Effect of Steel Fibers and Marble Dust on Strength Characteristics of Pavement Quality Concrete

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Abstract— **This study shows at that in view of the high flexural strength, high values of compressive strength and high values of split tensile strength, higher load carrying capacity and higher life expectancy, the combination of 10 to 20% marble dust replacement along with addition of 0.5 to 1% steel fibers is ideal for design of Pavement Quality Concrete (PQC). This study also shows developing pavement quality concrete mixtures incorporating marble dust as partial replacement of cement as well as steel fibers.**

Index Terms— **Pavement Quality Concrete (PQC), high strength concrete (HSC), Aggregates, Marble)**

I. INTRODUCTION

As we know Concrete is a versatile construction material. Firstly it was innovated as protective cover of steel members, after that it was revised and now a day's concrete is used as a structural member and steel is provided to modify its properties and give better strength to the concrete. Concrete has benefits like fire resistance, excellent resistance to water, has ability to mould into various shapes and sizes easily as per requirement, economic and readily available material on the job site. It was observed that the normal concrete have many inadequacy such as low value of strength to weight ratio as compared to steel. So as to overcome this inadequacy resulted in the development of high strength concrete (HSC).

Now a day, with the excessive use of admixtures and widely distributed application of concrete technology, it is easy to attain cylinder strength of 50MPa in 12 to 18 hours and near to 70MPa or above at 28 days. As per economic point of view, it is very important to design a higher proportion of the available strength of concrete with efficiency and effectively rather than a smaller proportion of much higher strength.

II. SELECTION OF MATERIAL

A. Cement :

The development of HSC will require the utilization of a Portland cement of optimum quality from workability and strength point of view. Variation in cement will cause the concrete compressive strength to fluctuate more than any other single material.

Following physical properties are required for cement to be used in HSC

Maximum Blaine fineness	: 4000 cm^2/gm
Minimum 7 days mortar cube strength	: 28.959 MPa
Mortar air content	: 7 to 10 percent

B. Other Cementitious Material :

The cementitious materials other than Ordinary Portland cement, mainly consist of silica fume or fly ash, which has been considered in the production of High Strength concrete (HSC) because as per requirement high cementitious materials content and low W/(C+P) ratio (W = water content, C = cement content, P = pozzolona cement). These materials can help control the temperature rise in concrete at early ages and can reduce the water demand for given workability. On the other hand the early strength gain of concrete may decrease.

C. Water- cement ratio :

The acceptability of water for High Strength Concrete (HSC) is not major problem if potable type water is used. The evolution of High Strength concrete (HSC) requires a w/c (water-cement) ratio in the range of 0.30 to 0.40.

The following are the maximum w/c (water-cement) ratio is necessary to produce the High Strength Cement (HSC) in the range of 41.38MPa to 62.07MPa.

Strength Specified	Max. W/c ratio
41.38MP	0.38
51.78MPa	0.36
62.07MPa	0.34

D. Coarse Aggregate :

Coarse aggregates make up the bulk of a concrete mixture. Sand natural gravel and crushed stone are used mainly for this purpose. Carefully consideration should be adopted at the time of giving proper size, shape, mineralogy and surface texture. High strength aggregate are not suitable for concrete because of their very high modulus of elasticity as compared with the modulus of a cement paste due to this contrary stress concentrations occur which damages the concrete in mechanical behaviour. The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material.

It was observed that the size of coarse aggregate regulate the concrete strength apart from W/c ratio. For a given W/c ratio, the strength of concrete is decreased as the maximum size of coarse aggregate is increased. It was also observed that for optimum compressive strength with high cement contents and low water cement ratios, the maximum size of coarse aggregate should be kept minimum at the rate of 12.5 mm or 9.5 mm. "It was suggested that ideal aggregate should be angular, clean, cubical, 100 percent crushed and continuously graded with a minimum of flat and elongated particles".

E. Fine Aggregate :

The characteristics property and quality of fine aggregates affect the properties of concrete in fresh as well as in hardened state. Redistribution of aggregates after compaction often creates in homogeneity due to the influence of vibration. This can lead to strength gradients. The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material.

The grading of fine aggregate regulate the workability of concrete at a particular water content of the concrete mix as the surface of these fine aggregates is relatively much higher than that of coarse aggregates. Sand which has fineness modulus below 2.5 produced concrete to sticky consistency due to this sticky behavior it is very difficult to compact However Sand which has fineness modulus of about 3.0 gave the optimum compressive strength and workability. Fine aggregate with fineness modulus in the range of 2.5 to 3.2 is suitable for production of High Strength concrete (HSC).

F. Admixtures :

Concrete is essentially made from five materials, namely, air, water, cement, fine aggregate, and coarse aggregates. The first three constituents, when mixed together, form the binder paste; on adding fine aggregates only to the paste forms mortar; whereas, when all the constituents are mixed together, concrete is formed.

