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A Review on Utilization of Steel Slag and C&D Waste as Filler in Asphalt Concrete

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ABSTRACT

A filler, defined as that fraction of inert mineral dust in a bituminous mixture that passes the 200-mesh sieve, can serve various functions. Filling voids in coarser aggregates is one of the functions, that increases the density, stability, and toughness of a traditional bituminous paving mixture.Bituminous mixes are made up of different-sized aggregates, filler, and bitumen. Mineral grains, the majority of which pass the 63m filter, make up fillers (filler aggregate). Regardless of the kind of asphalt combination (Stone Mastic Asphalt, Asphalt Concrete), this component accounts for 3–14 percent of the total aggregate by weight in the entire mixture. The filler level of Mastic Asphalt is in the range of 26-36 percent. The present reserch shows some literatures related to the use of steel slag and construction and demolition waste as fillers in the Asphalt concrte. Using Steel slag and construction and demolition waste leads to sustainable and environment friendly pavements. The study leads to the optimum use of waste in a productive manner.

Key Words:Steel slag, limestone filler, stone dust, glass powder, ceramic powder

1.INTRODUCTION

Trying to tackle economic concerns by reusing and restoring what is available is always a smart idea. On the other side, it is a great practice to dispose of garbage in an environmentally friendly manner, since this will result in structures that are both sustainable and environmentally friendly. Sustainable building is a key demand across the world, and it must be treated seriously for the sake of current and future generations.Slag is a waste product produced during the production of pig iron and steel. During the process of pig iron producing in a blast furnace and steel manufacture in a steel melting shop, it is formed by the action of different fluxes on gangue elements inside the iron ore. Slag is mostly made up of calcium, magnesium, manganese, and aluminium silicates and oxides in a variety of combinations. The cooling of slag is primarily responsible for producing the various varieties of slags required by various end-use users. Although the chemical composition of slag remains constant, its physical qualities alter dramatically as the cooling process continues.Slag is formed when molten steel is separated from impurities. The undesired carbon content in the molten steel is removed as gaseous waste throughout the process, while impurities like as phosphorous and silicon are eliminated as solid trash. One tonne of steel produced yields half tonnes of solid trash. Steel slag accounts for 20 to 40% of this solid waste. Given the 8% annual growth rate in steel production, the quantity of slag produced by 2020 is expected to reach 25 million tonnes. The sector faces a Herculean challenge with no adequate disposal strategy in sight.

Construction and demolition compounds are formed when a new building or structure is built, or when an old structure is renovated or demolished. Concrete, steel, wood, asphalt, and gypsum are examples of heavy materials utilised in vast quantities in modern building. The destruction of structures accounts for 90% of total garbage in the India, whereas waste created during construction accounts for less than 10%.According to the Building Material Promotion Council, the country creates an estimated 150 million tonnes of C&D waste each year. However, the stated recycling capacity is just 6,500 tonnes per day, or around 1% of total capacity.*The* present reserch shows some literatures related to the use of steel slag and construction and demolition waste as fillers in the Asphalt concrte. Using Steel slag and construction and demolition waste leads to sustainable and environment friendly pavements. The study leads to the optimum use of waste in a productive manner.

2. LITERATURE REVIEW

The literatures showing the effective use of steel slag and construction and demolition waste as a filler in Asphalt concrete

2.1 STEEL SLAG AS FILLER

Steel slag is a waste material or a by-product in steel industry. The disposal of this byproduct is challenge for the whole world. Using this in Asphalt concrete is the effective and economical way to use steel slag:

