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Utilization of Copper Slag in Bituminous Mix

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ABSTRACT-- There is a huge demand of aggregates for the construction of roads and concrete constructions in Pakistan. The construction of roads for high-speed traffic and heavy axle loads put enormous pressure on road materials. Many public sectors as well as private organizations are carrying out a wide range of research projects on the environmental, feasibility, and economic performance of using industrial waste products in the construction of roads. This study is attempted to fulfill the needs of society in the safe and economical disposal of waste material. This research aims to explore the potential use of copper slag (CS) as a replacement of fine aggregate and filler material. Comparison of conventional HMA samples and HMA samples having some percentage of copper slag as a replacement of fine aggregates. First, test aggregates and bitumen with 0% copper slag to determine their mechanical properties. Make samples and add bitumen percentage (3.5%, 4%, 4.5%, 5%, and 5.5%). Copper slag was added with 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% by weight. In the end, the tests were performed on the Marshal Apparatus. The experimental results showed that the addition of 20% of copper slag as fine aggregates has maximum Marshall Stability, a higher flow rate, maximum VFB and specific gravity slightly increases as compare to conventional HMA. Therefore, the strength is maximum by the addition of 20% copper slag, so we can use it in heavy traffic lanes and runways. Copper slag is economical as compared to other fine aggregates, so it should be implemented in Pakistan. Sufficient research has been conducted in Pakistan since it's not being implemented frequently. Therefore, we have some solid reasons, conclusion and recommendations in this research.

Index terms—Copper Slag,Hot Mix Asphalt,Aggregate,Bitumen,Stability

I. INTRODUCTION

Many countries are witnessing rapid growth in the construction sector, involving the use of natural resources for infrastructure development. To check & improve the performance of HMA addition of mineral filler & fine aggregates plays an important role. It is constantly compromised by the lack of available natural resources as aggregates are considered one of the important constituents of concrete. Lack of natural resources can be compensating by waste recycling of different raw materials. In recent decades, many environmental problems have been raised in a large amount of waste produced by industries. As these are producing waste products, such as acids, alkalis, oils, scrap metal, fly ash, slags, rubber waste, stone chips and various types of powders [1]. The main purpose of environmental protection agencies and government is to use the by-products/raw material in a safe way because of increasing population, industries, technology, and development [2]. On the other hand, recycling of waste avoids oversaturation of landfills, which also contributes to protecting the environmental problems [3].The reuse of waste material in road construction saves energy and natural resources [4]. The use of raw materials from industrial waste can be an alternative to aggregates & mineral fillers [5].Copper slag (CS) is the by-product which is obtained from the refining and smelting of copper material as it is classified as waste, therefore it is considered an environmental problem. Copper Slag can be used effectively for pavement construction that could have a promising future in the construction industry [6].Copper slag is granular solids, ranging from 0.2 mm to 3 mm, in the form of fine aggregates. A mixture of viscous black hydrocarbons obtained in the form of residue of petroleum distillation. As a result, many contemporary types of research have the been focusing on the application of copper slag in a bituminous mix as it offers benefits in environmental and economically, especially in those areas where a significant quantity of copper slag is produced [7]. Currently, a large number of roads are being constructed under the China-Pakistan Economic Corridor (CPEC) project in which assurance of road quality to stand with heavy traffic loads is a major concern.so, it is necessary to see the behavior of fillers & fine aggregates in the design process of HMA. This research objects to relate properties of conventional HMA samples and HMA samples having some percentage of (CS) in replacement of filler materials & fine aggregates. The main study of research is to improve the performance of HMA by using copper slag in 60/70 grade bitumen.