An admixture is a material added to the batch of concrete before or during its mixing to modify its freshly mixed, setting or hardened properties. About 80% of concrete produced in North America have one or more admixtures. About 40% of ready-mix producers use fly ash. About 70% of concrete produced contains a water-reducer admixture. One or more admixtures can be added to a mix to achieve the desired results. The main reasons for using admixtures are as enumerated below:

- Increase slump and workability;
- Retard or accelerate initial setting;
- Reduce or prevent shrinkage;
- Modify the rate or capacity for bleeding;
- Reduce segregation;
- Improve pump ability and finish ability;
- Retard or reduce heat evolution during early hardening;
- Accelerate the rate of strength development at early ages;
- Increase strength (compressive, tensile, or flexural);
- Increase durability or resistance to severe conditions of exposure
- Decrease permeability of concrete;
- Control expansion caused by the reaction of alkalis with potentially reactive aggregate constituents;
- Increase bond of concrete to steel reinforcement (bonding);
- Increase bond between existing and new concrete;
- Improve impact and abrasion resistance (hardness);
- Inhibit corrosion of embedded metal;
- Gas-forming;
- Anti-washout;
- Foaming; and
- Produce coloured concrete.

There admixtures are mainly classified into two groups, viz. chemical admixtures and mineral admixtures, respectively.

a) Chmeical Admixtures :

Chemical admixtures reduce the cost of construction, modify the properties of concrete and improve the quality of concrete during mixing, transportation, placing and curing. In production of High strength concrete, decreasing the W/C by decreasing the total cementitious materials content will usually produce higher compressive strength. Due to this reason, use of chemical admixture should be considered when developing High strength concrete (HSC). The various types of chemical admixtures are classified, based upon their use in concrete, as

1. Air-entrainment
2. Water-reducing
3. Set-retarding
4. Accelerating
5. Super-plasticizers
6. Corrosion-inhibitors
7. Shrinkage-reducers
8. Alkali-silica reactivity reducers

The water reducers which are capable of reducing water content by about 30 percent are popularly known as Super-plasticizers (SPs) or High range water reducers (HRWR). The super-plasticizers are classified into four categories:

A. Sulphonated melamine-formaldehyde condensates (SMF)
B. Sulphonated naphthalene-formaldehyde condensates (SNF)
C. Modified lignosulphonates (MLS)
D. Other such as sulphonic acid esters, carbohydrate esters etc.

Normal dosage of super-plasticizers in High strength concrete (HSC) is b/w 0.3 % and 1.5% by weight of cement. The potential advantages of HRWR include significant water reduction; reduced cement contents; increased workability; rapid rate of early strength development; increased long- term strength; and reduced permeability. However, with advantages there are some linked disadvantages of using HRWR in concrete, which are enumerated as below:

- Additional admixture cost (the concrete in-place cost may be reduced);
- Slump loss greater than conventional concrete;
- Modification of air-entraining admixture dosage;
- Less responsive with some cement;
- Mild discoloration of light-coloured concrete; and
- Air-void and colour blemishes on exposed and formed finishes.

b) Mineral Admixtures :

Mineral admixtures reduce cost, reduce permeability, increase strength and change other concrete properties.

The three main mineral admixtures, which are very frequently used in concrete, are as listed below:

1. Fly ash;
2. Silica fume, and
3. Ground Granulated Blast Furnace Slag.

III. OBJECTIVES OF THE PURPOSED WORK

The main objective of the proposed work is to study the effect of steel fibres on strength characteristics of Pavement Quality Concrete. Additionally, the effect of partial replacement of cement by marble dust had also been proposed to be studied

IV. LITERATUREREVIEWS

Bhikshmaet al. (2009) ,reported that high performance concrete are being widely used all over the world. Most applications of high strength concrete have been in high rise buildings, long span bridges and in some special applications in structures. In high strength concrete, it is necessary to reduce the water/cement ratio and which in general increases the cement content. To overcome low workability problem, different kinds of pozzolanic mineral admixtures fly ash, rice husk ash, metakaoline, etc. and chemical admixtures are used to achieve the required workability.

Nuruddinet al. (2010), concluded that the increase production of Portland cement causes great concern on the environment because of high carbon footprint. Besides CO2 emission, quarrying of raw materials (limestone and clay) for the production of cement is becoming the source of environmental degradation.

Katzer(2011),concluded the results of steel fibre reinforced cement composites (SFRCC) modified by super- plasticizers based on different chemical substances. The SFRCC were made on the basis of fine aggregate cement matrix modified by steel fibres of an aspect ratio 1/d= 50. Fine aggregate matrix composed of waste aggregate (obtained during hydro classification) was modified by an addition from 0% to 2.8% (by volume) of hooked steel fibres and 1% of super- plasticizer.

