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"Fibre Hybridisation For Resilient Structures – Polypropylene in Conjunction with Fly Ash - A Review"

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Abstract : This research study investigates the synergistic effects of polypropylene (PP) fibers as a partial replacement of sand and fly ash as a partial replacement for cement in the development of high grade (M 30 & M 40) fiber-reinforced concrete for high-exposure environments. Polypropylene fibers (Monofilament) with a length in the range of 30mm – 35mm and Fly Ash of Class F grade are chosen as key additives . The study involves the casting of six batches of concrete beams, with varying proportions of PP fibers and fly ash Fly ash is incorporated as an admixture to enhance the overall performance of the concrete, with a specific focus on mitigating thermal effects. The concrete beams are subjected to comprehensive testing, with a primary emphasis on evaluating flexural strength. The variations in fiber types, proportions, and the influence of fly ash substitution for cement are systematically analyzed to assess the structural performance of the developed concrete. The findings of this research aim to contribute valuable insights into the optimization of fiber-reinforced concrete for high-exposure conditions. Both PP Fibres and Fly Ash are used in 0%, 0.25%, 0.50%, 1% and 1.5 % by weight of cement in concrete. Fresh and harden properties for both concrete with polypropylene fibre and with fly ash is determined and hybrid of optimum values calculated is used in a single mix and flexural strength is determined. The % increase in strength of hybrid with optimum values and separate mixes are determined and correlated with the conventional concrete's strength. The findings of this research aim to contribute valuable insights into the optimization of fiber-reinforced concrete for high-exposure conditions. The results are anticipated to inform best practices for the utilization of industrial waste in concrete production and offer a pathway for the development of cost-effective and sustainable construction materials..

Index Terms - Fibre Reinforced Concrete , Flexural Strength , Fly-Ash , Fire Resistance , High exposure , Hybrid , Polypropylene-Fibre.

I. INTRODUCTION

Today, research continues to evolve, with ongoing efforts to optimize fiber types, proportions, and combinations for specific applications. The integration of fibers with other additives, such as fly ash, further enhances the performance of concrete in various environmental conditions.This study is focused on the use of " Polypropylene Fibres " which is basically a thermoplastic polymer and possesses significant material properties such as Aspect ratio , elasticity modulus , chemical inertness , adhesion and dispersion to concrete matrix which directly and indirectly contribute to the quality of concrete in terms of strength , durability , sustainability and serviceability.

The contemporary construction landscape demands innovative solutions to address the challenges posed by high-exposure environments, where structures are subjected to a myriad of environmental stressors. Concrete, as a fundamental building material, requires continual enhancement to ensure resilience, longevity, and sustainability in the face of extreme weather conditions, corrosive elements, and other external factors. This research endeavors to explore a holistic approach to meet these demands through the integration of polypropylene (PP) fibers and fly ash in the development of fiber-reinforced concrete.

The selection of materials for this study is informed by a dual commitment to sustainable practices and the utilization of industrial waste. Polypropylene fibers, known for their high tensile strength and durability , the inclusion of fly ash, a byproduct of coal combustion, not only contributes to the enhancement of concrete properties but also addresses environmental concerns by repurposing an industrial waste material. Of particular interest in this research is the examination of flexural strength in concrete beams cast from varying proportions of PP fibers and fly ash as a partial replacement for Cement. The length and diameter of the selected PP fibers, set at 30mm – 35mm and 1 mm respectively presents a deliberate choice to investigate the influence of fiber dimensions on concrete performance. The casting of numerous batches of concrete beams allows for a systematic exploration of different combinations of fibers and fly ash, providing a comprehensive understanding of their synergistic effects. The

overarching goal of this study is to contribute to the development of fiber-reinforced concrete tailored for high-exposure environments.

II. LITERATURE REVIEW

Sarah Khaleel Ibrahim et al (2023) conducted a study entitled " Experimental and Numerical Analysis of Steel-Polypropylene Hybrid Fibre Reinforced Concrete Deep Beams" The experiments involved the construction and testing of a pair of deep, simply supported beams with different proportions of hooked end steel fibers and monofilament polypropylene fibre subjected to symmetric two-point loading. The research concluded that The addition of fibres to concrete significantly affected the crack pattern and damage behavior of concrete beams , Fibres improved the load-carrying capacity of the beam by enhancing its strength and reducing deflection. While a combination of 0.75% SF and 0.25% PPF was recommended to enhance load-bearing capacity and crack distribution.