(Chao Li 2017), Physical indices, surface features, chemical compositions, phase distribution, and thermal properties of limestone filler and three steel slag fillers were investigated in this paper. The rheological characteristics of the respective mastics were also examined. The results shows that, Limestone Filler has a substantially lower density, specific surface area, and water absorption than steel slag fillers. Steel slag fillers are porous materials with coarse, bumpy surface features, as seen by SEM pictures. CaO and SiO_2 are the principal components of all fillers, according to the chemical compositional study. The Fe concentration in steel slag filler is increasing in tandem with the increasing particle size of raw steel slag. In the temperature range of making asphalt mixes, TG-DSC study which is used for thermal analysis reveals that all fillers have desirable thermal properties, and Limestone Filler is more stable than steel slag fillers. All asphalt mastics containing steel slag fillers have better high-temperature deformation resistance than the Limestone Filler corresponding mastic, which is due to a stable mastic structure reinforced by steel slag stiffness, as well as chemical action between alkaline components in steel slag fillers and asphaltic acid in bitumen. The ASSF i.e. type A Steel Slag Filler matching mastic has the least sensitive response to conditioning temperature and the best high-temperature rheological qualities of all steel slag filler based bituminous mixes.

(S. W. Chao Li 2018), Steel slag filler was employed in this study to boost heat release during microwave irradiation, improving the self-healing characteristics of asphalt mastic. Limestone Filler asphalt mastic and Steel Slag Filler asphalt mastic have initial self-healing temperatures of 46.5^oC and 45.2^oC, respectively. Steel Slag Filler asphalt mastics with 0.2, 0.4, and 0.6 filler-bitumen volume ratios have heating rates that are 35.89 percent, 51.22 percent, and 62.83 percent greater than Limestone Filler asphalt mastics. The results show that under microwave irradiation, Steel Slag Filler-based asphalt mastics may release more heat than Limestone Filler-based asphalt mastics. The heating rate of Steel Slag Filler-based asphalt mastics rises as the filler-bitumen volume ratio rises.

(Guanyu Tao 2019), This paper looked into the possibility of employing steel slag as a filler in an asphalt mixture. First, the physical and chemical features of Steel Slag Filler and Limestone Filler were investigated, including surface characteristics, morphological data, chemical compositions, and crystal structures. The rheological characteristics of asphalt mortar with Steel Slag Filler and Limestone Filler were then investigated. Steel Slag Filler has a rough surface with many micro-pores ranging in size from 0.5 to 5 µm, whereas Limestone Filler has a smooth surface. The angularity index of Steel Slag Filler has a shorter distribution range than that of Limestone Filler, suggesting that the angularity index of Steel Slag Filler has a more uniform distribution. Steel Slag Filler's Form 2D values are much higher than Limestone Filler's, indicating that Steel Slag Filler is rougher and sharper than Limestone Filler. The complex shear modulus of bituminous mortar increases when Steel Slag Filler is added as a mineral filler to the asphalt binder. The fact that the rutting factor continues to rise as the Steel Slag Filler concentration rises suggests that Steel Slag Filler increases the deformation resistance of bituminous mortar. The creep stiffness increases as the Filler to Asphalt volume ratio increases, but the m-value decreases which reflects stress relaxation of asphalt at low temperatures. The resistance of bituminous mortar to low-temperature cracking reduces dramatically as the Steel Slag Filler component rises. The creep stiffness of Limestone Filler based mortar is the highest, but when Limestone Filler is partially substituted with Steel Slag Filler, the stiffness values fall somewhat. The use of a mix of Steel Slag Filler and Limestone Filler as a filler in an asphalt mixture might be a viable option for recycling steel slag. The combined filler should have an Steel Slag Filler percentage of less than 75% by volume.

