Behavior of SBR Modified High Performance Fiber Reinforced Concrete Using Carbon Nano Tubes

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Abstract- *Construction industry is heading towards a new era with intensive use of High performance concrete (HPC) which overcomes the limitations of conventional concrete. Nanotechnology is an emerging field of material science related to the understanding and control of matter at the nanoscale. The addition of fine nano particles can improve the properties of concrete due to the effect of increased surface area on reactivity and through filling the nano pores of the cement paste and also leads to an increase of both short-term strength and long-term strength. The present study aims to investigate the integration of Carbon Nano tubes (CNTs)polypropylene ,steel fibers and SBR Latex with HPC of a designed mix of M60 grade of concrete. The influence of the cementations material dosage, nano material, cement/ultra-fine ratio, percentage of fibers, and the mixing procedures on the mechanical properties of nano based carbon concrete was studied. Carbon Nano tubes were first dispersed in water and surfactant using an ultrasonic mixer as per state-of-the-art techniques and then combined with SBR Latex and fibre reinforced high performance concrete. The various mechanical properties like Compressive, Flexural and Split tensile strength can be improved with the addition of low concentrations of CNT in SBR Modified high performance fiber reinforced concrete.*

Keywords- High Performance Concrete (HPC) , High Performance Fiber Reinforced Concrete (HPFRC), Carbon Nano tubes(CNTs), Crimped end steel fibers, polypropylene fibre, SBR Latex , Compressive Strength , Flexural Strength and Split tensile strength,

I. INTRODUCTION

Concrete is one of the oldest and most common construction materials, it is the most versatile and most widely used construction material worldwide and has played a very important role in the civilization of mankind. It has the unique distinction of being the only construction material actually manufactured. Mainly due to its low cost, availability, its long durability, and ability to sustain extreme weather environments. Concrete is a brittle material that has a high compressive strength, but a low tensile strength. HPC is an engineered concrete possessing the most desirable properties during fresh as well as hardened concrete stages. HPC is far superior to conventional cement concrete as the ingredients of HPC contribute most optimally and efficiently to the various properties. High performance concrete (HPC) is a specialized series of concrete designed to provide several benefits in the construction of concrete structures that cannot always be achieved routinely using conventional ingredients, normal mixing and curing practices. In general, a “High performance concrete” can be defined as that concrete which has the highest durability for any given strength class and comparison between the concretes of different strength classes is not appropriate. This means that, with the available knowledge, one can always strive to achieve a better (most durable) concrete required for a particular application. An official ACI definition: "High-performance concrete – concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices."

Addition of CNT into high-performance concrete leads to an increase of both short-term strength and long-term strength. The addition of nano fine particles can improve the properties of concrete due to the effect of increased surface area on reactivity and through filling the nano pores of the cement paste. Nano silica and nano titanium dioxide are probably the most reported additives used in nano modified concrete. Nano materials can improve the compressive strength and ductility of concrete. Carbon Nano Tubes or Nano Fibers (CNT-CNF) have also been used to modify strength, modulus and ductility of concretes. CNFs can act as bridges across voids and cracks that ensure load transfer in tension. Ultra high-performance concretes (UHPC) used in current practice have mainly been developed using some type of nano modification or the use of an admixture developed using nanotechnology methods. Some of the ways nanotechnology can be used to affect concrete include modifying the cement properties through nano modification, modifying the cement paste itself through admixtures, or affecting the concrete mixture using nano porous thin film (NPTF) coatings for the aggregates themselves. Durability of concrete can also be improved through reduced permeability and improved shrinkage properties. These effects can be accomplished through nano modified cements or the use of nano developed additives to the paste. Carbon Nano Tubes (CNTs) and Styrene Butadiene Rubber (SBR) latex are materials that are being developed to improve the properties of the concrete like brittleness, vulnerability to chemical attacks etc.This can be achieved by integration of CNTs, Fibers and Polymers in concrete. Hence, advanced researches have to be conducted to develop an advanced cement - based material. There are different types of polymer and are being used in cement concrete construction. They are aqueous polymer, powder emulsion, water-soluble polymer, liquid polymers etc. Rubber latex comes under aqueous polymer category. Recent studies indicate that both natural and synthetic rubber latex improve the engineering properties of concrete markedly.SBR Latex is Styrene Butadiene Rubber polymer, designed to use the latex for the modifying the cement composites.The adding of SBR Latex in cement improves the mechanical properties of the matrix. Hence an attempt has been made through the present experimental investigation to study the effect of High Performance Concrete modified with CNT, Fibers and SBR latex on the compressive strength, split tensile strength and flexural strength.