II. LITERATURE REVIEW

Copper slag is classified as waste; therefore it is considered an environmental problem. It can be used effectively for pavement construction. In order to save energy, material and reduce the amount of pollutants released during asphalt production. [8]. The influence of the replacement of aggregates by copper slag on the performance of HMA and Optimum binder (O.B.C) contents of mixes containing CS proportions of 0, 10, 20, 30 and 40% in total weight of the aggregates were determined using the Marshall procedure tests showed that 20% of CS in HMA improves Marshall Stability, Flow, and bitumen content [9].Copper slag is used as fine aggregate by varying the percentage of 20%, 30% and 40% with bitumen content and aggregate. The Marshall test was considered for the design of mixtures such as stability, voids filled aggregate, flow value, voids filled bitumen (VFB), air voids, and optimum bitumen content (OBC) was found suitable at CS 20% [10]. Copper slag is produced during the extraction of the metal from its ore. Copper slag is a non-plastic coarse grain material having a high CBR value of up to 70% and good permeability [11].Each year, the production and refining process of copper produces a large volume of CS and disposal of its waste remains an environmental problem.so, its annual production leads to an increase in volume and number of landfills which contains metals such as Pb, Cu, SO2, and Hg. The results showed that by addition of 20% CS is favorable as stability and flow values increases [12].Copper slag (CS) was used as a fine aggregate (up to 40%). The addition of Copper Slag, as fine aggregate in various bituminous mixtures, that makes it possible to obtain a good interlocking and possibly improves the volumetric and mechanical properties of the bituminous mixture [13]. Wastes such as zinc slag, copper slag & steel slag were examined for their suitability for road pavements, while zinc slag and Copper Slag can be used as a partial replacement in bituminous layers. The density of copper, zinc and steel slags ranged from 2.75 to 3.6 [14].The use of plastic scrap and copper slag in hot bituminous mixes to improve pavement performance. Mineral aggregate samples are also prepared with a Copper Slag composition (10%, 20%, 30% and 40%) [15]. Marshall Stability and bulk specific gravity increase with bitumen content, after which these two parameters starts decreasing. But the value of the flow increases with the bitumen content. In the same way, the air gap decreases with increasing bitumen content. [16].By Addition of Copper Slag has a significant role in increasing the stability and flow of HMA Mix [17]. From the above literature, it has been observed that Copper slag has been suggested as a fine aggregate in limited quantities for bituminous mixes but not as an alternative to aggregate asphalt.

III. RESEARCH METHODOLOGY

Firstly, test aggregates and bitumen with 0% copper slag to determine their mechanical properties. Classify aggregates in NHA Class "A" gradation. Then make samples and add bitumen percentage (3.5%, 4%, 4.5%, 5%, 5.5%).Copper slag is added with 5%, 10%, 15%, 20 %, 25%, 30%,35%,40% by weight of fine aggregates to the five sets of mixtures and the same procedure is repeated for each. In the end, the tests are performed on the Marshal Mix apparatus to achieve the best volumetric properties of Marshall Mix by the addition of Copper Slag. The following tests are performed shown in Table 1

TABLE 1. EXPERIMENTS PERFORMED

Aggregates test	Bitumen test
Sieve Analysis	Marshal stability & flow test
Loss Angeles Abrasion	Flash & Fire point
Impact Value	Softening Point
Specific Gravity	Penetration Test
Water Absorption	Specific gravity

FIG 1. SAMPLES OF HMA

FIG 2. SAMPLES OF CS WITH ASPHALT MIX

FIG 3.SAMPLES IN WATER BATH

FIG 4.SAMPLE IN MARSHALL APPARATUS

IV. RESULTS

The design mixes contain coarse aggregate, fine aggregate and stone dust. The fine aggregate and mineral filler proportion were replaced at 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by copper slag. The bitumen content was varied at 3.5%, 4%, 4.5%, 5% and 5.5% for various design mixes. The summary of the experimental results is presented in tables 2, 3 and 4. The performance of specimens has been checked by conventional samples. To fulfill the criteria of Marshall Mix Design addition of asphalt content was added from 3.5% to 5.5% with a positive increment of 0.5%.

TABLE 2. PHYSICAL PROPERTIES OF AGGREGATES

Sr #	Material properties	Specifications	Results	Range
1	Crushing Strength	B.S 812 & IS 383	6%	< 15%
2	Flakiness	ASTM D 4791	12.21%	< 15%
3	Angularity No	ASTM D 4791	08	0-11
4	Water Absorption	AASHTO T 85-88	0.29%	Max 2%
5	Specific Gravity	AASHTO T 85-88	2.69	2.5-3
6	Elongation	ASTM D 4791	11.82%	<15%
7	Impact Value	BS 812 & IS 383	8.17%	<10%
8	Abrasion value	ASTM C535 AASHTO T96	16%	<40%

TABLE 3. PHYSICAL PROPERTIES OF ASPHALT

Sr #	Physical Properties	Specifications	Results	Range
1	Asphalt Grade	AASHTO T49	60/70	60/70
2	Softening Point	AASHTO T53-89	42 ^{O}C	30-157 ^{O}C
3	Fire Point	ASTM-D-92(C)	268 ^{O}C	260-290 ^{O}C
4	Flash Point	ASTM-D-92(C)	248 ^{O}C	240-260 ^{O}C
5	Ductility Test	AASHTO T179	73cm	60-85cm
6	Penetration at 25^{O}C	AASHTO T49	64mm	50-70mm

