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A Review on Utilization of Steel Slag in Bituminous Concrete

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Abstract: ***The utilization of steel slag in bituminous mixes has been gaining popularity due to environmental concerns and the potential for cost savings. However, it's essential to manage steel slag properly to prevent environmental and health hazards. To control the impact of steel slag, various efforts have been undertaken. Bituminous concrete performance is influenced by factors like binder grade and the aggregate blend. While numerous studies have examined steel slag's performance in bituminous concrete, there is still a need of more research on optimal mix design. Typically, the ideal quantity of steel slag in bituminous mixes falls within the range of 10% to 15%. It's crucial to thoroughly understand the effect of steel slag on the mechanical properties of the mix, often measured using Marshall Stability Test. In India, there hasn't been extensive work on varying percentages of steel slag in bituminous concrete and its resistance against stripping, despite numerous studies on the properties of steel slag aggregates. This paper aims to consolidate the research studies on the enhancements in bituminous mix properties by partial replacement with steel slag, as well as exploring the potential benefits of incorporating steel slag in bituminous concrete mixes.***

Keywords: Marshall Stability, Bituminous Concrete, Steel Slag.

I. INTRODUCTION

Steel slag is a by-product of the steelmaking process and is generated during the separation of the molten steel from impurities in steel refining furnaces. This waste material is composed of various minerals such as calcium, iron, and silicon, and has similar chemical properties to volcanic rocks. Steel slag nowadays has been largely employed in civil engineering works such as road engineering as it has a rough surface to some extent. Steel slag waste can pose environmental and health hazards if not managed properly. It contains heavy metals, such as lead and cadmium, which can leach into soil and water sources, and potentially harm human health and the environment. The use of steel slag as a substitute for traditional aggregates in construction materials has gained attention in recent years due to its potential economic and environmental benefits. The use of steel slag in construction not only provides a sustainable solution for managing a by-product of the steelmaking process but also contributes to the improvement of the properties of construction materials. In particular, steel slag has been identified as a promising supplementary material for bituminous mixes including Bituminous Concrete (BC). There are several reasons why steel slag can be a beneficial material to use in bituminous pavement construction:

1) *Durability*: Steel slag is a highly durable material that can resist weathering, abrasion, and heavy traffic loads. It also has a high bearing capacity, which makes it suitable for use in the base and subbase layers of pavements.
2) *Cost-effective*: Steel slag is a by-product of steel manufacturing, so it is readily available at a low cost. Using steel slag in bituminous pavement construction can help reduce the cost of materials, which can make projects more affordable.
3) *Sustainable*: Using steel slag in bituminous pavement construction is a sustainable practice because it helps to reduce waste and promote the reuse of materials. This can help to conserve natural resources and reduce the environmental impact of construction projects.
4) *Improved Performance*: Steel slag has been shown to improve the performance of bituminous pavements in terms of resistance to deformation, cracking, and moisture damage. It can also improve the skid resistance of pavements, which can help to enhance safety for motorists.

Steel slag possesses several desirable properties that make it an attractive material for BC, such as high abrasion resistance, good frictional properties, and low permeability. Additionally, the use of steel slag in DBM can reduce the demand for natural aggregates and provide a sustainable solution for managing this industrial waste. However, before steel slag can be widely used in Bituminous Concrete (BC), further research is needed to investigate its mechanical properties, durability, and long-term performance. This proposed research is aimed to conduct a comprehensive study on the use of steel slag in BC materials.

II. REVIEW OF LITERATURE

The researchers can better comprehend the issues and knowledge gaps in their field of study with the use of a literature review. It provides the concept for future development as well as data and information about the issues being researched. Here are several research projects that are presented.