the use of advanced scientific equipment to monitor concrete microstructure. Therefore, many new macro-to-micro reinforcements have been utilized in order to increase the tensile strength and fracture toughness of concrete but all have led to marginal improvements but this can be achieved by integration of CNTs ,SBR-Latex and Steel Fibers in carbon concrete.

II. LITERATURE REVIEW

High-Performance-Concrete (HPC) has been defined as concrete that possesses high workability, high strength and high durability. Under the ACI (American Concrete Institute) definition, durability is optional and this has led to a number of HPC structures, which should theoretically have had very long services lives, exhibiting durability associated distress early in their lives. ACI also defines a high-performance concrete as concrete that has a specified compressive strength for design of 41 Mpa (6,000 psi) or greater. Special mixing, placing, and curing practices may be needed to produce and handle high-performance concrete.

High performance concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementatious materials such as fly ash, Silica fume or ground granulated blast furnace slag and usually a super plasticizer. The term 'high performance' is somewhat pretentious because the essential feature of this concrete is that it's ingredients and proportions are specifically chosen so as to have particularly appropriate properties for the expected use of the structure such as high strength and low permeabilityHence High performance concrete is not a special type of concrete, it comprises of the same materials as that of the conventional cement concrete. The use of some mineral and chemical admixtures like Silica fume. (1,2,3,4) FRC is widely used in structures, due to the property that fiber enhances toughness of concrete, FRC is used on large scale for structural purposes. The fiber is described by a convenient parameter called aspect ratio. The aspect ratio of the fiber is the ratio of its length to its diameter. The principle motive behind incorporating fibers into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation characteristics of the resultant composite. For FRC to be a valuable construction material, it must be able to compete economically with existing reinforcing system. FRC composite properties, such as crack resistance, reinforcement and increase in toughness are dependent on the mechanical properties of the fiber, bonding properties of the fiber and matrix, as well as the quantity and distribution within the matrix of the fibers. It improves fatigue resistance makes crack pattern distributed .(5,6,7,8) Styrene butadiene rubber latex is type of high polymer dispersion emulsion widely used as a polymer. SBR composed of butadiene, styrene, water and it can be successfully bounded to many materials. It is used to replace cement binders to improve tensile, flexural and compressive strength of concrete. SBR is a wide thick liquid in appearance with high viscosity 52.7% water content. Following are the papers studied on use of SBR latex in concrete. Previous research shows that some polymers added to the concrete mix cause a reduction in the water cement ratio (w/c), an increase in porosity, delayed setting (for a high amount of polymer) and shrinkage reduction. Polymers are widely used in structural concrete due to its high bonding strength with most aggregates, outstanding dimensions, stability from low creep/shrinkage during and after curing, low porosity and permeability, high thermal resistance, improved chemical resistance, outstanding fatigue resistance and good electrical insulation.(9,10,11) The use of nanotechnology-based nano-filaments such as carbon nano tubes (CNTs) and nano fibers (CNFs) as reinforcement in improving the mechanical properties of cement paste as a construction material Therefore, this study aspires to bridge the gap between nano-technology and construction engineering. Carbon nano-tubes (CNTs) have unique mechanical properties where their stiffness, strength, and resilience exceed any current material such that they offer tremendous opportunities for the development of fundamentally new material systems in modern construction.CNT are expected to have several distinct advantages as a reinforcing material for cements as compared to more traditional fibers. Carbon nanotube can significantly improve the properties of concrete. Carbon nanotubes, which consist of multiple sheets of graphite rolled to form a cylindrical structure and stacked concentrically were used. Due to strong Van der Waals forces & electrostatic forces carbon nanotubes tend to aggregate. Thus, ultrasonic dispersion techniques were adopted to disperse them uniformly.(12,13,14,15,16)

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Therefore, the research on integration of CNTs in cementatious materials is at a relatively novel stage; currently, very limited research regarding their effectiveness in enhancing the tensile strength or toughness of concrete has been conducted. Hence an attempt has been made through the present investigation to study the effect of CNTs in high performance concrete along polypropylene fibre , SBR Latex and steel fiber on the basic mechanical properties of concrete like compressive strength, split tensile strength and flexural strength.

