Experimental Investigation of Concrete Structures Using High Calcium Fly Ash

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Abstract- *Fly ash is a supplementary cementitious material (SCM) that has already been utilised and is a manufacturing process waste stream. According to the CaO concentration, there are basically two types of fly ash used in the construction industry: class C and class F. Bituminous, semi-bituminous, or lignite- and coal-based thermal power stations (TPS) are the sources of the various types of fly ashes. It is widely known how lignite forms naturally. It is quite helpful for implementation that several authors have specified the distinctive qualities of Class C and F varieties of fly ash in different countries.*

Most studies that have been reported so far substitute fly ash for cement to a degree between 20% and 30%. The most common siliceous material found on earth is fly ash. Only a very small portion of the fly ash supply is used in concrete construction. The purpose of this project is to determine whether it is feasible to replace more cement at much higher levels, which would enable a much higher proportion of readily available fly ash to be utilised in construction. The purpose of the study is to compare the high calcium fly ash (HCFA) concrete to conventional Portland cement systems in terms of engineering and microstructure. Increasing the usage of fly ash is thought to help with disposal problems. Develop mix proportioning techniques for various curing conditions and a large quantity of portland cement replacement to prototype high performance fly ash concrete. It is possible to substitute fly ash for both sand and cement by 50 to 60% to obtain the desired strength.

I. INTRODUCTION

Use of industrial or mining waste to meet demand has been stimulated by research into the implications of alternative building methods on energy and the environment. Developing a sustainable pattern of expansion is the largest challenge the concrete industry faces in this century. Although the task is challenging, ideas and experience show that it is feasible if we change our culture away from accelerated building speeds and towards resource and energy conservation. Industrial by-products include cementitious materials like ground granulated blast furnace slag (GGBFS) and pozzolanic materials like fly ash (FA). Pozzolanic materials are used as a partial alternative for cement or in combination with portland cement because they have properties similar to cement but cannot hydrate on their own. The end products of the fly ash-portland cement interaction, C-S-H, C4AH13, C8AFH26, and C4ASH12, are the same as those of portland cement alone, according to a study on synthetic fly ashes [5]. There are two major aspects that affect the characteristics of fly ash concrete. Its intrinsic variation in chemical and mineralogical composition as well as the mix proportioning method utilised to produce the fly ash-containing concrete [6] are factors. Most studies that have been reported so far substitute fly ash for cement to a degree between 20% and 30%. The most common siliceous material found on earth is fly ash. Only a very small portion of the fly ash supply is used in concrete construction. The purpose of this project is to determine whether it is feasible to replace more cement at much higher levels, which would enable a much higher proportion of readily available fly ash to be utilised in construction. The purpose of the study is to compare the high volume fly ash (HVFA) concrete to conventional Portland cement systems in terms of engineering and microstructure. Increasing the usage of fly ash is thought to help with disposal problems.

The production of cement uses a lot of heat, which is bad for the environment. For every tonne of clinker produced, a half-ton of CO_2 is created; this makes up more than 8% of total greenhouse gas emissions. By 2015, the net global cement production will be close to 3 billion metric tons, growing at a rate of 5% per year. The replacement of cement is necessary, and flyash appears to be the most effective material among those listed in appendix A.

The development of hydroelectric and thermal power facilities was sped up in the 1950s due to the sharp rise in energy demand. Research into the use of fly ash as a cement substitute material has been prompted by the production of fly ash as an industrial by-product from these power stations. In the 1960s, mostly in the Soviet Union and the United Kingdom, fly ash was first employed in Europe. High-quality fly ash may increase the workability, strength, water tightness, and durability of concrete while also lowering the heat of hydration and drying shrinkage. The economic reductions that result from the production of higher-quality concrete and the reduced cement content are perhaps fly ash's most important advantage. These advantages of fly ash, which have been documented in published literature, make up for many of the drawbacks of portland cement, and their usage as an essential component of structural concrete is now widely accepted. The use of relatively large volumes of fly ash in Portland cement concrete has a number of benefits for waste management, pollution reduction, and the preservation of material resources. The annual report on comprehensive resource utilisation published by China's National Development and Reform Commission (NDRC) in 2012 states that in 2011 there were 540 and 367 million tonnes of coal fly ash produced and used, respectively. The utilization rate was 67.96%, higher than that of the US (46.74%), India (46.74%), and China (55.79%) combined. Concrete (19%), brick and tiles (26%), and cement (41%), in that order, came in first, second, and third.