TABLE 4. AVERAGE OPTIMUM BINDER CONTENT (OBC %)

Test Properties	HMA %	5% CS	10% CS	15% CS	20% CS	25% CS	30% CS	35% CS	40% CS
Max Stability at B.C	5%	5%	5%	5%	5%	5%	5%	5%	5%
Max Bulk Sp. Gravity at B.C	5%	5%	5%	5%	5%	5%	5%	5%	5%
B.C at 4% air voids	4.55	4.65	4.81	4.90	4.93	4.75	4.68	4.60	4.53
Avg OBC %	4.85%	4.88%	4.93%	4.96%	4.97%	4.92%	4.89%	4.86%	4.84%

TABLE 5. COMPARISON OF CONVENTIONAL HMA AND HMA WITH DIFFERENT % OF COPPER SLAG

Mix	HMA %	5% CS	10% CS	15% CS	20% CS	25% CS	30% CS	35% CS	40% CS
OBC (%)	4.85	4.88	4.93	4.96	4.97	4.92	4.89	4.86	4.84
Air Voids (%)	3.9	3.51	3.92	4.11	4.15	3.92	3.62	3.5	3.39
Flow-0.01(inch)	11.3	9.22	10.9	11.11	11.52	10.82	10.39	9.62	9.25
Specific Gravity	2.409	2.391	2.421	2.441	2.471	2.487	2.499	2.521	2.548
Stability (kg)	922.5	820.25	852.23	915.1	1025.25	935.22	912.22	885.92	850.22
VFB (%)	71.8	72.1	72.52	72.9	73.3	72.5	72.1	71.8	71.4

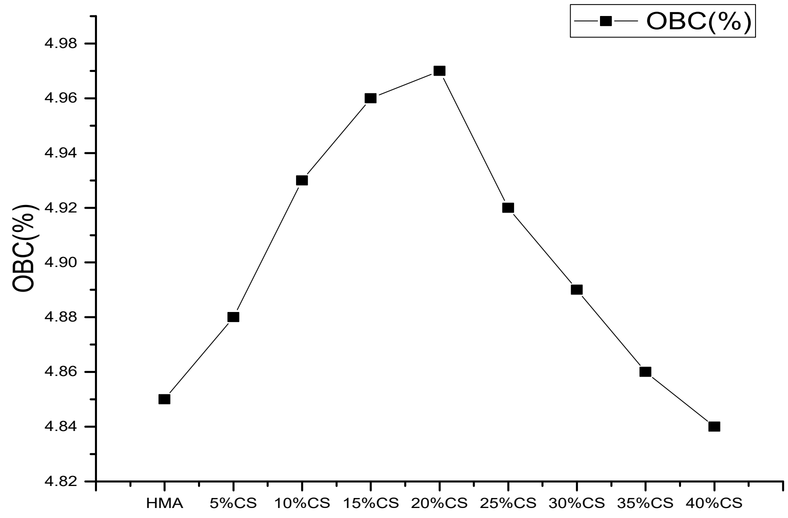

FIG 5.COMPARISON OBC OF HMA AND COPPER SLAG SAMPLES

OBC comes out to be a maximum of 4.97 at 20% CS than all other percentages of copper slag and conventional HMA.

