
PERFORMANCE OF HIGH STRENGTH CONCRETE PAVEMENT USING METAKAOLIN AND HYBRID FIBRES

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ABSTRACT

Cement concrete construction in today's developing countries is very common and the use of concrete is increased day by day. In the past few years, many research and modification has been done to produce concrete achieve desired characteristics. There is always a search for concrete with higher durability. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacturing have brought pressures to reduce cement consumption by the use of supplementary materials. Supplementary materials such as metakaolin, silica fume, quarry dust, fly ash, bottom ash and blast furnace slag can be used as a replacement of cement in mortar and concrete. Another main concern about concrete is its brittleness. Studies have reported that tensile strength and ability to resist cracking are also enhanced with the addition of fibers. The effect of using metakaoline and hybrid fiber on the mechanical properties of high strength concrete mixture is present in this thesis. The use of metakaoline and hybrid fiber decreases the use of concrete mix and also increases the strength of concrete pavement. Since the cost cement concrete pavement is governed by the cost of material, plant and labor. The high strength concrete mix decrease the use of both material and labor and the pavement in more also used by heavy load for long duration. The high strength concrete pavement required less maintenance and less labor which decrease the maintenance cost of pavement. The hybrid fibers used in the research is combination of steel fiber and polypropylene fibers. The cement is replaced by 0% to 25% of metakaolin. The hybrid fibers used at 1% by fractional volume. The results show that compressive strength increased by 10%. The gain in flexural strength is more as compared to compressive strength. The pavement thickness is also design with experiment result data. But form the economic analysis it is conclude that hybrid fibers at 1% increase the cost of pavement.

Keywords:- polypropylene fibre, metakaolin, silica fume, kaolinite.

1. INTRODUCTION

Concrete is one of the most common materials used in the construction industry and the use of concrete is increasing day by day. Concrete is a versatile construction material, it is plastic and malleable when newly mixed, yet strong and durable when hardened. These qualities explain why concrete can be used to build skyscrapers, bridges, sidewalks, highways, houses and dams. In the past few years, many research and modification has been done to produce concrete to achieve desired characteristics. There is always a search for concrete with higher durability. Concrete is a composite material, consisting mainly of Portland cement, water and aggregate (gravel, sand or rock). When these materials are mixed together, they form a workable paste which then gradually hardens over time. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacturing have brought pressures to reduce cement consumption by the use of supplementary materials. The consumption of use of cement can be reduces by the use of supplementary materials. Supplementary materials such as metakaolin, silica fume, quarry dust, fly ash, bottom ash and blast furnace slag can be used as a replacement of cement in mortar and concrete. Another main concern about concrete is its brittleness. The use of fiber in concrete overcomes the problems related to low tensile strength, poor fracture toughness and brittleness. The present area in concrete includes introducing metakaolin (clay) and hybrid fibers.

Clays have been and continue to be one of the most important industrial minerals. Clay and clay minerals are widely utilized in our society. Metakaolin is one of the innovative clay products in recent years. It is produced by the controlled thermal treatment of kaolin. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has pozzolanic properties. The use of metakaolin as the partial cement replacement material in mortar and concrete has been studied widely in recent years. Despite of the recent studies, there are still many unknowns with the use of metakaolin.

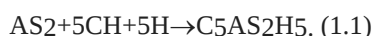
Study is needed to determine the contribution of metakaolin to performance to hardened concrete. There are great concerns on the stones and durability of mutak when used as the construction materials in the construction industries. If it is proven that concrete is durable and strong, this will lead to the use of metakaolin to replace part of the cement.

Concrete is also classified as a brittle material, however, reinforced concrete with short fibers distributed randomly improve strength of cementitious matrices by controlling the initiation, propagation, and merging of cracks. The fibers used for reinforced concrete are mainly steel fibers (SF), carbon fibers, and polymer fibers. Due to the outstanding toughness of concrete reinforced with polypropylene fibers (PPF), PPF attracted the attention of researchers over the last decades. Fiber reinforced concrete (FRC) was basically developed to overcome the problems related to cement based materials such as low tensile strength, poor fracture toughness and brittleness of cementations composites. The performance of FRC depends on a number of factors including fiber material properties, fiber geometry, fiber volume content, concrete matrix properties and concrete- fiber interface properties. The hybrid fibers are comprehensively being used in rigid pavements, airfield pavements, flexible pavements, earthquake- resistant and explosive- resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures. rock-slope stabilization, etc.