1) Sharma S., & Jethwa, K. B. (2022) carried out an investigation aimed to find a solution for reusing plastic waste, particularly LDPE (low-density polyethylene), and BOF steel slag in road construction to reduce overall construction cost and address solid waste management problems. The LDPE waste plastic was mixed with bitumen VG 30 at different percentages of bitumen content and subjected to softening point, penetration, and ductility tests. Steel slag in aggregate form was also used at different percentages and mixed with DBM Grade II according to Indian standards. The modified asphaltic mix was tested using the Marshall stability and flow test, and it was found that the maximum increase in stability value occurred at a binder content of 4.5% and steel slag content of 15%, resulting in a 2.4% increase in stability and a corresponding increase in flow value by 3.65%. These findings suggest that the modified mix is more resistant to rutting, distortion, and overall pavement stability compared to the unmodified mix.
2) Mishra, M. Mv, N., M, T. H., & V, N. M. (2021) aims to enhance the durability and performance of road bitumen material by investigating the effect of adding steel slag powder (SSP) as a filler in different percentages. The physical parameters of SSP are compared with those of the conventional mix, and the conclusion is that it can be useful as a filler to improve the quality and durability of pavement. The SSP is added in percentages of 2%, 4%, 6%, and 8% by weight of aggregates and mixed with bitumen to prepare the samples. A Marshall Stability Test is conducted to analyse the stability of the mix at different percentages of SSP. The results show that the maximum stability of bituminous concrete is obtained at 4% of SSP. It is also observed that SSP increases the binding between bitumen and aggregates due to its greater surface area. However, with an increase in SSP, the stability of the mix decreases. Therefore, it is concluded that SSP could be used as a filler in bituminous surface course for better performance and durability. The study provides a useful insight for engineers and researchers in the road construction industry to develop more sustainable and efficient road construction practices.
3) Georgiou, P., & Loizos, A. (2021) evaluated the performance-based properties of three mixtures for wearing courses of asphalt pavements that incorporate steel slag and varying amounts (25, 40, and 50%) of fractionated reclaimed asphalt (RA). The mixtures also included a warm mix asphalt (WMA) organic additive to reduce production temperatures compared to a reference hot mix asphalt (HMA). The results of the experiments showed that the warm recycled asphalt mixtures exhibit equivalent or superior performance to HMA in terms of stiffness, moisture susceptibility, rutting and fracture resistance, and surface macrotexture. Therefore, the combined use of RA and steel slag with WMA was demonstrated as an effective strategy for designing environmentally friendly and high-performance wearing course mixtures.
4) Aziz, M. M. A., Shokri, M., Ahsan, A., Liu, H. Y., Tay, L., & Muslim, N. H. (2020) This paper discusses the use of steel-furnace slag as a sustainable and recycling material in the transportation and highway industry to address global issues related to the environment and energy. Steel slag, which is a by-product of the steel industry, has properties similar to traditional aggregates and can replace them in road construction. Recent experimental research has shown that steel slag has favourable chemical, mechanical, and physical properties. Asphalt mixtures using steel slag have better mechanical characteristics than those using only natural aggregates, and a combination of 30% steel slag and 70% natural aggregates in bitumen mixture has been found to be an excellent surface course for roads. The use of steel slag in road construction reduces landfill, saves natural resources, and improves pavement strength to sustain heavier and higher volumes of vehicles. The paper aims to collect and present the chemical, physical, and mechanical characteristics of steel slag and highlight previous studies on its use in road construction, including the effect of different percentages of steel slag as a replacement for natural aggregates.
5) I. Rocha Segundo & E. Freitas, V. Castelo Branco, & S. Landi Jr. (2019) investigates the technical feasibility of using Reclaimed Asphalt Pavement (RAP) and Steel Slags (SS) in asphalt mixtures for surface layers. Three asphalt mixtures were designed and tested: one without recycled materials, one with 30% RAP, and one with 30% SS. Mechanical and superficial assessments were conducted, and the results showed that the water sensitivity and permanent deformation were similar for all mixtures. Mixture A, containing SS, had higher stiffness modulus and lower fatigue resistance but provided better sound absorption and mechanical impedance compared to the other mixtures. The study suggests that RAP and SS can be used in asphalt mixtures for surface layers.
6) Maharaj, C., White, D., Maharaj, R., & Morin, C. (2017) It is encouraging to hear that research has shown the possibility of utilizing electric arc furnace steel slag as a substitute for traditional road construction materials such as sand and limestone aggregates. This presents an opportunity to address the disposal and environmental challenges associated with this waste

material. The study's focus on investigating the optimal slag content for the mixture is important, as the chemistry of the asphaltic materials used can vary, and this can affect the mechanical properties of the resulting mixture. The use of Marshall stability testing to determine the optimal slag content is a standard method used in road construction, and the results of this study suggest that a slag content of 15% by mass of ¾ inch sized aggregates is optimal. By reusing steel slag aggregate in this manner, the study suggests that improvements in pavement performance can be achieved, and there will be a more efficient and environmentally friendly management of this waste material. This is a positive step towards reducing the environmental impact of the ferrous smelting process and preserving the environment.

