Comparison Of Mechanical Properties Of Steel Fiber-Reinforced Concrete And Normal Concrete

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Abstract: In order to be useful in construction, the product must meet minimum compressive requirements, which are determined through a Mechanical Test of Concrete and to check the strength of the concrete used for buildings and other structures, where the principal stresses are compressive, cube samples were obtained and tested in compression testing machine. As Pillars, beams and pipes needs high values of strength, different types of materials have been explored in order to increase life of such structures. Steel reinforcement is widely used in which cages of steel bars are used along with concrete. The use of steel fibers which are very smaller in size and diameter are also becomes familiar in these days. In present work, two types of steel fibers s named as straight and crimped steel fibers has been investigated in Mix 25 concrete design mix by proportion with weight of cement. Compressive strength and flexural strength tests are carried out on designed concrete mixes in which only original base mix, and four steel fiber induced concrete mixes are deigned each using straight and crimped steel fibers. 0.05, .1, .15 and .20 % ratio of steel fibers is used to make four types of concrete mixes. It has been found that there is 12.75% increase in compressive strength when ratio of steel fiber is increased from 0.05 to .20. Similar results have been noted for flexural strength which is approximately 13.5% increase when similar ratio of material is used after 28 days of curing. Workability test has been carried out by measuring slump value which is also shows moderate decrease in slump when steel fibers are used.

1. INTRODUCTION

Concrete is one of the most widely used construction material in the world. However, since early 18th century it has been known that concrete is weak in tension as its tensile strength is 1/10th to that of its compressive strength. Thus concrete requires some form of tensile reinforcement to compensate its brittle behavior and improve its tensile behavior. The concept of adding fibers to improve brittle behavior is ancient e.g. Mesopotamians used straw,horsehair, and other vegetable fibers of specific geometry to reinforce sunbaked bricks. Nowadays, fibers are produced from different materials such as steel, glass, carbon, and synthetic materials, each one having its specific benefits. However, steel fiber is the most common one. A typical length of steel fiber ranges from 0.25 - 2.5 in [6-64mm] and its diameter ranges from 0.02-0.04in [0.5-1mm].SFRC products are manufactured by adding steel fibers to the ingredients of concrete in the mixer and by transferring the green concrete into moulds. The product is then compacted and cured by the conventional methods.Steel fibers are added to concrete to improve the structural properties, particularly tensile and flexural strength. The extent of improvement in the mechanical properties achieved with SFRC over those of plain concrete depends on several factors, such as shape, size, volume, percentage and distribution of fibers. Steelfiber is used to improve the mechanical properties of concrete, especially the post cracking and tensile resistance. An example of recent use of steel fiber is the Gotthard base tunnel in Switzerland. SFRC is therefore found to be a versatile material for the manufacture of wide varieties of precast products such as manhole covers, slab elements for bridge decks, highways, runways, and tunnel linings, machine foundation blocks, door and window frames, piles, coal storage bunkers, grain storage bins, stair cases and break waters. Different approaches have been used to mitigate the effect of shrinkage induced cracking and also to increase its tensile strength. Fibers can provide a significant contribution in delaying crack propagation and limiting crack width. However the use of discrete, short, randomly distributed steel fibers can be considered as one of the best approaches. In this work, different types of steel fibers have been used in varying proportions and the same has been compared with that of normal concrete.