METAKAOLIN

Metakaolin, generally called "calcined clay" is a reactive alumina-silicate pozzolan produced by heating kaolinite at a specific temperature regime. Metakaolin is a chemical phase that forms upon thermal treatment of kaolinite. Kaolinite's chemical composition is $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_2$ and as a result of thermal treatment in the range 700-850°C, the water is driven away to form an amorphous alumina silicate called metakaolin. The range depends on the kaolin (kaolinite with minor impurities) characteristics such as degree of crystallinity and particle size.

The principal reaction is that between the metakaolinite and calcium hydroxide derived from cement hydration, in the presence of water. This reaction forms additional cementitious aluminum containing C-S-H gel, together with crystalline products, which include calcium aluminates hydrate and alumino-silicate hydrates. The crystalline products formed depend principally on the metakaolinite/calcium hydroxide ratio and the reaction temperature. In addition if carbonate is freely available carbon-aluminates may also be produced. This chemical reaction may be expressed in the equation as follows



Where $\text{C}_5\text{AS}_2\text{H}$ is an average composition representing a mixture of CSH, C_4AH_{13} , C_3AH_6 and C_2ASH_8 .



The optimum replacement levels of Portland cement by metakaolin are associated with changes in the nature and proportion of the different reaction products (depending on composition) temperature and reaction time, which are formed in the Portland cement- metakaolin system.

Metakaolin is white in colour and acts as a pozzolanic material. It may react with calcium hydroxide to form calcium silicate and calcium aluminates hydrates. The reactivity of the metakaolin may also be affected by grinding to finer particle size. The purity of the kaolin also affects the overall color and reactivity. The lower amount of siliceous and aluminous material will result in a lesser reactivity, which may be further diminished by a coarse particle size. Also, the color will not be white and depending on the impurity type and level may vary resulting in a consistent product. Metakaolin has an average particle size of the about 1.5µm in diameter, which is between silica fume (0.1 to 0.12µm) and Portland cement (15 to 20µm)²⁵. As a new mineral admixture for producing high performance concrete, metakaolin can produce concrete of compressive strength in excess of 110 MPa through replacing part of the cement in the mixture. Tests have shown that the use of 5 to 10% by weight cement can produce concrete with performance characteristics comparable to those of silica fume concrete with respect to strength to strength development, chloride ion penetration, drying shrinkage, and resistance to freeze-thaw cycle and scaling.

Table: Physical Properties of Metakaolin

Characteristics	Percent by mass
Alumina	36.0 – 39.0
Silica	45.0 – 47.0
Iron	1.0 max
Titanium dioxide	1.0 max
Potash	2.0 max
Sodium	2.0 max
Loss on ignition	12.5 min
Water of plasticity	7.0 max
Linear shrinkage	18.0 max

Table: Physical Properties of Metakaolin

Property	Description
Specific gravity	2.5 – 2.7
Luster	Earthy
Cleavage	Perfect in one direction, basal
Colour	White, greenish or yellow
Hardness	1.5 – 2



Fig. : Metakaolin image

Advantages of Metakaolin

A. Increased compressive and flexural strength. Metakaolin is used to boost the compressive strength of concrete mixes. The calcium hydroxide, which forms up to 25% of hydrated Portland cement, does not contribute to concrete's durability or strength. What Metakaolin does is to combine with the calcium hydroxide and produce added cementing compounds, which makes the concrete stronger.