V. METHODOLOGY

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the total volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Any variation in its quantity affects the compressive strength of the concrete mix. Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. It has been possible to upgrade the qualities of cement by using high quality limestone, modern equipments, maintaining better particle size distribution, finer grinding and better packing. Generally use of high grade cement offers many advantages for making stronger concrete. Although they are little costlier than low grade cement, they offer 10-20% saving in cement consumption and also they offer many hidden benefits. One of the most important benefits is the faster rate of development of strength.

Ordinary Portland Cement (OPC) of 43 Grade (UltraTech cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 8112:1989 are listed in Table1.1. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture

Table 1.1 Properties of OPC 43 Grade Concrete

Sr.No.	Characteristics	Values Obtained Experime	Values Specified By IS 8112:1989
1.	Specific Gravity	3.10	-
2.	Standard Consistency, percent	27	-
3.	Initial Setting minutes	149	30 (minimum)
4.	Final Setting minutes	257	600 (maximum)
5.	Compressive Strength 3 days 7 days 28 days	 27.8 N/mm² 36.5 N/mm² 48.6 N/mm²	 23N/mm²(minimum) 33N/mm²(minimum) 43Nimm²(minimum)

Table 1.2 Properties of Coarse Aggregates

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum Size	20 mm/10 mm
Specific Gravity	2.73/2.72
Water Absorption	0.20%/0.35%

SUPERPLASTICIZER

Super-plasticizers constitute a relatively new category and improved version of plasticizer. They are chemically different from normal plasticizers. Use of super-plasticizer permits the reduction of water to the extent up to 30 percent without reducing workability in contrast to possible reduction up to 15 percent in case of plasticizers. The mechanism of action of super-plasticizer is more or less same as in case of ordinary plasticizer. The super- plasticizers are more powerful as dispersing agents and they are high water reducers. It is use of super- plasticizer which has made it possible to use w/c as low as or even lower and yet to make flowing concrete to obtain compressive strength of the order of 120 MPa or more (Shetty 2005). It is the use of super-plasticizer which has made it possible to use fly ash, slag and particularly silica fume to make high performance concrete.

Super-plasticizers are also often used when pozzolanic ash is added to concrete to improve strength. This method of mix proportioning is especially popular when producing high-strength concrete and fibre reinforced concrete. Adding 1-2% super-plasticizer per unit weight of cement is usually sufficient. However, note that most commercially available super-plasticizers come dissolved in water, so the extra water added has to be accounted for in mix proportioning. Adding an excessive amount of super-plasticizer will result in excessive segregation of concrete and is not advisable. Some studies also show that too much super-plasticizer will result in a retarding effect (Shetty, 2005).

Super-plasticizers are chemical admixtures that can be added to concrete mixtures to improve workability. Unless the mix is "strayed" of water, the strength of concrete is inversely proportional to amount of water added or water-cement (w/c) ratio. In order to produce stronger concrete, less water is added which makes the concrete mixture very unworkable and difficult to mix, necessitating the use of plasticizers, water reducers, super-plasticizer or dispersants

The superplasticizer "GLENIUMTM B233" procured from SIKA India Pvt. Limited was used in present study. The technical data provided by manufacturer is given in Table 1.3

Table 1.3 Properties of Superplasticizer

Sr. No.	Character	Value
1.	Type	Polycarboxylic ether (PCE)
2.	Form	Liquid
3.	Colour	Light Brown
4.	Specific Gravity	1.09
5.	Relative density	1.09 ± 0.01 at 25^{0}C
6.	pH Content	> 6
7.	Setting Time	There may be mild extension of initial or final set

The dosage of superplasticizer recommended is 0.6% to 2% by weight of cementitous material. 1% superplasticizer by weight of cementitious material was selected in this study to get the medium range of workability.

Compressive Strength of Concrete:

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out form the curing tank at the ages of 28 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast The load as applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.

The quantities of cement, coarse aggregate (20 mm and 10 mm), fine aggregate, marble dust and water for each batch i.e. for different percentage of marble dust replacement was weighed separately. The cement and marble dust were mixed dry to a uniform colour separately. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix and then super-plasticizer was added. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Super- plasticizer was added in the remaining was and stirred to have uniform mix, added to the mix and then thoroughly mixed for further 2 to 3 minutes in mixer. Then the concrete was filled into the cube moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

VI. RESULT

The most common concrete structure subjected to flexure is a highway or airway pavement and strength of concrete for pavements is commonly evaluated by means of bending tests. When concrete is subjected to bending, then tensile and compressive stresses and in many cases direct shear stresses are developed.

