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IMPACT OF SYNTHETIC FIBERS ON THE FLEXURAL BEHAVIOUR OF HIGH PERFORMANCE ON CONCRETE BEAMS USING COPPER SLAG AND SILICA FUME

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Abstract:

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. There are many results of an experimental study on various durability tests on concrete containing copper slag as partial replacement of sand. For many years, by products such as fly ash, silica fume and copper slag were considered as waste materials. They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates.HPC is a construction material, which is being used in increasing volumes in recent years, due to its long term performance. High-performance concrete almost always has a higher strength than normal concrete. However, strength is not always the primary required proper.Synthetic fibers are most commonly added to concrete to reduce early plastic shrinkage cracking and increase impact- and abrasion- resistance and toughness. The fibers also can be added to precast concrete to improve resistance to handling stresses, to pumped concrete to improve cohesiveness, and to shortcrete to reduce rebound and material waste.

Keywords: HPC, Synthetic Fibers, Shrinkage, Abrasion, Impact, Shortcrete, Cohesiveness

I. INTRODUCTION

HPC is a construction material, which is being used in increasing volumes in recent years, due to its long term performance. High-performance concrete almost always has a higher strength than normal concrete. However, strength is not always the primary required property. For example, a normal strength concrete with very high durability and very low permeability is considered to have high- performance properties.Special mixing, placing, and curing practices may be needed to produce and handle high-performance concrete. Extensive performance tests are usuallyrequired to demonstrate compliance with specific projectneeds. High-performance concrete has been primarily usedin tunnels, bridges, and tall buildings for its strength, durability, and high modulus of elasticity.

Copper slag is a by-product of metallurgical operations which is used for the experimental investigation. Many Researchers have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use copper slag in cement and concrete provides potential environment as well as economic benefits for all related industries, particularly in areas where a considerable amount of slag is produced

One of the most widely used supplementary cementitious materials (SCMs) in the production of high-performance concrete (HPC) is silica fume. Also known as micro silica, silica fume is a by-product of producing silica metal or ferrosiliconalloys. As an admixture in HPC, it makes concrete stronger and more durable.Silica fume consists of very fine particles about 100 times smaller than the average cement particles. The extreme fineness of the silica fume particles allows it to fill themicroscopic voids between cement particles.Synthetic fibres are no substitute for structural (primary) reinforcement in concrete because they add little or no strength. But structural reinforcement doesn’t provide its benefits until concrete hardens. That’s why some contractors add synthetic fibres to concrete as secondary reinforcement. Unlike structural reinforcement, synthetic fibres provide benefits while concrete is still plastic. They also enhance some of the properties of hardened concrete.

II. EXPERIMENTAL INVESTIGATION

A. CEMENT

It is a binding material in concrete which binds the other materials to forms a compact mass. Generally Ordinary Portland Cement is used for all engineering construction works. Selection of cement for high-strength concrete should not be based only on mortar-cube tests but should also include tests of comparative strengths of concrete at 28, 56,and 91 days. Hence, selection of proper grade and quality of cement is important for obtaining HPC. The specific gravity of all grades of OPC is 3.15. In this project work, 53 grades OPC cement is used for experimental study. The Physical properties of cement OPC 53 grade

SL.NO.	DESCRIPTION	VALUES
1	Specific Gravity	3.15
2	Standard Consistency	32%
3	Grade of Cement	53
4	Initial Setting Time	70 mins
5	Final Setting Time	290 mins

B. FINE AGGREGATE

A concrete with better quality can be made with sand consisting of rounded grains rather than angular grains. River or pit sand must be used and not sea sand as it contains salt and other impurities. In this study, river sand has been used as fine aggregate. By conducting sieve analysis, it is found that sand confirms to grading zone II as per table 4 of IS 383-1970.