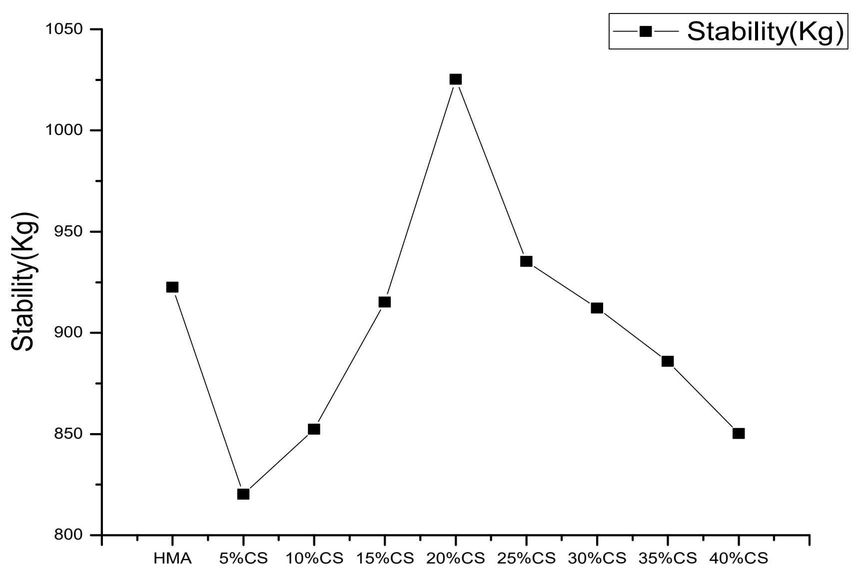

FIG 6.COMPARISON STABILITY OF HMA AND COPPER SLAG SAMPLES

The value of stability at 20% copper slag is a maximum of 1025.25kg as compare to all other percentages of copper slag and conventional HMA.

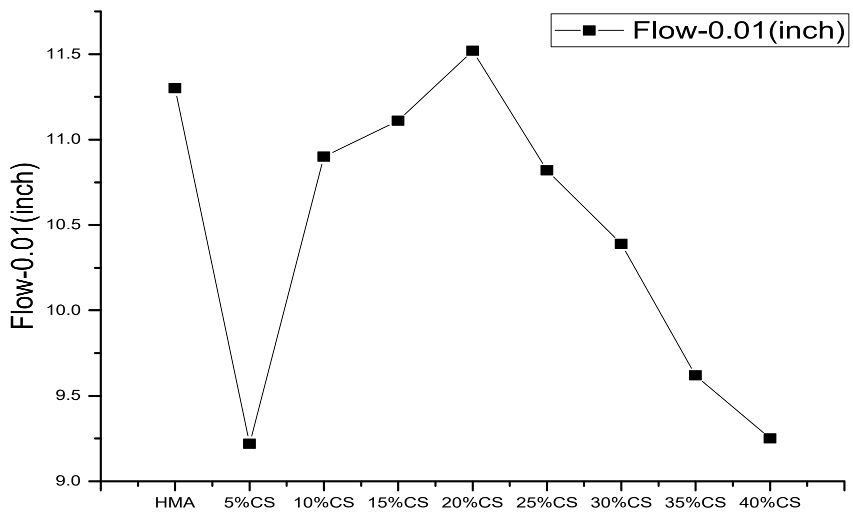

FIG 7.COMPARISON FLOW OF HMA AND COPPER SLAG SAMPLES

The value flow is at 20% copper slag is a maximum of 11.52mm as compare to all other percentages of copper slag and minimum when compared with conventional HMA.

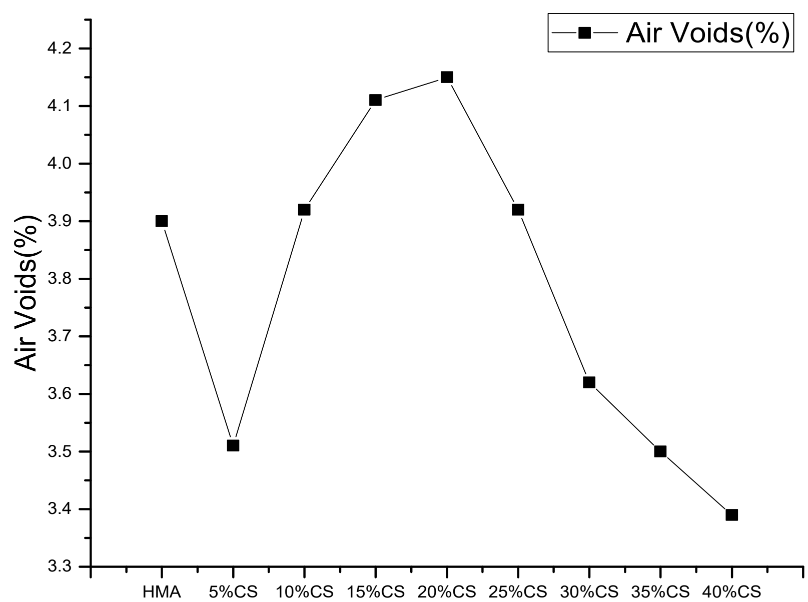

FIG 8.COMPARISON AIR VOIDS OF HMA AND COPPER SLAG SAMPLES

The value of Air voids is at 20% copper slag minimum 4.15% as compared to all other percentages of copper slag and little higher when compared with conventional HMA.