Guanzhi Liu et al (2023) had added a detailed knowledge in the research paper titled "Recycling of Polypropylene Fibre Reinforced Concrete: Use of Recycled Aggregate and Recovered Fibre in New Concrete". The study investigated the feasibility of using recycled aggregate (RA) and recovered fibres (RF) from recycling polypropylene fibre reinforced concrete (PPFRC) in new concrete production. The mechanical properties of the parent concrete, polypropylene fibre reinforced recycled aggregate concrete (PPRAC), and recovered polypropylene fibre concrete (Re-PPRFC) were compared. The outputs of the study were that the concretes with 100% coarse RA can achieve the same compressive strength as the parent concrete ,When the mix design is the same, concrete with 100% recycled fibres has a reduction in compressive strength and modulus of elasticity compared to concrete with virgin fibres , when 100% of the virgin fibres are replaced by RF, the residual flexural and tensile strength of the concrete decreases more.

Guanzhi Liu et al (2023) proposed a study named as "Effect of free and embedded polypropylene fibres recovered from concrete recycling on the properties of new concrete" The study explored the effect of incorporating different quantities of free or embedded PP fibres recovered during PPFRC recycling on the mechanical properties of new FRC. The results of this study are valid for the range of parameters and variables tested, but uncertainties exist in the collected data due to a limited number of specimens and parameters.The residual tensile strength was influenced by the fibre content and the replacement ratio of RF.

Tamilisetti Bhuvaneswara Reddy and Dr. B. Madhusudana Reddy (2023) conducted a research study titled as "Destructive and Non-Destructive Analysis of Polypropylene Fibre Reinforced Concrete" The study compares the mechanical properties of control concrete (CC) and fibre reinforced concrete (FRC) at different ages. The study includes destructive and non-destructive tests to analyze the mechanical properties and behavior of FRC.Optimum results for compressive strength, split tensile strength, and flexural strength are achieved with 1.6% polypropylene fibre in the concrete. The quality of FRC is found to be better than normal concrete based on rebound number and compressive strength tests.The addition of polypropylene fibre in concrete improves its fire resistance and reduces cracks and shrinkage.

Arooba Rafiq Bhat and Rayat Bahra (2022) conducted an experimental analysis named "Experimental Investigation on the Effect of Poly-propylene Fibre and E-Waste Fibre Embedded in Concrete" to assess the reinforcement capability of polypropylene fibres along with the E-waste fibres by casting concrete cubes with varying proportions of both the fibres and then subjected them to compressive loads and checked them for the strength. Results show that 0.75% and 0.50% is optimum value of concrete with electronic waste fibre and concrete with polypropylene fibre with 49% and 17.5% increase in concrete strength compared to normal concrete respectively.Hybrid fibre reinforced concrete shows maximum increase in compressive strength with 39.55N/mm2 that's 56% increase than standard concret e mix, 5% increase than EFRC and 32% increase than PPFRC.

Bhawani Antarvedi (2022) followed a experimental approach in their study entitled " Experimental investigation of steel fibres and polypropylene fibres effect on Fibre reinforced concrete"The experimental work involved assessing the influence of polypropylene fiber, crimped steel fiber, and hooked end steel fiber on the workability of concrete mixes.The analytical work focused on evaluating the behavior of the fibers in the concrete mix, as well as the effects of fiber addition on workability, flexural strength, and compressive strength. The outcomes of the study were that The workability of the concrete mixes is affected by the type and dosage of steel fibers , Polypropylene fibers have not been found to affect workability,The compressive strength of concrete increases with the use of steel fibers and the uniformly dispersed fibers create a bridging effect, increasing tensile strength.

Zhenhuan Xu et al (2022) proposed a study named "Blast resistance of hybrid steel and polypropylene fibre reinfornced ultra high performance concrete after exposure to elevated temperatures" in which The blast resistance of fibre reinforced ultra-high performance concrete (UHPC) components after exposure to elevated temperatures (upto 1000 degree celciuus) was investigated and the Results shows that with a hybrid steel and polypropylene (PP) fibre reinforcement, this fire resistant UHPC maintained approximately 60% of its original compressive strength after exposed to 800 °C temperature.

Shiyu Yang et al (2022) assessed the "Mechanical and fracture properties of fly ash-based geopolymer concrete with different fibers" for which Different samples with different types of fibres of varying proportions were casted , cured and tests for mechanical properties were conducted. The outcomings of the study suggested that fiber type, fiber volume fraction and fiber-matrix interface properties contribute greatly to the mechanical properties and fracture behavior of FGPC members, thus improving the mechanical property and fracture toughness of FGPC.

