The Study of Effect of Steel Fibres and Marble Dust on Strength Characteristics of Pavement Quality Concrete

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***Abstract*— The present study aims at, developing pavement quality concrete mixtures incorporating marble dust as partial replacement of cement as well as steel fibres. The aim is to the design of slab thickness of PQC pavement using the achieved flexural strength of the concrete mixtures. In this study, the flexural, compressive and split tensile strength for pavement quality concrete mixtures for different percentage of steel fibres and replacement of cement with marble dust are reported. It is found out the maximum increase in flexure strength, compressive strength and split tensile strength is for 0% Marble Dust and 1% Steel fibre. Also it has been possible to achieve savings in cement by replacing it with marble dust and adding fibres.This study also shows 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 fibres is ideal for design of Pavement Quality Concrete (PQC).**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

The aggregate is generally coarse gravel or crushed rocks as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement and other cementitious materials such as fly ash and slag cement serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a robust stone like material. Concrete has relatively high compressive strength. For this reason is usually reinforced with materials that are strong in tension (often steel). Concrete can be damaged by many processes, such as the freezing of trapped water.

The environmental impact of concrete is a complex mixture of not entirely negative effects; while concrete is a major contributor to greenhouse gas emissions, recycling of concrete is increasingly common in structures that have reached the end of their life. Structures made of concrete can have a long service life. As concrete has a high thermal mass and very low permeability, it can make for energy efficient housing.

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.

Cement:

The development of HSC will require the utilisation 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

Other Cementitious Materials:

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

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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.

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
41.38MPa	0.38
51.78MPa	0.36
62.07MPa	0.34

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".

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 behaviour 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).

Admixtures:

Concreteis 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 admixtureis 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 pumpability and finishability;
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 admixturesare mainly classified into two groups, viz. chemical admixtures and mineral admixtures, respectively.

Split Tensile Strength of Concrete:

The split tensile strength of concrete is determined by casting cylindersof size 150 mm X 300 mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Universal Testing Machine (UTM). The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

T= 0.637P/di

Where,

T = Split Tensile Strength in MPa

P = Applied load,

D = Diameter of Concrete cylinder sample in mm.
L =Length of Concrete cylinder sample in mm.
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. Fine aggregate was mixed to this mixture in dry form. 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 mix and stirred for further 2 to 3 minutes in mixer to have uniform mix. Then the concrete was filled into the cylindrical 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.

MIX DESIGN OF PAVEMENT QUALITY CONCRETE (PQC)
Step 1: As per clause 602 of MORTH Specification
)=' Cement - 43 grade OPC as per IS 8112 as per 602.2.2
Coarse aggregate - 20 mm and 10 mm as per 602.2.4
Los angles Abrasion value not greater than 35%
Impact value not greater than 30%
)=- Fine aggregate - Natural sand as per IS 383
Admixture - Conplast AEA (if required)
Air entrained concrete 5% maximum (optional)
Step 2: Design Parameter:
Characteristics flexural strength required at 28 days = 4.5 N/mm^2
Maximum water cement ratio = 0.40 as per clause 602.3.3.1
Maximum size of coarse aggregate = 25 mm
Degree of quality control = Good
Minimum cement content = 350 kg/m^3 as per clause 602.3.2
Maximum cement content = 425 kg/m^3as per clause 602.3.2
Step 3: Calculation of fine aggregate content:
After determining the weight per cubic meter of cement, water, coarse aggregate and percentage of air content, the fine aggregate is calculated so as to produce one cubic meter of concrete using absolute volume method. On converting the weight per cubic meter into volume,

Test Procedure and Results
Test specimens of size 150 x 150 x 150 mm were prepared for test
the compressive strength of both controlled as well as marble dust-steel fibre reinforced pavement quality concrete. The modified concrete mixtures with varying percentages of steel fibres and partial replacement of cement with marble dust were prepared and cast into cubes.
In this study, the mix was done by manually. The cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. In case of SFRC the fibres were added just before adding water and mixed dry thoroughly. Same in the case of marble dust, cement in different percentages was replaced with marble dust and added before adding water. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of $27^0 \pm 2^0$C for 28 days curing. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Test results of compressive strength test at the age of 28 days .