Potential Uses of Fiber Reinforced Concrete FRC

Steel fiber is used to improve the mechanical properties of concrete, especially the post cracking tensile resistant. Moreover, it has recently been used as an alternative engineering material instead of steel bars/steel stirrups in short-span concrete slabs. Steel fibers reinforced concrete (SFRC) construction is more economical than conventional construction. In addition to cost reduction, SFRC has other beneficial properties such as higher stiffness, higher ductility, lightweight, low repair costs, and better post-cracking and dynamic behavior. SFRC has been used extensively in construction of industrial floors, bridge deck overlays, airport runways, highway pavements, tunnel linings, spillways, dams, slope stabilizations, and many precast products. An example of recent use of steel fiber is the Gotthard Base Tunnel. Nevertheless, relatively little use of SFRC in the building structure is mainly due to the lack of design provisions in building codes. Steel fibers can improve the characteristics of hardened concrete, and polypropylene fibers can have significant effects on the fresh concrete. Polypropylene fibers significantly reduce the slump of the fresh concrete resulting in an increase in the adhesion and cohesion of the concrete. Polypropylene fibers also reduce the plastic shrinkage cracks. Polypropylene fibers can increase concrete durability against fire, freezing, and chemical attacks. Due to its benefits, polypropylene fiber reinforced concrete (PPFRC) is used in pile foundations, piers, highways, industrial floors, bridge decking and others.

Objectives

The aim of this research is the evaluation of the performance of steel fibers in various dosages as an alternative to the conventional steel reinforcement. Tests are carried out to evaluate the following objectives:

1) To collect different types of steel fibers along with other materials needed for the performance of various tests.

2) To perform basic tests on cement and aggregates.
3) To determine material properties of concrete with different percentages of steel fiber reinforcement.
4) To evaluate the effectiveness of each type of fiber on various mechanical properties of concrete.
5) To compare the results with normal concrete.
Tests are to be carried out by making cube and beam specimens from the proposed material.

METHODOLOGY

These will be the general steps that will be carried out for testing and report making. The flowchart for the material processing and testing phases has been shown in figure 3.1

COLLECTION OF MATERIALS

Generation of samples
Lab testing
Report making and comparison of results using and tables and graphs

Tests on Concrete Mix.
Compressive Strength Test
The compressive strength of concrete is obtained by loading a cylinder axially until failure. The load magnitude applied at failure is therefore the load capacity of the concrete excluding buckling effects, by axially loading a specimen uniformly over its bearing area, the axial strain throughout the material would be uniform and constant

Compressive strength of M25 concrete mix specimens

Mix design	Sample No.	Compressive strength test plain concrete (N/mm2)		
		7 Days	14 days	28 days
M25	1	17.35	22.05	27.33
	2	17.20	22.15	27.05
	3	17.60	22.35	27.80

Compressive Strength test results for straight steel fibres

Type of steel fibre	Mix design	Sample No.	Compressive strength test (N/mm2)		
			7 Days	14 days	28 days
Straight	Straight.05	1	17.80	22.30	27.51
		2	17.85	22.33	27.56
		3	17.95	22.41	27.49
	Straight.1	1	18.05	22.95	27.92
		2	18.07	23.01	27.89
		3	18.15	22.92	27.99
	Straight.15	1	18.66	23.36	28.31
		2	18.72	23.30	28.40
		3	18.80	23.41	28.36
	Straight.2	1	19.02	23.92	28.92
		2	19.10	24.03	28.96
		3	19.20	23.98	29.03

Compressive strength test results for crimped steel fibres

Type of steel fibre	Mix design	Sample No.	Compressive strength test (N/mm2)		
			7 Days	14 days	28 days

Crimped	Crimped.05	1	18.20	23.10	28.02
		2	18.23	23.03	28.05
		3	18.19	23.17	27.96
	Crimped.1	1	18.70	23.43	28.66
		2	18.67	23.47	28.63
		3	18.75	23.56	28.70
	Crimped.15	1	19.03	24.50	29.24
		2	19.09	24.61	29.10
		3	18.98	24.49	29.19
	Crimped.2	1	20.03	25.15	30.14
		2	19.98	25.30	30.30
		3	20.07	25.22	30.19

Flexural Strength Test

Flexural strength is a form of tensile strength and M25 mix with steel fiber reinforcement tends to increase its flexural strength from original basecontrol concrete. For this testing, beam specimens of size 500*100*100 mm3 are casted and tests has been taken for 7, 14 and 28 days of curing of beams in water.