S.NO	Characteristics	Value
1	Type	River sand
2	Specific gravity	2.51
3	Fineness modulus	2.67
4	Grading zone	II

C. COARSE AGGREGATE

The maximum size of coarse aggregate is generally limited to 20mm. Aggregate of size 10 to 12mm is desirable for structures having congested reinforcement. Well graded cubical or rounded aggregates are desirable. Aggregate should be having uniform quality with respect to shape and grading

SL.NO.	DESCRIPTION	VALUES
1	Specific Gravity	River sand
2	Grade of Cement	2.51
3	Specific Gravity	2.67
4	Grade of Cement	II

D. SUPERPLASTICIZER

In this study, GLENIUM B233 polycarboxylic ether based superplasticizer is used. The product is primarily developed for applications in high performance concrete where the high durability, workability and performance is required. GLENIUM B233 ensures that rheoplastic concrete remains workable in excess of 45 minutes at +25°C. Workability loss is dependent on temperature, and on the type of cement, the nature of aggregates, the method of transport and initial workability. Optimum dosage of GLENIUM B233 should be determined with trial mixes.

SL.NO.	DESCRIPTION	VALUES

1	Apperance	Brownish Liquid
2	Type	Polycarboxylate based
3	Relative density	1.08 ± 0.01 at 25°C
4	Ph	>6.0

E. SILICA FUME

Silica fume is a by-product in the industrial manufacture of the ferrosilicon and silicon alloys. Silica fume is produced during the high temperature reduction of quartz, to give silicon or Ferrosilicon metal. As the quartz is heated to 2000^{o}c and an electric arc is fired through the furnace, it releases silicon monoxide gas besides forming the metal. The gas rises and reacts with oxygen the upper parts of the furnace and the stack and condenses as it cools, into the pure spherical particles of micro silica or silica fume. Density of silica fume is 500 to 700 kg/m^{3}and it can be easily handled like cement.

Silica Fume

SL.NO.	DESCRIPTION	VALUES
1	Apperance	Whitish grey
2	Sp.Gravity	2.10 to 2.30
3	Bulk density	500 to 750 Kg/m^3
4	Ph	Approximate 6.5
5	Moisture	Nil

F. COPPER SLAG

The slag is a black glassy and granular in nature and has a similar particle size range like sand. The specific gravity of slag lies between 3.4 and 3.98. The bulk density of granulated copper slag is varying between 1.9 to 2.15 kg/ m^{3}which is almost similar to the bulk density of conventional fine aggregate.Copper slag used in this work was bought from M/s Sterlite industries (India) ltd, Tuticorin, India which produces an annual average

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SL. NO.	DESCRIPTION	VALUE
1	Appearance / colour	Black Glassy Granules
2	Grain shape	Granular
3	Moisture%	0.1
4	Water absorption%	0.16
5	Bulk density g/cc	2.08
6	Specific gravity	3.91

G. SYNTHETIC FIBRES

The number of synthetic fibre suppliers has grown in recent years, giving contractors a wide range of fibre products from which to choose. The primary types of synthetic fibres commercially available in the United States are polypropylene, polyester, and nylon. Though the fibres within each type come in various lengths, thicknesses, and geometries, synthetic fibres provide similar benefits when used as secondary concrete reinforcement.

H. POLYPROPYLENE FIBRE

Polypropylene fibres are hydrophobic, so they don't absorb water and have no effect on concrete mixing water requirements. They come as either fibrillated bundles or monofilaments. Monofilament fibres are fine, cylindrical strands that separate during mixing. Because monofilament fibres are smooth and have a small surface area, they don't anchor into the cement matrix as well as fibrillated fibres. With fibrillated fibres, cement paste penetrates into the network of fibre filaments resulting in better mechanical anchoring to the concrete. Research shows that lower volumes of fibrillated fibres than of monofilament fibres are needed to improve the post-cracking load carrying capacity and ductility of concrete.

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Monofilament Polypropylene Fibres

SL.NO	DESCRIPTION	VALUES
1	Type	Monofilament
2	Specific Gravity	0.91
3	Length (mm)	12
4	Tensile Strength (psi)	40 - 100
5	Youngs modulus	500-700

I. POLYESTER FIBRE

Though not as widely used as polypropylene fibres. The fibre bundles come only in monofilament form in lengths from 3⁄4 to 2 inches. Like polypropylene, polyester fibres are hydrophobic. However, they have a tendency to disintegrate in the alkaline environment of Portland cement concrete. To retard this degradation, manufacturers of polyester fibres coat the fibres to resist alkali attack. But the long-term performance of the coated fibres has not been determined.

