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Influence of Silica Fume on Strength and Permeability of Porous Concrete

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ABSTRACT: The main purpose of selecting porous concrete is, it avoid problems such as water logging but the main disadvantage of Porous concrete is it has lower compressive strength than conventional concrete. To enhance compressive strength some supplementary cementitious materials were added due to its physical properties like early strength, increase in density, binding properties etc. By referring literatures four common supplementary cementitious material (Silica fume, Fly Ash, GGBS, Metakaolin) were identified. Silica Fume has better physical properties, it is locally available and cheap than other supplementary cementitious material. The Porous concrete's permeability and compressive strength were examined in relation to the impacts of silica fume. To provide uniform and accurate samples for testing, the researchers followed a certain procedure for specimen preparation and curing. That has been discovered that the silica fume and aggregate size combination had a sizable impact on the compressive strength and permeability of the Porous concrete. The outcomes demonstrated that silica fume usage enhanced the concrete's porous compressive strength. A medium-sized aggregate and silica fume mixture produced a higher strength and tolerable permeability. However, the pozzolanic reaction and filler effect of the silica fume addition also resulted in a loss of strength. A 10% replacement level of silica fume in place of cement produced an excellent balance between permeability and strength. The split tensile test findings showed that the silica fume mixture had a greater split tensile strength at a 5% silica fume. The test additionally revealed that the split tensile strength was sensitive to the porosity or voids in the previous concrete's structural framework. The cement paste layer around the aggregate particles and the spaces in the aggregate both have an effect on the porous concrete's permeability. The permeability dropped when the aggregate's voids were filled. When assessing the permeability of porous concrete at various percentages, these parameters should be taken into account. In brief, this study demonstrated that aggregate size and silica fume addition selection are significant factors in affecting the porous concrete's permeability and compressive strength. As stated by the research, silica fume can be substituted for cement to increase the strength and permeability of concrete. to create Porous concrete mixtures with the optimal balance of strength and permeability, however, significant consideration is required.

I. INTRODUCTION

Porous concrete is hydraulic cement concrete that has been sized with enough dispersed, interconnected macroscopic voids to for water to pass through it using just gravity. To achieve permeability, open-graded coarse aggregate with little to no fine aggregate is typically employed. Due to the greater void area it integrates for water flow, Portland cement concrete loses some of its mechanical properties when made with porous concrete, even though it has advantages in terms of decreasing water runoff [4].

Due to its many advantageous qualities that lessen the negative impact of impermeable areas, porous concrete, a porous building material, has received a lot of attention recently [3]. Concrete that is permeable or pervious is also known as porous concrete [7]. Porous concrete is one of the best solutions for urban paving and drainage. By utilising supplementary cementitious material and smaller-size coarse aggregate, porous concrete was able to attain better strength as well as good permeability [2]. Due to the numerous environmental issues that supplementary cementitious material, by-products of industrial production processes, raise, it is essential to use them in place of OPC in some circumstances due to their pozzolanic action, which enhances strength and durability attributes. Supplementary cementitious material have pozzolanic qualities that react using calcium hydroxide $[Ca(OH)_2]$ and water to create calcium silicate hydrates (CSH), which are comparable to those produced during the hydration of cement. This facilitates the efficient substitution of Supplementary cementitious material for cement in concrete, increasing both the

long-term strength of the concrete as well as the materials' longevity [5]. Additionally, as mixture spaces are filled with incredibly tiny admixture particles, producing a micro filler effect, the bulk density of concrete increases [10]. A variety of supplemental Fly ash, silica fume, metakaolin, latex polymers, and polypropylene fibres are examples of cementitious materials can be used to strengthen permeable concrete [2]. Utilising silica fume, porous concrete's strength and toughness can be improved[4]. Because of the pozzolanic reaction that occurs during the hydration process between silica fume and calcium hydroxide, the transition interfacial zone gradually thickens. Concrete's microstructure can significantly change due to the silica fume's chemical and physical effects [10].

As porosity increases, compressive strength may decrease. The contact area between the particles is thought to have an impact on the porosity, strength, and compressive strength of porous concrete. Smaller aggregates might enhance the contact area [7]. Only coarse aggregate, cement, and water are used to create porous concrete. The most common coarse aggregate used is one with a single size of 12.5 mm [12]. It is challenging to create high-strength materials with the same material and combination proportions because porous concrete contains voids. The use of smaller-sized aggregate can increase the strength of the current concrete. However, the amount of cement must be changed appropriately. Silica fume and superplasticizer can be added to porous concrete to considerably boost its strength[11]. There is a significant linear relationship between the constant head approach and the decreasing head method. The declining head permeability coefficient was found to be higher than the constant head permeability coefficient. The coefficient of permeability rises as aggregate size rises. Additionally, the disparity between the constant head method and the decreasing head strategy expands as the aggregate size increases [3].