Flexural tensile strength test for M25 tested beam specimens

Mix design	Sample No.	Flexural strength test (N/mm2)		
		7 Days	14 days	28 days
M25	1	1.82	2.39	2.79
	2	1.91	2.30	2.74
	3	1.85	2.37	2.65

Flexural Strength test results for straight steel fibres

Type of steel fibre	Mix design	Sample No.	Flexural strength test (N/mm2)		
			7 Days	14 days	28 days
Straight	Straight.05	1	1.99	2.53	2.97
		2	2.02	2.54	2.86
		3	2.11	2.52	2.94
	Straight.1	1	2.162	2.713	3.186
		2	2.178	2.727	2.994
		3	2.293	2.702	3.130
	Straight.15	1	2.299	2.874	3.383
		2	2.302	2.889	3.144
		3	2.472	2.887	3.315
	Straight.2	1	2.456	3.013	3.554
		2	2.507	3.068	3.352
		3	2.676	3.063	3.455

Flexural Strength test results for crimped steel fibres

Type of steel fibre	Mix design	Sample No.	Flexural strength test (N/mm2)		
			7 Days	14 days	28 days
Crimped	Crimped.05	1	2.139	2.717	3.167
		2	2.147	2.729	3.015
		3	2.286	2.680	3.141
	Crimped.1	1	2.302	2.826	3.381
		2	2.293	2.875	3.147
		3	2.488	2.860	3.265
	Crimped.15	1	2.437	3.015	3.582
		2	2.462	3.022	3.361
		3	2.660	3.090	3.462
	Crimped.2	1	2.607	3.172	3.740
		2	2.700	3.278	3.512
		3	2.831	3.217	3.659

Workability test

The quantity of sand, gravel, cement, steel fibers and water were carefully calculated and weighed out in such a quantity that can fill three cube moulds at a time, using a valid mix proportion. Cement, aggregates and sand were thoroughly mixed using shovel on a non-absorbent surface, before the gravel was added and mixed again, before water was added and the final mixing was done until the paste became uniformly plastic. The paste was fed in three layers into the slump cone placed on the glass plate. Each layer was uniformly tamped 25 times. The cone was raised and the slump measured.

Slump test results

%weight of steel fiber	Mix design used	Slump value in (mm)
0.0%	M25	69.8
0.05%	Straight.05	68.6
0.10%	Straight.1	67.5
0.15%	Straight.15	65.2
0.20%	Straight.2	63.9
0.05%	Crimped.05	67.4

0.10%	Crimped.1	65.8
0.15%	Crimped.15	63.7
0.20%	Crimped.2	61.1

CONCLUSION AND FUTURE SCOPE

CONCLUSION

The aim of this research was the evaluation of the performance of steel fibers in various dosages as an alternative to the conventional steel reinforcement in dry-cast concrete pipes, beams, pillars etc. The performance was evaluated based upon the workability test in which slump values are noted down for all types of mixes.It has been observed that when steel fibers are added, thickness and surface attraction has been increase results in lower values of slump than the base mix design. Also crimped wires has lower values of slump than straight steel fiber mixes which causes due to irregularity in the surface of the material and hence founds higher workability than original base mix as well as straight steel fiber based concrete mixes. In order to test mechanical properties of the concrete mixes, compressive strength and flexural strength tests has been carried out after 7, 14 and 28 days of curing. It has s been found that the compressive strengths of concrete containing steel fibers at 7, 14 and 28 days were higher than that of M25 mix concrete for all mixes. Further when comparing concrete mixes with two types of steel fibers in it, crimped steel fiber mix concrete shows higher value compressive strength than the straight fibers. For Flexural strength tests,It has been found that the 28-day flexural strength increases from 2.97 to 3.45 MPa, for straight steel fibers when 0.05 and .2% of stright steel fiber is used which is approx. 13.9 % increase. Similar increase has been noted for crimped wire based mix designs where 3.167 N/mm2 compressive has been noted when 0.05% ratio of crimped steel fiber is used and 3.659N/mm2 is noted when 0.2% crimped steel fiber is used. This is alomost 13.4% increase. Similarly patterns are noted for 7 and 14 days testing values.

