An Experimental Investigation on Mechanical and Durability Properties of Blended Concrete having Fly Ash with Combination of Nano Silica

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***Abstract*— Around the entire world, high performance concrete, or HPC, is often utilised in the construction of giant skyscrapers, long-distance bridges, rising buildings, as well as renovation and enlargement of preexisting structures. Portland cement is thus used more often as high-strength concrete is used. Furthermore, as the amount of cement used in the concrete industry rises, so do CO2 emissions, which further exacerbate global warming. Consequently, it would be better for the environment to use less cement overall by substituting mineral additives for a portion of the cement. It is thought that using high-performance concrete in constructions is both efficient and financially viable. In comparison to regular concrete, high-strength concrete has a lower water-to-cement ratio and better-quality cement. The low processability of the HPC due to the reduction in water content is overcome by the addition of mineral or chemical impurities. Commonly used pozzolanic mineral supplements include fly ash, rice husk, GGBS, Silica Fume metakaoline etc to achieve the desired effectiveness.**

***Index Terms*—Stone Dust, Over Burnt Brick Aggregate, Compressive Strength, Split Tensile Strength, Flexural Strength**

I. INTRODUCTION

Concrete can be considered as the most widely used product in the construction industry. Concrete has been commonly used in structures such as schools, highway bridges, and airport terminals. The mechanical and durability properties of concrete have a similar meaning in the modern construction experience. Cement is the most commonly found product in concrete. Therefore, the consumption of cement increases. This absorbs a significant amount of energy in the manufacture of cement, which produces carbon dioxide, which produces emissions into the atmosphere. Consequently, the solution to this problem is to reduce the use of cement and use Pozzalanic products for the preparation of concrete. Previous studies indicates that the use of Fly-Ash (FA), Micro Silica (MS) and Ground Granulated Blast Furnace Slag (GGBS) as partial replacement of cement that reduces the consumption of cement and also increases the strength and durability of concrete. For further improvement of concrete properties Nano materials are currently used as supplementary materials. Recent advances in nanotechnology and the use of nano silica have allowed the use of concrete materials. Any type of mineral admixtures in concrete can be used with combination of Nano silica. According to the American Institute of Concrete, high-strength concrete (HPC) is classified as concrete that meets certain criteria of consistency and uniformity, which usually cannot be achieved only with traditional materials and standard methods of mixing, laying and curing. HPC is currently used in airports and on road surfaces, in underwater buildings, concrete prestressed bridges, nuclear containers and vehicle frames.

The combustion of pulverized coal at very high temperatures in coal thermal power plants produces various types of ash .The 'fine' ash material is carried upwards along with the flue gases and these particles are collected by using ESP. This material is known as 'Fly ash'(FA). FA is a fine grained glassy powder particulate material, which is a byproduct from industrial plants using pulverized coal, after it is used as fuel, and collected by using ESP. In the year 2012, 175 million ton of FA was expected to be generated in our country.

II. LITERATURE SURVEY

The advantages of using fly ash as a Supplementary Cementing Material (SCM) in fibre cement sheets were investigated by Jagadesh.Sunku . Fly ash-containing fibre cement sheets show reduced early strength even at the ideal dose of 10–20%. This research looks at ways to enrich fly ash with more calcium, either by adding calcium as an additive or directly during coal burning. For calcium enrichment, the study makes use of additions like gypsum and hydrated lime. The results indicate that calcium-enriched fly ash, at a dose of 30–35%, may successfully substitute cement in the manufacturing of fibre cement sheets.

D.P. Bentz et al. examined the assessment of high-volume fly ash concretes that are sustainable, as reported that A comparative study was carried out using controlled concrete, which included fly ash replacements of 15% to 75% in mass instead of cement. Significant water savings were achieved by minimising the total water content via the application of an optimal superplasticizer dose. A number of concrete characteristics, including slump loss, setting times, compressive strength, and static modulus of elasticity (E), were shown to be correlated with the replacement of fly ash. Along with correlations between modulus of rupture and either splitting tensile strength at 28 days or compressive strength development up to 56 days, the research also reported on these topics. Using high-volume fly ash concrete, Vanitha Aggarwal et al. (2010) investigated the durability of concrete. According to the findings, the addition of fly ash to concrete lowers its compressive strength initially but increases it significantly over time. Increased replacement percentages cause the early strength to decline even more. Less than 40% replacement of cement results in concrete that has a greater characteristic strength after 28 days, but more than 40% replacement of cement causes the concrete to lose strength after 28 days but to gain strength after 90 days or beyond.

