Investigation on Flexural Behavior of HPFRC Beams Subjected To Monotonic And Cyclic Loading

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Abstract- *The present project is directed towards developing a better understanding on the contribution of metakaolin and fly ash along with Polyolefin Macro-Monofilament fibers on the strengths of High Performance Concrete. The experiments are carried out by adopting a constant water-binder ratio of 0.3 for M60 grade concreteis designed as per ACI 211.4R-08 Guide for selecting proportions for high strength concrete with Portland cement and other cementitious materials. The Portland cement was partially replaced with the mineral admixtures metakaolin and fly ash of each 10%. The fibers adopted are ranging from 0%, 0.1%, 0.2% ,and 0.3%.*

The strength studies were going to be conducted to investigate the influence Polyolefin Macro-Monofilament fiber at the various ratios 0.1, 0.2, & 0.3 percentage. The specimens are to be tested for young's modulus, Poisson's ratio, and flexural toughness of HPFRC. The HPFRC beam specimens are about to be cast and to be tested for Monotonic and Cyclic loading. A recommend guideline for improving the flexural capacity of beam with fiber and replacement of the mineral admixtures metakaolin and fly ash are to be suggested. The load–deflection curve and stress-strain relationships as a function of the fiber volume fraction have to be been formulated.

I. INTRODUCTION

Any concrete which satisfies certain criteria proposed to overcome limitations of conventional concretes may be called High-Performance concrete (HPC)." It may include concrete which provides either substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. It may also include concrete which significantly reduces construction time to permit rapid opening or reopening of roads to traffic, without compromising long-term serviceability. Therefore, it is not possible to provide a unique definition of HPC without considering the performance requirements of the intended use of the concrete.

Normal concrete relatively have low strength and elastic modulus are the result of high heterogeneous nature of structure of the material, particularly the porous and weak transition zone, which exists at the cement paste-aggregate interface. By densification and strengthening of the transition zone, many desirable properties can be improved many fold. A substantial reduction of quantity of mixing water is the fundamental step for making HPC. Reduction of w/ c ratio will result in high strength concrete. But reduction in w/ c ratio to less than 0.3 will greatly improve the qualities of transition zone to give inherent qualities expected in HPC.

To improve the qualities of transition zone, use of silica fume is also found to be necessary. Metakoline becomes a necessary ingredient for strength above to 65 MPa. The best quality fly ash may be used for other nominal benefits. Inspite of the fact that these pozzolanic materials increase the water demand, their benefits will out weigh the disadvantages. The crux of whole problem lies in using very low w/ c ratio, consistant with high workability at the time of placing and compacting.

Adopting w/ c ratio in the range of 0.25 to 0.3 and getting a high slump is possible only with the use of superplasticizer. Therefore, use of appropriate superplasticizer is a key material in making HPC.

1.1 NEED FOR HIGH PERFORMANCE CONCRETE

Cementitious materials have been in existence for a long time and it is a well known fact that their use in construction activity dates back to the time of Babylonians, Romans and Egyptians. These materials had undergone several changes over the ages and during the past four decades. Changes both in the process and production have established that cement and concrete composites are the most economical construction materials as on today.

Inspite of these advancements, the rapid deterioration of concrete structures especially, in coastal regions and in industrial locations having aggressive environments, necessitated enhancing the durability aspects of concrete mixers. As a first step, it has been established that the lower w/c ratio results in HSC that can resist the environment degradation better. But the requirements of workability inhibited the initial attempts in this direction, until super plasticizers or high range water reducers were developed. These materials facilitated the production of reasonably high strength concrete having low w/c ratio; through mostly with higher cement contents. However, it was soon learnt that this approach to improve the performance levels necessitated an increase in cement content, making the concretes much more relative to the environments. These aspects resulted in prescribing norms to the minimum and the maximum cement contents permissible in the different environments.

Also, it was realized that the high strength alone will not be an effective method for achieving high performance and that the durability of these materials in various environments need a better understanding to achieve an appropriate solution. These necessitated the utilization of industrial wastes having pozzolanic properties in concrete and showed the possibilities of obtaining improvements in durability, besides attaining HSC composites. The important milestone of these works is probably the introduction of recycled concrete aggregate, metakoline and fly ash with the use of both pozzolanic materials and super plasticizers; it is now possible to incorporate both high strength and high performance in concrete composites.

1.2 METAKAOLIN

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration.

Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete’s strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete.