II. LITERATURE REVIEW

Ramesh et al., 1997. The physical, chemical, and mineralogical features of fly ash, as well as their particular relationship to concrete performance, have been studied. There is a comprehensive evaluation of the benefits of fly ash as a mineral additive in concrete, including increased strength and chemical resistant durability. A complete survey of various other fly ash products, such as bricks, mineral wool, and gypsum wall boards, as well as the use of fly ash in waste management, is provided, along with an extensive reference list and a complete survey of various other fly ash products, such as bricks, mineral wool, and gypsum wall boards.

Stadhouders, 2010. The lower the moisture and ash level of the produced coal, and the greater its fuel quality, the longer the exposure duration. Because lignite is a relatively new form of coal, it is regarded as a low-rank fuel. Lignite is not a uniform substance. Within and between the lignite strata, there exist quality differences.

Adamidou et al., 2007. These changes may also be seen in the amount and composition of LFAs. Processing becomes more difficult when there are large differences in the composition. A continual mix of varying lignite quality is delivered into the lignite power plant to manage the burning process. As a result, the makeup of the LFA will be more consistent.

Yun Luo and colleagues, 2011.The mobilization of trace elements that may pollute water is a key environmental problem linked with fly ash. Understanding the speciation of trace elements in fly ash and their potential environmental effect is critical for evaluating proper usage of fly ash, determining acceptable disposal techniques, and monitoring post-disposal conditions. In five typical class C fly ash samples, the speciation of selenium, arsenic, and zinc was measured.

Ledbetter et al. (1982) looked at five distinct class C flyashes generated in Texas to see whether they might be used as highway building materials. To evaluate the variability, a new test technique called the calcium oxide heat evolution test was developed, which allows the total calcium oxide content of class C flyashes to be measured rapidly and accurately in the field as a quality control test. The diversity of typical flyashes generated in Texas was determined utilizing this test in conjunction with usual physical and chemical characterizations. They were found to meet the ASTM standards for class C flyash in general. Aside from the study, the possible use of this sort of flyash is examined, as well as the calcium oxide content testing protocols.

Pistilli and Majko (1984) presented the findings of five different concrete mixes incorporating class C flyash comprising 9-12 %, 15%, and 25-30 % CaO, with the optimal proportion of flyash being 20-50 % cement replacement. Even at high flyash levels, suitably air-entrained materials demonstrated outstanding freeze-thaw endurance (85 to 95 % relative durability factor [RDF]) and acceptable air-void properties. In the presence of a water reducer and extremely high flyash levels, the setting times for the flyash combinations were extended by 4 to 6 hours.

Subasi (2009) used artificial neural networks and regression methods with ash content to investigate the effects of using different amounts (0, 5, 10, 15, and 20%) of class C fly ash in cement on the mechanical properties of mortar, such as compressive and flexural tensile strength, and found that the multilayer feed-forward neural network models prediction was better than regression techniques

