

Effects of Black Steel Wire Fibre Reinforcement on Concrete

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ABSTRACT: Inherent micro cracks of concrete result low tensile strength, limited ductility and nominal resistance to cracking leading to brittle failure. Volume change of concrete also results structural crack development in plain concrete. Under stress concentration these cracks propagate and are opened up forming additional cracks resulting inelastic deformation.¹ Addition of fibres to the concrete arrests such crack development and improves properties of concrete under static and dynamic loading condition. For this study, target strength of 37.77 MPa is obtained for M30 grade design mix concrete at w/c 0.375. Flexural and split tensile strength for this design mixed M30 concrete are found to be 4.45 MPa and 3.20 MPa respectively. On adding black steel wire fibre 0.25%, 0.50%, 0.75%, 1.0% and 1.25%, compressive strength improved by 10%, 14.25%, 18%, 20.35% and 22% respectively. For the same value of fibre, flexural strength increased by 4%, 14.6%, 19.10%, 23%, and 26.29% and split tensile strength improved by 13.12%, 22.00%, 31.25%, 35.00%, 37.50% for fibre content of respectively.

KEYWORDS: Fibre reinforced concrete, Black wire steel fibre, Compressive strength, Flexural strength, Split tensile strength.

I. INTRODUCTION

Plain cement concrete has very low tensile strength, limited ductility and little resistance to cracking. Micro cracks are inherently present in the transition zone of concrete and propagation of such micro cracks results poor tensile strength leading to its brittle fracture¹. Using conventional reinforced steel bars and restraining techniques tensile strength concrete increases. This fails to increase the inherent tensile strength of plain concrete. Due to drying shrinkage or other reasons, volume of concrete changes and structural cracks develop in plain concrete even before loading. On loading, micro cracks propagate and due to stress concentration these are further opened up forming wider cracks. These structural cracks are the main factor of inelastic deformation in the concrete. For minimising such adverse conditions, fibre reinforced concrete (FRC) is used. FRC contains uniformly distributed and randomly oriented short discrete fibres. steel, glass, carbon, synthetic and natural fibre are commonly used. Properties of fibre reinforced concrete vary with different grade of concrete, type fibre material, their geometries, distribution, orientation and densities. Fibre reinforcement is mainly used in shot-crete and normal concrete for construction of pavements, beams, pillars, foundations etc. either alone or with conventional reinforcement.

Steel fibre is available in different lengths (30 to 80 mm) and shapes. During service life steel fibre may get corroded resulting rust stains on surfaces. In some cases, a steel fibre surface is finished with other materials. Glass fibre is inexpensive and corrosion-proof, but not as ductile as steel. Spun basalt fibre is stronger and less expensive than glass fibre but has least resistance to the alkaline environment of Portland cement hydrates. New materials are used, plastic binders, to isolate the basalt fibre from the cement. The premium fibres, graphite reinforced plastic fibres, are nearly as strong as steel, lighter in weight and corrosion-proof.

American Concrete Institute (ACI) Committee 544, suggested use of SFRC (Steel Fibre Reinforced Concrete), GFRC (Glass Fibre Reinforced concrete), SNFRC (Synthetic Fibre Reinforced Concrete) and NFRC (Natural Fibre Reinforced Concrete) in concrete.² Ganesan et.al. (2006) conducted a study on ultimate strength of steel fibre reinforced self-compacting concrete beams and found that strength and ductility of fibre reinforced self-compacting

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concrete specimens have increased substantially over conventional concrete beam.³ Plain concrete is weak flexural strength and the same can be increased by adding fibre reinforcement in highway pavement concrete. Soni K.M (2007) studied the effects of fibre reinforcement in highway pavement and concluded that fibre reinforced concrete has advantages over normal concrete particularly in case of cement concrete pavements. Polymeric fibers such as polyester or polypropylene are being used due to their cost effective as well as corrosion resistance though steel fibres also work quite satisfactorily for a long time.⁴ As black steel wire is commonly available and black wire steel fibre is locally made by cutting it into the required length for mixing in concrete.

II. MATERIALS AND METHODOLOGY

For design mix M30 grade concrete, Portland pozzolana cement (PPC) was used. Crushed angular aggregate of maximum nominal size 20 mm having specific gravity (Sp. Gr.) 2.94 in saturated surface dry (SSD) condition was used. River sand in SSD condition was used in design mix concrete. It was conforming to zone III and its specific gravity was 2.67. For relevant data / exposure conditions and codal provisions under IS 456 : 2000 and IS 10262 : 2009, different trial mixes for M30 grade concrete were calculated, cubes casted, cured and tested after 28 days curing.^{5,6} Based on the compressive strength of trial mix samples appropriate W/C for final mix for required target strength was calculated. Using the same water cement ratio final mix proportion was calculated.

For assessing the improved strength of M30 grade design mixed fibre reinforced concrete, branded crimped steel fibre and glass fibre were used in the recommended dose in the same concrete for reference strength. Locally available black steel wire were cut into fibre and used for study the improvement in strength with varying percentage. Based on strength of trial mixes, final mix proportion was calculated for achieving target strength. In the final mix 0.75% crimped steel fibre (on volume basis of concrete) and 2% glass fibre (volume of cement mortar) were used for accessing improved strengths to be used as reference. Black wire steel fibre (locally available material) 0.25%, 0.50%, 0.75%, 1.00% and 1.25% was mixed in M30 designed mix concrete and improvement of compressive, flexural and split tensile strength of black wire steel fibre mixed concrete with M30 grade plain concrete, crimped steel fibre and glass fibre mixed concrete is assessed.