Monofilament Polyester Fibres

J. SLUMP CONE TEST

The slump is taken for each mixing of concrete with 7.5% replacement of silica fume for cement in high performance of concrete and polypropylene and polyester added with some percentage of fibers and also 40 %

replacement of copper slag from river Sand in high performance of concrete and polypropylene and polyester added with some percentage of fibers. The results show that slump of concrete made with high performance concrete with added polypropolyne and polyester and some of fibers

K. COMPACTION FACTOR TEST

Compacting factor test also used to determine the workability of fresh concrete. It is not used on site testing because the apparatus is very heavy. According to Street works the compacting factor test gives a more accurate workability of fresh concrete than slump test. It mentioned that the compacting factor test also known as the "drop test", which measures the weight of fully compacted concrete and compare it with the weight of partially compacted concrete Compacting Factor = Mass of partially compacted concrete (M1) /Mass of fully compacted concrete (M2)

Specimen	% of Replacement of Silica Fume	% of Replacement of Copper Slag	% of Addition fibre	CF Value (mm)
Trial 1 CHPC	0	0	0	0.87
Trial 2 HPC	7.5	40	0	0.85
Trial 3 PP			0.2	0.86
			0.3	0.88
			0.4	0.87
Trial 4 PE			0.02	0.86
			0.04	0.86
			0.06	0.88

L. COMPRESSIVE STRENGTH

The compressive strength was performed on cubes of sides 100 mm in accordance with IS: 516 – 1959. The compressive strength was determined for curing ages of 7 and 28 days. For each mix, three specimens were tested for each curing age. The testing was carried out on the specimens in wet condition. The specimens were tested in Compression Testing Machine of capacity 3000 kN. The cubes were placed in the machine such that the loading is applied to the opposite sides of the cube as cast. The loading was increased continuously at a rate of 140kg/cm^2/min and the maximum load that can be sustained by the specimen was noted. The maximum load divided by the cross sectional area of the specimen gives the compressive strength. For each mixture, the average of the three specimens is considered to be the compressive strength of the particular mixture at a specified curing age. The variations between the three specimens should not exceed ±15 percent.

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$$\text{Compressive Strength} = \frac{\textit{Ultimate load}}{\textit{Area of specimen}}$$

Specimen	% of Replacement of Silica Fume	% of Replacement of Copper Slag	% of Addition fibre	Slump Value (mm)
Trial 1 CHPC	0	0	0	28
				28
				26.5
Trial 2 HPC	7.5	40	0	28
				28
				26.5
Trial 3 PP				23.2
				27.4
				28.4
Trial 4 PE				26.4
				27.1
				27.2

COMPRESSIVE STRENGTH TEST SETUP

S. No.	Specimen ID	Density (kg/m^3)		Compressive Strength (MPa)	
		7 Days	28 Days	7 Days	28 Days
1	CHPC	2573.3	2560.0	34.80	63.60
2	HPC	2613.3	2653.3	40.90	66.50
3	PP – 1	2560.0	2580.0	23.93	66.60
4	PP – 2	2540.0	2538.2	34.46	67.80
5	PP – 3	2560.0	2570.0	30.86	64.70
6	PE – 1	2480.0	2593.3	31.90	65.30
7	PE – 2	2553.3	2600.0	35.06	68.46
8	PE – 3	2533.3	2620.0	25.80	62.86

M. SPLIT TENSILE STRENGTH

The splitting tensile strength of concrete is determined at the age of 7 and 28 days of curing using 150 x 300 mm cylinder as per BIS: 5816-1999. The test specimen shall be placed in the centring jig with packing strip and/or loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen. The jig shall then be placed in the machine so that the specimen is located centrally in Figure 4.2.Maintain the rate, once adjusted, until failure. On manually controlled machines as failure is approached the loading rate will decrease; at this stage the controls shall be operated to maintain as far as possible the specified loading rate. The maximum load applied shall then be recorded. The appearance of concrete and any unusual features in the type of failure shall also be noted.Table 4.3 shows that the split tensile strength test results. The measured splitting tensile strength (F_{ct}) of thespecimen shall be calculated to the nearest 0.05 N/mm^2 using the following formula,

