A STUDY ON THE POROSITY AND PORE SIZE DISTRIBUTION OBTAINED THROUGH MIP OF CEMENT PASTE AND CEMENT SAND MORTAR INCORPORATING SILICA FUME

By

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Dedicated

To

My Father

CERTIFICATE

This is to certify the thesis entitled "**A Study on the Porosity and Pore size Distribution Obtained Through MIP of Cement Paste and Cement Sand Mortar Incorporating Silica fume**" being submitted by Mr. Suresh. G. Patil to the Indian Institute of Technology, Delhi, India, for the award of the degree of "**DOCTOR OF PHILOSOPHY** in Civil Engineering", is a record of original bonafide research work carried out by him. Mr. Suresh. G. Patil has worked under my guidance and supervision.

To the best of my knowledge, the thesis has reached the requisite standard. The material contained in this thesis has not been submitted, in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Porosity and pore sizes affect many properties of cement based materials such as strength, durability etc. Many mineral admixtures such as fly ash, ground granulated blast furnace slag, silica fume are used to improve porosity and pore sizes of cement based materials. Silica fume play an important role in modifying the porosity and pore sizes of these materials. Therefore silica fume is most widely used in the production of very high strength cement based materials. That's why it is necessary to study porosity and pore sizes of cement silica fume based materials through a suitable method. MIP is the most suitable method among all the available method for measurement of porosity and pore sizes. In the present study work is divided into two phases, cement silica fume paste in phase I and cement silica fume sand mortar in phase II.

In the first phase three paste mixes with three w/(c+sf) ratio (0.25,0.35 and 0.50) with four replacement of silica fume (0,5,10 and 15%) were used. An optimal dosage of superplasticiser was determined using Marsh cone test for all these paste mixes. Control paste mixes were prepared for w/(c+sf) ratio 0.35 and 0.50 without silica fume and superplasticiser but the paste mix with w/(c+sf) ratio 0.25 could not be prepared without superplasticiser. Three ages of curing (3, 7 and 28 days) were adopted. For a total of fourteen paste mixes with three replicates each 126 cubes of 50 mm side length were cast for compressive strength measurement. The size of the specimen used in Porosimeter test is governed by the size of sample cell used in Porosimeter (i.e. 25 mm length and 11 mm diameter) cylindrical specimen of size 9.5 mm diameter, 23 mm height were cast from different paste mixes for MIP test. It has

been reported in earlier literature that the number of sample should be six to obtain results within accuracy of ± 15%. Therefore six replicates were used for measurement of porosity. Thus a total number of specimens for 14 mixes with three ages and six replicates is 252. MIP test was conducted for 252 samples.

In the second phase i.e. cement silica fume sand mortar mix, three locally available sand with average particle sizes of 600μm, 300μm and 150μm were selected for the mortar mixes. Mass fractions of 0.49, 0.21 and 0.30 respectively of these three sand resulted in maximum packing density and minimum void content as determined from a set of preliminary investigations. Minimum paste content in excess of void content to give good workability for three water cementitious ratios namely 0.15,0.20 and 0.25 is determined from flow table test and are 60%, 50% and 40% respectively. Thus to vary the paste content for water cementitious ratios 0.15,0.20 and 0.25, paste contents of 160%, 150% and 140% of the measured void content and another set with paste content of 10% higher i.e. 170%,160% and 150% of the void content were used. Silica fume replacement by mass of cement namely 15%, 20% and 25% were used. Optimal dosages of superplasticiser determined from flow table tests were used in the experimental programme for all these mortar mixes. A total of eighteen mortar mixes were prepared using optimal dosage of superplasticiser for each mortar mix. Two types of curing regimes were used i.e. curing under water immersion and hot water curing at a temperature of 62±2 ^{0}C. Specimens were cured for 2 days excluding 1 day casting. After 2 days of curing specimens were exposed to laboratory environment for 7 days and 28 days including casting and curing days. Thus with 18 mixes, two ages, two curing regimes and six replicates each in total 432 number of cubes 50mm side length were cast and tested for compressive strength. For MIP test, a total number of 432 cylindrical specimens of size 9.5mm dia with 23mm height were cast.

Low pressure and high pressure data set are combined together to obtain a single complete data set of pressure versus intrusion volume. This complete data set is transferred to MS Excel spread sheet. Six such data set were obtained for six replicates. Since pressure value in each set differs from one another, therefore intrusion volume corresponding to the pressure also differed from one set to another set. Software supplied with MIP instrument is not capable of obtaining average of pressure versus intrusion volume curves for number of replicates. Therefore simple averaging could not be performed. The average of these six data set were obtained through a regression procedure using "Curve Expert 1.3" with these data sets as input and using curve finder option in the software best possible curve fit was obtained. Since all six sets of data were inputted together, the resultant fitted curve represented the average variation of intruded volume against pressure. The general form of this sigmoidal model is derieved from MMF function used in biological sciences. The correlation coefficients obtained are more than 0.98 in all cases. Using this fitted model a general relationship between intruded volume porosity and pore radius is obtained. It is demonstrated that by and large this relation holds good for cement silica fume paste, cement silica fume sand mortar, concrete, brick and soil cement etc. From this relation a generalized form of the relationship between " lnr versus dv/dlnr" for differential pore size distribution curve is also obtained. Further it is shown that mean distribution radius is nearly equal to the radius at 50% intrusion i.e. the median radius.

Porosity model for cement silica fume paste system is developed and porosity values for various w/(c+sf) ratio and curing ages are obtained through this model and these values are then compared with experimental porosity values. Discussion on experimental porosity vis-à-vis theoretical values is also presented. Effect of experimental factors such as w/(c+sf) ratio, curing age, silica fume content on strength, porosity, mean distribution radius and retention have been discussed and further the role of porosity and pore size distribution on strength for cement silica fume paste and cement silica fume sand mortar is presented. Further implications of porosity and pore sizes on hydraulic diffusivity is also presented.

CONTENTS

Flow Charts