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Experimental Investigations on Low Volume CC Pavements Replacing Natural Sand by Manufactured Sand

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Abstract

Concrete has been in use since time immemorial. There are evidence that the earliest civilizations of this planet used concrete for its utility in different purpose and ways. It is a composite material composed mainly of water, aggregates and cement. Now a days concrete is playing vital role in highway constructions as rigid pavement. As there is increase in highway developmental activities, it leads to higher demand of sand, which can be fulfilled by sand mining from surface water bodies. Due to disastrous environmental consequences, extraction of sand from surface water bodies is restricted to some extent. This leads to scarcity of sand, to overcome this manufactured sand (M sand) can be used as partial replacement of natural sand. Aim of present study is to find optimum content of M sand in M25 grade concrete as partial replacement of natural sand from 0% up to 45% with 15% variation. To find the optimum content of M sand the mechanical strength parameters viz., compressive strength and flexural strength tests were conducted.

Keywords- Low volume CC pavements, M sand (manufactured sand,), M 25 grade concrete.

I. INTRODUCTION

The word concrete comes from the Latin word "concretus" (meaning compact or condensd), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow).Perhaps the earliest known occurrence of cement was twelve million years ago. A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned due to natural causes. These ancient deposits were investigated in the 1960s and 1970s. The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years. Concrete is a composite material composed mainly of water, aggregate, and cement. Natural or River sand are weathered and worn out particles of rocks and are of various grades or sizes depending upon the amount of wearing. Now-a-days good sand is not readily available, it is transported from a long distance. Those resources are also exhausting very rapidly. So it is a need of the time to find some substitute to natural river sand. The artificial sand produced by proper machines can be a better substitute to river sand. The sand must be of proper gradation (it should have particles from 150 microns to 4.75 mm in proper proportion). When fine particles are in proper proportion, the sand will have fewer voids. The cement quantity required will be less. Such sand will be more economical. Demand for manufactured fine aggregates for making concrete is increasing day by day as river sand cannot meet the rising demand of construction sector. Natural river sand takes millions of years to form and is not repleneshible. Because of its limited supply, the cost of Natural River sand has sky rocketed and its consistent supply cannot be guaranteed. Under this circumstances use of manufactured sand becomes inevitable. River sand in many parts of the country is not graded properly and has excessive silt and organic impurities and these can be detrimental to durability of steel in concrete whereas manufactured sand has no silt or organic impurities however, many people in India have doubts about quality of concrete/mortars when manufactured or artificial sand are used. Manufactured sand have been regularly used to make quality concrete for decades in India and abroad.

1.1. Manufactured sand:

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminium silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling. In an integrated steel plant, 2 to 4 tons of wastes (including solid, liquid and gas) are generated for every ton of steel produced. Accordingly, today the emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimizing the adverse impact of disposal on the environment. Among all the solid/liquid wastes, slags generated at iron making and steel making units are created in the largest quantities. With increasing capacities, disposal of large quantities of slag becomes a big environmental concern and a critical issue for steel makers. At the same time, the re-use of iron and steel making slags has also been expanded, and has led to a significant reduction in the environmental impact of these by-products. However, slag generation remains inevitable and emphasis on its recycling remains the greatest concern.

1.1.1 Properties of slag:

Physical properties

Steel slag aggregates are highly angular in shape and have rough surface texture. They have high bulk specific gravity and moderate water absorption (less than 3 percent).

Table 1: *Physical properties of slag*

Property	Value
Specific Gravity >	2.6 - 3.0
Unit Weight, kg/m^3 (lb/ft^3)	1600 - 1920 (100 - 120)
Absorption	Up to 3%

Chemical properties

The chemical composition of slag is usually expressed in terms of simple oxides calculated from elemental analysis determined by x-ray fluorescence. Virtually all steel slags fall within these chemical ranges but not all steel slags are suitable as aggregates. Of more importance is the mineralogical form of the slag, which is highly dependent on the rate of slag cooling in the steel-making process.

Table 2: *Chemical properties of slag*

Property	Value
CaO	40 – 52
SiO_2	10 – 19
FeO	10 – 40 (70 - 80% feo, 20 - 30% Fe2O3)
MnO	5 – 8
MgO	5 – 10
Al_2O_3	1 – 3
P_2O_5	0.5 – 1
S	< 0.1
Metallic Fe	0.5 – 10

Mechanical properties

Processed steel slag has favorable mechanical properties for aggregate use, including good abrasion resistance, good soundness characteristics, and high bearing strength.

Table 3: *Mechanical properties of slag*

Property	Value
Los Angeles Abrasion (ASTM C131), %	20 – 25
Sodium Sulfate Soundness Loss (ASTM C88), %	<12
Angle of Internal Friction	40° - 50°
Hardness (measured by Mohr's scale of mineral hardness)*	6 – 7
California Bearing Ratio (CBR), % top size 19 mm (3/4inch)**	Up to 300
* Hardness of dolomite measured on same scale is 3 to 4. ** Typical CBR value for crushed limestone is 100%.	