Bhanumathidas and Mehta (2004), A preliminary research study on the impact of RHA in improving the characteristics of large volume fly ash concrete was conducted. They claimed that using RHA in ternary blends was an effective way to improve the early-age engineering qualities of concrete made using high-volume fly ash mixed cement. Such ternary mixes helped to progress by conserving cement, improving durability, and protecting the environment. Rice husk ash and Portland cement react to form a magnesium, calcium, and sodium silicate gel. The gel coats and fills up the pores between the RHA materials right away. To make silicate gel, the calcium in Portland cement has been replaced with magnesium and salt in the solution. The calcium then interacts with CO_2 to generate calcium carbonate, which precipitates in RHA. Ca2+, Mg2+, and Na+ removal %ages in brine vary from 2.6 to 86.1 %, 41.9 to 100 %, and 48 to 92 %, respectively, while bitterns had 35.6-94.1 % Ca2+, 38.6- 100 % Mg2+, and 39.4-94.6 % Na+ removed. As a result, RHA mixed with Portland cement may be used to rehabilitate salt-affected soils.

Halit Yazici et al. (2005). The impact of normal and steam curing on concrete adding ASTM class C flyash was studied Concrete compressive strength, volume stability of mortar bar specimens, and paste setting durations were also tested. Only 1-day strength of fly ash concrete was found to be poor under conventional curing circumstances, according to test findings. Even 50 % and 60 % of flyash concretes had adequate strength values at later ages. The 1-day strength was increased by steam curing, but the long-term strength was considerably diminished. For standard specimens, the setting time of fly ash–cement pastes and the volume stability of mortars with 50% or less flyash content were determined to be adequate.

III. METHODOLOGY

GENERAL INFORMATION

The experimentation is divided into three phases in order to build concrete that uses class C flyash in large quantities. According to trial mix proportions, the initial study proposes M30 grade concrete made using common constituents. The second fold takes into account replacing some of the high-level cement with class C flyash and using the planned concrete to assess its workability, strength, and durability properties. After evaluating the drawbacks of replacing cement with flyash, the third step proposes partially replacing flyash with silica fume. There are a total of 20 mix proportions produced, ten of which do not contain super plasticizers and ten of which do.

MATERIALS USED

Cement (OPC), river sand (fine aggregate), granite jelly (coarse aggregate), mixing water, admixtures (super plasticizer), flyash, and silica fume are the materials used in the study. Here, the specifics of how the qualities of all the materials utilised in this study were determined are described.

TESTS PERFORMED

1. Different Types of Test Used in Methodology

Specimen details for various strength tests

For the creation of the different specimens, traditional casting techniques such weigh batching, machine mixing, and casting on table vibrators are used. Achieved and reported strength after 360 days of treatment.

Tests for Compressive and Tensile Strength

According to IS: 516 - 1959, compressive strength of 100mm cube specimens and 100mm x 200mm cylinder specimens is assessed in relation to the age of curing. For each mix combination, three identical samples were tested at ages 7, 28, 60, 90, 180, and 360 days. The split tensile strength is achieved in a similar manner, and both test setup views are shown in Appendix H. Given that a cement replacement of greater than 60% results in an unacceptable compressive strength, future research will focus on cement replacements between 50% and 60%.

Flexural Strength Test

Concrete mixes with and without superplasticizer are mixed in varying amounts, and prismatic specimens of 100x100x500mm are cast to test the flexural strength of the material. The specimens are evaluated in a flexural testing machine as illustrated in Appendix H after 7, 28, 60, 90, 180, and 360 days of wet curing at a consistent rate of loading of 18 N/mm2/min. The formula and steps outlined in IS: 516-1959 are then used to compute the flexural strength of the specimens represented as the modulus of rupture describe the findings of flexure tests, and Figure 4.6 depicts the experimental setup for flexural strength testing.

IV. EXPERIMENTAL RESULTS

The experimental portion was completed via a number of experiments, and the findings are categorized and presented in according to the sequence in which the tests were conducted. The cube compressive strength of the twenty mix proportions is determined by tests, and 14 mix proportions are positively chosen for detailed examination. Workability, strength, and durability traits are categorized and studied for each of the 14 mix proportions. Here, a full study and comparison of test findings is offered.