Shreyas S. Murthy et al (2021) conducted a research study titled "Mechanical and durability characteristics of flyash and GGBFS based polypropylene fibre reinforced geopolymer concrete"which investigates the durability and mechanical characteristics of Polypropylene fiber reinforced geopolymer concrete and its use in Concrete in-Filled Steel Tube (CFST) columns.PP fibers were added by varying proportions as 0.5%, 1% and 1.5% by mass of binder. The results showed that the mix with 1% PP fibers had the best mechanical and durability characteristics.
The square CFST columns showed consistent failure due to edge weakness.
A maximum average axial compressive strength of 43.27 MPa was obtained for the CFST columns.

V Sathish Kumar et al (2021) proposed a research paper entitled "Engineering Properties of Hybrid Fibre Reinforced Ternary Blend Geopolymer Concrete". The study investigated the effect of crimped steel fibre and polypropylene fibres hybridisation on ternary blend geopolymer concrete (TGPC) engineering properties using fly ash, ground granulated blast furnace slag (GGBS) and metakaolin as the source materials. The properties like compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of ternary blend geopolymer concrete were tested. Test results showed that the addition of fibers and hybrid fibers increased the stiffness of the concrete.The modulus of elasticity of the concrete gradually increased with the addition of fibers, improving by 2.13% to a maximum of 32.31%.

A Chithambar Ganesh and M Muthukannan (2019) performed an experimental research named as "Effect of Polypropylene fibers over GGBS based Geopolymer Concrete Under Ambient Curing" in which the experimental work consisted of casting specimens with and without polypropylene fibers in the form of cubes, cylinders, and prisms to determine the mechanical properties of the fiber-reinforced geopolymer concrete at the end of 7 and 28 days which added the knowledge that the geopolymer has low workability and it further decreases with the increase in the addition of polypropylene fibers.The incorporation of fibers increases the compressive strength and split tensile strength in small proportions till 0.5% and then it decreases.There is a significant increase in the flexural strength of the polypropylene fiber reinforced geopolymer concrete with the increase in the addition of polypropylene fibers.

JayShankar T et al (2018) conducted a comprehensive research study on the "Strength Properties of Fly Ash, GGBS, M-Sand Based Polypropylene Fiber Reinforced Geopolymer Concrete" This study explored the strength properties of fly ash, GGBS, M-Sand based polypropylene fiber reinforced-geopolymer concrete, as an alternative to ordinary pozzolana cement.Materials used in the investigation include GGBS, M-Sand, and Coarse aggregates.Alkaline activator solution, super plasticizer, water, and polypropylene fiber were used in the preparation. The study found that the compressive and split tensile strength of PFRGPCC was slightly higher than GPCC, indicating the potential for its use in construction.

D. Naveen Kumar et al (2017) studied the "Durability Characteristics of Fiber Reinforced Geopolymer Concrete Incorporated with Fly-ash" the research work incorporates tests for durability characteristics and strength properties of fiber reinforced geopolymer concrete.The geopolymer concrete was made using alkaline liquids, sodium hydroxide, and sodium silicate, and the dosage of fibers was varied in volume fractions. The outcomings of the study were Geopolymer concrete is a viable alternative to ordinary Portland cement based concrete, as it uses less hazardous materials and reduces CO2 emissions.

Ramamohana Reddy Bellum(2017) conducted a detailed comprehensive research study titled "Influence of steel and PP fibers on mechanical and microstructural properties of fly ash-GGBFS based geopolymer composites"in which Different percentages of PP and steel fibers are used in geopolymer mortars (fly ash +GGBFS) to find the mechanical properties such as compressive, splitting tensile and flexural strengths were investigated to understand the strength behaviour which came to an conclusion that the addition of PP fibers up to 2.0% (volume fraction) enhanced the flexural properties of geopolymer mortar samples. The compressive strength of the steel fiber-reinforced geopolymer composite reached a maximum of 2.5% volume fraction, being a 13.26% improvement over the control mix and the flexural toughness index of the PP and steel fiber reinforced composites improved with increasing the fraction.