FUTURE SCOPE

After conducting the research on straight and crimped wires, it can be stated that in future the rice husk can be used as a proportion of sand or aggregate along with steel fiber reinforcement. It will be good if rice-husk waste can be utilized while maintain workability and strength of the concrete

REFERENCES

[1] ACI 544, "Design Considerations for Steel Fiber Reinforced Concrete," ACU Jornl Proceedings, vol. 1, no. 2003, pp. 1-23, 2003.
[2]AlirezaKhaloo, et al., Mechanical performance of self-compacting concrete reinforced with steel fibers.Construction and Building Materials, 2014. 51: p. 7.
[3]Babych, E. M., &Andriichuk, O. V. (2017).Strength of Elements with Annular Cross Sections Made of Steel-fiber-Reinforced Concrete under One-Time Loads. Materials Science, 52(4), 509-513.
[4]Buyukkaragoz, A. (2019). Shear behavior of aerated concrete and hollow brick walls strengthened with steel fiber-reinforced concrete panels. Mechanics of Advanced Materials and Structures, 1-9.
[5]Caggiano, A., Etse, G., &Martinelli, E. (2011). Interface model for fracture behavior of fiber-reinforced cementitious composites (FRCCs) Theoretical formulation and applications.European journal of environmental and civil engineering, 15(9), 1339-1359.
[6]Ganesan, N., J.B. Raj, and A. Shashikala, Flexural fatigue behavior of self-compacting rubberized concrete.Construction and Building Materials, 2013. 44: p. 7-14.
[7]Gifta, C. C., &Prabavathy, S. (2018). Study on Energy Absorption Capacity of Steel–Polyester Hybrid Fiber Reinforced Concrete Under Uni-axial Compression. Journal of The Institution of Engineers (India): Series A, 99(3), 547-553.
[8]Gencel, O., Brostow, W., Datashvili, T., &Thedford, M. (2011).Workability and mechanical performance of steel fiber-reinforced self-compacting concrete with fly ash.Composite interfaces, 18(2), 169-184.
[9]Ghailan, D. B., & Al-Ghalib, A. A. (2019).Magnetic alignment of steel fibers in self-compacting concrete. Australian Journal of Structural Engineering, 1-9.
[10]Häßler, D., & Barros, J. A. (2013).Exploring the possibilities of steel-fiber reinforced self-compacting concrete for the flexural strengthening of masonry structural elements. International Journal of Architectural Heritage, 7(1), 26-53.
[11] Hameed, R., Turatsinze, A., Duprat, F., &Sellier, A. (2013). Bond stress-slip behavior of steel reinforcing bar embedded in hybrid fiber-reinforced concrete. KSCE Journal of Civil Engineering, 17(7), 1700-1707.
[12] Hernandez, O., El Naggar, H., & Bischoff, P. H. (2015). Soil-structure Interaction of Steel Fiber Reinforced Concrete Slab Strips on a Geogrid Reinforced Subgrade. Geotechnical and Geological Engineering, 33(3), 727-738.
[13] Kamal, M. M., Safan, M. A., Etman, Z. A., &Kasem, B. M. (2014). Mechanical properties of self-compacted fiber concrete mixes. HBRC Journal, 10(1), 25-34.
[14] Kareem, A.S., Rheological Properties, Mechanical Strength And Structural Behavior of Reused Steel Fiber Self compacting concrete. 2016.
[15] Kawashima, K., Zafra, R., Sasaki, T., Kajiwara, K., & Nakayama, M. (2011). Effect of polypropylene fiber reinforced cement composite and steel fiber reinforced concrete for enhancing the seismic performance of bridge columns. Journal of Earthquake Engineering, 15(8), 1194-1211.