7) Goli, H., Hesami, S., & Ameri, M. (2017) presents the results of a laboratory study that investigates the damage behavior of warm mix asphalt (WMA) mixtures containing electric arc furnace (EAF) steel slag. The steel slag was used as both the fine and coarse portions of aggregate gradation in hot mix asphalt (HMA) mixtures and as the coarse portion of aggregate gradation in a WMA mixture. The physical, chemical, and mechanical properties of the aggregates and binders were evaluated, and the moisture susceptibility, fatigue, and rutting behavior of the asphalt mixtures were analyzed. The results showed that using coarse SS aggregate in WMA mixtures enhances the resistance of asphalt mixtures to moisture damage and permanent deformation, and WMA mixtures containing SS aggregates as the coarse portion of aggregates have better fatigue performance than HMA mixtures. The study recommends the use of WMA mixtures containing EAF steel slag aggregates as an eco-friendly, economical, and suitable mixture for pavement industries.

8) Papayianni, I., Anastasiou, E., Papachristoforou, M., & Liapis, A. (2016) describes the properties of concrete made using steel slag, a by-product of the steel industry produced through the Electric Arc Furnace method, and its potential use in road pavement. The research has been mainly conducted in South Europe. The study suggests that the use of steel slag in pavement construction is advantageous from a technical perspective, as it enhances the compressive strength, ductility, resistance to abrasion, and anti-slipping properties of pavements. The paper also compares the cost and environmental impact of using conventional concrete pavement versus steel slag concrete, taking into account the maintenance cost during the service life of the pavement. Overall, the study highlights the potential benefits of using steel slag in pavement construction.

9) Magadi, K. L., Anirudh, N., & Mallesh, K. M. (2016) discusses the use of steel slag as a replacement material for coarse aggregates in different sizes for various bituminous mixes. The study examines the physical and chemical properties of the steel slag and aggregates, and evaluates the mechanical characteristics of the bituminous mixtures using Marshall Stability and Indirect Tensile Strength tests. The results show that the gradation requirement was fulfilled for all the replacement percentages for the DBM grade-II, and that the steel slag used as a coarse aggregate improved the mechanical properties of the bituminous mixtures. The mixtures containing steel slag satisfied the MoRT&H standards and were compared with those containing virgin aggregates. The findings demonstrate that the steel slag can be effectively used in road construction to enhance the durability and performance of bituminous mixtures. Overall, the study suggests that the utilization of steel slag as a replacement material for coarse aggregates has the potential to reduce the cost and increase the efficiency of road construction.

10) Hainin, M. R., Aziz, M. A., Ali, Z., Jaya, R. P., El-Sergany, M. M., & Yaacob, H. (2015) The paper discusses steel slag, a byproduct of the steel industry that is generated during the production of steel. Steel slag has been recognized as a useful construction material and is recycled as an aggregate for road construction, soil stabilization, and flexible pavement surfacing. Despite this, a large amount of steel slag is still disposed of in stockpiles, which results in the sacrifice of land for its disposal. Researchers have investigated the use of steel slag as an aggregate in asphalt concrete for road construction, and the paper aims to review the engineering properties of steel slag and its utilization for road construction in different ways. The recycling of steel slag can reduce the need for landfills, save natural resources, and have a positive impact on the environment.

11) Thangaselvi, K. (2015) addressed the issue of resource depletion and environmental degradation and he investigated about the use of steel slag as a replacement for natural coarse aggregate in concrete. The replacement proportions ranged from 0% to 80% for M40 grade concrete with a water-cement ratio of 0.40. Specimens were tested for compressive strength, split tensile strength, and flexural strength at 7 and 28 days. Results showed that the optimal strength was achieved at a 60% replacement of coarse aggregate with steel slag. This research presents a promising solution for the effective use of slag in concrete, thereby reducing environmental pollution and promoting sustainable development.

12) Tarawneh, S. A., Gharaibeh, E. S., & Saraireh, F. M. (2014) compared the physical and mechanical properties of steel slag aggregate concrete to conventional crushed limestone stone aggregate concrete. Steel slag, a by-product of the steel industry consisting mainly of calcium carbonate, was used as a replacement for conventional aggregates in concrete mixes. The results showed that steel slag aggregate had better abrasion factor and impact value than conventional aggregate. The compressive strength of the concrete with steel slag aggregate increased more at 7 days than at 28 days, indicating that the added slag

worked as an accelerator at early ages. Fine slag replacement had the highest effect. The use of steel slag as an aggregate in concrete can help conserve natural resources and protect the environment.