1.2. Pavements:

A highway pavement is designed to support the wheel loads imposed on it from traffic moving over it. Additional stress also imposed by changes in environment. It should be strong enough to resist the stresses imposed on it and it should be thick enough to distribute the external loads on the earthen sub-grade, so that the subgrade itself can safely bear it. Pavements are categorized as Flexible pavements, Rigid pavements, Semi-rigid pavements and Composite pavements. A rigid pavement derives its capacity to withstand loads from the flexural strength or beam strength permitting the slab to bridge over minor irregularities in the subgrade, sub-base or base upon which it rests. This implies the inherent of slab itself is called upon to play a major role in resisting the wheel load. Minor imperfections or localized week spots in the material below the slab can be taken care of by the slab itself. This not to under-rate the role of the subgrade soil In fact a good, stable and uniform support is necessary for a rigid pavements as well. But as long as certain minimum requirement is met with in this regard, the performance of rigid pavement is more governed by strength of the slab itself than by the subgrade support. Low volume roads may be looked upon as a special category of roads subjected to relatively small number of heavy loads not exceeding 30kN. AASHTO recommends a low level reliability (50%) for design. In terms of number of commercial vehicles plying per day, low volume roads are generally considered to be receiving more than 50 and less than 450 CVPD. The rural roads in INDIA are essentially low volume roads covering the categories of other district roads (ODR) and village roads (VR). Low volume rigid pavement design is considered as per IRC:SP:62-2014. The guidelines contained in this document are applicable only to low volume roads with average daily traffic less than 450 commercial vehicles per day. This document covers the design principles of rigid pavements of low volume roads 3.75m wide made up of conventional concrete, roller compacted concrete and self-compacting concrete. Transfers joints spacing ranging from 2.5-4m may be selected.

1.3. Problem statement and objectives of present study:

Problem statement

Aim of this experiment is to study the strength aspect of low volume cement concrete pavements. Natural sand was replaced with three percentages (15%, 30% & 45) of manufactured sand by weight. Tests were performed for strength properties, like flexural and compressive at the age of 3, 7 and 28 days for each percentage of replacement. The study was done on M25 grade of concrete. The study is experimental oriented.

Objectives

Following are the broad objectives of the dissertation work:

1. To investigate the effect of partial replacement of natural sand by manufactured sand on the strength properties of M25 grade concrete.
2. To determine optimum percentage replacement of M sand in low volume cc roads.

II. MATERIALS AND METHODOLOGY:

2.1 Cement:

Cement is a very important building material used in the construction industry. In this experiment 43 grade ordinary Portland cement (OPC) with brand name ZUARI was used for all concrete mixes. The testing of cement was done as per IS: 8112-1989. The specific gravity of cement was found to be 3.15.

2.2. Fine Aggregates:

It's all consist of clean natural sand or crushed stone sand or a combination of the two and each individually shall conform to IS:383 soil aggregate shall be free from soft partials, clay, shale, cemented particles, mica and organic and other foreign matter. The sand used for the experimental program was natural river sand (Badami sand) locally procured and was confirming to zone-II of IS 383:1970. The specific gravity of fine aggregate was found to be 2.67.

2.3. Coarse Aggregates:

Its shall consists clean, hard, strong, dense, nonporous, and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular and splintery pieces. Locally available coarse aggregate having the maximum size of 20 mm and down as per IS 383:1970 were used in the present work. The specific gravity of coarse aggregate was found to be 2.8.

2.4. Manufactured Sand:

M sand has been shown to be an effective addition for concrete providing increased compressive strength and flexural strength. M sand used in the experiment was obtained from Bellary Karnataka, available with brand name JSW GGBS sand. Specific gravity was found to be 2.7.

2.5. Water:

Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful for the finished concrete. It shall meet the requirements stipulated in IS:456. Clean water available in the laboratory, was used for the preparation of specimens and for the curing of specimens.

2.6. Mix Design:

Mix design was obtained as per IS:10262-2009 with water-cement ratio 0.48 and mix proportions presented in table 4 below.

Table 4: *Mix proportions for M25 grade concrete*

Materials	Proportion (kg/m^3)
Cement	390
Fine aggregates	700
Coarse aggregates	1180

2.7. Mixing Procedure:

First Cement, Sand, coarse aggregates were dry mixed and small quantity of water was added to make concrete paste and then remaining water was added. Mixing is done till paste become uniform. Pan mixer was used for mixing ingredients.

2.8. Casting and Curing:

The casting of specimens was done as soon as mixing was over. The concrete is filled in three layers in the cubes mould as well as in the beams mould. To remove the entrapped air in the concrete, proper compaction is carried out. Second day the mould were de-moulded and taken for curing. The curing of specimens is done by conventional curing the specimens were cured in normal water for 28days.

2.9. Testing:

For evaluating the compressive strength, specimens of size 150 x 150 x 150 mm were prepared. They were tested on 2000 kN capacity Compression Testing Machine (CTM) as per IS 516:1959. To determined flexural strength of concrete universal testing machine of 1000 KN capacity was used. For evaluating the flexural strength, beam specimens of size 100x100x500 mm were prepared. The two point loading were placed at a distance of 133 mm from each end and bottom was placed at an effective span of 400 mm as per IS 516-1959.