(Minghua Wei 2021), The goal of this research is to evaluate steel slag filler and determine if it can be used to replace limestone filler in bituminous concrete by testing asphalt mastic resilience to various ageing processes. Steel slag filler, limestone filler, virgin asphalt, steel slag filler asphalt mastic, and limestone filler asphalt mastic were all made first. Following that, the fillers' grain size distribution, surface characterisation, and pore characterization were assessed. Finally, using a dynamic shear rheometer and a Fourier transform infrared spectrometer, the asphalt mastics' rheological performance, self-healing capability, and chemical functional groups were examined using various ageing procedures. In contrast to Limestone Filler, characterisation of Steel Slag Filler revealed similarities in particle size distribution but better uniformity in particle size distribution, which is connected to the filler preparation processes. The disparity in surface and pore characteristics of the fillers, on the other hand, is noteworthy. Steel Slag Filler has a rougher surface and more numerous pores, whereas Limestone Filler has a reasonably smooth surface with dull pore characteristics. In comparison to Limestone Filler Asphalt mastic, Steel Slag Filler Asphalt mastic performs better in the environments of acid solution and pure water, but worse in the environments of alkali solution and NaCl solution, under the same ageing time conditions. The addition of f-CaO to Steel Slag Filler alters the reaction orders with solutions because the f-CaO tends to conduct the processing more readily.

(Zhifeng Xiao 2019), The fundamental characteristics of steel slag powder and three inorganic fillers, limestone, cement, and slaked lime, were investigated in this study. In the meantime, the impact of the four fillers on Bitumen-aggregate adhesion and moisture resistance of asphalt mixes was investigated. In comparison to Limestone Filler and Cement, the Steel Slag Powder has a harsher surface texture with visible lumps or holes, as well as a finer particle size. Steel Slag Powder has a much higher specific surface area than the other three fillers, implying that it has a bigger contact area with asphalt and, as a result, affects the performance of asphalt mixes. Without water treatment, it was discovered that replacing Limestone Filler with Cement, Slaked Lime, and Steel Slag Powder with the same substitution amount i.e. 25% had minimal influence on Marshall stability and indirect tensile strength, and that increasing the Steel Slag Powder replacement amount enhances the growth of Marshall Stability and Indirect Tensile Strength. The impact of Cement, Slaked Lime, and Steel Slag Powder on enhancing water damage resistance will become more obvious after water treatment, and the three fillers will be able to withstand the decrease of water on mixture performance, which is attributable to their enhancement of asphalt-aggregate adhesion. The most noticeable impact of slaked lime is that it improves water damage resistance. The Marshall Stability Ratio and Tensile Strength Ratio of the mixes combined with Slaked Lime increased by 11.72 percent and 10.15 percent, respectively, when compared to the control group of 0 percent Steel Slag Powder. Cement had a somewhat worse effect in improving water damage resistance. Steel Slag Powder improved the water stability of the asphalt mixture, but when the replacement quantity was increased, Marshall Stability Ratio and Tensile Strength Ratio declined; the best dose is 25 percent. Regardless of the quantity of replacement, the inclusion of Steel Slag Powder increased the water damage resistance of asphalt mixes when compared to the whole group.

(Yongjie Xue 2019), The rheological characteristics of a compound rubber and steel slag filler modified asphalt composite were studied in this study. The Rubber and Steel Slag filler modified Asphalt Composite particles were created to increase the storage stability of modified asphalt composites and make transportation easier. Rubber and Steel Slag filler modified Asphalt Composites had a better viscosity–temperature susceptibility than a modified bitumen with only one ingredient. Steel slag filler reduced the storage stability of the amended asphalt samples somewhat, whereas crumb rubber increased storage stability due to rubber deterioration and its subsequent reactivity with the asphalt component. The addition of steel slag filler to rubber modified asphalt reduced the sensitivity of asphalt materials' frequency.

2.2 C&D WASTE AS FILLER

The literature showing C&D waste as filler in Asphalt concrete are shown below:

(Mei-zhu Chen 2011), The goal of this study was to evaluate the mechanical performance of asphalt mixes made with recycled brick powders in the lab. A comparative study was conducted utilising recycled brick powder and limestone filler for two distinct asphalt compositions. At 40 degrees Celsius, the combination with recycled brick filler had a greater indirect tensile modulus than the control mixture, indicating that the mixture with recycled brick filler had improved rutting resistance. The use of recycled brick filler might increase the water sensitivity and fatigue life of asphalt mixes when compared to the limestone filler used in this study.By both static and dynamic creep tests, the use of recycled brick filler may greatly reduce permanent deformation at 60^oC, resulting in enhanced rutting resistance of asphalt mixtures at high temperatures. It can be stated that employing recycled brick powder as a building material is a good idea. It is possible to use mineral filler in an asphalt mixture.