Our experience has shown that optimal performance is achieved by replacing 10% to 15% of the cement with metakaolin. While it is possible to use less, the benefits are not fully realizeduntil at least 10% metakaolin is used.The advantage of replacing some of the cement with metakaolin, rather than simply addingmetakaolin to the mix, is that any existing color formulas or mix designs won’t change, or willonly very slightly change. This is because the dosage of pigments and superplasticizers arebased on the cement content in the concrete.Of course, it is OK to simply add metakaolin to an existing mix, but it’s important to realizethat the total equivalent cement content will increase. Be aware that this will affect not only the pigment and admixture dosages but also the water to cement ratio, a critical factor in mix design.How well metakaolin behaves depends on your mix design and, more critically, on how much mix water is used. Keep in mind that any admixture must be used wisely. All the other factors (good mix design, proper reinforcing, etc) must also be properly designed and accounted for in order to take advantage of the benefits metakaolin can give you. For example, making a very high compressive strength concrete is pointless if the reinforcing is inadequate.

1.3 EXPERIMENTAL INVESTIGATION

A total of Eight HPC beams were cast. All the beams were cast with flexure reinforcement. All the beams were rectangular in cross section. They are 100mm wide, 200mm deep and the overall length is 1700mm. All the beams are tested for an effective span of 1500mm. The beams are designed as under reinforced and consisted of 4 numbers of 10 mm diameter bars in the tension face and 2 numbers of 8 mm diameter bars in the compression face. Two legged 8mm diameter stirrups at a spacing of 135 mm were provided throughout the section. The curing process was done by using wet gunny bag and water used daily to ensure the sack is under wet condition for 28 days

1.4 FLY ASH

Fly ash is finely divided residue resulting from the combination of ground or powered coal. They are generally finer then cement and consist mainly of glassy spherical particles as well as residue of hematite and magnetite, char and some crystalline phases formed during cooling.

1.5 FIBRE REINFORCED CONCRETE

Fiber Reinforced High Performance Concrete (FRHPC) is a composite material consisting of hydraulic cement, sand, silica fume, fly ash, coarse aggregate, water and fibers. FRHPC results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. In this composite material, short discrete fibers are randomly distributed throughout the concrete mass.

Fiber Reinforced High Performance Concrete (FRHPC) represents potential alternative for providing more cost-effective ductile beam–column joints for structures constructed in active seismic zones. This can be achieved by reducing the amount of confining steel reinforcement in the joint regions and compensating for the required shear strength by steel-fiber reinforced concrete.

Fiber Reinforced High Performance Concrete (FRHPC) results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. Due to the superior performance characteristics of this category of HPC, its use by the construction industry has significantly increased in the last 5 years. A very good guide to various Portland cement-based composites as well as their constituent materials is available in book. It provides information on fabrication, mechanical and long-term properties of concretes with short discrete fibers

Polyolefin Macro-Monofilamentfibers:

PMMF fibres is a macro-synthetic fibre designed specifically for the reinforcement of concrete and other cementitious mixes. These fibres have an engineered contour profile,which serves to effectively anchor the fibres into concrete thus resisting matrix pullout and enhancing the concrete's performance even after it has developed stress cracks. These fibres are non-corrosive and can be considered,in many applications, as an alternative to both steel fabrics and steel fibres.

1.6 SUPER PLASTICIZER

Superplasticizers or high range water reducers or dispersants are chemical admixtures that can be added to concrete mixtures to improve workability. Unless the mix is "starved" of water, the strength of concrete is inversely proportional to the amount of water added or water-cement (w/c) ratio. In order to produce stronger concrete, less water is added (without "starving" the mix), which makes the concrete mixture very unworkable and difficult to mix, necessitating the use of plasticizers, water reducers, superplasticizers or dispersants.

Superplasticizers are also often used when pozzolanic ash is added to concrete to improve strength. This method of mix proportioning is especially popular when producing high-strength concrete and fiber-reinforced concrete.

Adding 1-2% superplasticizer per unit weight of cement is usually sufficient. However, note that most commercially available superplasticizers come dissolved in water, so the extra water added has to be accounted for in mix proportioning. Adding an excessive amount of superplasticizer will result in excessive segregation of concrete and is not advisable. Some studies also show that too much superplasticizer will result in a retarding effect.

