EXPERIMENTAL STUDY ON OPTIMIZATION OF BINDER CONTENT IN HIGH PERFORMANCE CONCRETE

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Abstract

The concept of particle packing is of basic importance in optimization of concrete mix. The particle packing of a system is a function of particle size distribution, particle shape, surface area, method of compaction, grain size and presence of liquid. While particle packing has a significant influence on the properties of concrete, which contains different sizes of particle, the paste properties are also affected by the interaction between the cementitious particles. Improvement in the packing density of the cement by blending with cementitious materials plays a major role in enhancement of particle distribution, reduction of thermal cracks and in improving mechanical properties of high performance concrete. In the present experimental study, Punkte test conducted to determine the packing density of cement and cementitious material combinations to evaluate optimization in mortar paste. The optimization of different mixes evaluated based on the packing density. It is observed that, Punkte test gives a good indication of optimum packing and significantly helps in designing the mix proportion of the binder materials for high performance concrete.

Keywords: *Optimization of Concrete, cementitious materials, Punkte test, particle packing*

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1. INTRODUCTION

High performance concrete has increasing used in high-rise construction as a result of decrease in the amount of steel, and thus the dead load. One of the important parameter to achieve high performance in concrete is to reduce the void content in the paste matrix. The cementitious paste, which goes into the voids between the aggregate, containing various sizes and shape of particles in suspension plays an important role in the rheological properties of fresh concrete. Adding fine particles, helps in filling up the voids in the particle structure leaving only minimum space for water.

Particle packing density of concrete mixtures has several advantages for concrete properties in the wet as well as in the hardened state. With a high packing density in the mixture, cement and other particles are close to each other, reducing the space that needs to be filled by hydration products. It has been learnt that the improvement in the packing density of the cementitious materials by blending cement with mineral admixture plays a major role in enhancement of the properties of the mortar produced.

Research in the past has provided clear understanding about the significant role of particle packing on the properties of concrete. [1] conducted study on partial replacement of mineral admixtures on a volume basis to determine packing density using Punkte test. It [2] is apprehended that higher packing densities reduces the water /cement ratio and increases the strength of concrete mixtures. Experiments showed [3] that packing is a function of the particle shape and it affected by the fine aggregate to total aggregate ratio. Review studies [4] shown that, packing is affected by shape, size and proportion of aggregates. Experimental work indicated that, [5] water demand varies with different composition of cementitious materials using Puntke test. Compared [6] to flyash, GGBS has more water demand in Punkte test.

Present work emphasize on the optimization of cement and micro silica in the cement paste for a high performance concrete.

2. MATERIALS

2.1 Cement

Ordinary 53 grade Portland cement (OPC) with specific gravity of 3.15 and confirming to IS 12269-1987 was used in this study.

2.2 Fine Aggregate

Manufacture sand with a specific gravity of 2.62, and fineness modulus 2.70 conforming to grading zone II as per I.S 383-1970 was used.

2.3 Coarse Aggregate

Crushed granite stone with a specific gravity of 2.70 conforming to single sized aggregate having maximum size of 20mm with 40 percentage replacement by 12.5 mm as per IS 383- 1970 used in the present study.

2.4 Micro Silica

Commercially available micro silica (supplied by M/S NUCHEMS, Bangalore) with specific gravity 2.20 used in the present study.

2.5 Water

Potable water conforming to the requirements of water for concreting and curing as per IS: 456-2000 used.

3. EXPERIMENTS PROGRAMME

3.1 Punkte Test

The basic principle of Puntke test is that the water, which is added to the dry materials, fill the voids in between the particles and acts as a lubricant to make the materials compact efficiently. The water, which is in excess after completely filling the voids, appears at the surface of the mixture, indicating the saturation limits. Puntke test involves the selection of binder proportion by volume.

3.2 Procedure of Punkte Test

Dry mix of selected volume of solid materials are mixed minimum four times for homogenization. Calculated increment of potable water added to the dry mixture with continuous manual mixing and simultaneous pressing of mixture against the sides of the container wall. Twenty times the container needs to be tapped by keeping on the flow table. This procedure need to repeat for addition of each increment of water until the saturation point (shinning/glossy surface) is reached. The experiment is done in three stages to get the least water required to achieve saturation.

3.3 Experiment

Different combination of cement and micro silica are consider for Punkte test to find best combination. Table 1. shows the combination and weight of the cement and micro silica used for Punkte test. The surface texture of the wet combination of cement and micro silica will indicate the saturation of the voids and availability of the excess water in the mixture. Figure 1 and 2 indicating the different surface texture of the wet combination of cement and micro silica.