III. EXPERIMENTAL PROGRAM

The present experimental program consists of Casting and testing of test specimens for compressive strength, tensile strength and flexural strength which consists of five different concrete matrix mix 1, mix2, mix3, mix4 ,mix5, mix6, mix7, mix8 and mix9. This experimental program is designed to investigate the integration of Carbon Nanotubes, SBR-Latex ,Steel fibre and Polypropylene fibers with High Performance Concrete of a design mix of M60 grade of concrete. The influence of the cementations material dosage, SBR-latex, carbon nano material, fibre content, and the mixing procedures on the mechanical properties of Behavior of SBR Modified High Performance Fiber Reinforced Concrete Using Carbon Nano Tubes together with the workability was studied by preparing different concrete matrix.

IV. MATERIALS USED IN THE PRESENT STUDY

In this present experimental investigation OPC 53 Grade. IS-12269:1987 is used to ascertain the physical characteristics of the cement, fine aggregates passing through 4.75 mm sieves and entirely retaining on 150µ sieve are used , to determine specific gravity and fineness modulus requirement of grading Zone II as per IS: 383 – 1970 were used. Crushed Granite stone with a maximum nominal size 12.5 mm & down was adopted as the coarse aggregate. IS 2386-1963 is used to test coarse aggregate to determine specific gravity and fineness modulus. In the present investigation for mix design of HPC, Glenium ACE 30, with Poly carboxylic based ethers as Super Plasticizer chemical admixture are used and SBR-Latex .Micro silica a dry powder available in densified form and Ground Granulated Blast Furnace Slag (GGBFS) is a dry powder are used as mineral admixtures. Crimped end steel fibers having aspect ratio of 80 is used. Ordinary potable water was used for mixing and curing purpose. Multi walled carbon Nanotubes (MWCNT) ,which are water dispersible and mixed as per state-of-the-art techniques .

To determine the mix proportions for M60 grade concrete (HPC), tests on trial mixes were carried out and was finally selected with required workability of 25-75mm slump, 9% of silica fume is replaced by weight of cement, 15% of GGBS, 0.125% of CNT by weight of cement, 0.8% of superplasticzier (Glenium ACE 30) 10% SBR latex by weight of cementatious material, 0.65% steel fbers by volume of concrete and polypropylene fibers 125gm/ bag of cement were used in the concrete mix in the present investigation. Detailed mechanical properties of materials are shown in Table No.1

Parameter	Specification
Cement Specific Gravity	3.15
Fineness modulus of FA	2.64
Specific Gravity of FA	2.63
Fineness modulus of CA	5.7
Specific Gravity of CA	2.65
Specific Gravity of Silica Fume	2.26
Specific Gravity of GGBS	2.32
Nano Material	MWCNTs
Nano Material Colour	Black
Purity of MWCNTs	>92%
Specific Surface Area of MWCNTs	$350m^2/Kg$
Average diameter of MWCNTs	20 n m
Steel fiber	Crimped end Aspect ratio-80
polypropylene fibers- Specific gravity Tensile strength	 0.9- 0.91 gm/ 25-33 Mpa
SBR latex Solids content pH Colour	 48% 10-11 White

Table No.1

V. TEST SPECIMENS

A series of specimens are chosen for the investigation and all are having a unique nominal standard dimensions for cubes 150 mm, cylinders 150 mm dia. and 300mm height and prisms 100 X 100 X 500mm respectively The test specimens consists of Nine different concrete matrix with CNT, SF, PF, SBR Latex (Mix1, Mix2, Mix3, Mix4, Mix5, Mix6, Mix7, Mix8, Mix9) The various mix combinations are as shown in table No.2