4.1 COMPRESSIVE STRENGTH TEST

The rate of increase in compressive strength at 7, 28, 60, 90, 180, and 360 days for flyash concentrations of 50, 60, 70, 80, and 90 % with and without SP is shown in Figure 4.2. It has been demonstrated that compressive strength declines at earlier ages by introducing additional flyash. However, the strength could not be satisfactorily obtained when flyash was used in place of cement to the level of 70%, 80%, and 90%. When flyash replaces 50 or 60 % of the cement at 28 days, the compressive strength is decreased by 17 or 23 % without SP and by 9 or 16 % with SP. Compressive power went raised. The %ages for 50% and 60% of cement replacement by flyash at 60 days are 1.90 % and 0.76 % without SP, 10% and 5% with SP, 13% and 4% without SP, 19.84 % and 8.98 % with SP, and 19% and 7% % with SP. There were 25% % and 10.5% without SP after 180 days, and 29% and 17% with SP at 360 days of cure, respectively.

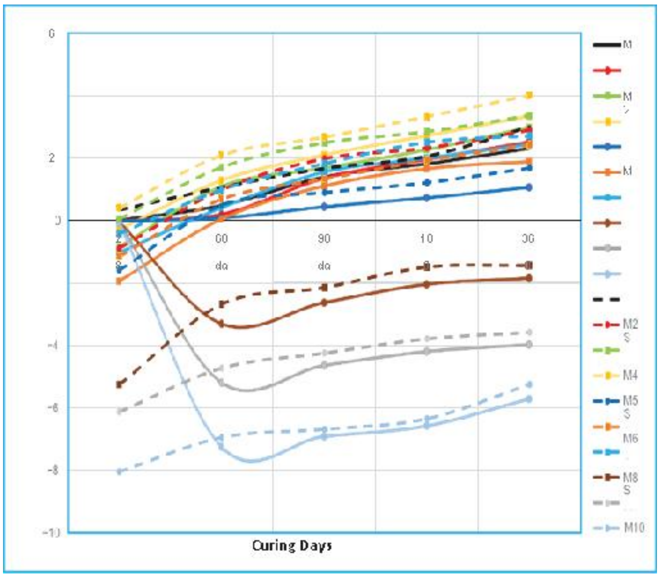

Fig-1 Comparison of Change of Compressive Strength

4.2 SPLIT TENSILE STRENGTH

The most used technique for determining the indirect tensile strength of concrete is the spilt tensile test. The tensile strength of concrete with and without flyash, silica fume, and super plasticizer is thoroughly investigated and compared. For the flyash mixes M2 and M5 without SP, M2S and M5S with SP, and silica fume added mixes M3, M4, M6 and M7 without SP, M3S, M4S, M6S, and M7S with SP at the ages of 7, 28, 60, 90, 180, and 360 days, respectively, the rate of increase in split tensile strength is shown in Fig below.

At 28 days, the split tensile strength of the flyash mixes M2 and M5 decreased by 25.40 and 43.44 % without SP, 18 and 37% with SP, and 14 and 29.50% without SP, 8.2 and 22.4 % with SP, respectively. Flyash mixes M2 and M5 gain split tensile strength by 17% and 1.6%, respectively, while M2S and M5S gain split tensile strength by 28% and 7%, respectively, at 90 days with SP and at 360 days of curing without SP, 29% and 8% without SP, 32% and 16% with SP at 180 days, 32% and 15% with SP, and 36.5% and 19% with SP.

Without SP, silica fume-based concrete mix tensile strength decreases by 0.80 %, 23.75 %, and 11.5% for M3, M6, and M7, respectively, and by 14.75 % and 3.25% after 28 days of curing for M6S and M7S. After 28 days of curing, M4's tensile strength rose by 19.70% without SP and by 9% and 26% with SP in comparison to the control concretes M1 and M1S.