$$F_{ct} = \frac{2P}{\pi LD}$$

Where,

P = maximum load in Newton’s applied to the specimen,

I = length of the specimen (in mm), and

d = cross sectional dimension of the specimen

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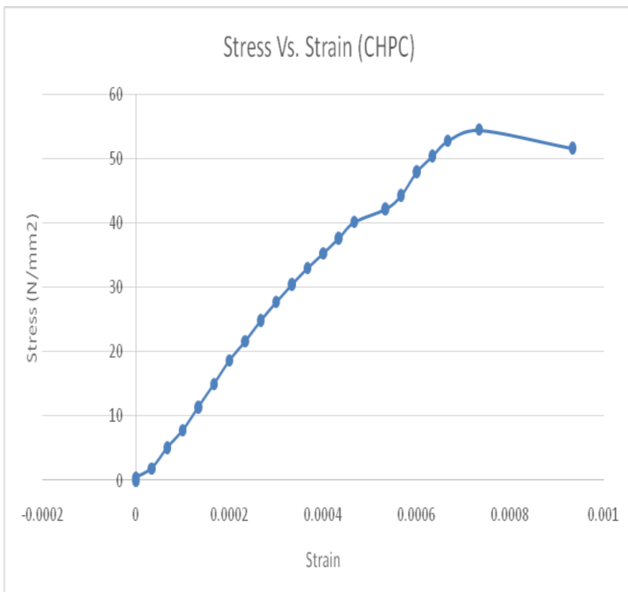
Split tensile strength test setup

S. No.	Specimen ID	Density (kg/m3)	Split tensile strength (MPa)
		28 Days	**28 Days**
1	CHPC	2513.20	5.56
2	HPC	2554.71	6.38
3	PP – 1	2528.30	6.40
4	PP – 2	2566.03	6.73
5	PP – 3	2603.77	6.25
6	PE – 1	2608.47	6.41
7	PE – 2	2566.03	6.86
8	PE – 3	2603.77	5.88

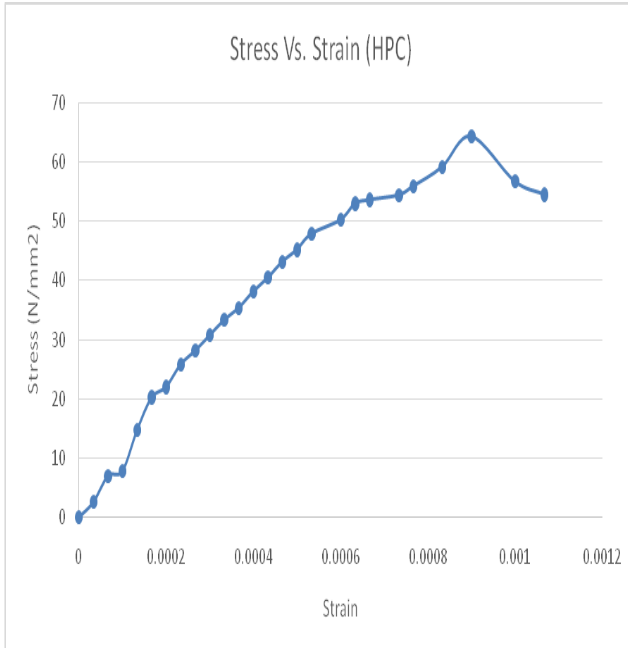
N. STRESS – STRAIN RELATIONSHIP

The stress – strain relationship is obtained from concrete cylinders of diameter 150 mm and length 300 mm. The testing is done after curing for 28 days. The cylinder is fitted with extensometer having gauge length not less than 10.2 cm and not more than half the length of the specimen. On removing the cylinder from the water and while it is still in the wet condition, the extensometers are attached at the ends, in such a way that the gauge points are symmetrical about the centre of the specimen and in nose are nearer to either end of the specimen. The specimen is immediately placed in the Compression Testing Machine and accurately centred. The load is applied continuously and without shock at a rate of 140 kg / sq cm / min. The extensometer readings corresponding to the load increments were noted.