II. MATERIALS

The ingredients of porous concrete include cement, water, and coarse aggregate, typically using only a single-sized coarse aggregate of 12.5 mm. However, obtaining high-strength porous concrete can be challenging due to the voids present in the material. One way to enhance the strength is by using smaller-sized aggregate, but this requires adjusting the amount of cement in the mixture.

A 53-grade OPC cement was employed in this investigation. Incorporating silica fume and superplasticizer is another practical method for boosting porous concrete's strength, which can greatly increase it. The particle size of silica fume is very small, typically ranging from 0.1 to 0.3 microns, making it an excellent pozzolan. It can react with calcium hydroxide to form a strong cementitious material. Silica fume is typically used in densities between 200 and 350 kg/m³.

III. SPECIMEN PREPARATION AND CURING

The researchers used a specific method to prepare and cure the specimens as they looked at how wet curing affected the characteristics of porous concrete. During the mixing phase, the fixed compaction and void Porous concrete work were added to the mixer together with the aggregate, two-thirds of the mixing water, and superplasticizer. After three minutes of mixing, the cementitious ingredients were added, then the remaining water. Then, the mixing procedure was resumed.

The void content was allowed to vary while the compaction energy was maintained constant in the fixed compaction Porous concrete process. Samples of the cylinder and cube were installed by a single operator using three lifts and 25 tamping rods.

The fixed void content Porous concrete combinations were designed to ensure consistent unit weight and void content throughout all specimens. Using a compression testing machine, the samples were crushed to the right height all at once. The appropriate adjustments were made to the compaction factor in order to achieve the desired void content.

After 28 days of curing, the specimens were taken out and dried for a further seven days in an environment chamber with a relative humidity of 50% and a temperature of 23 °C. The samples were re-saturated for 24 hours after the drying phase, followed by the initial testing.

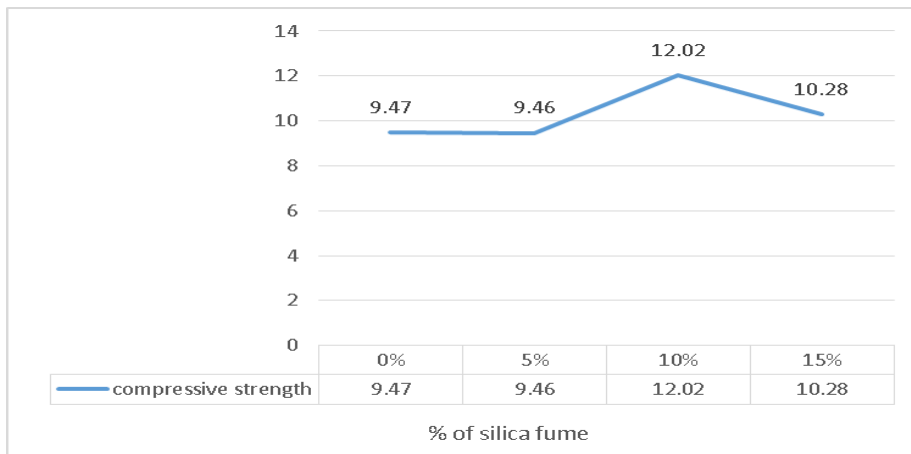
By following this specimen preparation and curing procedure, the researchers aimed to obtain reliable and consistent samples for subsequent testing and analysis of the Porous concrete properties.



IV. RESULT AND DISCUSSION

4.1 Compressive Strength

The compressive strength of porous concrete that has silica fume partially replaced it is depicted in graph



Due to the pozzolanic activity of silica fume and the filler effect, the silica fume combination was more robust than other mixtures. The medium size of the aggregate and silica fume mixture significantly enhanced both permeability and compressive strength.

The aggregate's small dimension raises compressive strength while lowering permeability. Comparing several mixes, one with silica fume at 0% had the lowest compressive strength; at 5% or 10%, silica fume mixtures achieved good strength and acceptable permeability.

In compressive strength, coarse aggregate size plays a significant part. The shape or size of aggregates affects the interconnection of voids. On the other hand, due to the lesser contribution of small Cementous paste, the latter are curing militarily and aid in the development of strength. The enhancement because of the pozzolanic reaction of the silica fume and the filler effect used to make the porous concrete, a decrease in strength was seen cementitious material. Only 9% to 10% more strength was gained with partial replacement, although 5% to 10% more silica fume content increased strength by 5%.