Table -1: Percentage, weight of cement and micro silica selected for Puntke test

Sl. No.	OPC %	Micro silica %	Weight of OPC (gm)	Weight of micro silica (gm)
1	95	05	59.85	2.22
2	90	10	56.70	4.44
3	85	15	53.55	6.66
4	80	20	50.40	8.88
5	75	25	47.25	11.10
6	70	30	44.10	13.32
7	65	35	40.95	15.54
8	60	40	37.80	17.76

Fig -1: Not statured: Humid soil look

Fig -2: Saturated: Glossy/Sticky surface

The sample calculation of packing density for 80:20 combination of cement and micro silica is shown below:

Volume of solid materials = 20 cm³

Mass = specific gravity × volume

Mass of cement = 3.15×0.80×20 cm³ = 50.40 gm

Mass of micro silica = 2.22×0.20×20 cm³ = 8.88 gm

Packing density ($Ø_p$) = 1 - [V_w / (V_s+V_w)]

= V_s / (V_s + V_w)

= 20 / (20 + 17)

$Ø_p$ = 0.540

Where,

V_w = *Volume of water in cm³*

V_s = *Volume of solid particle in cm³*

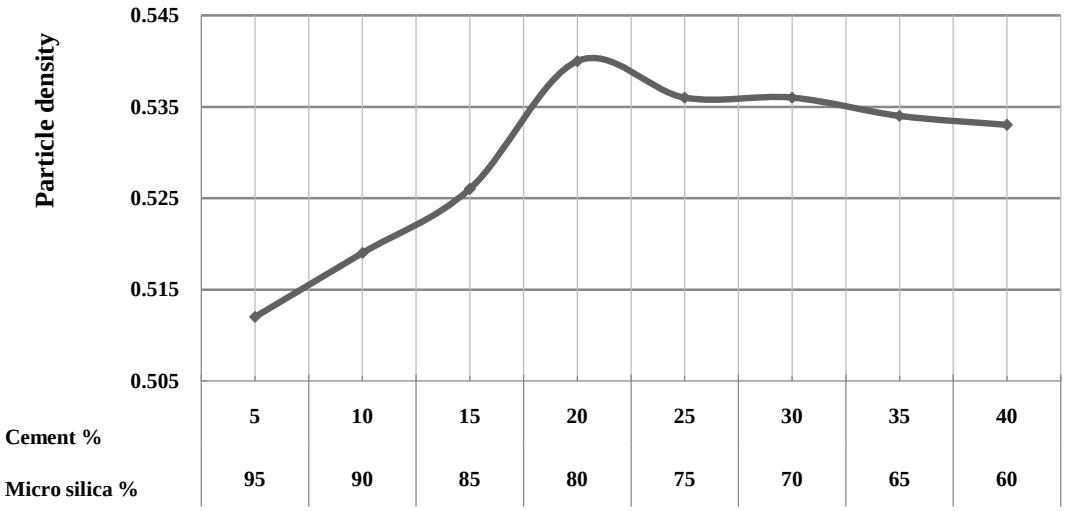
4. RESULT AND DISCUSSION

The best combination of the cement and micro silica is determined by observing the surface texture of the wet mixture after Punkte test. Table 2 shows the values of water consumption and packing density for different combination.

Table -1: Water requirement and Particle density for each combination

Sl. No.	OPC %	Micro Silica %	Water requirement (cm^3)	Packing density
1	95	05	19.00	0.512
2	90	10	18.50	0.519
3	85	15	18.00	0.526
4	80	20	17.00	0.540
5	75	25	17.30	0.536
6	70	30	17.30	0.536
7	65	35	17.40	0.534
8	60	40	17.50	0.533

The wet combination of 80 percentage of cement and 20 percentage of micro silica required less water and attained maximum packing density. Graph 1 indicates the various packing density with different combination of cement and micro silica.



Graph 1 Packing density of binder content for different percentage of cement and micro silica

It is observed that the among different combination of cement and micro silica, 80% of cement and 20% of micro silica shows the highest packing.

5. CONCLUSION

In high performance concrete it is extremely necessary to ensure the use of fine and ultrafine materials along with cement. Particle size distribution is not only beneficial for the water demand, but it can also decrease the space between the cement particles. In the present study, Punkte test provide the experimental solution to find the best combination of cement and micro silica among different combination. Based on experimental result following conclusion can be drawn:

- Punkte test provide the solution for optimization of cementitious materials in wet condition, which closely resembles the real situation of cementitious materials in paste.
- Increased packing density, improves the strength of concrete.
- A optimized paste matrix, results in high packing density and restrain the amount of shrinkage and creep.
- From the result, it is evident that, the water requirement is increases with increase in micro silica content.
- Packing density, increases linearly upto, the wet mix reaches the saturation. Beyond the saturation point, the packing density decreases in a slow rate.

- Visual observation of the surface texture in Punkte test is the quick and reliable method to find the optimization between cement and mineral admixtures.
- Among all different combinations, the 80:20 combination of cement and micro silica has exhibit the highest packing density.

ACKNOWLEDGEMENTS

The authors acknowledge the UG student and the management for their support during successful conduction of this experimental work.

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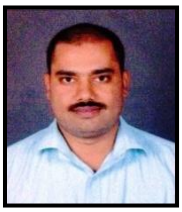
BIOGRAPHIES



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