
NATURE OF HIGH-PERFORMANCE CONCRETE FOR HIGHWAY PAVEMENT USING ALCCOFINE AND FLYASH

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ABSTRACT

Concrete is the backbone of the construction industry, and the demand for solid pavements in road construction is also growing. However, the production of cement in large quantities causes environmental problems such as the release of greenhouse gases (CO) and the depletion of natural resources. Therefore, it is necessary to use industrial by-products such as Ash, Alccofine, etc. without changing the technical properties of the concrete. Today, most concrete mixes contain additional cementitious materials that form part of the cement component. These materials are mostly by-products from other processes. Developing countries like India are witnessing massive construction activities in infrastructure sectors. The transport sector in particular has seen significant construction of highways, roads, ports, railways and airports in the last decade. The vast amount of civil infrastructure in the world includes a vast stretch of the road network. Today, high performance concrete (HPC) is mostly used for highway pavements due to its high durability even under high repeated loads. Due to the high resistance and strength, HPC demand in the construction industry from railways, bridges, buildings, pavements. Sidewalks are an important part of the road infrastructure. The need for HPC is growing due to its high demands in road construction. The initial cost of concrete may be higher than asphalt pavement, but concrete costs less over the life cycle of the pavement. Roads can be opened faster than ever and can be easily repaired with the right equipment, materials, processes or procedures. Concrete road infrastructure around the world requires innovative and cost-effective rehabilitation solutions. An extensive literature is presented on recent research on high-quality concrete using different admixtures in different proportions to improve physical and mechanical properties in order to design high-strength concrete that can be used in road pavements. This research deals with the mechanical and rheological properties of high-performance concrete with the replacement of cement with industrial by-products such as Alccofine and Ash. The study is conducted to check the behavior of HPC using fly ash and Alccofine for road applications. Because Alccofine and Fly ash exhibit cementing properties, they can be easily used to produce high-performance concrete. The main objective of the study is to design HPC class M60 according to the ACI method and to determine the mechanical properties. Concrete is produced by mixing a solid proportion of fly ash (17%) and various proportions of Alccofine (3%, 6%, 9%, 12%, 15%) at a water-cement ratio of 0.25. A superplasticizer (3% cement) is added to increase flow and reduce water requirements. Mechanical properties such as compressive strength, tensile strength and flexural strength are determined at the age of 28 days. Alccofin and Flyash increase rheological properties due to their smaller particle size. The addition of Alccofine and Flyash helps to gain strength properties and makes the concrete environment friendly without much impact on the price.

Keywords: Alccofine, Flyash, concrete, Portland cement, rheological properties.

1. INTRODUCTION

Concrete is an important building material in the construction industry. In this scenario, concrete is considered as one of the best building materials. However, the progress of the concrete industry also causes many other natural problems such as pollution, disposal of waste materials, emission of greenhouse gases (CO₂), depletion of vegetation and natural resources. Currently, ordinary portland cements (OPC), binders and other inexpensive materials are available to enhance the properties of concrete. But for the production of each ton of cement, about 1 ton of CO₂ is produced. Therefore, the production of cement plays an important role in the formation of greenhouse gases, which contribute about 5 percent to the total CO₂ emissions. Developed countries such as the US and the UK are aware of these situations and have also introduced climate change taxes to reduce carbon emissions. Therefore, the concept of sustainable development is introduced with the aim of using industrial waste products to improve the properties of concrete. These industrial wastes or by-products play a vital role in the sustainable development of the concrete industry and provide the most suitable, economical and technical solutions for waste disposal that lead to less damage to nature. These by-products and wastes can be used as a partial replacement for cement, making them an important component of concrete.

2. LITERATURE REVIEW

To explain the objectives of the proposed research work, a comprehensive literature survey is conducted in terms of experimentation and theory related to the proposed research work. Zubair SM investigated the use of fly ash, Alccofin and silica fumes in different ratios. The investigation was conducted on fresh and hardened concrete and compressive strength tests were conducted on cast cubes on specified days and it was analyzed that the mixture containing Alccofine and fly ash had higher compressive strength compared to the mixture containing silica fume and fly ash. Since the size of the silica fume was small, the workability decreased and a higher dosage of superplasticizer was required to achieve the same workability.

