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Replacement of sand by marble dust and furnace slag in pavement quality concrete of rigid pavement

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ABSTRACT

The demand for usage of industrial by-products and wastes in road pavements is increasing and becoming more important. Government policies and public awareness are also contributing to the enhancement of both this demand and utilization. Various slags such as blast furnace and steel slag have been widely used in road pavements. Therefore, it could be possible to prevent the environmental pollution and to consume fewer natural resources as well through its utilization in increasing demand for road construction. The present study aims at developing pavement quality concrete mixtures incorporating marble dust and furnace slag as a partial fine aggregate replacement material. In this study, the use of marble dust and furnace slag by replacing sand in pavement quality concrete of rigid pavement s are reported and the effect on the slab thickness of PQC pavement for the achieved strength of the concrete mixtures incorporating marble dust and furnace slag has also been studied. The study shows that the marble dust cab be effectively replaced sand up to 15% and furnace slag can be used up to 20% as replacement of sand in PQC. The maximum flexural strength is achieved for the mix containing 10% marble dust and 10% furnace slag as partial replacements of sand. The flexural strength increase is significant for mixes containing marble dust and furnace slag, with a combination up to certain limits of 25 to 30% in development of pavement quality concrete.

Keywords— *Pavement quality concrete (PQC), Dry lean concrete (DLC), Marble dust (MD), Furnace slag, Sand*

1. INTRODUCTION

Concrete is a material that is used everywhere, serving as the core material of modern structures and our many miles of roadways. Modern concrete is composed of an aggregate that is bonded with fluid cement. The aggregate is basically bits of rocks and gravel that serve to reinforce and strengthen the concrete. Aggregates are the most mined materials in the world. Most modern concrete uses Portland cement and water. The Portland cement usually comes from limestone and is turned into a fine powder that is produced by heating it to high temperatures. It is also called hydraulic cement, which means it hardens by reacting with water.
Cement concrete pavements represent the group of rigid pavements. The load carrying capacity is mainly due to rigidity and high modulus of elasticity of the slab.

1.1 Introduction of concrete pavement

The first strip of concrete pavement was completed in 1893; concrete has been used extensively for paving highways and airports as well as business and residential streets. There are four types of concrete pavement:

- Plain pavements with dowels that use dowels to provide load transfer and prevent faulting.
- Plain pavements without dowels, in which aggregate interlock transfers loads across joints and prevents faulting.
- Conventionally reinforced pavements that contain steel reinforcement and use dowels in contraction joints.
- Continuously reinforced pavements that have no contraction joints and are reinforced with continuous longitudinal steel.

1.2 There are three main components of road pavement

- Foundation
- Base
- Surfacing

The foundation comprises of some grade soil (cut or fill), capping and sub the base. The foundation is designed to provide a certain standard quality of support for the higher layers. The base is the main structural layer of the pavement. Meanwhile, an asphalt surfacing compromise of a surface course and a binder course. The function of the surfacing is to enable good ride quality to be combined with appropriate resistance to skidding and resistance to crack formation.

A concrete pavement, in general, consists of three layers, compromising of a sub-grade, base layer, and the concrete slab. Generally, bound base layers are used for concrete pavement construction. As per Indian specification, some example of such base layers is Dry Lean concrete (DLC), Roller Compacted Concrete (RCC) (IRC: 15-2002). The concrete slab is generally of M40 to

M50 grade of concrete as per Indian specifications and is called as paving quality concrete (PQC). There are two methods for paving with concrete-slip form and fixed form. In slip form paving, a machine rides on treads over the area to be paved—similar to a train moving on a set of tracks. Fresh concrete is deposited in front of the paving machine which then spreads, shapes, consolidates, screeds, and float finishes the concrete in one continuous operation. This operation requires close coordination between the concrete placement and the forward speed of the paver. Fixed-form paving, stationary metal forms are set and aligned on a solid foundation and staked rigidly. Final preparation and shaping of the subgrade or sub base are completed after the forms are set. Forms are cleaned and oiled first to ensure that they release from the concrete after the concrete hardens. Once the concrete is deposited near its final position on the subgrade, spreading is completed by a mechanical spreader riding on top of the preset forms and the concrete. The spreading machine is followed by one or more machines that shape, consolidate, and float finishes the concrete. After the concrete has reached a required strength, the forms are removed and curing of the edges begins immediately.

2. DESCRIPTION AND MATERIAL TESTING

2.1 Portland cement

It is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, and non-specialty grout. It was developed from other types of hydraulic lime in England in the mid-19th century and usually originates from limestone. It is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. Several types of Portland cement are available. The most common, called ordinary Portland cement (OPC), is grey in color, but white Portland cement is also available

2.2 Coarse aggregates

Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve and will pass through the 3-inch screen are called coarse aggregate. The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area

2.3 Fine Aggregate

Those particles passing the 9.5 mm (3/8 in.) sieve, almost entirely passing the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregate. For increased workability and for the economy as reflected by the use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

2.4 Marble Dust

Marble waste as a by-product is a very important material which requires adequate environmental disposal effort. In addition, recycling waste without proper management can result in environmental problems greater than the waste itself. Marble dust is a waste product formed during the production of marble. A large quantity of powder is generated during the cutting process. The result is that about 25% of the original marble mass is lost in the form of dust. Leaving these waste materials to the environment directly can cause environmental problems such as increases the soil alkalinity, affects the plants, affects the human body etc. Marble powder can be used as an admixture in concrete, so that strength of the concrete can be increased. It is a solid waste material generated from the marble processing and can be used either as a filler material in cement or fine aggregates while preparing concrete. The production of cheaper and more durable concrete using this waste can solve to some extent the ecological and environmental problems

2.5 Blast Furnace Slag

Blast furnace Slag is a non-metallic by-product produced in the process of iron production by chemical reduction in a blast furnace. It consists primarily of calcium silicates, alumina silicates, and calcium-alumina-silicates.