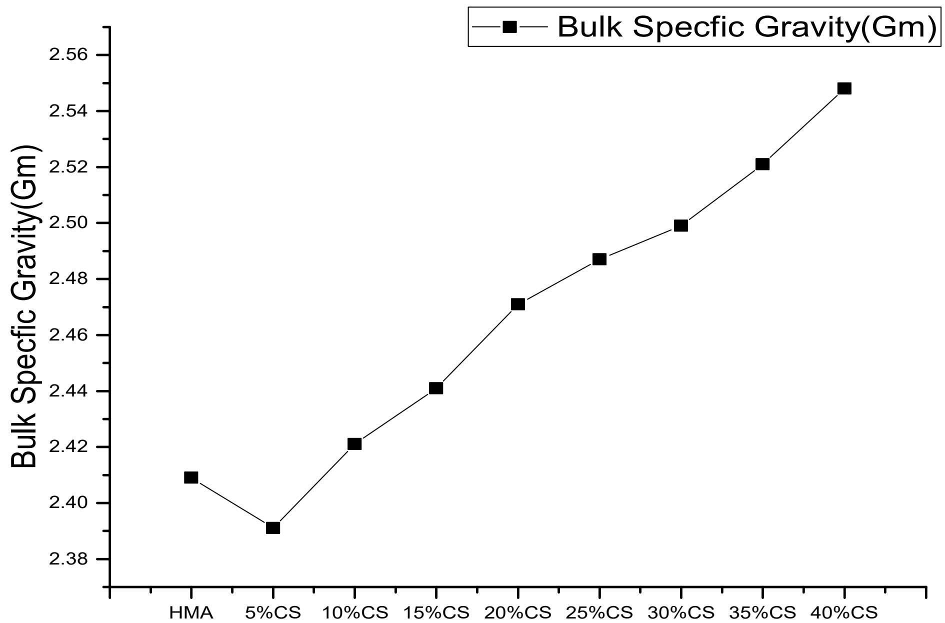

FIG 9.COMPARISON BULK SPECIFIC GRAVITY OF HMA AND COPPER SLAG SAMPLES

The value of Bulk Specific Gravity is increasing as the percentage of copper slag increases. Bulk Specific Gravity of Copper Slag is 3.30.

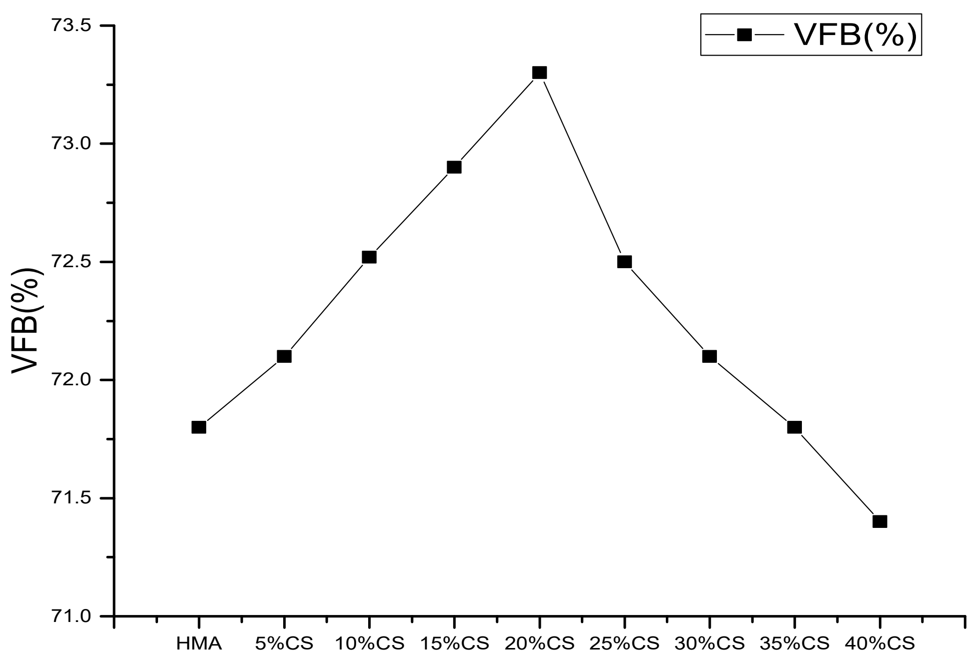

FIG 10.COMPARISON OF VFB OF HMA AND COPPER SLAG SAMPLES

The VFB is at 20% copper slag maximum 71.5% as compared to all other percentages of copper slag and it's slightly minimum compared with conventional HMA.