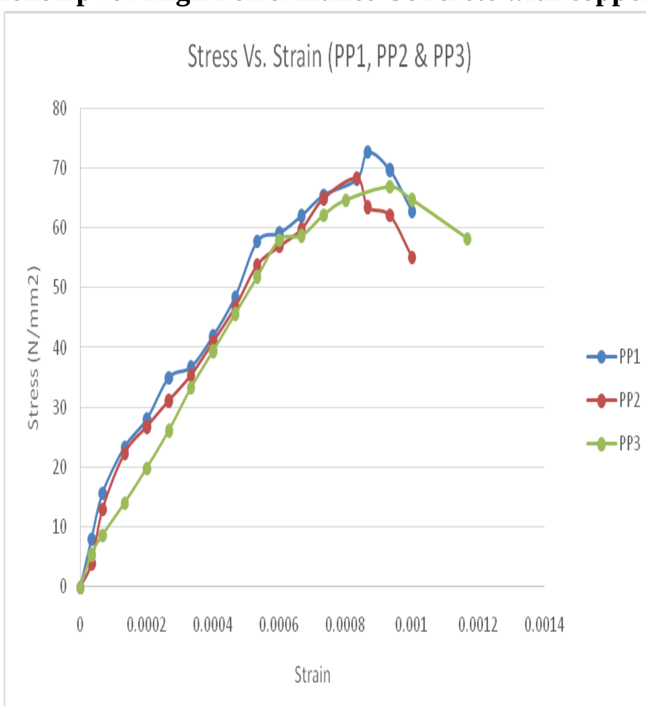
Testing setup for stress – strain relationship



Stress – Strain relationship for Conventional High Performance Concrete



Stress – Strain relationship for High Performance Concrete with copper slag and silica fume



Stress – Strain Relationships for the proportion of polypropylene fibres added high performance concrete

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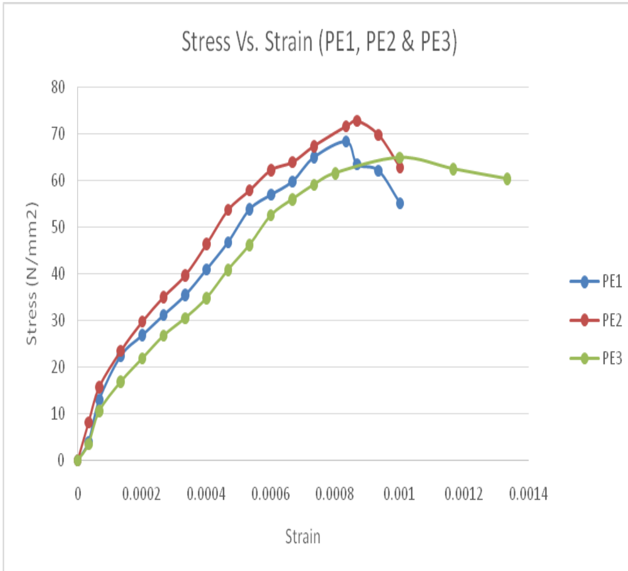
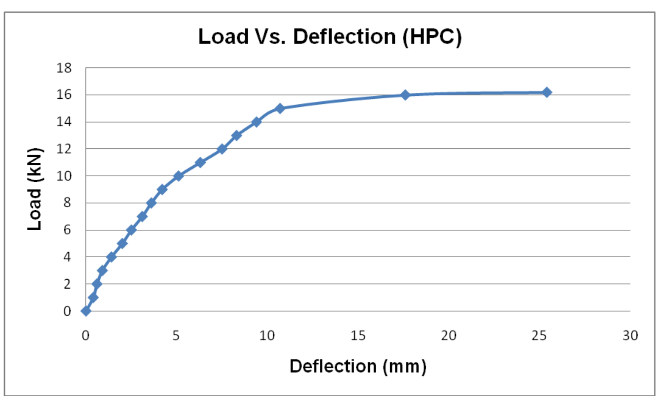


