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EVALUATING THE MECHANICAL PROPERTIES OF THE AGGREGATES WITH PARTIAL REPLACEMENT OF CERAMICS

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Abstract— *A* ***ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments. Ceramics generally can withstand very high temperatures, ranging from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F). Glass is often not considered a ceramic because of its amorphous (non crystalline) character. However, glassmaking involves several steps of the ceramic process, and its mechanical properties are similar to ceramic materials. In this context, ceramics are being used as aggregates and then these ceramics are being replaced with aggregates by 30% of the total weight of ceramics. The tests performed are Aggregate impact test, aggregate crushing test, aggregate abrasion test, and specific gravity and water absorption test. The results of both the cases i.e. tests performed only on ceramics and tests performed by replacing 30% of ceramics are compared and the appropriate conclusions are given.***

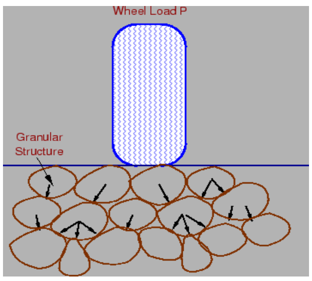
Keywords— Bitumen, Crushed stones, Ceramic Materials

I. INTRODUCTION

Pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

A. Flexible Pavements:

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure



The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement,
- Full - depth asphalt pavement, and
- Contained rock asphalt mat (CRAM).

1. Conventional flexible pavements are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

2. Full - depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.

3. Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers. Modified dense graded asphalt concrete is placed above the sub-grade will significantly reduce the vertical compressive strain on soil sub-grade and protect from surface water

B. Layers Of A Flexible Pavement:

1. Seal Coat: Seal coat is a thin surface treatment used to water-proof the surface and to provide skid resistance.

2. Tack Coat: Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layers of binder course and must be thin, uniformly cover the entire surface, and set very fast.

3. Prime Coat: Prime coat is an application of low viscous cutback bitumen to an absorbent surface like granular bases on which binder layer is placed. It provides bonding between two layers. Unlike tack coat, prime coat penetrates into the layer below, plugs the voids, and forms a water tight surface.

Surface course: Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course: This layer provides the bulk of the asphalt concrete structure. It's chief purpose is to distribute load to the base course The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course: The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course: The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade: The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

II. CERAMICS

Ceramics are classified as inorganic and nonmetallic materials that are essential to our daily lifestyle. Ceramic and materials engineers are the people who design the processes in which these products can be made, create new types of ceramic products, and find different uses for ceramic products in everyday life. Ceramics are all around us. This category of materials includes things like tile, bricks, plates, glass, and toilets. Ceramics can be found in products like watches (quartz tuning forks-the time keeping devices in watches), snow skies (piezoelectric-ceramics that stress when a voltage is applied to them), automobiles (sparkplugs and ceramic engine parts found in racecars), and phone lines. They can also be found on space shuttles, appliances (enamel coatings), and airplanes (nose cones). Depending on their method of formation, ceramics can be dense or lightweight. Typically, they will demonstrate excellent strength and hardness properties; however, they are often brittle in nature. Ceramics can also be formed to serve as electrically conductive materials, objects allowing electricity to pass through their mass, or insulators, materials preventing the flow of electricity. Some ceramics, like superconductors, also display magnetic properties. Ceramics are generally made by taking mixtures of clay, earthen elements, powders, and water and shaping them into desired forms. Once the ceramic has been shaped, it is fired in a high temperature oven known as a kiln. Often, ceramics are covered in decorative, waterproof, paint-like substances known as glazes.

Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%- 30% waste material generated from the total production. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

USE OF CERAMICS IN ROAD CONSTRUCTION

HMA(Hot Mix Asphalt) which is composed of bitumen and aggregate is used in road construction all over the world. HMA contains approximately %5 bitumen and %95 aggregate materials, by weight. Bitumen is obtained from the distillation of petroleum. Because of the reduction in natural resources like petroleum and high quality aggregate, the production cost of HMA is increasing day by day. On the other hand at the construction of base and sub-base courses under pavement, the usage of determined aggregate gradations due to natural sub grade increases the importance of aggregate. Day by day industrial waste reduction becomes priority for governments due to pollution and because of that the importance of waste material usage in road construction increases.

III. TESTS AND RESULTS OF CERAMIC MATERIALS

In order to know the behavior of ceramic waste, the following tests are performed. They are

- Impact test
- Crushing test
- Abrasion test
- Specific gravity test
- Water absorption test

COMPARISION OF THE RESULTS

property	waste ceramic tiles	ceramic waste along with aggregates
1. Impact Value	30.77%	23%
2. Crushing Value	25.4%	28.8%
3. Abrasion Value	51.6%	30%
4. Specific Gravity	2.5	2.5
5. Water	14.14%	10.10%

IV. MARSHALL MIX DESIGN

The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded.

The important steps involved in marshal mix design are summarized next. 26.3 Specimen preparation approximately 1200gm of aggregates and filler is heated to a temperature of 175−190oC. Bitumen is heated to a temperature of 121 − 125oC with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154 − 160oC. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138oC to 149oC. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0.5% and repeat the above procedure. Numbers of trials are predetermined. The prepared mould is loaded in the Marshall Test setup.

TABLE: 1.SPECIFIC GRADING OF AGGREGATES AND BINDER FOR BITUMINOUS CONCRETE

Nominal aggregate size	19 mm	13 mm
Layer thickness	50-65 mm	30-45 mm
Sieve size in, mm	Percentage passing by wt.	
	Grade-I	Grade-II
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10

The test was initially performed with pure ceramic tiles. As there is no binding property between the ceramics and the bitumen, the sample broke immediately after removing the mould as shown in fig.


The ceramics are then replaced by aggregates by 50% of the total weight and the sample is prepared. The sample is failed as shown in fig.

V. CONCLUSION

Laboratory tests were performed for defining the physical properties of ceramic aggregate and found to be within acceptable limits as per the Indian standards which show that ceramic waste is feasible to utilize as aggregate material in flexible pavement. Ceramic waste used in bituminous macadam up to certain limits gives considerable value of marshal stability and lower marshal flow value. By increasing the value of ceramic waste in replacement of natural aggregate decrease in marshal value and increase in flow value. Optimum bitumen content varies with the increase with the ceramic waste content.

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