Concrete Type	Slump (mm)
Mix 1 = M60 (SF 9% + GGBS 15%)	75
Mix 2 = M60 (SF 9% + GGBS15%+0.125 CNT)	75
Mix 3 = M60 (SF 9% + GGBS 15% +0.125 CNT + STEEL FIBER 0.65%)	75
Mix 4 = M60 (SF 9% + GGBS 15% +0.125 CNT + POLYPROPYLENE FIBER 125gm per bag cement)	75
Mix 5 = M60 (SF 9% + GGBS 15% +0.125 CNT + SBR LATEX 10% by weight of binder)	75
Mix 6 = M60 (SF 9% + GGBS 15% +0.125 CNT + STEEL FIBER 0.65% + POLYPROPYLENE FIBER 125gm per bag cement)	75
Mix 7 = M60 (SF 9% + GGBS 15% +0.125 CNT + SBR LATEX 10% by weight of binder + POLYPROPYLENE FIBER 125gm per bag cement)	75
Mix 8 = M60 (SF 9% + GGBS 15% +0.125 CNT + SBR LATEX 10% by weight of binder + STEEL FIBER 0.65%)	75
Mix 9 = M60 (SF 9% + GGBS 15% +0.125 CNT + SBR LATEX 10% by weight of binder + POLYPROPYLENE FIBER 125gm per bag cement + STEEL FIBER 0.65%)	75

Table No.2

VI. CASTING THE SPECIMENS

In casting the specimen, Weigh Batching is used for the experimental study. Cement is weighed & slowly mixed with weighed Silica fume and GGBS the whole dry sample is mixed for 5 minutes. The Known weight of Fine aggregate, coarse aggregate, SBR Latex, Polypropylene fibers and steel fibers are mixed then water is measured in a measuring jar and mixed with Super plasticizer and dispersed CNTs of known volume. The Concrete mix is mixed until a uniform homogeneous mix is obtained, the mixing time should not exceed 3-4 minutes. The dispersed solution of CNTs is added to the mix & the mixing is continued until the lump free homogeneous mix is obtained. While preparing specimens in the laboratory, quality of concrete was maintained by standardizing the materials, proper batching of material, mixing compaction, adequate compacting , compaction time, initial hardening, curing and method of testing.

VII. METHODOLOGY OF TEST

In the present study Compressive strength, Split tensile strength & flexural strength are taken in to account. The experimental setup, casting, curing of nine specimens and testing procedure in accordance with as per IS 456-2000 and IS 516-1959 for determination of compressive strength, split tensile strength and flexural strength for below mentioned concrete matrix respectively.

i. High Performance concrete (M60 grade of concrete).
ii. High Performance concrete with Carbon nanotubes (M60+CNT)
iii. High performance concrete with carbon nanotubes and steel fibers (M60+CNT+SF)
iv. High performance concrete with carbon nanotubes and poly propylene fibers (M60+CNT+PF)
v. High performance concrete with carbon nanotubes and SBR latex (M60+CNT+SBR)
vi. High performance concrete with carbon nanotubes, Steel fibers and poly propylene fibers (M60+CNT+SF+PF)
vii. High performance concrete with carbon nanotubes, SBR latex and poly propylene fibers (M60+CNT+SBR+PF)
viii. High performance concrete with carbon nanotubes, SBR latex and steel fibers (M60+CNT+SBR+SF)
ix. High performance concrete with carbon nanotubes, SBR latex, steel fibers and poly propylene fibers (M60+CNT+SBR+SF+PF)