A research on the early-age strength development of concrete containing fly ash and condensed silica fume was carried out by G. Carette et al. in 2010. Concrete that has low-calcium fly ash used in lieu of some Portland cement often develops its early-age strength gradually. Fly ash plays a major role in the development of strength at later ages by acting as a relatively inert component throughout this hydration phase. The work used tiny quantities of condensed silica fume, a finely reactive pozzolan, to solve the problem of poor early-age strength. When compared to control concrete (70% Portland cement + 30% fly ash), the study's findings, which included 30% low-calcium fly ash with varying quantities of condensed silica fume (0 to 20%), showed higher compressive strength at all ages. At seven days, the addition of 10% condensed silica fume reduced the loss of compressive strength brought on by fly ash replacing some of the cement. Concretes with greater water ratios have to include 15–20% silica fume. At 28 days, adding less than 5% silica fume was usually sufficient to provide the desired result. Condensed silica fume did not impede the later age strength development of Portland cement-fly ash concrete, suggesting that there was enough lime available for fly ash pozzolanic activity.

George Quercia et al. (2012) studied the impact of amorphous nano-silica additives on the mechanical and durability performance of SCC mixes. Nano-silica, with its pozzolanic properties, improves compressive strength and decreases permeability in hardened concrete. The study used two types of nano-silica, manufactured using different methods but with similar particle size distributions. The findings showed that effective application of nano-silica in SCC enhances mechanical qualities and durability, and early reactivity of colloidal-type nano-silica affects the overall characteristics of SCC.

Langan et al. (2012) investigated the impact of fly ash and silica fume on the heat of hydration of Portland cement. They discovered that at low water/cementitious ratios, silica fume slows down cement hydration, but at high ratios, it speeds up. Fly ash considerably slows down cement hydration, especially at high water/cementitious ratios. The reactivity of silica fume is inhibited when cement is added, which causes a notable delay in the hydration of the cementitious system.

Anil Kumar Nanda et al. came to the conclusion that the silica fume seems more homogeneous and thick than the controlled concrete, and that the concrete structure is composed of nanosilica based on the results of the SEM test. Following a seven-day curing period, X-ray diffraction examination revealed a rise in the quantities of CH and C-S-H at all levels of replacement of nanosilica and silica fume. However, during a 28-day curing period, all degrees of substitution showed a drop in CH and an improvement in C-S-H. It is very resistant to the entry of chloride ions into concrete, as shown by lower test results for the quick penetration of chlorides.

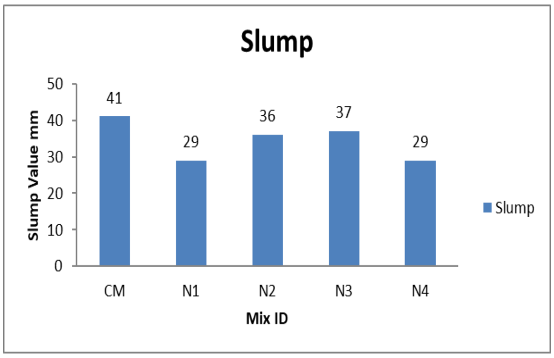
III. METHODOLOGY FOR EXPERIMENTS

This chapter covers the material selections, work plan and the test procedure followed for this study. It discusses the testing of materials, trail mixes, quantity replacement of cement and its proportions for various mixes, concrete mixing, casting of specimens and curing of the specimens. The mechanical and durability properties of concrete specimens are taken up for this study. Consistency is a general term indicates degree of fluidity. This test was conducted according to IS 4031 (part4)-1988.

For conducting this test we use Vicat's apparatus with a 10mm diameter plunger and a needle of 1mm square section. Oil is applied to vicat mould for separate the cement from the mould easily, and the mould is placed on non-porous plate. Weigh 400 grams of cement and then find out the volume of water to give a 25 % of by weight of cement and add this amount of water carefully to that cement. Gauging time is in between 3-5 minutes.The homogenous cement paste is fill in the mould and level the surface. Keep the mould under vicat plunger and then the plunger released quickly. If the needle penetration is in between 5 to 7mm from bottom of the mould. The % of water obtained is called consistency of that particular mix. If this condition is not satisfied, if this condition is not satisfied, repeat the same procedure with different percentage of water until the penetration depth is 5mm or 7 mm. The Standard consistency of cement=30%

IV. RESULTS AND DISCUSSIONS

The flexibility with which concrete can be mixed, moved, set, and compacted with the least amount of homogeneity loss is known as workability, and it is greatly impacted by the amount of water used during mixing. The amount of water needed for concrete varies depending on the additives and particles used. In fact, one of the main requirements for big grades of concrete is that the water consumption reduces as the aggregate size increases. The water need and processing capabilities of the concrete mixture are greatly impacted by the physical characteristics of the mineral additions added to the slurry. In order to keep the workability of concrete within the desired range, superplasticizer is often given to it.



