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DESIGN OF BITUMINOUS MIX WITH WASTE CERAMIC POWDER

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Abstract:

In recent decades, there has been a significant surge in industrial and economic growth, leading to an enhanced quality of life for citizens. However, it is crucial to acknowledge that every production system generates by-products and waste, posing potential environmental impacts. These effects can manifest at various stages in a product's life cycle, from the extraction of raw materials to manufacturing, distribution, and the disposal of end-of-life products by users.To address both economic concerns and environmental pollution, recycling waste materials emerges as a paramount solution. This investigation aims to explore the stability and properties of bituminous pavement materials through the partial replacement of fine aggregate with waste ceramic dust, with an incremental replacement of 10%.Ceramic waste originates from two primary sources – the ceramic industry and construction sites involving ceramics. Utilizing ceramic dust in pavement construction holds the potential to minimize disposal issues and reduce pollution. The primary objective of this study is to ascertain the appropriate bitumen content and mix stability necessary for ensuring a durable pavement following the partial replacement of ceramic dust. Additionally, the study seeks to identify a cost-effective blend through a meticulous examination conducted in accordance with Marshall Mix design principles. Ultimately, this investigation aims to analyze the percentage of ceramic dust that can be economically replaced in bituminous mixtures for flexible pavement design. By doing so, the study endeavors to contribute to sustainable and environmentally conscious practices within the realm of pavement construction.

Keywords: Ceramic dust, Bitumen, Aggregate, Marshall Stability test and Cost Effective

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Introduction:

The global population is continually increasing, leading to a proportional rise in various types of waste production. Unfortunately, many of these waste materials persist in the environment for extended periods. Ceramic CERAMIC dust is among the waste products generated, accounting for approximately 15%-30% of the total production in the ceramic industry (Bhavin and Bhatt, 2017).Numerous studies have explored the utilization of various waste materials, including Fly ash, Lime, Fibers, Silica Fumes, Plastics, Rubber, Synthetic, Polythene, to assess their impact on the compressive strength and durability properties of concrete. For instance, Torgal (2009) investigated the replacement of 20% of cement with ceramic waste. Sharma and Chandra (2011) examined the use of fly ashes, along with conventional stone dust, as fillers in bituminous concrete, concluding that fly ashes are effective fillers up to 7%, with a favorable outcome for those rich in calcium oxide.Reducing the optimum bitumen content in bituminous mixes by incorporating plastic-coated aggregates has been studied as an economic and environmentally beneficial solution for bituminous concrete construction (Rema and Stephen, 2013). Kumar et al. (2013) explored the replacement of Ordinary Portland Cement (OPC) with ceramic waste in M-3 grade concrete, varying the replacement percentage from 0% to 50%, and assessed the compressive strength compared to conventional concrete.Studies have also delved into the effects of using crushed ceramic in the production of interlocking paving units (Sadek et al., 2013) and the incorporation of ceramic wastes in concrete production to reduce cement and fine aggregate content (Zimbili et al., 2014). Furthermore, research has been conducted on the impact of waste ceramic CERAMICs in bituminous concrete mixes (Singh and Patel, 2015) and their utilization in flexible pavement construction (Bhavin and Bhatt, 2017).

2. Methodology:

Ceramic waste originates from various sectors like ceramic bricks, roof and floor CERAMICs, and stoneware industries, contributing significantly to the total Indian ceramic production of 100 million tons annually. Within the ceramic industry, a substantial 15%-30% of waste material is generated during production, primarily in the form of ceramic powder. For this study, ceramic dust was collected from a local construction site, and its properties are detailed below. Ceramic materials, like all substances, derive their properties from atomic-scale

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structures, influenced by the types of atoms present, bonding between atoms, and their packing arrangement. Ceramics typically consist of two or more elements, forming compounds with covalent and ionic bonds. This variety in chemical bonds results in ceramics exhibiting a wide range of properties, making them suitable for diverse applications, including being hard, wear-resistant, brittle, refractory, thermal and electrical insulators, nonmagnetic, oxidation-resistant, and chemically stable.In the study's mix design phase, the aim is to conduct a comparative analysis of asphalt mixes, incorporating partial replacements of fine aggregate with ceramic dust at varying percentages to identify optimum mix proportions. Six mix types, labeled A, B, C, and D, were investigated, each representing different combinations of fresh fine aggregate and ceramic dust.The Marshall Properties test was conducted to evaluate the performance of each mix type. Parameters such as Optimum Bitumen Content (OBC), Marshall stability, flow value (0.25mm), and Marshall stiffness (KN/mm) were measured and tabulated. Graphs depicting bitumen content versus Marshall properties were plotted to determine OBC, ensuring compliance with Ministry of Road Transportation Highways (MORTH) standards, which stipulate air voids between 3%-5%.Material selection and preparation followed industry standards and best practices, including specific gravity measurements and sieve tests for aggregates. Asphaltic materials were sourced, considering natural deposits or refined products, adhering to Indian standards.The casting of specimens for the Marshall Stability Test, a common method for assessing asphalt mix strength and stability, involved the preparation and testing of cylindrical specimens comprising asphalt binder and aggregate mixtures. The results of these comprehensive tests contribute valuable insights for optimizing asphalt mixes with the inclusion of ceramic waste, aligning with sustainable and efficient construction practices.