V. CONCLUSIONS

The Marshall Stability value for the addition of 20% copper slag is more than 5%, 10%, 15%, 25%, 30%, 35%, 40% and conventional HMA samples. The value of the flow increases with the addition of 20% copper slag. It decreases by 20% to 40%. It is slightly higher than conventional HMA. The value of OBC increases with the addition of a 20% copper slag. It begins to decrease by 20% to 40%. Bulk specific gravity increases with an increasing percentage of copper slag because copper slag has a high specific gravity. The value of VFB at 20% copper slag is maximum compared to all other percentages of copper slag. The value of the air voids at 20% of copper slag is maximum after it begins to decrease.

REFERENCES

[1] H. Ziari, A. Moniri, R. Imaninasab, and M. Nakhaei, "Effect of copper slag on the performance of warm mix asphalt," *Int. J. Pavement Eng.*, vol. 8436, no. June, pp. 1–7, 2017.

[2] K. S. Al-Jabri, R. A. Taha, A. Al-Hashmi, and A. S. Al-Harthy, "Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete," *Constr. Build. Mater.*, vol. 20, no. 5, pp. 322–331, 2006.

[3] C. Celauro, C. Bernardo, and B. Gabriele, "Production of innovative, recycled and high-performance asphalt for road pavements," *Resour. Conserv. Recycl.*, vol. 54, no. 6, pp. 337–347, 2010.

[4] B. Kumar, "Properties of pavement quality concrete and dry lean concrete with copper slag as fine aggregate," *Int. J. Pavement Eng.*, vol. 14, no. 8, pp. 746–751, 2013.

[5] M. Khanzadi and A. Behnood, "Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate," *Constr. Build. Mater.*, vol. 23, no. 6, pp. 2183–2188, 2009.

[6] K. S. Al-Jabri, M. Hisada, S. K. Al-Oraimi, and A. H. Al-Saidy, "Copper slag as sand replacement for high-performance concrete," *Cem. Concr. Compos.*, vol. 31, no. 7, pp. 483–488, 2009.

[7] B. Arino, A.M., Mobasher, "Effect of Ground Copper Slag on Strength and Toughness.pdf," *ACI Mater. J.*, no. January-February, pp. 68–73, 1999.

[8] C. Shi, C. Meyer, and A. Behnood, "Utilization of copper slag in cement and concrete," *Resour. Conserv. Recycl.*, vol. 52, no. 10, pp. 1115–1120, 2008.

[9] H. Ziari, A. Moniri, R. Imaninasab, and M. Nakhaei, "Effect of copper slag on performance of warm mix asphalt," *Int. J. Pavement Eng.*, vol. 8436, no. June, pp. 1–7, 2017.

[10] M. K. Chetan and N. J. Sowmya, "Utilization of Copper Slag in Bituminous Concrete with a Stone Dust and Flyash as a Filler," vol. 3, pp. 425–431, 2015.

[11] S. Singh and A. K. Mishra, "Utilization of Copper Slag and Stone Dust in Bituminous Pavement with Hydrated Lime as Filler Material," pp. 237–250,2013.

[12] A. C. Raposeiras, A. Vargas-Cerón, D. Movilla-Quesada, and D. Castro-Fresno, "Effect of copper slag addition on mechanical behavior of asphalt mixes containing reclaimed asphalt pavement," *Constr. Build. Mater.*, vol. 119, pp. 268–276, 2016.

[13] N. K. S. Pundhir, C. Kamaraj, and P. K. Nanda, "Use of copper slag as construction material in bituminous pavements," *J. Sci. Ind. Res. (India).*, vol. 64, no. 12, pp. 997–1002, 2005.

[14] M. Šešlija, N. Radović, and N. Vatin, "Construction of Road Embankment with Waste Materials," *Appl. Mech. Mater.*, vol. 725–726, no. January 2016, pp. 596–601, 2015.

[15] N. K. S. Pundhir and A. Chandra, "Use of waste plastics and copper slag for low cost bituminous roads," vol. 66, no. November, pp. 938–940, 2007.

[16] B. Huang, X. Shu, and X. Chen, "Effects of mineral fillers on hot-mix asphalt laboratory-measured properties," *Int. J. Pavement Eng.*, vol. 8, no. 1, pp. 1–9, 2007.

[17] B. Gorai, R. K. Jana, and Premchand, "Characteristics and utilisation of copper slag - A review," *Resour. Conserv. Recycl.*, vol. 39, no. 4, pp. 299–313, 2003.