Table 3: Mix Proportion

Mix	cement	Fine aggregate	Coarse aggregate	w/c	water	SBR	Polypropylene fiber	Super plasticizer	GGBS	Silica fumes	CNT	Steel fiber
	(kg/m^3)	(kg/m^3)	(kg/m^3)		(kg/m^3)	$(litres/m^3)$	(kg/m^3)	$(litres/m^3)$	(kg/m^3)	(kg/m^3)	(gm/m^3)	(gm/m^3)
M60	450	441	1084	0.28	126	-	-	4.85	113	43	-	
M60+CNT	450	441	1084	0.28	126	-	-	4.85	113	43	0.562	
M60+CNT+SF	450	441	1084	0.28	126	-	-	4.85	113	43	0.562	51
M60+CNT+PF	450	441	1084	0.28	126	-	1.225	4.85	113	43	0.562	
M60+CNT+SBR	450	441	1084	0.27	122	9.15	-	-	113	43	0.562	
M60+CNT+SF+PF	450	441	1084	0.28	126	-	1.225	4.85	113	43	0.562	51
M60+CNT+SBR+PF	450	441	1084	0.27	122	9.15	1.225	4.85	113	43	0.562	
M60+CNT+SBR+SF	450	441	1084	0.27	122	9.15	-	4.85	113	43	0.562	51
M60+CNT+SBR+SF+PF	450	441	1084	0.27	122	9.15	1.225	4.85	113	43	0.562	51

VIII. RESULTS AND DISCUSSIONS

The experimental values obtained for different concrete mixes used in the present investigation are tabulated in following tables and corresponding graphs.

Results for Compressive Strength

The compressive strength is the main criteria for the purpose of structural design, the compression tests are relatively easy to carry out. The test for determining compressive strength for concrete, employs a cube specimen of 150mm size and cured for 3, 7, and 28 days which is subjected to uniaxial compression in a compression testing.

Table 3.1: Compressive Strength for all Compressive Strength (N/mm^2) obtained

AGE	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9
3days	25.78	28.06	32.56	29.012	26.96	33.12	28.86	29.87	27.98
7days	41.789	48.28	49.76	45.56	39.28	50.02	44.98	48.69	46.83
28days	64.29	68.10	71.12	70.03	58.00	72.18	66.70	67.70	69.97

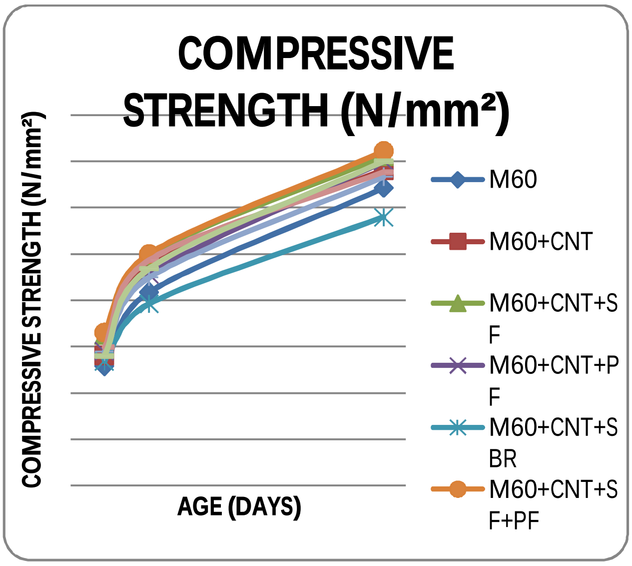

Fig 1: Variation of compressive Strength

Results for split tensile strength

This is an indirect test for tensile strength of concrete. This method is developed in Brazil and has come in to general use and been standardized throughout the world. The specimen is a 150Φx300mm cylinder made and cured in the same manner as similar to compressive test. Two wooden strips are placed. One at the top and the other at the bottom of the specimen and the same is loaded in compression. The tensile strength computed in this manner is apparently about 15% higher than that determined by direct tension tests. In order to obtain the split tensile strength for 3, 7 and 28 days, tests are conducted on cylinders. The results of split tensile strength test were tabulated below in the Tables – 5,6 & 7 shown if fig-3 & 4 It is observed that 1.0% of steel fiber content, obtain maximum split tensile strength than other concrete matrix used.