Experimental study

The testing procedure involves a series of evaluations to assess the characteristics of coarse aggregates, such as fineness modulus, specific gravity, water absorption, Los Angeles abrasion, impact value, crushing strength, penetration, ductility, and softening point of bitumen. Here's a detailed summary of each test:

Fineness Modulus:

The fineness modulus is determined using a set of IS sieves of various sizes. A 2000-gram sample of coarse aggregate is taken and sieved manually or mechanically. The weights of

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aggregates retained in each sieve are recorded, and the fineness modulus is calculated to assess the mean size of particles.

Specific Gravity:

The specific gravity of the coarse aggregate is determined using a specific gravity bottle. The sample is weighed in air, weighed in water, and weighed in a kerosene-filled bottle. The specific gravity is then calculated based on these measurements.

Water Absorption:

Water absorption is determined by placing an oven-dried soil sample in a pycnometer, adding water, and measuring the mass changes. The specific gravity of the sample is calculated using the formula provided.

Los Angeles Abrasion:

This test assesses the percentage wear due to rubbing action between aggregates and steel balls. The aggregates, placed in a Los Angeles abrasion testing machine, undergo rotations based on their grading. The crushed aggregates are sieved, and the material retained is weighed.

Impact Test:

The aggregate impact test evaluates the toughness of stones by subjecting aggregates to impact in a cylindrical steel cup. The apparatus includes a cylindrical metal measure, steel tamping rod, balance, and sieves. The crushed aggregates are sieved on a 2.36 mm IS sieve, and the material passing through is weighed.

Crushing Strength:

The aggregate crushing test involves applying a gradually increasing compressive load until failure. The apparatus includes a steel cylinder, cylindrical measure, steel tamping rod, and compression testing machine. The crushed aggregates are sieved, and the material passing through is weighed.

Penetration:

The bitumen penetration test measures the depth to which a standard needle penetrates a bitumen sample. The test is performed at specific conditions of temperature, load, and time. Various grades of bitumen are classified based on penetration values.

Ductility:

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The bitumen ductility test determines the distance of elongation before breaking. A briquette of bitumen is stretched until it breaks, and the distance is recorded. Ductility is crucial for the formation of ducCERAMIC thin films around aggregates in flexible pavement construction.

Softening Point of Bitumen:

The softening point test measures the temperature at which a cylindrical bitumen sample softens enough for a steel ball to fall through. The apparatus includes a ring and ball apparatus, a bath, and a mechanical stirrer.

Marshall Stability:

The Marshall Stability Test assesses the resistance of a compacted bituminous mixture to deformation and failure under compressive loads. It involves proportioning and mixing aggregates and bitumen, compacting the mixture, and conducting stability and flow tests.

This comprehensive testing regimen ensures a thorough evaluation of coarse aggregate properties, aiding in the selection and design of optimal bituminous mixes for pavement construction.

3. Results and Discussion

Air voids and Bitumen

Air Voids	$V_u = \frac{(G_t - G_m)X100}{G_t}$			
Bitumen Content	CERAMIC Powder			
	0	10	20	30
4	6.533	5.347	4.372	3.575
4.5	6.683	4.117	3.857	3.716
5	8.281	6.563	4.299	3.992

Percentage of volume of Bitumen

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Percentage of Volume of Bitumen	$V_b = \dfrac{\frac{W_b}{G_b}}{\frac{W_1 + W_2 + W_3 + W_b}{G_m}}$			
Bitumen Content	CERAMIC Powder			
	0	10	20	30
4	0.098	0.100	0.101	0.102
4.5	0.106	0.109	0.109	0.109
5	0.115	0.177	0.120	0.120

Voids in Mineral Aggregate

Voids in Mineral Aggregate	$VMA = V_v + V_b$			
Bitumen Content	CERAMIC Powder			
	0	10	20	30
4	6.632	5.447	4.473	3.677
4.5	6.790	4.226	3.967	3.826
5	8.397	6.681	4.420	4.113