Three samples of cubes, beams and cylinders using final mix proportion as plain concrete, mixed with 0.75% steel crimped fibre by volume of concrete and 2.0% glass fibre by weight of cement. After curing cubes, beams and cylinders were tested for compressive strength, flexural strength and split tensile strength respectively. These values were used as reference compressive, flexural and split tensile strength for comparison. Cubes, beams and cylinders were casted by adding 0.25%, 0.50%, 0.75%, 1.00% and 1.25% in M30 grade designed mix concrete. After 28 days curing, all samples of cubes, beams and cylinders were tested. Result were tabulated for analysis and discussion.

III. EXPERIMENTAL RESULTS AND DISCUSSION

For design mix M30 grade concrete(target strength of 37.77 MPa) water cement ratio was found as 0.375 Workability of same mix in terms of slump value was 37 mm. After mixing standard crimped steel Fibre @ 0.75 %, the slump value observed to be 37 mm. A slump value of 33 mm was found by adding Glass Fibre @ 2 % by weight of cement in the concrete mix. On addition of black steel wire fibre @ 0.25%, 0.50%, 0.75%, 1.0% and 1.25% slump values were 32.50 mm, 31 mm, 30.40 mm, 28 mm and 26.50 mm respectively. A reduction in bleeding was observed by addition of glass fibre in the concrete mixes. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks.

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Fig. 1 Compressive strength test

The increase in Compressive Strength of M30 grade concrete mix using Steel Fibre @ 0.75 % by volume of concrete at 28 days is observed to be 20.50% when compared with 28 days strength of ordinary M30 grade concrete. Compressive strength of M30 grade of concrete mix using glass fibre @ 2% by weight of cement at 28 days had increase from 37.77 to 44.78 MPa which is 18.50 % higher compared with compressive strength of reference concrete at 28 days. The increase in compressive strength of M30 grade concrete mix using black wire fibre @ 0.25%, 0.50%, 0.75%, 1.0%, and 1.25% by volume of concrete at 28 days is observed to be 10%, 14.25%, 18%, 20.35% and 22% higher strength respectively as compared to the compressive strength of reference concrete at 28 days.

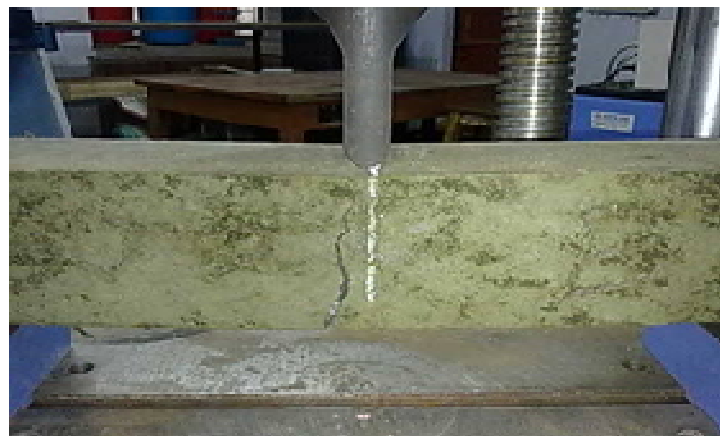


Fig. 2 Flexural strength test

The percentage increase of the flexural strength of M30 grade concrete mix using steel fibre @ 0.75 by volume of concrete after 28 days of water curing is observed to be 20.22% compared with reference concrete at same days of curing i.e. 28 days. The increase in flexural strength of the same concrete mix using glass fibre @ 2% by weight of cement at 28 days is observed to be 5.20 MPa i.e.17.00% higher than the flexural strength of ordinary concrete i.e. 4.45 MPa at 28 days of curing. The flexural strength of M30 grade concrete mix using black wires steel fibre @ 0.25%,

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0.5%, 0.75%, 1% and 1.25% by volume of concrete was found 4%, 14.6%, 19.10%, 23%, and 26.29% higher respectively.



Fig. 3 Split tensile strength test

The split tensile strength of M30 mix design using steel fibre @ 0.75% by volume of concrete is observed to be 4.30 MPa as compared to the ordinary concrete i.e.3.20 MPa which is 34.37% higher. The percentage increase of the split tensile strength of same mix design using glass fibre @ 2% by weight of cement at 28 days of water curing is observed to be 39.68% compared with the split tensile strength of ordinary concrete at 28 days. The increase in strength of Split Tensile strength of M30 grade concrete mix using black wire steel fibre @ 0.25%, 0.50%, 0.75%, 1.0%, and 1.25% by volume of concrete at 28 days is observed to be 13.12%, 22%, 31.25%, 35% and 37.50% respectively compared with Split Tensile Strength of ordinary concrete at 28 days of water curing. Use of black wire steel fibre reinforcement has higher strength gain upto 0.75% dose for compressive, tensile and split tensile strength.

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Table – 1 Strength of M30 grade fibre reinforced concrete									
Sl. No	Mix type	Type of fibre	Dose of fibre	Compressive strength		Flexural strength		Split tensile strength	
				MPa	% increase	MPa	% increase	MPa	% increase
1	A1		-	37.77	-	4.45	-	3.20	-
2	A2	Crimped steel fibre	0.75	45.50	20.50	5.35	20.22	4.30	34.37
3	A3	Glass fibre	2.00	44.78	18.50	5.20	17.00	4.15	39.68
4	A4	Black wire steel fibre	0.25	41.56	10.00	4.60	4.00	3.60	13.12
5	A5		0.50	43.15	14.25	5.15	14.60	3.90	22.00
6	A6		0.75	44.56	18.00	5.22	19.10	4.20	31.25
7	A7		1.00	45.45	20.35	5.30	23.00	4.40	35.00
8	A8		1.25	46.12	22.00	5.52	26.29	4.40	37.50