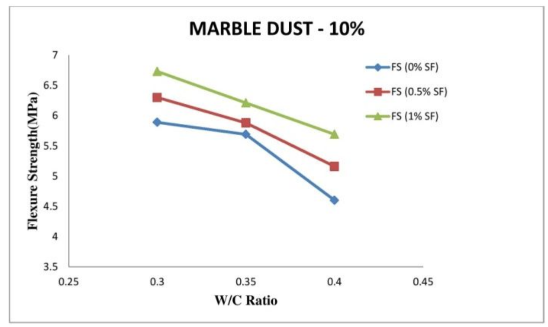

Fig. 4.5 Variation of flexure strength of concrete with different W/C for 10% M.D and different percentage of S.F.

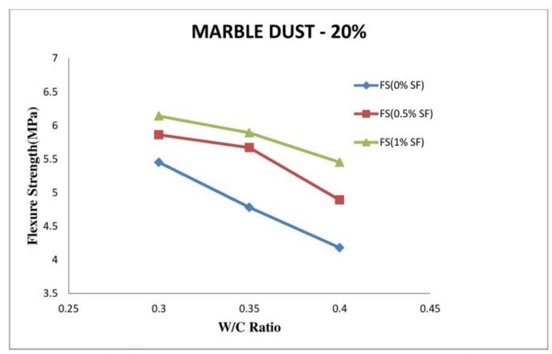

Fig. 4.6 Variation of flexure strength of concrete with different W/C for 20% M.D and different percentage of S.F.

CHARACTERISTICS OF SUBGRADE AND SUB BASE
Strength
The strength of subgrade is expressed in terms of modulus of subgrade reaction k, which is defined as pressure per unit deflection of the foundation as determined by plate bearing tests. As the limiting design deflection for cement concrete pavements is taken as 1.25 mm, the k-value is determined from the pressure sustained at this deflection. As k-value is carried out by test plate diameter, the standard test is to be carried out with a 75 cm diameter plate. IS:9214- 1974, "Method of Determination of Modulus of Subgrade Reaction of Soil in the field" may be referred. A frequency of one test per km per lane is recommended for assessment of k-value,
unless the foundation changes with respect of subgrade soil, type of sub-base or the nature of formation i.e. cut or fill when additional tests may be conducted. An approximate idea of k-value of a homogenous soil subgrade may be obtained from its soaked CBR value using Table 5.1. It is advisable to have a filter layer above the subgrade for

drainage of water to prevent (i) excessive softening of subgrade and (ii) erosion of the subgrade particularly under adverse moisture condition.

The approximate increases in k-values of subgrade due to different thickness of sub-bases made up of untreated granular, cement treated granular and dry lean concrete (DLC) layers may be taken from Table 5.2. 7-day unconfined compressive strength of cement treated granular soil should be a minimum of 2.1 MPa. Dry Lean Concrete should have a minimum compressive strength of 7 MPa at 7 days.

Table 5.1 Approximate K-Value Corresponding to CBR Values For Homogenous Soil Subgrade

Soaked CBR value %	2	3	4	5	7	10	15	20	50	100
k-value ($kg/cm^2/cm$)	2.1	2.8	3.5	4.2	4.8	5.5	6.2	6.9	14.0	22.2

Table 5.2 K-Values with Dry Lean Concrete Sub-Base

k-valueof subgrade $kg/cm^2/cm$	2.1	2.8	4.2	4.8	5.5	6.2
Effective k over 100 mm DLC, $kg/cm^2/cm$	5.6	9.7	16.6	20.8	27.8	38.9
Effective k over 150 mm DLC, $kg/cm^2/cm$	9.7	13.8	20.8	27.7	41.7	

The maximum value of effective k will be 38.9 $kg/cm^2/cm$ for 100 mm of DLC and 41.7 $kg/cm^2/cm$ for 150 mm of DLC.

Separation layer between sub-base and pavement: Foundation layer below concrete slabs should be smooth to reduce the inter layer friction. A separation membrane of minimum thickness of 125 micron polythene is recommended to reduce the friction between concrete slabs and dry lean concrete slab-base (DLC).

CONCLUSIONS

From the experimental results, the following conclusion can be drawn:

Strength Characteristics

Concrete mix with 10 percent marble dust as replacement of cement is the optimum level as it has been observed to show a significant increase in compressive strength at 28 days when compared with nominal mix.

Concrete mixes when reinforced with steel fibre show an increased compressive strength as compared to nominal mix.

The split tensile strength also tends to increase with increase percentages of steel fibres in the mix.

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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