B. Reduced permeability. The Pozzolanic and hydraulic reactions of ultrafine Metakaolin, results in densification of the micro structure. This makes the resultant concrete to withstand varied conditions and helps in adding to its long term durability. Even can achieve lower level of Rapid Chloride Permeability of the concrete by adding Super Pozzolanic Mineral Admixture i.e. Metakaolin

C. Increased resistance to chemical attack. Metakaolin became more compact, and the migration of harmful particles or ions are restricted. Results both of the chloride migration and the gas adsorption measurements indicated the more compact structure in case of metakaolin containing samples. In case of treatment with sulphuric acid ettringite crystals are formed on the mortar surface

D. Increased durability. The increase in the resistance to chemical attack and reduction in permeability by using metakaolin in concrete mean that the durability also increased

E. Reduces shrinkage due to particle packing and making concrete denser. The particle size of metakaolin is finer than cement particle. The use of metakaolin in concrete makes concrete more dense and therefore there is less space for shrinkage.

F. Enhanced workability and finishing of concrete. The use of a mineral admixture like metakaolin gives concrete a non-sticky and creamy job easier to pump to greater distance either vertically or horizontally.

G. It controls consumption of cement. The use of Metakaolin helps in reducing clinker content in concrete. This way the mineral admixture helps in obtaining energy savings, apart from helping to reduce greenhouse gas emissions

FIBER TYPE

Fiber reinforced concrete (FRC) can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous discrete, uniformly dispersed suitable fibers. A fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat the fiber is often described by the parameter aspect ratio which is ratio of fiber length to its diameter. Typical aspect ratio varies from 20 to 1502. The use of fibers to reinforce a brittle material was done first by Egyptians they used straw to reinforce sun baked bricks and horsehair was used to reinforce plaster. In the early 1900's asbestos fibers were used in concrete. The modern development of steel fiber reinforced concrete may have begun in 1960's Glass fibers came into picture by the 1980's and Carbon fibers from 1990's. And now a day's many types of fibers are available as a construction material and among them consumption of steel and polypropylene fibers is large.

Depending upon the parent material used for manufacturing fibers can be broadly classified as:

1. Metallic fibers (eg. low carbon steel, stainless steel, galvanized iron, aluminum)
2. Mineral fibers (eg asbestos, glass, carbon)
3. Synthetic fibers (polyester, nylon, polypropylene, polyethylene)
4. Natural fibers (bamboo, coir, jute, sisal, wood, sugarcane bagasse)

The usefulness of hybrid fiber reinforced concrete in various Civil Engineering applications is thus indisputable. Hence this study explores the feasibility of hybrid fiber reinforcement with a given grade of concrete. Hybrid Fiber Reinforced Concrete (HFRC) is formed from a combination of different types of fibers, which differ in material properties, remain bonded together when added in concrete and retain their identities and properties. The hybridization of fibers provides improved specific or synergistic characteristics not obtainable by any of the original fiber acting alone. Until today mainly three types of hybrid composites have been used by the researchers using the combinations of polypropylene-carbon, polypropylene fibers.

It has been suggested that, for a number of structural application, the use of more than one type of fiber as reinforcement results in a hybrid fiber composite that is better able to meet the material performance requirements than mono-fiber composite for the given application. For instance, to use Engineered Cementitious Composite (ECC) in protective structures, the material is required to possess sufficient strength to resist penetration, while at the same time it is required to absorb a large amount of energy, thereby minimizing fragmentation and reducing the velocities of the fragments (ie, need material of sufficiently high strain capacity). For using ECC in corrosion-resistant structures, a low crack width is required to reduce the ingress of aggressive substances reaching the steel reinforcement, while at the same time a high strain capacity is also required to prevent delamination and concrete cover spalling. Further, given that mono fiber ECCs containing high modulus fibers (eg, steel or carbon fibers) normally exhibit high ultimate strength, low crack width and low strain capacity, while those containing low modulus fibers (eg. polyvinyl alcohol and polyethylene fibers) exhibit opposite behaviors, it becomes clear that a hybrid-fiber ECC with proper volume ratio of high and low modulus fibers can be designed to achieve an optimal balance between ultimate strength, crack width and strain capacity, and is therefore better able to meet the functional requirement for these applications.