Anthony Ede et al (2016) studied the " Effect of Coconut husk Fibre and Polypropylene Fibre on the fire resistance of Concrete" The research aims to evaluate the fire resistance of normal Portland cement concrete reinforced with coconut fiber and polypropylene fibers for which cube samples were casted and heated on various temperature and strength was calculated at 7 , 14 & 28 days. The Laboratory tests show that the presence of coconut and polypropylene fibers increases the compressive strength and fire resistance of concrete.At 28 days, coconut fibre reinforced concrete has a higher compressive strength and higher fire resistance having as much as 19.03% of strength gain at ambient temperature and 10.74% residual strength after exposure at 1000oC. The polypropylene reinforced concrete had a strength gain of 13.03% at the ambient temperature and 4.64% at 1000oC.

Shanthini D et al (2016) proposed a study named "Fibre Reinforced Concrete – A Review "In this study, geopolymer concrete contains fly ash, ground granulated blast furnace slag (GGBS), alkaline solutions, fine aggregate. Coarse aggregate and polypropylene fibre and checked for strength. The results of the study concluded that the strength of geopolymer concrete is about 1.5 times more than that of ordinary Portland cement concrete and Due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries.

III. MATERIALS USED

The concrete formulations proposed in this research project encompass a carefully selected combination of key materials to achieve optimal performance and sustainability.

CEMENT - Ordinary Portland cement of grade 53 (OPC GRADE 53) is used as per IS8112:1989 renowned for its high compressive strength and durability.

The Tests to be Performed for the physical properties of OPC GRADE 53 Cement are as follows.

- Standard Consistency
- Specific gravity
- Initial setting time
- Final setting time
- Fineness
- Soundness

FINE AGGREGATE - Aggregates which passed through 4.75 mm sieve and retained on 15µm (0.150 mm) IS sieve. Specifications of fine aggregates are followed as per IS 383: 2016. Locally available River sand is used as fine aggregate.

COARSE AGGREGATE - The aggregates which is passed through the 20 mm IS sieve and retained on 4.75 mm IS sieve are called coarse aggregates. Specifications of coarse aggregates are as per IS 383: 2016 (clause 6.1.1). Crushed stone with maximum 20 mm graded aggregates (nominal size) are used.

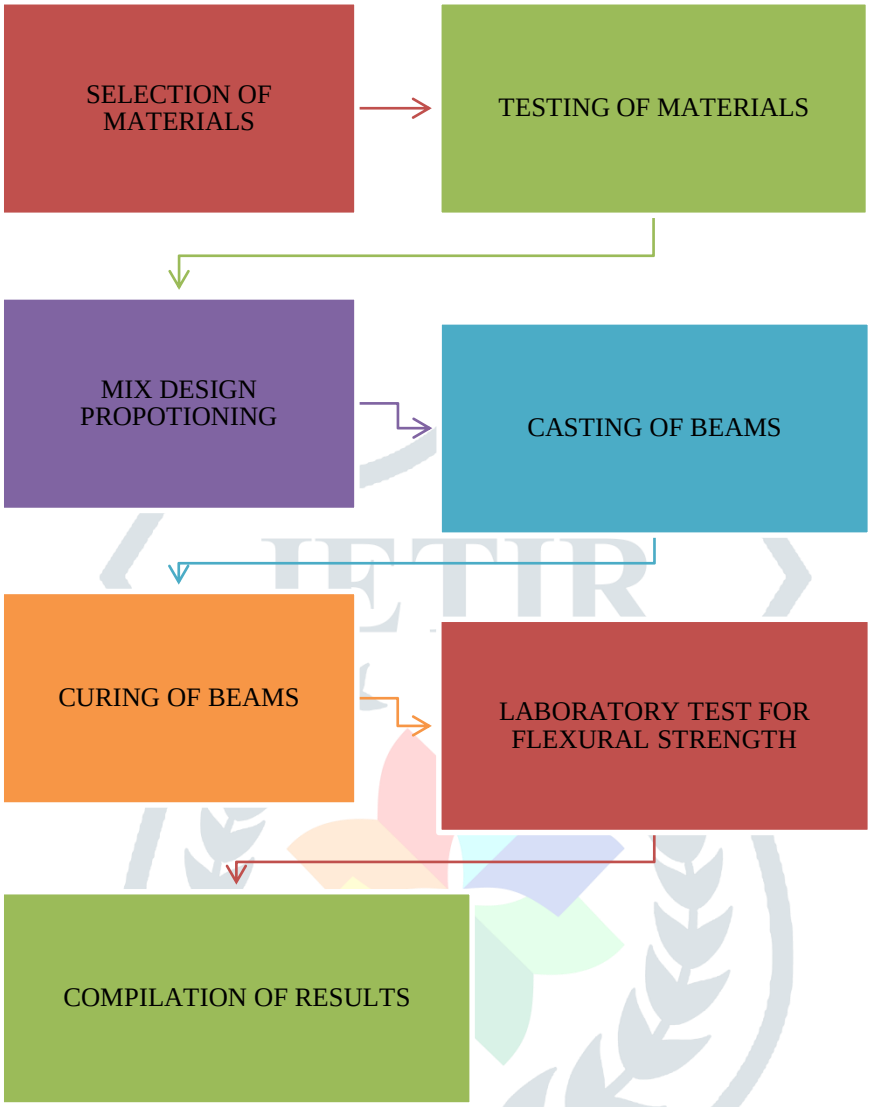
WATER - Portable water free from impurities and of allowable pH value is being used as per IS 456-2000 for casting and curing of concrete.