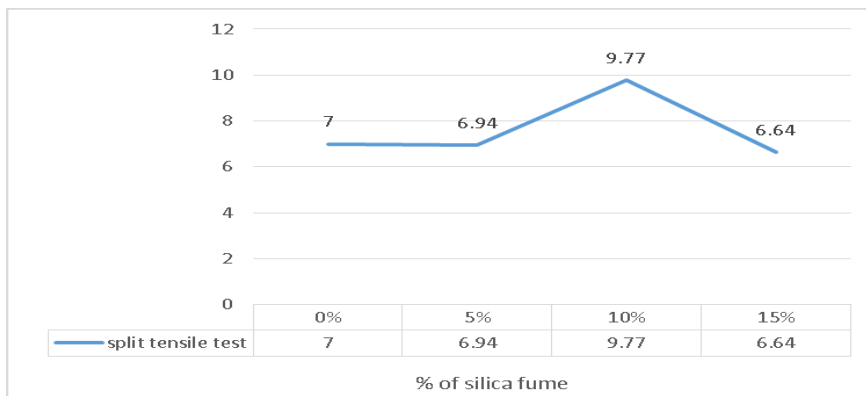
4.2 Split Tensile Test

A silica fume mixture's split tensile strength is higher with 5% silica fume mix.

The split tensile test is low at 15% of the mix of silica fume.

Because even a small difference in porosity significantly affects the split tensile strength, the split tensile test is very susceptible to porosity or cavities in the porous concrete's structural framework.

The split tensile test variation is shown in graph,

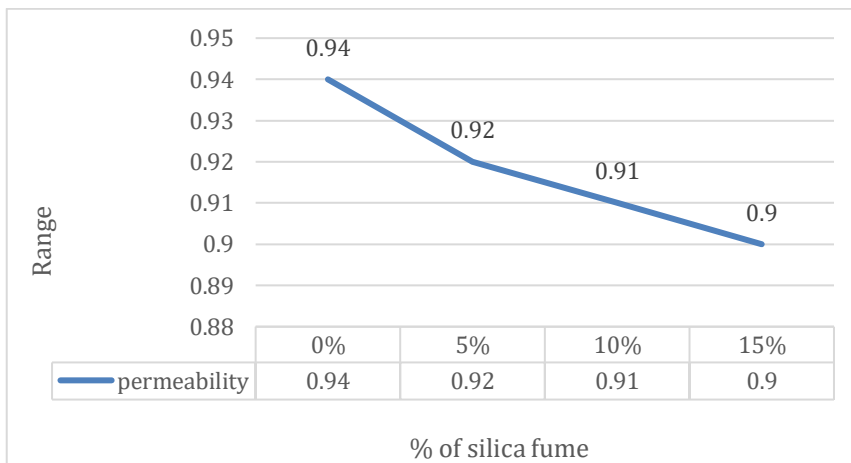


A cylindrical specimen of 300 mm by 150mm was casted and tested after 7 days, 14 days, and 28 days.



4.3 Permeability

Graph depicts the permeability of porous concrete. Because of the substantial cement paste layer that surrounds the aggregate particles, porous concrete can achieve greater strength. However, as voids in aggregates were filled, permeability decreased. Comparing permeability to other percentages, 0% has a higher value.



V. MIX PROPORTION

In this study, two major elements influencing the compressive porous concrete's strength and permeability characteristics were investigated. The components and mixing ratio of the concrete mixture were found to play a crucial role in determining these properties.

Aggregate size was identified as a critical factor in the mixture. There was a finding that using higher values were obtained from smaller aggregates compressive strength, while larger-sized aggregates led to lower compressive strength but improved permeability.

To ensure uniform mixing, the paste was prepared using manual compaction instead of vibration, as vibration tends to segregate the materials. The silica fume, cement, superplasticizer, and aggregates were mixed simultaneously, ensuring that the paste uniformly covered the aggregate particles.

To evaluate the concrete's performance, two types of moulds were used. Cylinder moulds with a diameter of 150mm and a height of 300mm were employed for the split tensile test, while cube moulds with dimensions of 150mm by 150mm they served for measuring compressive strength and permeability.

After the specimens were sealed in the moulds, they were demoulded after 48 hours and subjected to water curing for different durations: 7 days, 14 days, and 28 days.

VI. CONCLUSION

Based on the results of the experiment and the parameters examined in this study, The main objective of the study is to examine the impact of silica fume on the strength and permeability of porous concrete. The particle size of silica fume is greater as compared to fly ash which is greatly affects the permeability, as well as silica fume is available locally. Mixture of concrete takes a final setting time of up to 48 hours, and manual compaction is more suitable than vibration because vibration segregates the material. In this study the admixture dosage was fixed for all mixtures. Silica fume was replaced by 0%, 5%, 10% and 15%. In this study, when the cement is replaced by 10% silica fume, it gives an acceptable amount of permeability as well as strength. This result clearly indicates that instead of increasing cement content, it can be partially replaced by silica fume. The outcome suggests that aggregate size also influences the interconnectivity of voids in porous concrete and that silica fume fineness and permeability both play significant roles.

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