As a research work on FRC has established that addition of various types of fibers such as metallic (steel) and nonmetallic fibers (glass, synthetic, natural and carbon) in plain concrete improves strength, toughness, ductility, post cracking resistance, etc. For optimal result therefore different types of fibers may be combined and the resulting composite is known as hybrid-fiber reinforced concrete in this experiment steel fiber and polypropylene fibers have been tried.

Steel fiber

A number of steel fiber types are available as reinforcement. Round steel fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular c/s are produced by silting the sheets about 0.25mm thick.

Fiber made from mild steel drawn wire. Conforming to IS: 280-1976 with the diameter of wire varying from 0.3 to 0.5mm has been practically used in India.

Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets

Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.



Fig. : Steel fibres

Polypropylene fiber

Polypropylene is one of the cheapest & abundantly available polymers polypropylene fibers are resistant to most chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees centigrade). So that a working temp. As (100 degree centigrade) may be sustained for short periods without detriment to fiber properties.

Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix. Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete,



Fig. : Polypropylene Fibers

Table : Properties of steel fibre and Polypropylene fibre

Properties	Steel fibers	Polypropylene fibers
Specific gravity (Gr/cm ³)	7.86	0.91
Tensile strength (MPa)	400-1200	550-700
E(GN/m ²)	200	3.5-6.8
Elongation at failure (%)	3.5	21

Glass Fiber

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm

The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used varieties of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR- glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

Asbestos Fibers

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement. Asbestos fibers have thermal mechanical & chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements Asbestos cement board is approximately two or four times that of unreinforced matrix. However, due to relatively short length (10mm) the fiber have low impact strength.

Carbon Fibers

Carbon fibers from the most recent & probably the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expensive. Their strength & stiffness characteristics have been found to be superior even to those of steel. But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resin coating.

Organic Fibers

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a super plasticizer.

Necessity of Fiber Reinforced Concrete

- 1) It increases the tensile strength of the concrete.
- 2) It reduces the air voids and water voids the inherent porosity of gel. 3) It increases the durability of the concrete.
- 4) Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibers have a significant influence on the creep performance of rebar's/tendons.
- 5) Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fiber and the concrete as the matrix It is therefore imperative that the behavior under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
- 6) It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties

OBJECTIVES OF THE STUDY

1.To evolve mix design for M60 grade high strength concrete with varying proportion of metakaolin and hybrid fibers. The mix designing is done in the research is based on the trial mix design. The hybrid fibers using in the study is the combination of steel fiber and polypropylene fiber at 1% of fractional volume. The research also includes the use metakaolin at various percentages that is 0 to 25%.

2. To investigate compressive and flexural strength of high strength concrete. The compressive is investigated by casting concrete cubes and flexural strength is investigated by casting concrete beam. The compressive strength and flexural strength is tested at 28 days. The casting of cubes and beams is done for different concrete mix replacing cement with various percentage of metakaolin. The hybrid fibers used in the concrete mix is fixed at 1% of fractional volume.
3. To design high strength concrete rigid pavement. In pavement, the thickness of the concrete pavement slab is calculated. The thickness is calculated by using IRC58 code of design of rigid pavement. The pavement thickness is calculated for the maximum flexural strength obtained in the lab using experiment
4. To study cost evaluation of rigid pavement using high strength pavement The cost evaluation is done for the thickness calculated by designing pavement thickness. The cost evaluation is done in the thesis to study the cost of construction of pavement slab. The pavement cost evaluation included the cost of metakaolin and hybrid fibers used the concrete mix.

2. LITERATURE REVIEW

Ambroise et al (1985) studied the improvement in the strength of metakaolin cement activated with calcium hydroxide. It was found that the more convenient curing process implied the immersion water after the removal of sample from the moulds at 7 days and drying at 50°C for one day before mechanical testing. The process led to considerable improvement of strength.