Tsai CT studied the construction of cement concrete pavement on bus lanes in Taipei City, in which HPC and high performance steel fiber reinforced concrete (HPSFRC) were used. The compressive and flexural strength behavior of HPC and HPSFRC was investigated at 3, 28 and 56 days of age. This successful investigation provided the basis for the establishment of a transportation policy in Taipei City that cement concrete pavement was strongly designed instead of conventional bitumen pavements of bus lanes at bus stops.

P. Muthupriya(4) studied the behavior of highly resistant reinforced concrete with partial replacement of ordinary Portland cement with metakaolin and fly ash. The author concluded that the development of high strength in the reinforced concrete column was due to the pozzolanic reaction and the filling effects of metakaolin. Replacement with metakaolin and fly ash resulted in greater cohesion and less segregation along with a denser microstructure of the concrete matrix that improved durability properties. It was also found that the water absorption rate of the test sample is lower compared to the normal concrete sample.

Reddy MVS studied the characteristic properties of HPC grades M80 and M90 with and without supplementary cementitious materials (SCM). The author concluded that when designing the HPC mix, because the adopted water/cement ratio was low, a superplasticizer was necessary to maintain workability. A higher percentage of superplasticizer was needed to increase the workability with an increase in the mineral admixture content of the mixture for thorough mixing and the desired strength. With the replacement of the specified percentage of fly ash and metakaolin, the total passed charge for HPC grade M80 and M90 was very low compared to conventional concrete. SCM pozzolanic reactions improved the pore structure of concrete and resulted in lower permeability causing higher resistance to chloride ion penetration at higher percent replacement compared to conventional concrete.

Patil BB presented a study in which metakaolin was used for weight cement along with some suitable plasticizer and various properties like workability, compressive strength and durability of M60 grade concrete were studied. Improvements in workability and strength properties were observed when using highly reactive metakaolin (HRM), and resistance to chemical attack was also observed. With an increase in HRM content up to 7.5 percent, compressive strength was found to increase, but excessive contents reduced the w/b ratio and retarded pozzolanic activity, leading to a slight decrease in compressive strength. The increase in compressive strength was attributed to sufficient HRM available for reaction with calcium hydroxide, which accelerates the hydration of the cement and the C-S-H gel formed.

Patel V and Shah N" presented a detailed report on the development of high-performance concrete over the last few years. The paper included the effects of mineral and chemical admixtures used to improve the properties of concrete. The paper also highlighted the properties and exposure conditions along with the requirements. It was found that the strength of high-performance concrete completely depends on proper mix design, production, placing and curing of concrete.

Patil Shreekedar further investigated the compressive strength and workability properties of a concrete mixture containing fly ash and micro-silica and also optimized the dosage of micro-silica and fly ash to achieve M60 strength. Concrete containing micro-silica and fly ash was found to have higher compressive strength, increased durability and reduced workability. Small particle size reduced voids, which indirectly lead to increased strength.

3. EXPERIMENTAL INVESTIGATION

Number of tests are done on the concrete samples to get the strength properties of HPC using fly ash and Alccofine at different proportions for application in highway pavements. This chapter deals with the results that obtained from the experimental work. The results of samples on various tests such as compressive test, split tensile, flexure test have been discussed.

Compressive strength results

The results of compressive strength for HPC cubes at the age 28 days for water-binder ratio of 25 with the partial replacement of cement by Alccofine and flyash are evaluated. The value of compressive strength of concrete cubes are given in the Table 1 and graph between compressive strength and mixes at 28 days is also plotted as shown in Figure

2. From the test results, it is observed that the maximum compressive strength is recorded for MFA4 mix with 12% Alccofine at age of 28 days with water-binder ratio of .25. The reaction of Alccofine or flyash with calcium hydroxide of cement formed C-S-H gel during the cement hydration. Testing of cubes in CTM is shown in Figure 1.