III. EXPERIMENTAL RESULTS AND DISCUSSION:

3.1. Compressive strength test results:

Compressive strength test was conducted on the specimens with varying percentage of M sand after 3, 7 and 28 day's curing. Table 4 shows the test results in MPa and Figure 1 presents the variation in compressive strength with increase in % of M sands.

Table 4: *Compressive strength with variation of M sand*

Type of mix	Compressive strength in MPa		
	3 days	7 days	28days
M_0	15.50	20.59	32.08
M_{15}	17.04	25.63	38.82
M_{30}	19.40	24.34	33.70
M_{45}	12.67	22.22	28.28

Where M_0 – 100% natural sand,
M_{15} – 85% natural sand + 15% M sand,
M_{30} – 70% natural sand + 30% M sand,

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M_{45} - 55% natural sand + 45% M sand.

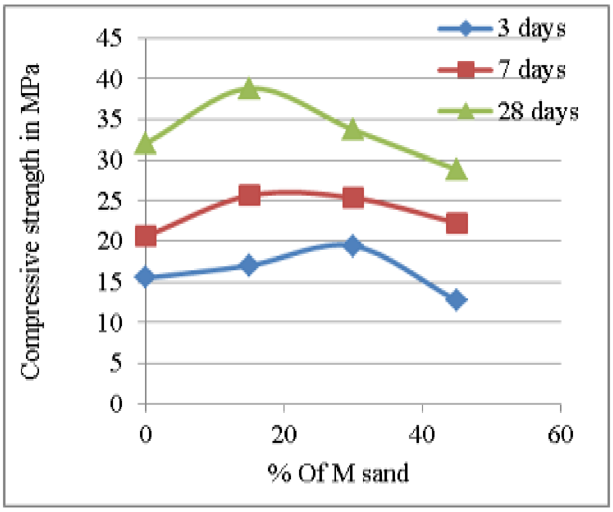

Figure 1: Variation in compressive strength with M sand

3.2. Flexural strength test results:

Flexural strength test was conducted on the specimens with varying percentage of M sand after 3, 7 and 28 day's curing. Table 5 shows the test results in MPa and Figure 2 shows the variation in flexural strength with increase in % of M sand.

Table 5: *Flexural strength with variation of M sand*

Type of mix	Flexural strength in MPa		
	3 days	7 days	28days
M_0	3.05	3.68	5.02
M_{15}	3.43	4.07	5.72
M_{30}	3.90	4.22	5.20
M_{45}	3.87	4.11	4.62

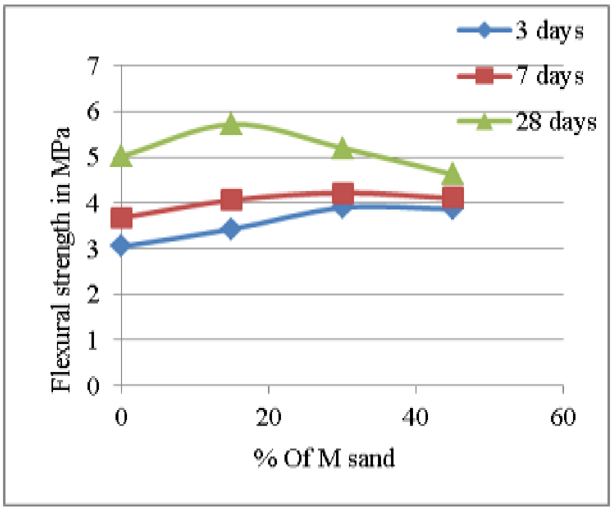

Figure 2: Variation in flexural strength with M sand

3.3. Discussions:

[1] The target compressive strength achieved for conventional concrete after 28 days curing is 32.02 MPa also flexural strength achieved for conventional concrete is 5.02 MPa
[2] When 15% of natural sand is replaced by M sand for M25 grade of concrete the compressive strength achieved after 28 days curing is 1.2 times the target compressive strength. i.e, 38.82N/mm^2 whereas flexural strength is 1.14 times the target flexural strength. i.e, 5.72N/mm^2
[3] When 30% of natural sand is replaced by M sand for M25 grade of concrete the compressive strength achieved after 28 days curing is 1.1 times the target compressive strength. i.e, 33.7 MPa where as flexural strength is 1.1 times the target flexural strength. i.e, 5.2 MPa
[3] When 45% of natural sand is replaced by M sand for M25 grade of concrete the compressive strength achieved after 28 days curing is 28.89 MPa whereas flexural strength is 4.62N/mm^2 both are less than target strength.

IV. CONCLUSIONS

M sand can be used as partial replacement of natural sand which reduces the negative environmental impact of slag and replaces the need of natural sand. The optimum replacement for natural sand by M sand was found to be 15%, also results obtained were satisfactorily good. Whereas even 30% replacement also showed higher strength which was above target strength but less than 15% replacement. Hence 15 % replacement can be used as optimum replacement and 30% can also be ued as replacement where ever availability of sand is very less.. From using M sand illegal sand mining can be stopped which preserves natural resource.

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