Qian and Stroeve (1998) investigated the optimization of fibers size and fiber content and fly ash content with the hybridization of steel fibers and polypropylene fibers. The results show that fine particles such as fly ash is necessary in some amount to evenly disperse the hybrid fibers in the cement concrete mixture. Addition of a small fibers type had a significant influence on the compressive strength but the splitting tensile strength is slightly affected. A large fiber type gave rise to negative mechanical effect which was further fortified by optimization of the aspect ratio.

Chunxiang et al (1999) studied the polypropylene fibers and three sizes of steel fibers in concrete mixture. A four point bending test is done by varying the total fibers content ranges from 0% to 0.98%. The research result shows that large steel fibers and polypropylene fibers have positive synergy on the load bearing capacity and fracture toughness in the small displacement of the beam. The large steel fibers show the most significantly effect on the energy absorption capacity in the large displacement range,

Wei et al (2000) studied the effect of expansive agent and hybrid fibers of steel fibers, polyvinyl fibers and polypropylene fibers in high performance concrete. Test results indicate that different type and size of hybrid fibers can reduce the amount and size of crack at different scales. The use of expansive agent with hybrid fibers improves the shrinkage resistance and impermeability of high performance concrete. The shrinkage compensation due to expansive agent could not be neglected.

Poon et al (2001) showed that the cement paste containing 5 to 20% metakaolin had higher compressive strength than the control mixture at all ages from 3 to 90 days. The paste containing 10% of metakaolin perform best. The cement paste containing silica fume or fly ash had lower compressive strength the control mixture at 28 and 90 days. The fly ash replacement resulted in high compressive strength than the control mixture only at 90 days. The above results indicated that at early ages the metakaolin contributed better to the compressive strength development of high performance cement paste than silica fume.

Zongjin and Ding (2003) investigated that a 10% blend of metakaolin reduces the fluidity of the concrete mixture. The water demand was increased by roughly 11%, which is attributed to the plate like particle shape and it is tendencies to absorb water. Setting time was also shown to decrease by 26 and 36% for initial and final setting time respectively.

Justice.J.M et al (2005) made a comparative study by replacing 8% by weight of cement with Metakaolin and Silica fume. Metakaolin addition proved to be beneficial, resulting in concrete with considerably higher strengths and greater durability than the normal mixes. The use of finer Metakaolin was more effective in improving concrete properties than the coarser Metakaolin. Addition of Metakaolin increased the use of super plasticizers. Addition of Metakaolin exhibited improvements in shrinkage, durability and other strength aspects.

Nabil M. Al-Akhras (2005) carried out an investigation by replacing cement with Metakaolin to find out the durability of concrete against sulphate attack Three replacements of cement with Metakaolin (5, 10 and 15% by weight of cement) were taken with w/c ratio at 0.5 and 0.6. After the specified days, the samples were immersed in 5% sodium sulphate solution for 18 months. The effect of metakaolin addition proved to be beneficial in improving the resistance of concrete to sulphate attack. Metakaolin with a w/c ratio of 0.5 exhibited better results in sulphate resistance than 0.6. Autoclaved cured specimens had better resistance against sulphate than moist cured specimens.

Abid Nadeem et al (2008) made an investigation on the chloride permeability of high strength concrete and mortar specimens containing varying proportions of Metakaolin (MK) and Fly ash at elevated temperatures. A total of seven

concrete and three mortar mixes were tested after exposing each mix to 200, 400, 600 and 800°C. In concrete, the dosage levels of MK were 5, 10 and 20% and for Fly ash the dosage levels were 20, 40 and 60%. In mortar, the dosage level of Metakaolin and Fly ash was 20%. All concrete specimens investigated in this study had a minimum compressive strength of 85 MPa. At normal temperatures, concrete and mortar specimens had very low chloride ion Penetrability. At normal temperature, metakaolin mixes had lower chloride permeability than Fly ash and Portland cement mixes. At normal temperatures, mortar specimens were more chloride permeable than concrete specimens. At 200°C and 400°C, mortar was still more chloride permeable than concrete but the ratio of mortar to concrete chloride permeability was less than that at normal temperature.