Plasticizers are commonly manufactured from liqnosulphanates a by-product from the paper industry. High Range Superplasticizers have generally been manufactured from sulphonatenaphthalene condensate or sulfonate melamine formaldehyde, although new-generation products based on polycarboxylic ethers are now available. Traditional lignosulfonate-based plasticisers, naphthalene and melamine sulfonate-based superplasticisers disperse the flocculated cement particles through a mechanism of electrostatic repulsion In normal plasticisers, the active substances are absorbed on to the cement particles, giving them a negative charge, which leads to repulsion between particles.Lignin, naphthalene andmelamine sulfonatesuperplas ticisers are organic polymers. The long molecules wrap themselves around the cement particles, giving them a highly negative charge so that they repel each other.

II. SCOPE AND OBJECTIVES OF THE INVESTIGATION

The main objective of the present investigation is to study the behavior of high performance reinforced concrete beams (replacement of cement with metakaolin and fly ash). Metakaolin and fly ash are used as a partial replacement of cement and super plasticizer is used to achieve require workability.

- ✓ To study the strength characteristics of Fiber Reinforced High Performance Concrete (FRHPC) and stress and strain behavior by testing these specimens made of FRHPC and normal concrete
- ✓ To compare the variation of strengths for different mixes..
- ✓ To identify the optimum amount of replacement of metakaolin and flyash with 10% volume of cement and with the fibrecontant of 0.1%, to ,0.3%.

Table 1.1 HPFRC Beams specimens for Monotonic and Cyclic loading:

Concrete Grade	Specific name	Percentage of Fly ash	Percentage of Metakaolin	Percentage of fiber	TOTAL
M60	BS1	10	10	0	2
M60	BS2	10	10	0.1	2

M60	BS3	10	10	0.2	2
M60	BS4	10	10	0.3	2

CONCLUSION

The review of literature in this Chapter has concentrated largely on the behavior of beam subjected to cyclic bending and their seismic behavior**.** At the micro level, the **effect of metakaolin in enhancing compressive strength have been assessed.** At the macro level, **the durablity of flyash, fibre were observed.** Thus this Chapter provides a basis for the next in which the observations were resulted in clear knowledge of applying HPFRC for beam members which is subjected to monotonic and cyclic loading.

DISCUSSION OF BEAM TEST RESULTS

- Test results of beams under flexure indicate that, the beam with 10% of Metakaolin and Fly Ash has the highest load carrying capacity of 45 kN. This is about 1.25 times higher than that of the control mix beam (CM).
- The ultimate load carrying capacity obtained experimentally is greater than the value obtained theoretically. The first crack appeared at the jack load of 38kN for HPC beam where as the first crack load was 45kN for HPFRC 0.3% FD beam which is 18.5% higher than that of the control beam.
- From the Moment-Curvature relationship, within the yielding stage the 0.1% HPFRC beams show higher stiffness than the control and 0% HPC beams.
- The Displacement ductility, rotation ductility and curvature ductility is greatly increased in the beams when compared to control and HPFRC beams. Hence it is understood that the performance and energy absorption are greatly increased.
- The inclusion of fiber increases the load carrying capacity for 0.3% HPFRC beam about 12.5% compared with the Control specimen .

III. CONCLUSIONS

Based on the general investigations made the following the following conclusions were made:

- The Flexural toughness of test prism was measured for HPFRC prisms for 28, days, for water binder ratio of 0.3 and at a replacement levels such as 10% of fly ash and CM,0,0.1, 0.2, and0.3% PMMF fibre
- The deflection to the corresponding loading with age and for different percentage of PMMF fiber were plotted in the form of graphs
- From the test results it was observed that the CM and HPC carrying a same load with very small decreasing deflection.
- The poisson’s ratio and young’s modulus for the HPC is slightly more then the CM and gradually increasing for fibre dosages such as 0.1,0.2,and 0.3%.
- The main aim of the addition of PMMF fibre results in a decrease in deflection and increase in flexural strength when compared to control and HPC beams.
- The fibers hold up the broken pieces in the specimen, which reduces the spalling of concrete.
- The first crack load and Ultimate Load of HPC beams with 0.1%, 0.2% and 0.3% Fibre were compared with control beams which is gradually increased.
- The Displacement Ductility, Rotation Ductility , Curvature Ductility of HPC beams with 0.1%, 0.2% and 0.3% Fibre gradually increased when compared to Control beam.
- With the above findings from this work, the potential of using HPFRC with the inclusion of PMMF fibers eliminates the sudden failure of the specimens compared to conventional concrete and the performance of HPFRC is superior to HPC and conventional concrete and hence can prove to be beneficial for the production of structural sections.
- The addition of fibers does not change the crack pattern as such but there were reduced crack widths, which were observed.

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