Table 1. Observations of Tested Samples at 28 days

Design ation	Cement	Fly ash	Alcco fine	F.A	C.A (10mm)	Water	Super Plasticizer	f_{ck}	f_{ct}	f_b
MFA1	648	135	20	585	1040	201	24.09	59.89	3.94	5.25
MFA2	628	135	40	585	1040	201	24.09	64.81	4.11	6.12
MFA3	608	135	60	585	1040	201	24.09	65.44	4.66	6.40
MFA4	588	135	80	585	1040	201	24.09	66.53	5.55	7.35
MFA5	568	135	100	585	1040	201	24.09	65.01	5.19	6.25

f_{ck} =compressive strength(MPa), f_{ct} =split tensile strength (MPa), f_b = flexural strength(MPa)



Fig. 1 Cube testing in compression testing machine

Flyash and Alccofine at 28 days

Split tensile strength results

Concrete cylinder sample of size 15cm diameter and 30 cm length according to IS:5816- 1999 ⁽⁴⁴⁾ are made blending with flyash and Alccofine as partial replacement of cement and results are calculated. The results show that it is possible to obtain high split tensile strength after 28 days. In addition, strength upto 5.5 MPa is obtained at 28 days. The split tensile strength value of concrete cylinders are provided in the Table 1 and graph between split tensile strength and different mixes 28 days is also plotted. From the test results, it is observed that the maximum compressive strength is recorded for MFA4 mix with 12% Alccofine at age of 28 days with water-binder ratio of 0.25. Figure 3 shows cylinder testing in compression testing machine.

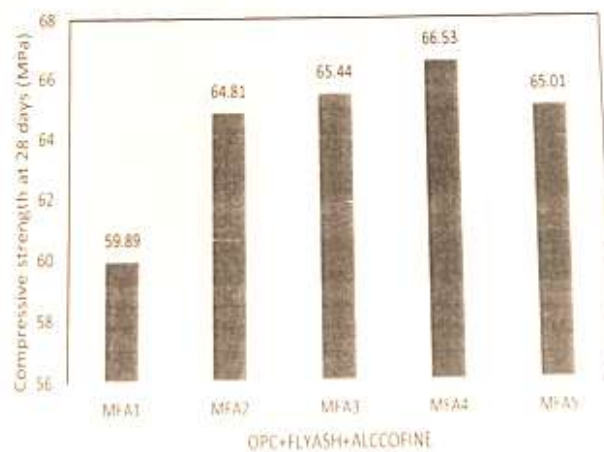


Fig. 2 Compressive strength results HPC blending with



Fig. 3 Cylinder testing in compression testing machine.

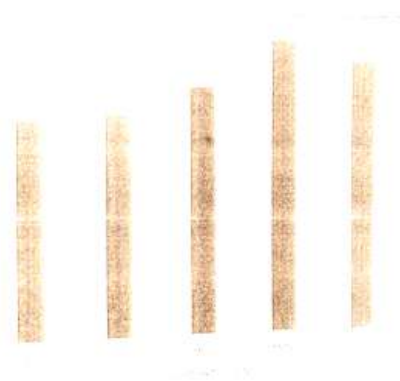


Fig. 4 28 days split tensile strength results HPC blending with Flyash and Alccofine

Flexural Strength Results

The results show that the Fly Ash and Alccofine have pronounced effect on the flexural strength of concrete. On the other hand, the flexural strength of concrete using SCMs is seemed to be higher values due to very high fineness of particles and pozzolanic reaction of fly ash and Alccofine. The test beam 10 x 10 x 50 cm is symmetrically supported on two parallel steel rollers 38 mm in diameter and the distance between the centers of the two rollers adjusted to 40 cm. The load is applied through one rollers mounted at the center point of the supporting span. The load is applied without shock and increased continuously at constant rate for the specimen. The load is increased till the specimen fails and the maximum load sustained and deflection at point of loading is recorded. The flexural strength is expressed as the modulus of rupture (f_i) according to the IS-51643). Observations and results recorded at 28 days are tabulated in following Table 1. Flexural testing machine used for testing for flexural strength of beam is shown in Figure 5.



