable development in highway construction.

Based on the above results, it can be concluded that industrial waste by-products can be adopted as an alternative to conventional paving material.Further studies on industrial by-products such as creep test, durability, fire resistance, and permeability will be carried out to recommend these materials as the alternative for paving material.

References

[1] B. Jayashree, S.Santhanu and B.Kalaiarasan, "Utilization of Copper Slag in Bituminous Mix," *International Journal of Chemical Sciences*, vol. 14, pp. 188-192, 2016.

[2] Chetan M.K. and Dr.Sowmya N.J, "Utilization of Copper Slag in Bituminous Concrete with a Stone Dust and Flyash as a Filler Material," *International Journal for Research in Applied Science & Engineering Technology*, vol. 3, no. 6, pp. 425-431, 2015.

[3] DipankarSarkar, Manish Pal and Ashoke K. Sarkar, "Study on Plastic Coated Overburnt Brick Aggregate as an Alternative Material for Bituminous Road Construction," *Advances in Materials Science and Engineering*, DipankarSarkar, Manish, vol. 4, pp. 1-8, 2016.

[4] Pal, Ashoke K. Sarkar, and Umesh Mishra, "Evaluation of the Properties of Bituminous Concrete Prepared from Brick-Stone Mix Aggregate," *Advances in Materials Science and Engineering*, vol. 1, pp. 1-7, 2016.

[5] DipuSutradhar, MintuMiah, GolamJilanyChowdhury and Mohd.AbdusSobhan, "Effect of Using Waste Material as Filler in Bituminous Mix Design," *American Journal of Civil Engineering*, vol. 3, pp. 88-94, 2015.

[6] Dr.HasanHamodi Joni, "Effect of Adding Used- Foundry Sand on Hot Asphalt Mixtures Performance," *Engineering and Technical Journal*, vol. 34, no. 6, pp. 1253-1264, 2016.

[7] Federal Highway Administration, "Foundry Sand Facts for Civil Engineers," U.S. Department of Transportation, Washington D.C. Tech Report, FHWA- IF-04-004, pp. 80, 2004.

[8] Hassan Ziari,Ali Moniri, Reza Imaninasab, and MostafaNakhaei, "Effect of Copper Slag on the Performance of Warm Mix Asphalt," *International Journal of Pavement Engineering*, vol. 2, pp. 775-781, 2019.

[9] "Indian Standard, IS: 1918 - 1966 (Reaffirmed 2003), Methods of Physical Tests for Foundry Sands," *Bureau of Indian Standards*, New Delhi, 2003.

[10] "Indian Standard, IS 2386 (Part III) – 1963 (Re-Affirmed 2002), Methods of Test for Aggregates for concrete (Part Ill) Specific Gravity, Density, Voids, Absorption and Bulking," *Bureau of Indian Standards*, New Delhi, 2016.

[11] "Indian Standard, IS 1077: 1992 (Re-affirmed 2007), Common Burnt Clay Building Bricks – Specification (Fifth Revision)," *Bureau of Indian Standards*, New Delhi, 2007.

[12] Salim G. Shaikh, Dinesh U. Mahajan, Mohammad Nubairshah S. Shaikh, Abhijeet P. Wadekar, "Scientific Study of Asphalt Road Surface Distress and their Role in the Design of Flexible Pavements," *International Journal of Engineering Trends and Technology*, vol. 70, no. 1, pp. 220-232, 2022. Crossref, https://doi.org/10.14445/22315381/IJETT-V70I1P227

[13] IvicaAndrojic and GordanaKaluđer, "Influence of Recycled Filler on Asphalt Mix Properties," *Gradevinar*, vol. 3, pp. 207-214, 2017.

[14] J. Premlatha, G. L. Sathyamoorthy and S. Anita, "Utilization of Plastic Waste and Foundry Waste in Flexible Pavements," *International Journal of Recent Technology and Engineering*, vol. 7, pp. 231-233, 2018.

[15] K. R.Sankarlal, Dr.S.Palanivelraja and Dr.E.Ravi, "A Study of Alternative Materials for Flexible Pavement using Copper Slag, Fly Ash and Waste Plastics in Bituminous Concrete," *International Journal of Engineering Research & Technology*, vol. 6, no. 12, pp. 342-345, 2017.

[16] Manoj K. Sahis, DipeshMajumdar, Partha P. Biswas, SouravHalder and AgnimitraSengupta, "Characterisation of Bituminous Mix Using River Bed Materials," *International Journal of Engineering and Technology*, vol. 3, pp. 1911-1916, 2017.

[17] Mei-zhu Chen, Jun-tao Lin, Shao-peng Wu and Cong-hui Liu, "Utilization of Recycled Brick Powder as Alternative Filler in Asphalt Mixture," *Construction and Building Materials*, vol. 25, no. 4, pp. 1532-1536, 2011.

[18] O. Yazoghli-Marzouk, N. Vulcano-greullet, L. Cantegrit, L. Friteyre and A. Jullien, "Recycling Foundry Sand in Road Construction–Field Assessment," *Construction and Building Materials*, vol. 61, pp. 69-78, 2014.

[19] Prof.A.G.Chaudhari, PriyankaS.Patekar,JamilK.Khan,VaishnaviJ.Rokade and M AquilS.Siddiqui, "On Replacement of Fine Aggregate by Foundry Sand in a Pavement," *International Journal of Innovative Research in Science and Engineering*, vol. 3, pp. 402-405, 2017.

[20] S.K. Khannna, C.E.G Justo and A. Veeraragavan, "*Highway Engineering*," 10th Edition, Nem Chand and Bros, Roorkee, India, 2015.

[21] Shiva Prasad K, Manjunath K. R and K. V R Prasad, "Study on Marshall Stability Properties of BC Mix Used In Road Construction by Adding Waste Plastic Bottles," *Journal of Mechanical and Civil Engineering*, vol. 2, no. 2, pp. 12-23, 2012.

[22] Suvarna P, YateenLokesh and Dr.S.P.Mahendra, "Study on the Effect of Stone, Dust, Ceramic Dust and Brick Dust as Fillers on the Strength, Physical and Durability Properties of Bituminous Concrete (B.C.–II) Mix," *International Journal of Applied Engineering Research*, vol. 13, pp. 203-208, 2018.

[23] MoRT&H, "*Specification for Road and Bridge Works*," 4thEdition, Ministry of Road Transport and Highways, Indian Roads Congress, New Delhi, India, 2001.

[24] "I.S. 1201-1220-1978, Methods for Testing Tar and Bituminous Materials," 1978.

[25] "I.S. 73-2006, Paving Bitumen – Specifications, Third Revision," *Bureau of Indian Standards*, 2006.

[26] "IS 383: 2016, Coarse and Fine Aggregate for Concrete – Specification (Third Revision)," *Bureau of Indian Standards*, New Delhi, 2016.

[27] R.Sundharam, R.Tamil Elakkiya, P.Vinoliya, P.S.suvetha, B.Sugapriya, "Experimental Report on Flexible Pavement by Using Hydrophobic Silica Sand, Zeolite and Steel Mesh," *SSRG International Journal of Civil Engineering*, vol. 6, no. 6, pp. 39-45, 2019. Crossref, https://doi.org/10.14445/23488352/IJCE-V6I6P108