Stress – Strain Relationships for the proportion of polyester fibres added high performance concrete

III.BEAM

CONVENTIONAL HIGH PERFORMANCE CONCRETE BEAM

HIGH PERFORMANCE CONCRETEBEAM WITH COPPER SLAG AND SILICA FUME



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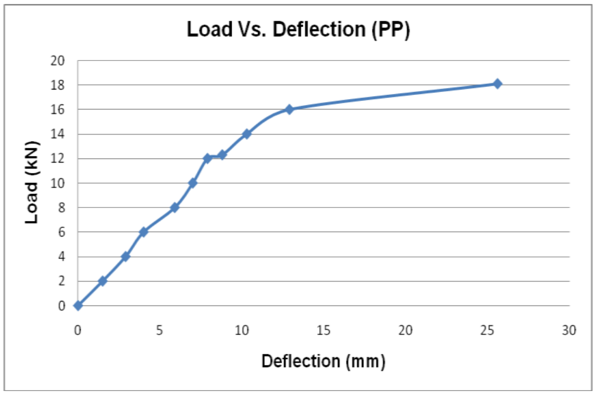
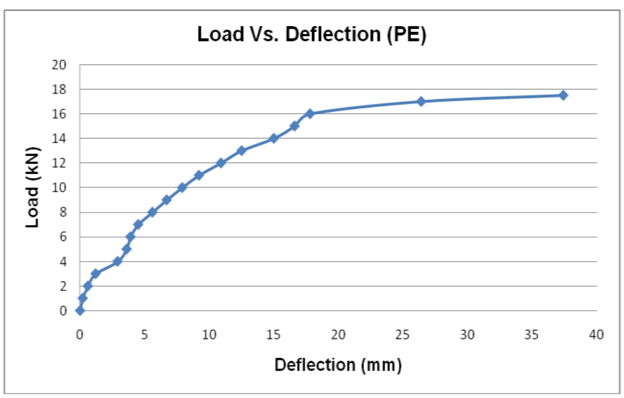
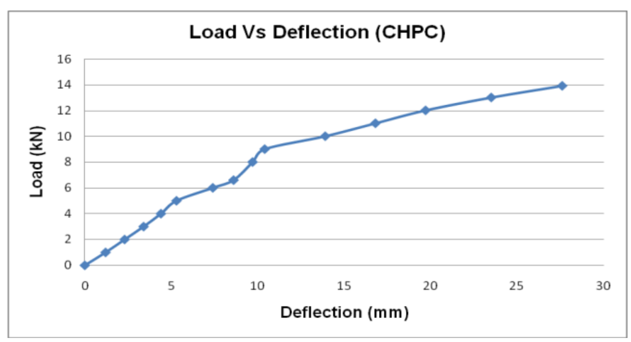
POLYPROPYLENE BEAM



POLYESTER BEAM





IV. CONCULUSION

In this study, four reinforced concrete specimens of M60 grade of Conventional HPC,HPC Beam with copper slag and silica fume, HPC Beam of copper slag and silica fume in addition to polypropylene fibre and HPC beam of copper slag and silica fume in addition to polyester fibre were cast and tested under two point loading to determine the flexural behaviour. The following conclusion were obtained from this experimental study with replacement of copper slag, silica fume and addition of polypropylene and polyester fibres.

- From this experimental study,Polypropylene beam (PP) shows maximum ultimate load of 18.1kN than the other beams and the corresponding deflection of 25.6mm
- The Polyester beam (PE) shows a maximum deflection of 37.4mm than the other beams with a corresponding ultimate load of 17.5kN.
- The results exhibited by the synthetic fibres concludes that the polypropylene beam has more tensile stress than the polyester beam.

- The initial crack was developed at 40%-50% of ultimate load for all beams. The location of initial crack was formed at the centre of the span and near loading point.
- There is no crack within shear span till the % of ultimate load. All the cracks responsible for the beam to fail were occurred in the flexural zone of the beams.

Hence the optimum level of addition of polypropylene was found to be 0.30% and polyester was found to be 0.040% and The Polypropylene beam results were better than that of CHPC, HPC and Polyester beam

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