(Meizhu Chen 2011), A series of laboratory studies are being conducted to determine the possible usefulness of recycling waste fine aggregates as Recycled Fine Aggregate Powder in asphalt mixtures. The Recycled Fine Aggregate Powder was mostly made up of quartz (SiO_2) and calcite, according to X-Ray Diffraction data from characterisation experiments ($CaCO_3$). The surface of Recycled Fine Aggregate Powder particles is much harsher than that of Limestone Powder, according to Scanning Electron Microscope (SEM) data. The three principal elements contained in these fillers, according to X-Ray diffraction data, are silicon, calcium, and aluminium, with Recycled Fine Aggregate Powder having more silicon and less calcium than Limestone Powder. The use of Recycled Fine Aggregate Powder as a filler can increase the asphalt mixture's water sensitivity, high-temperature characteristics, and fatigue life. Recycled Fine Aggregate Powder, on the other hand, may produce a little reduction in the low-temperature properties of asphalt mixtures. The use of Recycled Fine Aggregate Powder as a filler in asphalt mixtures is feasible, particularly in hotter climates as per the research.

(Jayvant Choudhary 2021), The impact of the properties of construction waste fillers on the modified asphalt mixtures was investigated. Initial physical and chemical analysis revealed that almost all waste fillers have good filler properties. The Marshall and volumetric properties of waste filler modified bituminous concrete mixes were equivalent to the normal Stone Dust mix. The strength and volumetric qualities of mixtures are influenced by the physical features of the filler. Asphalt mixes with greater porosity fillers (Brick Dust, Concrete Dust and Glass Powder) than Stone Dust had higher Optimum Asphalt Content, however the Limestone Dust mix had the lowest Optimum Asphalt Content due to the lowest porosity of its filler. To evaluate the overall performance of asphalt mixtures, a ranking approach is used. According to an examination of 16 hypothetical scenarios, Limestone Dust was shown to be the best filler, following Stone Dust, Concrete Dust, Brick Dust and Glass Powder. The fineness of Limestone Dust's composition and the inclusion of calcite within the constitution were credited with its good performance. Glass Powder was determined to be worst filler due to its high silica content, which caused it to operate poorly in the influence of moisture. Apart from GP, it is determined that the wise use of other materials (Brick Dust, Concrete Dust and Limestone Dust) as fillers may provide benefits such as the conservation of natural aggregates, the manufacture of low-cost mixes, the reduction of Greenhouse Gas emissions, and the development of higher quality mixes.

(Hasan Taherkhani 2020), The mineral filler in an asphalt concrete was substituted with brick powder in various quantities in this study, and several engineering aspects were explored. As the quantity of mineral filler replaced with brick powder is increased, the mixture's Marshal Stability and Marshal Quotient improves. The resistance of the mixes to deformation rises as the fraction of mineral filler substituted with brick powder increases. The amount of air spaces, voids in mineral aggregate, and voids filled with asphalt are not affected much when mineral filler is replaced with brick powder. The indirect tensile strength of the combination improves as the fraction of mineral filler replaced with brick powder increases. At intermediate temperatures, integrating the brick powder has a greater influence on improving the indirect tensile strength of the combination. The moisture damage tolerance of the brick powder mixes is more than that of the mineral filler control mixture.

(Mrinali Rochlani 2020), The study looked at the viability of employing discarded ceramic powder as a filler in asphalt mastic. Ceramic's qualities were compared to those of limestone filler to prove its usability as a filler. Different experiments were carried out for this, ranging from a physical and chemical analysis of the fillers to various Dynamic Shear Rheometer testing on mastics to assess the rheological, rutting, and fatigue properties.