3. MATERIALS COLLECTED

In order to achieve the stated objectives, this study was carried out in few stages. On the initial stage, all the materials and equipments needed were collected and checked for availability. The coarse and fine aggregates were collected from Kurukshetra region of Haryana. The aggregates were selected in such a manner that they represent the usual kind of aggregates available in the state. Metakaolin used in the study was obtained from Surat, Gujarat. The steel and polypropylene fiber has been purchased from Okhla, Delhi. HRWRA was collected for Construction Chemical Division Mundka, New Delhi.

MATERIAL USED

Metakaolin is the product conforming to engineering requirement in terms of physical and chemical properties. Reinforced concrete with hybrid fibers distributed randomly was found to improve strength characteristics of cementitious matrices by controlling the initiation or spread of cracks. So in our present study we are going to put our great diligence in the study of metakaolin and hybrid fibers, metakaolin which can be made as a partial cement replacing material simultaneously achieving the required strength testing on concrete cubes. We are going to use Metakaolin as cement replacement material in different percentage 0%, 10%, 15%, 20%, 25% and study the 28 days compressive strength and flexural strength of concrete with 1% of Hybrid fibers by the volume while maintaining the water cement ratio in the range of 0.028.

Different materials used in the study along with their properties are given below.

Aggregates Coarse aggregates

Fine Aggregates

The coarse aggregates used in present study have maximum size 10mm. We used IS: 383 specified grading of 10mm aggregates.

Fine aggregates are material passing through an IS sieve of 4.75mm. Fine aggregate forms the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregates also help the cement paste to hold the coarse aggregate particle in suspension.

According to IS 383:1970 the fine aggregates are classified into four different zones, that is Zone-I, Zone-II, Zone-III, and Zone-IV. Fine aggregate conforming to grading Zone-II has been used in the study.

Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of the silicates and aluminates of lime obtained from limestone and clay. The cement used in the study is OPC 43 grade (Brand JK).

Metakaolin

Hybrid Fibers

Metakaolin used in the study is obtained from 20 Microns Company from Surat in India. It is in powder form. The particle size of metakaolin is significantly smaller than cement particles. IS:456-2000 recommends the use of metakaolin as a mineral admixture.

When two or more types of fibers are used in a combined matrix to produce a composite that will reflect the benefit of each of the individual fibers used are often called hybridization. This study investigates the combination of different fiber proportions of steel and polypropylene in the presence of metakaolin for M60 grade concrete. The total amount of hybrid fiber used is 1% of volume fraction. The ratio of short fiber (polypropylene fiber) and long fiber (steel fiber) are 30% and 70% of total hybrid fibers used respectively.

Super plasticizer

Super plasticizer are water reducers, retarders, and super plasticizers are admixture for concrete, which are added in order to reduce the water content in a mixture or to slow the setting rate of the concrete while retaining the flowing properties of a concrete mixture. Admixtures are used to modify the properties of concrete or mortar to make them more suitable to work by hand or for other purposes such as saving mechanical energy. The HRWR used in the concrete mix of the study is Polycarboxylate ether based super plasticizer.

Water

MIX DESIGN PROCEDURE

Water is needed for the hydration of cement and to provide workability during mixing and for placing. There is not much limitation for expect that the water must not severely contaminated. In this study, normal portable tap water is used.

High strength concrete mix is designed to achieve M60 grade concrete using admixture. Several trial mixes were carried out to achieve high strength concrete using high range water reducer (HRWR). Concrete mix with mix proportion corresponding to 1:1.29:0.685 (by weight) with water cement ratio 0.28, HRWR dosage of 2.78% by the weight of cement, provided a concrete mix with compressive strength corresponding to 58.9 after 28 days without metakaolin and hybrid fibers.