Percentage of volume of Bitumen

Percentage of Volume of Bitumen	$VFB = \dfrac{V_b x100}{VMA}$			
BITUMEN CONTENT	CERAMIC POWDER			
	0	10	20	30
4	1.491	1.838	2.262	2.775
4.5	1.565	2.584	2.761	2.867
5	1.376	1.762	2.727	2.941

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Percentage of CERAMIC Powder

CERAMIC Powder Percentage	Bitumen content, %	Air voids (%)	VMA (%)	VFB (%)	Stability (kg)	Flow value (mm)	Bulk Density (g/cc)
0	4	6.533	6.632	1.491	1457.345	5.633	2.361
	4.5	6.683	6.790	1.565	1626.269	6.466	2.365
	5	8.281	8.397	1.376	1549.406	7	2.351
10	4	5.347	5.447	1.838	1851.934	6.233	2.343
	4.5	4.117	4.226	2.584	1584.581	5.566	2.345
	5	6.563	6.681	1.762	1475.584	5.5	2.353
20	4	4.372	4.473	2.262	1288.277	4.433	2.323
	4.5	3.857	3.967	2.761	1388.878	4.533	2.333
	5	4.299	4.420	2.727	1347.190	3.733	2.354
30	4	3.575	3.677	2.775	1204.611	5.466	2.361
	4.5	3.716	3.826	2.867	1136.868	6.766	2.348
	5	3.992	4.113	2.094	1237.614	3.433	2.381

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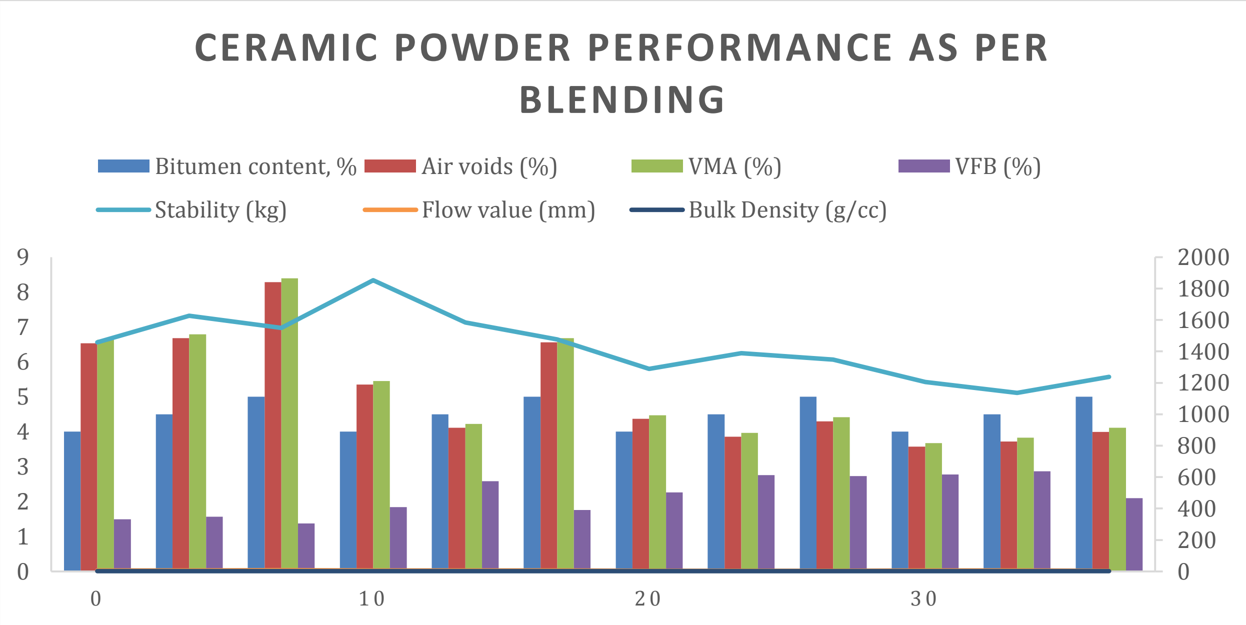

Conclusions

The chips derived from waste CERAMICs prove to be suitable as fine aggregates in bituminous mixes, as confirmed by their favorable physical properties. When utilized as fine aggregates in bituminous mixes, these CERAMIC waste chips successfully meet the criteria outlined in the Marshall Mix design. The incorporation of ceramic waste in bituminous macadam, within specific limits, yields noteworthy values for Marshall stability and lower Marshall flow. As the content of ceramic waste increases, the optimal bitumen content varies accordingly. The gradual increase in Marshall stability corresponds to higher percentages of ceramic CERAMIC dust. Consequently, it is advisable to consider using elevated replacement percentages, up to 30%, for fine aggregates to optimize the performance of bituminous mixes.

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