Fig. 5 Beam testing in Flexural testing machine

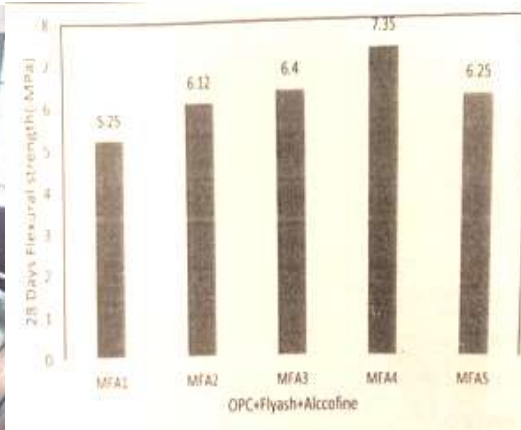


Fig. 6 Flexural strength results HPC blending with Flyash and Alccofine

4. CONCLUSION

High Performance Concrete has achieved the status of an exceptional advance in the field of concrete technology. The use of HPC is expanding worldwide due to its highly efficient properties. This new technology has attracted the attention of researchers, practical engineers and several industries, including cement and admixture manufacturers, due to its high performance achieved in the fresh and hardened state. Increased productivity, lower labor requirements and a better working environment are also important factors. characteristic. The need for HPC development is growing rapidly due to the demand placed by the construction industry in recent times. The main objective of any mix design method is to determine a suitable and economical combination of concrete materials that can be used for the first trial batch to produce a particular concrete that approaches a good balance of the various desired concrete properties at a lower cost. . The batching of the mixture provides only a design of the starting mixture, which will have to be modified more or less to meet the desired properties of the concrete. Experimental work was carried out to prepare and check the acceptability of the proposed mixtures. The proportioning of the mix is done according to the ACI mix proportioning method which is completely based on material properties with mixing of HPC grade M60 with different percentage replacements of fly ash and Alccofine. To check the suitability of the designed concrete mixture, the performance of the designed mixture is evaluated in terms of rheological properties in the fresh state. Compressive strength, tensile strength at tear and flexural strength are calculated after 28 days with different volumes of fly ash and Alccofine.

Laboratory tests covering the mechanical and rheological aspects of high strength concrete are carried out. The main experimental conclusions of this work are as follows;

- High performance concrete is modified by mixing with fly ash and Alccofine as SCM. These modifications reduce CO₂ emissions and make the concrete environmentally friendly.
- From the compressive strength of different mixture ratios considering all available SCMs, it was found that the mixture containing fly ash and Alccofine gave good results. The minimum and maximum compressive strength achieved after 28 days of curing were found to be 59.89 N/mm² and 66.53 N/mm².
- The compressive strength of concrete increases with an increase in Alccofine content by up to 12%. It was therefore concluded that, based on the research, there is a possibility of producing concrete with a compressive strength higher than 60 MPa from a mixture containing Alccofine and fly ash as SCM in a ratio of 0.25 w/b. The use of fly ash and Alccofine in the mixture showed a substantial improvement in the strength characteristics of HPC.

- iv. There was a significant improvement in the flexural behavior of the concrete mixture containing fly ash and Alccofine. The maximum obtained bending strength is 7.35 MPa.
- v. The minimum and maximum tensile strength after 28 days of curing were found to be 3.94 N/mm² and 5.55 N/mm². The high strength achieved by using SCM reduces the maintenance costs of the structure.
- vi. When using a superplasticizer admixture with HPC made from aggregate, adding the admixture at the final mixing stage consistently improves the properties of fresh and hardened concrete compared to the traditional practice of adding the admixture to the mixing water.
- vii. Cubic compressive strength studies show that the optimum percentage of Alccofine is about 12%. HPC density increases with increasing Alccofine content.

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