FLY-ASH - Class F Fly Ash with varying percantages as a replacement for Cement in the Concrete is being used with the following chemical composition.

Compound	**Mass (% by Weight)**
SiO2	55.9
Al2O3	27.8
Fe2O3	7.093
TiO2	2.25
CaO	3.95
V2O5	0.096
SO3	0.33
K2O	1.55

POLYPROPYLENE FIBRE - PP Fibres are available in a vast variety and types , in this study Monofilament Polypropylene Fibres of length ranges from 30 – 35 mm , Diameter – 1 mm and Aspect Ratio (Length to diameter ratio) ranging from 30 – 35 is being used .

IV. RESEARCH METHODOLOGY



SELECTION OF MATERIALS

The selection of materials for this study is informed by a dual commitment to sustainable practices and the utilization of industrial waste.

Cement - Ordinary Portland cement of grade 53 (OPC GRADE 53) is used as per IS8112:1989. Fine, dry and lump free cement is stored in humid free room is used.

Fine Aggregate - Aggregates which passed through 4.75 mm sieve and retained on 15µm (0.150 mm) IS sieve. as per IS 383: 2016 is procured from locally available sources.

Coarse Aggregate - The aggregates which is passed through the 20 mm IS sieve and retained on 4.75 mm IS sieve as per IS 383: 2016 (clause 6.1.1).

Water - Potable water free from impurities and of allowable pH value is being used as per IS 456-2000 for casting and curing of concrete.

Fly Ash - Class F Fly sourced from Industrial Waste from locally available sources . The inclusion of fly ash, a byproduct of coal combustion, not only contributes to the enhancement of concrete properties but also addresses environmental concerns by

repurposing an industrial waste material.

Polypropylene Fibre- The utilization of India MART as a procurement avenue underscores the practical aspects of obtaining PP Fibres for this study. Monofilament Polypropylene fibers, known for their high tensile strength and durability aligning with the principles of waste recycling and repurposing are being used . The length and diameter of the selected PP fibers, set at 30-35mm and 1 mm respectively presents a deliberate choice to investigate the influence of fiber dimensions on concrete performance.

TESTING OF MATERIALS

Testing of Materials is crucial to undertake a systematic research study , various properties of different materials has impacts on the overall performance and quality of the final product. Therefore in order to deliver a meaning conclusion to this study various tests on Materials are performed which are mentioned below :

Tests For Cement

- Standard Consistency
- Specific gravity
- Initial setting time
- Final setting time
- Fineness
- Soundness

Tests For Fine Aggregate

- Sieve Analysis
- Silt Content
- Water absorption

Tests For Coarse Aggregate

- Sieve Analysis
- Specific Gravity
- Aggregate Impact Value
- Crushing Strength

MIX DESIGN PROPOTIONING

With the help of concrete mix designing quantity of concrete ingredients are determined. The process of determining these ingredients will be done as per the specifications given in IS 10262. The research study is focused on proposing concrete of grade M-30 and M-35 . Special considerations are taken in the mix design to design the concrete to withstand high exposures.

CASTING OF BEAM

CURING OF BEAMS

LABORATORY TEST FOR FLEXURAL STRENGTH

- Flexural Strength Test – Flexural strength is one measure of the tensile strength of concrete. Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending.

  For assessing the strength of the concrete beam specimens with various proportions of fibres and their hybrids , in the further proceedings of this research test the batches of prepared concrete beams of grade M30 & M35 for their flexural strength.

COMPILATION OF RESULTS

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