Because ceramic has a porous structure and a larger percentage of smaller particles, it has a higher specific surface area. As a result, there was more bitumen adsorption on the surface. As a result, the bitumen–filler interaction was projected to be greater. Throughout the temperature-frequency range, ceramic mastic showed a substantially higher stiffness than limestone mastic, but with lower phase angle values, indicating a desirable elastic behaviour. With the utilisation of leftover ceramic powder as a filler, there is a huge improvement potential. The use of ceramic filler would minimise waste that ends up in disposal sites by improving the rheology, rutting, and fatigue performances of mastics, and most likely also of asphalt mixtures, and will be a step forward to sustainable pavements.

(Jizhe Zhang 2020), The feasibility of employing red mud filler to replace limestone powder in asphalt mixes was studied in this research with the goal of lowering the use of non-renewable limestone filler material in asphalt mixtures. A number of experimental tests were used to evaluate the effect of red mud on asphalt mastic qualities as well as the related upgrading approaches. The surface morphologies and particle sizes of the four mineral powder materials employed as filler in asphalt mixes (limestone powder, red mud, hydrated lime, and white mud) were all distinct. The surface morphologies of powder materials may have an impact on bitumen absorption, which might affect the service qualities of asphalt mastics. The addition of red mud to the asphalt mastic stiffened it, resulting in an increase in the softening point but a decrease in penetration and ductility. The addition of a little amount of white mud can lower the softening point of red mud amended asphalt mastic and increase penetration and ductility. The asphalt mastic made using limestone powder had the lowest viscosity, whereas replacing it with red mud resulted in a roughly fourfold increase in viscosity. The viscosity of the red mud asphalt mastic was enhanced much further with the addition of hydrated lime. The viscosity of red mud asphalt mastic was marginally reduced when white mud was added. In conclusion, using red mud to replace limestone filler in asphalt mastic has proven to be feasible when a little amount of white mud is used as a modification agent.

From all the literatures shown above it can be concluded that we can use C&D waste and steel slag in Asphalt concrete in an effective manner.

3.CONCLUSION:-

The literature shows that steel slag and C&D waste in concrete plays a major role in the construction sector. Some important points are given below-

- Steel Slag Filler matching mastic has the least sensitive response to conditioning temperature and the best high-temperature rheological qualities of all steel slag filler based bituminous mixes
- under microwave irradiation, Steel Slag Filler-based asphalt mastics may release more heat than Limestone Filler-based asphalt mastics. The heating rate of Steel Slag Filler-based asphalt mastics rises as the filler-bitumen volume ratio rises.
- The use of a mix of Steel Slag Filler and Limestone Filler as a filler in an asphalt mixture might be a viable option for recycling steel slag. The combined filler should have an Steel Slag Filler percentage of less than 75% by volume.
- The inclusion of Steel Slag Powder increased the water damage resistance of asphalt mixes when compared to the other fillers.
- The addition of steel slag filler to rubber modified asphalt reduced the sensitivity of asphalt materials' frequency.
- By both static and dynamic creep tests, the use of recycled brick filler may greatly reduce permanent deformation at 60°C, resulting in enhanced rutting resistance of asphalt mixtures at high temperatures.
- The use of Recycled Fine Aggregate Powder as a filler in asphalt mixtures is feasible, particularly in hotter climates.
- Apart from Glass Powder, it is determined that the wise use of other materials (Brick Dust, Concrete Dust and Limestone Dust) as fillers may provide benefits such as the conservation of natural aggregates, the manufacture of low-cost mixes, the reduction of Greenhouse Gas emissions, and the development of higher quality mixes.
- using red mud to replace limestone filler in asphalt mastic has proven to be feasible when a little amount of white mud is used as a modification agent.

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