Comparative analysis of the amount of superplasticizer applied to a very low amount of nanosilica means that with the addition of nanosilica, the water demand for concrete becomes higher. This is due to the fact that, due to the high specific surface area of nanosilica, an increase in the nanosilica content decreases the volume of water present in the mixture and its constancy. Therefore, an increase in the amount of mineral additives reduces the workability of concrete with a constant ratio of water to binder. Due to their high specific surface area and high reactivity, water molecules are easily attacked by silica particles. The volume of free water required to increase the fluidity of the mixture is greatly reduced. Thus, it has been observed that the viscosity of the mixture improves as concrete containing nanosilica reduces its workability.

Compressive strength test 150 x 150 x 150 mm concrete specimens of each combination at the corresponding curing age are evaluated in the compressive testing machine at 7, 28, and 90 days. Three specimens are cast for each combination, and the average compressive strength.

It can be shown from the results that the HPC cubes composed of fly ash and nano silica combination obtain a compressive strength of 21.17% to 37.88% at 7 days, 6.58% to 8.26% at 28 days, and 7.59 to 10.35% at 90 days. Comparing the early age (7 days) compressive strength of mixes N1, N2, N3, and N4 to a normal concrete mix, the improvements were 23.76%, 37.88%, 29.41%, and 21.47%, respectively. Analogous outcomes were seen at 28 and 90 days of age. When compared to the standard concrete mix after a 28-day curing time, the mixes including fly ash and colloidal nano silica, or N1, N2, N3, and N4, showed an increase in compressive strength of 7.42%, 8.26%, 7.70%, and 6.58%, respectively. In comparison to the 28-day compressive strength, the later age compressive strength (90 days) showed a little gain in strength but no change at all. Compared to the normal concrete mix, the improvements in compressive strength are 8.28%, 10.35%, 8.70%, and 7.59%, respectively, after a 90-day curing time. The improvement in strength is due to the ultra-high reactive nano-sized silica with a high filler effect forming the CSH gel quickly. When the Nano Silica level exceeds 2 percent, the intensity starts to diminish because too little nano-silica leads to particle aggregation within the concrete. This might possibly be a result of the extensive usage of calcium hydroxide in early pozzolanic silicon processes.

The test findings indicate that, for all ages, a mixture containing 30% fly ash and 2% nano-silica yields the highest compressive strength. Therefore, as cement replacement materials, the ideal replacement rate for nano-silica is 2% nano-silica and 30% fly ash, respectively. The compressive strength is significantly increased when fly ash and nano-silica are used in lieu of cement. Increased intensity is primarily caused by filler, nano-silica, and fly ash effects, as well as improvements in the pozzolanic reaction. An extra C-S-H gel is produced during hydration as a result of fly ash and nano-silica interacting with the excess calcium hydroxide. To increase efficiency, the interfacial transition zone for HPC in general has to be robust, uniform, and dense. This is usually accomplished by the addition of mineral admixtures that act as filler and pozzolanic content. The effect of the introduction of nano-silica has a moderate effect on strength development associated with later age, since the role of nano-silica in increasing strength is achieved at an early age. The slight improvement in strength at 90 days is may be due to the pozzolanic effect of Fly ash, it can process pozzonalic till 90 days curing period.

Sample failure template for the cube sample shown in fig. 6.3 it is shown that the fracture plane is along the aggregates. It can be seen that the interfacial transition zone is stronger due to the addition of nano-silica and Fly ash. The specimen fails when the unit reaches its ultimate load; otherwise the specimen is able to withstand more loads.

VII. CONCLUSIONS

Based on the test findings, we may draw the following conclusions:

1. Concrete's strength and durability qualities improve when 30% fly ash and 2% nano-silica are added, and these properties tend to decline as the amount of nano-silica increases.
2. It's also noteworthy that concrete containing fly ash of the M60 grade with varying percentages of nano-silica has improved in compressive strength, tensile strength, flexural strength, water absorption, and acid resistance. These results point to a similar trend.
3. The strength and durability qualities tend to rise with an increase in the proportion of nano silica content up to 2%. This might be because there is an extra binder present when there is nano-silica present. Fly ash, nano-silica, and calcium hydroxide mix to form an extra binder. The qualities of concrete generated from a fly ash and nano-silica combination are improved when a second binder is added because it increases the paste's adherence to the mortar.

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