Split Tensile Strength (N/mm2)

AGE	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9
3days	2.2	2.29	2.41	2.34	2.08	2.45	2.27	2.32	2.39
7days	3.1	3.13	3.63	3.44	2.91	3.91	3.42	3.58	3.76
28days	4.04	4.76	5.51	5.03	4.27	5.77	4.68	5.13	5.29

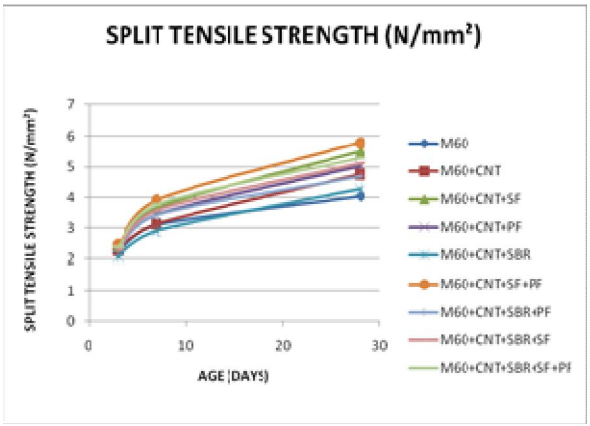

Fig 2: Variation of Split Tensile Strength

Results for flexural strength

When concrete is subjected to bending, Tensile, compressive stresses and in many cases direct shearing stresses occur. The most common example of concrete structure subjected to flexure are highway pavements and the strength of concrete for pavements is commonly evaluated by means of bending tests on 100x100x500mm beam specimens. Flexural strength is expressed in terms of "Modulus of rupture" which is the maximum tensile (or compressive) stress at rupture as tabulated in Tables – 8, 9 & 10 and shown in fig – 5 & 6. Experimental results, shows that 1.0% of steel fiber content obtain maximum flexural strength than other concrete matrix used.

Flexural Strength (N/mm2)

AGE	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9
3days	4.13	4.73	4.80	5.06	4.12	5.33	4.76	4.48	5.01
7days	5.73	6.46	7.86	7.80	6.27	8.53	6.93	7.81	8.36
28days	8.13	8.93	11.86	10.46	8.54	12.12	9.73	10.68	11.33

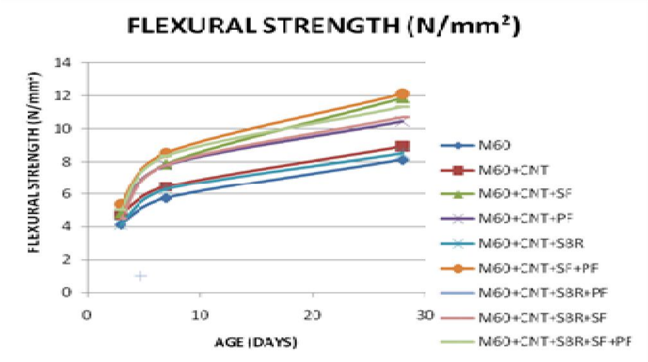

Fig 3: Variation of flexure Strength

XI. SUMMARY AND CONCLUSION

The Experimental program deals with Behavior of SBR Modified High Performance Fiber Reinforced Concrete Using Carbon Nano Tubes, in which High Performance Concrete is modified with CNT, SBR Latex, polypropylene fibre and Steel fiber. A concrete mix of grade M60 was designed to which CNT"s , SBR latex, polypropylene fibre and Steel Fiber were added. The test specimens consists of Cubes ,cylinders and prisms for five different concrete matrix such as Mix1, Mix2 Mix3, Mix4, Mix5, Mix6, Mix7, Mix8and Mix9, and are tested for compression strength , split tensile strength and flexural strength respectively.

Based on the results of the experimental investigation the following conclusion are drawn.

a.Compressive Strength:

A number of variables can cause changes in the physical and mechanical behaviour of concrete. These include the composition of concrete mix, type of aggregate and their shape, admixtures and addition of fibres and other complementary reinforcement. The rate of gain of 28 days compressive strength is more for test beam-6 in comparison with M60 grade of concrete used in this investigation. The compressive strength of test beam-6 is 12.27% more than that of 28 days strength of M60 grade of concrete (mix 1).

b. Split Tensile Strength:

The rate of gain of the 28 days split tensile strength is more for test beam specimen 6 in comparison with M 60 grade of concrete used in this investigation. The split tensile strength of beam 6 is 42.82% more than that of 28 days strength of M60 grade of concrete (mix 1).

c. Flexural Strength:

The rate of gain of the 28 days flexural strength is more for test beam specimen 6 in comparison with M60 grade of concrete used in this investigation. The flexural strength of beam 6 is 49.07% more than that of 28 days strength of M60 grade of concrete (mix 1).

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