13) Pandey S., & Jain, P. K. (2014) investigated the effects of utilizing steel slag as a coarse aggregate on the properties of hot mix bituminous concrete. To comply with the Ministry of Road Transport and Highway Specification for Road and Bridge Works in India, the physical characteristics of the ingredients in the bituminous mix, including natural aggregate, steel slag aggregate, and bituminous binder, were examined. The mechanical properties of the unmodified (using natural aggregate) and modified (using steel slag as coarse aggregate) bituminous mixes were evaluated using the Marshall Method of mix design. Several performance tests were conducted on the unmodified and modified mixes to assess the suitability of steel slag as an aggregate for high-performance bituminous concrete mix preparation. These tests included retained Marshall Stability, indirect tensile strength, static creep test, wheel-tracking test, and resilient modulus test. The laboratory study confirmed that the mechanical properties of the steel slag-modified mixes improved significantly, while the temperature and moisture susceptibility were reduced.

III. INFERENCES AND GAPS DRAWN FROM LITERATURE REVIEW

1) Field Studies: While laboratory studies have shown promising results for the use of steel slag in pavement surface, there is a need for more field studies to evaluate its performance under real-world conditions. Field studies can provide valuable data on the long-term durability and effectiveness of using steel slag in pavement surface.
2) Performance evaluation: There is a need for more research on the performance of steel slag pavement surface under different types of loading, such as heavy truck traffic and harsh weather conditions. This can help to determine its suitability for different applications and to identify any potential issues that may arise.
3) Effectiveness of different sizes of steel slag: Research is needed to investigate the effects of using different sizes of steel slag in pavement surface. This can help to identify the optimal size of steel slag that provides the best performance in terms of strength, durability, and surface texture.
4) Environmental impact: While the use of steel slag in pavement surface can be a sustainable alternative to conventional materials, there is a need for more research on its potential environmental impacts. This includes evaluating its potential to leach heavy metals into the soil and groundwater and its contribution to air pollution.
5) Cost-effectiveness: The cost of using steel slag in pavement surface can vary depending on the location and availability of the material. Further research is needed to evaluate the cost-effectiveness of using steel slag compared to other pavement surface materials and to determine the optimal applications for its use.
6) While there have been studies on the use of steel slag in asphalt concrete, there may be limited studies on the use of steel slag aggregates in warm mix asphalt, which is a relatively new technology.
7) Although some studies have investigated the performance of steel slag in bituminous concrete, there is still a lack of research on the optimal mix design.
8) The influence of environmental factors on performance: The performance of bituminous concrete containing steel slag may be affected by environmental factors such as temperature, moisture, and freeze-thaw cycles. However, the current research lacks a comprehensive understanding of how these factors affect the mechanical properties and durability of the concrete.
9) Durability performance: There is a lack of research on the `long-term durability performance of bituminous concrete containing steel slag, including resistance to rutting, fatigue, and cracking.
10) The studies need to be done to ascertain effect on skid resistance of pavements.
11) There is a need for further investigation of its durability under different environmental conditions, such as freeze-thaw cycles or exposure to chemicals.
12) There is no study on the potential variability in the properties of steel slag from different sources such as BOF slag, EAF slag, stainless steel slag, ferroalloy slag, Ladle Furnace slag etc.
13) Changes can be proposed in the current bituminous mix design for steel slag to enhance the performance of mixes.

IV. PROPOSED STUDY

Further research in this field involves the preparation of BC specimens by adding a certain trial percentage of steel slag. By Marshall Method, stability of each sample under maximum load will be measured in compression. The density and voids will also be determined. Also, the effect of steel slag on the properties of BC is compared on the basis of Marshall Test result. A comparative study will be made in this investigation between Bituminous Concrete (BC) with varying percentages of steel slag (i.e., 10%, 12.5%, 15% and 17.5%) and Bituminous Concrete (BC) without steel slag.