3. PROCEDURE: COMPRESSIVE STRENGTH TEST OF CONCRETE CUBES

For cube test, two types of specimens either cubes of 15cm ×15cm ×15cm or 10cm ×10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

The concrete is poured into the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on the whole area of the specimen.

Compressive strength is one of the most important engineering properties of concrete. It is a standard industrial practice that the concrete is classified based on grades. This grade is nothing but the Compressive Strength of the concrete cube or cylinder. Cube or Cylinder samples are usually tested under a compression testing machine to obtain the compressive strength of concrete. The test requisites differ from country to country based on the design code.

As per Indian codes, the compressive strength of concrete is defined as the compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 28 days (fck). The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

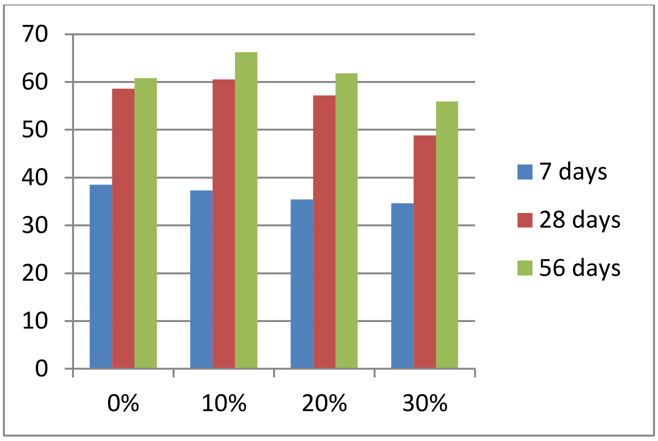

Fig. 1: Variation of compressive strength of concrete with different % replacement levels of furnace slag for 5% marble dust at different curing age

3.1 Flexural Strength Of Concrete

Most of the concrete, which is used in highway or airport pavements, is subjected to flexure and is evaluated by applying bending tests. As the flexural strength of concrete has a direct relationship with the thickness of the slab its evaluation become the most important component of the pavement design. When concrete is subjected to bending, then tensile and compressive stress and in many cases direct shear stresses are also developed. The deflection and cracking behaviour of the concrete structure to a large extent depend upon the flexural strength of the concrete, particularly the level of stress, size, age and confinement to the concrete flexural member.

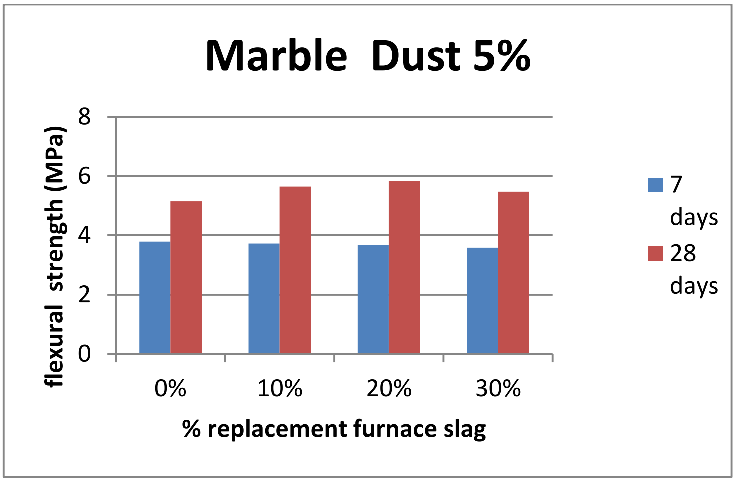

Fig. 2: Variation of flexural strength of concrete with different % replacement levels of furnace slag for 5%MD at different curing ages

4. CONCLUSIONS

4.1 The conclusions drawn from the study are elaborated as under:

1) Furnace slag, being a pozzolanic material, results in less early age compressive strength, It is used as an ideal replacement for sand if strengths are required at a later stage is a priority, whereas marble dust would serve well for mixes where strength at an early stage is a priority.
2) To achieve higher than designated compressive strength, the optimum replacement level of sand with both the materials, marble dust and furnace slag used in combination is 20 to 25% only.
3) Highest early stage strength, 7 days, could be achieved by using only 10% marble dust as sand replacement and highest strength at 28 days could be achieved by using 10% furnace slag and 15% marble dust and strength at 56 days could be achieved by combination of 20% furnace slag and 5% marble dust.
4) Furnace slag, being a pozzolanic material can be used as an ideal replacement for sand if later stages flexural strengths are a priority, whereas marble dust would serve well for mixes where early-stage flexural strength is the need.
5) Highest strength flexure at 7 days could be achieved by using only 15% marble dust as a sand replacement with 10% furnace slag in combination and highest flexural strength at 28 days could be achieved by using a combination of 10% marble dust and 10% furnace slag.
6) As the compressive strength increase is significant for mixes containing marble dust and furnace slag, these materials can be used in combination up to certain limits of 20% and for the flexural strength the material can be used in limits of 25 to 30% in development of pavement quality concrete that will not only fulfill the conditions but also save the other ingredients in the concrete and lead to an economic design for the concrete slab for the concrete slab of the pavement.

5. SCOPES FOR FURTHER WORK

In the present study experimental program was devised to study the strength characteristics of mixes containing marble dust and furnace slag. The work can be extended to study the durability characteristics as well.

The performance of the pavement quality concrete slabs containing marble dust and furnace slag can be evaluated by constructing the trial stretches. The behavior of these PQC slabs can be analyzed under repetitive loading for the fatigue life consumed.

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