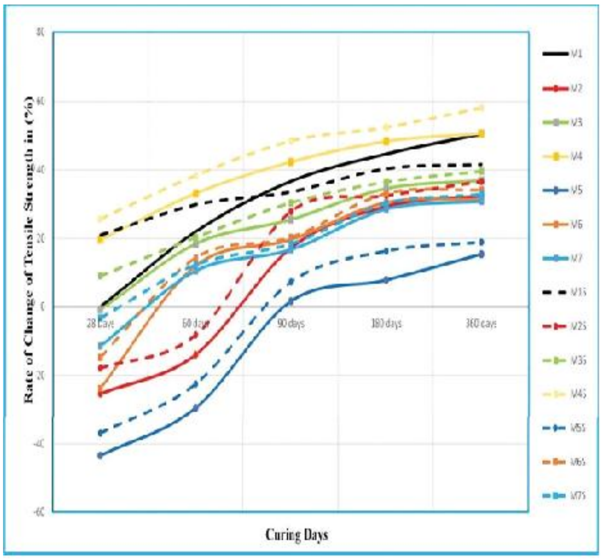

Fig-2 Comparison of Change of Flexural Strength

It has been demonstrated that mixes M3, M4, M6, and M7 without SP and M3S, M4S, M6, and M7S with SP showed higher tensile strength when compared to control concretes. The breakdown is as follows without SP: Additionally, 20.32 %, 38.34 %, 12.0%, and 10.50%; 18%, 33%, 14% and 12% with SP at 60 days, 25.50%, 42%, 19.7%, and 16.7 % without it, and 30.5%, 48.4%, 20%, and 18.4% with SP at 90 days, in that order, were observed. Without SP, there were 30.4 and 28.5%, while with SP, there were 36.4, 52, 33, and 30% 180 days; SP was missing in 37%, 50.5%, 31%, and 31% of cases, and in 39.5%, 58%, and 30.5% of cases. The %ages were 34 and 33 with SP at 360 days.

V. CONCLUSIONS

1. When silica fume is added, the flyash-based concrete becomes even more workable when compared to regular cement concrete. To improve the strength, which is inversely related to the water-to-cement ratio, the slump value is, however, somewhat lowered (0 to 20mm).
2. For M30 grade concrete, investigations were conducted on both concrete with and without SP, however the SP-containing concrete performed better overall in terms of workability, strength, and durability characteristics.