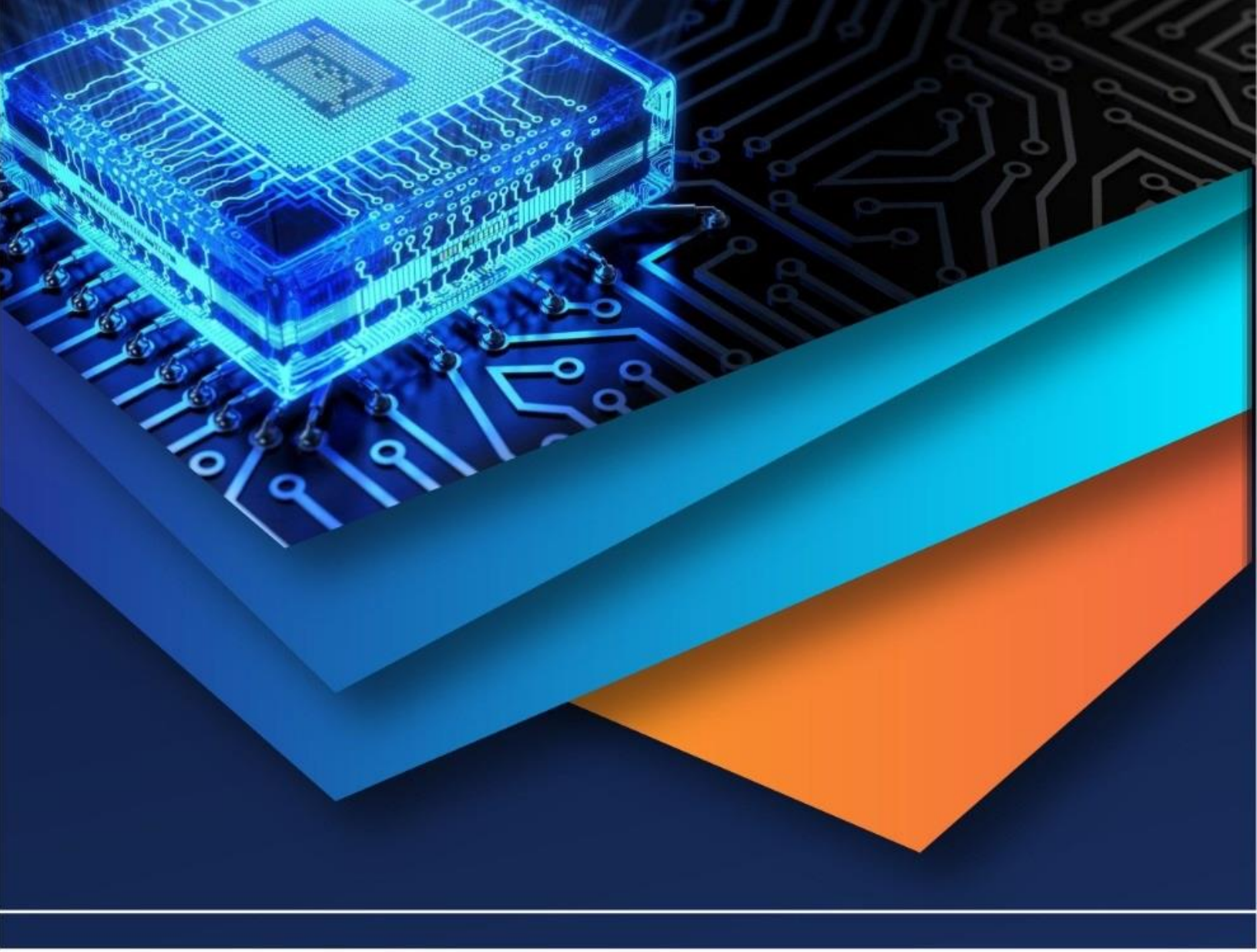
V. CONCLUSION

A review of prior studies on the addition of steel slag in different bituminous mixes was conducted. This paper aims to shed light on the enhancements in bituminous mix properties when partially replaced with steel slag, as well as exploring the potential benefits of incorporating steel slag in Bituminous Concrete mixes. Some studies have investigated the performance of steel slag in bituminous concrete, there is still a lack of research on the optimal mix design.

The integration of steel slag in asphalt and bituminous concrete is a promising avenue for sustainable infrastructure development. However, there are critical research gaps that need urgent attention. Utilization of steel slag aggregates in warm mix asphalt, a relatively new technology, requires more comprehensive investigation to assess its viability and benefits fully. The lack of research on optimal mix design for steel slag in bituminous concrete is a significant impediment. This gap hinders the development of guidelines that could maximize the material's advantages. Additionally, the influence of environmental factors like temperature, moisture, and freeze-thaw cycles on bituminous concrete containing steel slag remains inadequately understood, impeding its reliable performance. Further research in this field involves the preparation of BC specimens by adding a certain trial percentage of steel slag in order to obtain optimal mix design. By Marshall Method, stability of each sample under maximum load will be measured in compression. The density and voids will also be determined. Also, the effect of steel slag on the properties of BC is compared on the basis of Marshall Test result. A comparative study will be made in this investigation between Bituminous Concrete (BC) with varying percentages of steel slag and Bituminous Concrete (BC) without steel slag.