When fibre reinforced concrete and composite beams are loaded in pure bending, then the tensile strains develop. The load at first crack would increase with respect to steel fibre reinforced concrete due to crack arresting mechanism of the closely spaced fibres. After the concrete matrix cracks, the fibres continue to take higher load which is provided. Thus the ultimate flexural strength is increased. The experimental program included the following:

- Testing of properties of materials used for making concrete.
- Design of mixes for pavement quality concrete and steel fibre reinforced concrete by making trials.
- Casting and curing of specimens.
- Tests to determine the flexural strength, compressive strength and Split Tensile strength of high strength steel fibre reinforced concrete.

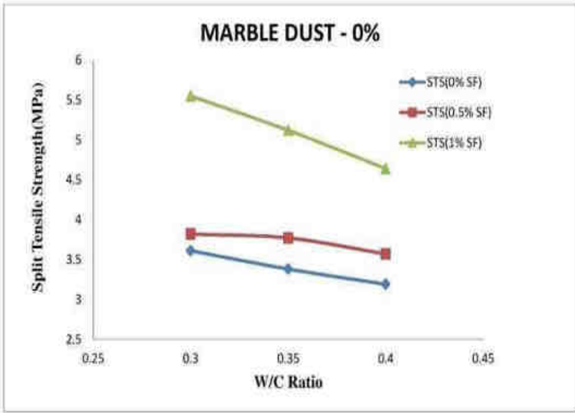

Fig. 4.1 Variation of split tensile strength of concrete with different W/C for 0% M.D and different percentage of S.F.

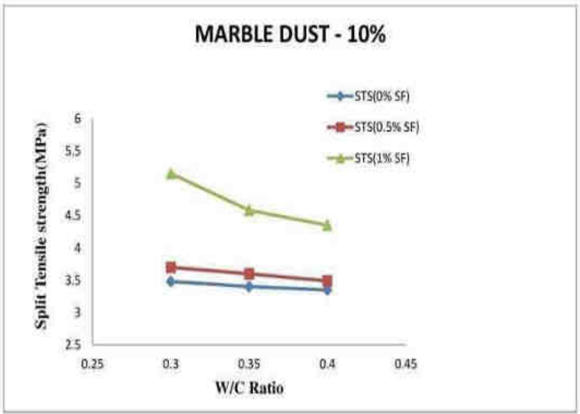

Fig. 4.2 Variation of split tensile strength of concrete with different W/C for 10% M.D and different percentage of S.F.

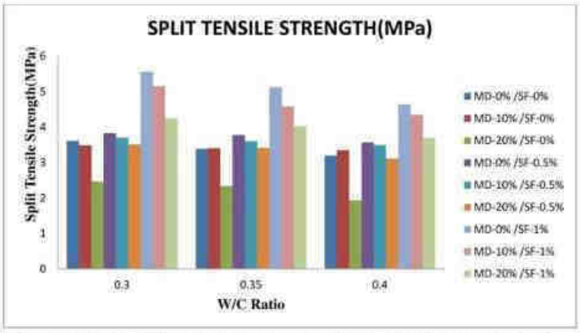

Fig. 4.21 Variation of split strength of concrete Vs W/C with different percentage of S.F and different percentage of M.D.

4.5 DISCUSSION OF RESULTS

4.5.1 Effect of Marble Dust Replacement on Strength Characteristics;

Figures 4.1 to4.9 show the effect of marble dust replacement on strength characteristics of pavement quality concrete. The effect on each strength parameter is discussed in succeeding sub-sections.

a) Effect on compressive strength:

Table 4.4 Test Results of Compressive Strength vs. W/C Ratio

Compressive strength W/C = 0.3		
Sample ID	**Percentage decrease in compressive strength**	**Percentage increase in compressive strength**
10% M.D / 0% S.F	-7.08%	
20% M.D / 0% S.F	-53.56%	
0% M.D / 0.5% S.F		11.97%
10% M.D / 0.5% S.F		5.05%
20% M.D / 0.5% S.F	-5.47%	
0% M.D / 1% S.F		78.70%
10% M.D / 1% S.F		63.30%
20% M.D / 1% S.F		38.60%

CONCLUSIONS

- On increasing the percentage replacement of cement with marble dust beyond 10%, there is a slight reduction in the tensile strength value.
- The flexure strength also tends to increase with the increase percentages of steel fibres, a trend similar to increase in split tensile strength and compressive strength.
- On increasing the percentage replacement of cement with marble dust beyond 10%, there is decrease in the flexure strength value.
- Maximum strength (flexure, compressive as well as split tensile) of pavement quality concrete incorporating marble dust and steel fibres, both, is achieved for 10% marble dust replacement and 1% steel fibres. However, if the marble dust content is increased to 20%, even with 1% steel fibre, the increase is not very significant.

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