CONCRETE MIX PREPARATION

For mix preparation, in the first stage the weight of coarse aggregate and fine aggregate is taken. In the second stage binders (cement) are weighted accordingly and added to aggregate. By using hand mix all the material were mixed until all the constituents are mixed uniformly. This was made to ensure that all the binder was mixed thoroughly to produce a homogenous mix. At the final stage, measured water and measured HRWRA were added to the mix. This step was crucially important to make sure that the water and super plasticizer distributed evenly so that concrete will have similar water binder ratio for every cube. After that, the concrete was poured in the mould and compacted by using mechanical vibrator.

PREPATING TEST CUBES

The cube mould plates should be removed and properly cleaned assembled and all the bolts should be fully tight. A thin layer of oil shall be applied on all the faces of the mould. It is important that cube side faces must be parallel. After taking concrete samples and mixing them, the cubes should be casted as soon as possible. The concrete sample shall be filled into the cube moulds in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete with in the mould. Each layer shall be compacted using a steel bar and vibrations were given on vibrating machine. The cubes were removed from the moulds after 24 hour.

CURING

The test specimens were stored in moist air for 24 hours and after this period the specimens were marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

TESTING OF SPECIMEN

For mix preparation, in the first stage the weight of coarse aggregate and fine aggregate was taken. In the second stage binders (cement) were weighted accordingly and added to aggregate. By using hand mix all the material until all the constituents are mixed uniformly. This was made to ensure that all the binder was mixed thoroughly to produce a homogenous mix. At the final stage, measured water and measured HRWRA were added to the mix. This step was crucially important to make sure that the water and HRWRA were distributed evenly so that concrete will have similar water binder ratio for every cube. After that, the concrete was poured in the mould and compacted by using mechanical vibrator.

COMPRESSIVE STRENGTH TEST

Compressive strength test is initial step of testing concrete is primarily meant to withstand compressive stresses. Concrete is strong in compression but it is weak in tension and has low strain at fracture. The low tensile strength of concrete is due to the presence of numerous micro cracks. These micro cracks further propagate under load resulting in poor strength of concrete. In this study, the effect of metakaolin and hybrid fibers on compressive strength is studied by casting cubes and testing them in compression. With given proportions of aggregates, the compressive strength of concrete depends primarily upon age, cement content and water-cement ratio. This study focuses on the performance of concrete blended with metakaolin in terms of its compressive strength. The compressive test is an important concrete test to determine the strength development of concrete specimens.

Compressive strength tests were performed on the cube specimens at the ages of 7 and 28 days. The test specimens after removal from the curing tank were cleaned and after one hour of removing of specimens tests were conducted as per standard procedure. The test was carried out on cubes with compression testing machine of 3000 KN capacity.

FLEXURAL STRENGTH TEST

This test is used for determining the flexural strength of concrete by the use of a simple beam with two point load. The test specimens were removed from water tank in same manner as in compression test. The specimens cast for this test were of shape of a square prism of side 100mm and axis length of 500mm. The support bearing should be in correct position.

The load at which beam gets fractured is noted and measurements is done with respect to the edge of the beam and where fracture occurs in beam.

Calculate flexural strength of beam as follows Flexural Strength, $s = PL/BxD^2$

Where,

P-Load at which the beam fails, given by the machine

L-Span length

B-Depth of beam

4. CONCLUSIONS

The study 'Study of Performance of High Strength Concrete Pavement Using Metakaolin and Hybrid Fibers have been taken up with a view to investigate the effects of addition of metakaolin as partial replacement of cement and hybrid fibers on the strength of concrete. Various investigations were made on M60 grade concrete for pavement with varying proportion of metakaolin from 0 to 25% and at 1% hybrid fibers. The main conclusions drawn from the study are:

- There is a reduction in workability of the concrete with the addition of metakaolin due to its finer particle size as compared to cement. The hybrid fiber used in concrete mix reduces workability of the concrete.
- The content of polypropylene fibers, combined with the high stiffness steel fibers and various percentage of metakaolin results in enhanced behavior in term of compressive strength and flexural strength.
- Compressive strength at 28 days is found to increase with addition of metakaolin and hybrid fibers. The maximum increase in compressive strength occurs at 20% replacement level of cement by metakaolin and at 1% hybrid fibers.

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