3. When comparing the compressive strength of a cube to typical cement concrete. The concrete's compressive strength is sufficient when 50% and 60% of the cement is replaced with flyash, but not at higher replacement levels, even when silica fume is added under normal circumstances.
4. For flyash-based concrete, the rate of increase in compressive strength is plainly sluggish. For 60-day-cured samples, the strength is increased by 9.92% and 4.96% for replacements of 50% and 60% of the cement with flyash and superplasticizer, respectively. Strength increases noticeably in samples that have been cured for more than 60 days (1.9 % to 29 % up 360 days of curing).
5. For concrete of the M30 grade, flyash should be used in lieu of cement to the extent of 50%, and silica fume should be used in place of flyash to the extent of 10%. Similarly, it is reasonable to replace flyash with cement to the tune of 60% and to replace silica fume with flyash to the tune of 20%.
6. Despite the fact that samples that had been preserved for more than 28 days had greater strength, waiting longer than 60 days is not really practicable.
7. The same trend as for compressive strength was shown when comparing flyash-free ordinary cement concrete to split tensile strength.
8. When flexural strength is compared to conventional cement concrete without flyash, the strength of the concrete for 50 and 60% cement substitution with flyash is sufficient with the addition of 10 and 20% more silica fume, respectively. With the addition of super plasticizer and silica fume, the strength of samples that have been cured for more than 28 days is higher than it would otherwise be At 60 days of curing for the concrete mixes M3S, M4S, M6S, and M7S, respectively, SP increased their strength by 17.15%, 20.95%, 6.95%, and 9.95%.
9. When silica fume is added in amounts of 10% and 20%, respectively, the modulus of concrete for 50% cement substitution with flyash is adequate when compared to conventional concrete in terms of modulus of elasticity. Due to the inclusion of superplasticizer and silica fume, samples that have been cured for more than 28 days often have elasticity that is higher. After 28 days, 1 %, and 60 days of curing with and without SP, the modulus of elasticity of concrete mixes rose by 3.25%, 1%, and 3.75 %, respectively.
10. In terms of durability qualities, flyash-based concrete exhibits more saturated water absorption than normal cement concrete, but the addition of silica fume significantly lowers the SWA. For the concrete mixes M3, M4, M6, M7, M3S, M4S, M6S, and M7S, the SWA is decreased by 7.75%, 15.85%, 1.5%, 5.85%, 12.55%, 18.95%, 4.65%, and 8.75% at 28 days of curing, respectively. But after 60 days of healing, there is a noticeable improvement in performance (25 % to 49 % from 60 to 360 days of curing)
11. Flyash-based concrete has higher porosity, coefficient of water absorption, and sorptivity than ordinary cement concrete (1.45% to 8.65% after 28 days), however the addition of silica fume has significantly decreased these properties (2.35% to 9.35% at 28 days). But after 60 days of healing, there is a noticeable increase in performance (6.15% to 20 % from 60 to 360 days of curing).
12. With regard to durability traits like acid attack, flyash-based concrete exhibits greater weight loss (11 to 19.5 %) and compressive strength reduction (6.4 to 7.2 %) than conventional cement concrete. However, the addition of silica fume by 20 % has reduced the weight loss by 7.5 % and the compressive strength reduction by 4.7 % at 28 days of curing with and without SP, respectively. But after 60 days of cure, there is a noticeable increase in performance (8 % to 13.5 % up to 360 days).
13. The weight loss (5.4 to 5.9%%) and reduction in compressive strength (6.9% to 7.7%%) are higher for flyash-based concrete when compared to conventional cement concrete with regard to durability characteristics like sulphate attack, but the addition of silica fume by 20% has decreased the weight loss by 3.8 % and the loss in compressive strength by 3.4 % at 28 days of curing with and without SP, respectively. Continuous soaking is shown to have the worst impact when compared to alternating wet and dry cycles. After 60 days of healing, performance does, however, improve.
14. For flyash-based concrete, weight loss ranges from 4.2 to 4.8 % and compressive strength loss ranges from 1.7% to 0.95 % at 28 days of curing with and without SP, respectively. However, compared to conventional cement concrete, flyash-based concrete exhibits greater weight loss (4.2 to 4.8 %) and compressive strength loss (1.7 %). But after 60 days of cure, there is a noticeable increase in performance (2.9 % to 6.8 %).
15. However, in general, acid resistance is superior to sulphate attack, and alkaline resistance is superior to both attacks.
16. The performance of flyash-added concrete is subpar (less by 31%) when compared to conventional cement concrete with regard to durability characteristics, particularly through rapid chloride permeability testing. But the addition of silica fume significantly enhanced the performance (less by 60 %). However, the performance enhancement is more apparent after 60 days of cure (68 %).
17. According to the polarization research, the addition of flyash decreases the durability characteristics of ordinary cement concrete (bad performance by 8.3% to 16.7%) but

increases the breaking time of concrete at early stages (28 days) (4.2%). In situations of 60 and above, the tendency is in the other direction (2.5 % to 9 %).Concrete with 60 % cement replacement for flyash crumbled before concrete with 50 % cement replacement for flyash (16.7% earlier). The cracking time for all concrete, both with and without SP demonstrating greater performance, rose with the addition of silica fume, which largely replaced flyash. In both 50 % and 60 % flyash-based concretes, a 20% replacement of flyash with silica fume produced better results than a 10 % substitution.

18. As SP was added, all concretes had longer breaking times, which enhanced their overall polarization resistance when compared to concretes without SP.
19. Based on the findings of the experiments, it is discovered that equation predicts the compressive strength of concrete utilizing a variety of data sets (6.1).The GRNN did a good job of predicting compressive strength.

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