REFERENCES

[1] Sharma, S., & Jethwa, K. B. (2022) An Experimental Analysis of Using Steel Slag and Plastic in Dense Bituminous Macadam. November 2022| IJIRT | Volume 9 Issue 6 | ISSN: 2349-6002
[2] Mishra, M., Mv, N., M, T. H., & V, N. M. (2021) Investigational Study on Behaviour of Bituminous Concrete by Addition of Steel Slag Powder as Filler. Vidyabharati International Interdisciplinary Research Journal. ISSN 2319-497 https://doi.org/10.13140/RG.2.2.14783.64166
[3] Georgiou, P., & Loizos, A. (2021) Characterization of sustainable asphalt mixtures containing high reclaimed asphalt and steel slag. *Materials (2021)*, *14*(17). https://doi.org/10.3390/ma14174938.
[4] Aziz, M. M. A., Shokri, M., Ahsan, A., Liu, H. Y., Tay, L., & Muslim, N. H. (2020) An Overview on Performance of Steel Slag in Highway Industry. Journal of Advanced Research in Materials Science, 67(1), 1–10. https://doi.org/10.37934/arms.67.1.110
[5] I. Rocha Segundo & E. Freitas, V. Castelo Branco, & S. Landi Jr. (2019) Incorporation of steel slag and reclaimed asphalt into pavement surface layers. 1st Edition CRC Press (2019) eBook ISBN9780429289798. DOI: 10.1201/9780429289798-72
[6] Maharaj, C., White, D., Maharaj, R., & Morin, C. (2017) Re-use of steel slag as an aggregate to asphaltic road pavement surface. Cogent Engineering, 4(1). https://doi.org/10.1080/23311916.2017.1416889
[7] Goli, H., Hesami, S., & Ameri, M. (2017) Laboratory Evaluation of damage behaviour of Warm Mix Asphalt containing Steel Slag aggregates. Journal of Materials in Civil Engineering, 29(6). https://doi.org/10.1061/(asce)mt.1943-5533.0001832
[8] Papayianni, I., Anastasiou, E., Papachristoforou, M., & Liapis, A. (2016) Steel Slag Concrete for Pavement Construction. 3rd International Balkans Conference on Challenges of Civil Engineering, 3-BCCCE, 19-21 May 2016, Epoka University, Tirana, Albania
[9] Magadi, K. L., Anirudh, N., & Mallesh, K. M. (2016) Evaluation of Bituminous Concrete Mixture Properties with Steel Slag. Transportation Research Procedia, 17, 174–183. https://doi.org/10.1016/j.trpro.2016.11.073
[10] Hainin, M. R., Aziz, M. A., Ali, Z., Jaya, R. P., El-Sergany, M. M., & Yaacoba, H. (2015) Steel slag as a road construction material. Jurnal Teknologi, 73(4), 33–38. https://doi.org/10.11113/jt.v73.4282
[11] Thangaselvi, K. (2015) Strength and Durability of concrete using Steel Slag as a partial replacement of coarse aggregate in concrete. In ijartet.com International Journal of Advanced Research Trends in Engineering and Technology (IJARTET) (Vol. 2). www.ijartet.com
[12] Tarawneh, S. A., Gharaibeh, E. S., & Saraireh, F. M. (2014) Effect of using Steel Slag aggregate on mechanical properties of concrete. American Journal of Applied Sciences, 11(5), 700–706. https://doi.org/10.3844/ajassp.2014.700.706
[13] Pandey S., & Jain, P. K. (2014) Mechanical Performance of Bituminous Concrete incorporating Steel Slag with natural aggregate. International Journal on Pavement Engineering & Asphalt Technology, 14(2). https://doi.org/10.2478/ijpeat-2013-0003
[14] MoRTH (Ministry of Road Transport and Highways), "Specifications for road and bridge works", 5th Edition, Indian roads congress, New Delhi, India, 2013.
[15] IRC:120 -2015, "Recommended Practice for Recycling of Bituminous Pavements", Indian Road Congress,2015.
[16] ASTM D6927, "Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures", 2017.



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