ASPS Conference Proceedings 1: 1199-1202 (2022)

Proceedings of

12th Structural Engineering Convention-An International Event (SEC 2022)

Available at https://asps-journals.com/index.php/acp

Empirical Relationship between the Impact Energy and Compressive Strength for Slurry Infiltrated Fibrous Concrete (SIFCON)

A.P. Shelorkar [1, *], P.D. Jadhao [2]

[1] Department of Civil Engineering, Research scholar, K K Wagh Institute of Engineering Education & Research, Nashik 422 103, India
[2] Department of Civil Engineering, Professor & Head, K K Wagh Institute of Engineering Education & Research, Nashik 422 103, India

Paper ID - 090030

Abstract

In this research, an empirical relationship between the impact of energy and compressive strength is developed using regression analysis. For this, simple, practical, and economical drop weight test was performed on Slurry Infiltrated Fibrous Concrete which was based on the testing procedure recommended by ACI committee 544. Hook ended steel fibre of 35 mm length and an aspect ratio of 60 was used as the reinforcing material in four different volume fractions such as 0%, 2%, 3% and 4% with water cement ratio of 0.4. The test results indicated that increasing volume fraction of fibre increased the impact resistance of concrete specimen. It is also found that the empirical relationship obtained from the regression analysis is accurate and preferable to evaluate the impact energy by using compressive strength of Slurry Infiltrated Fibrous Concrete thus eliminating the drop weight test.

Keywords: Drop-weight test, Impact energy, Compressive strength.

1. Introduction

Impact or toughness strength is a really essential mechanical property for structures or materials subject in shock loading and particularly in cold and stormy conditions in bridges. Recently, concrete impact resistance is recognized as an important property in infrastructure construction. Numerous methodologies were recommended by different guidelines that evaluate FRC impact resistance such as projectile impact test, Charpy test, explosive test and weight drop test. Between them, weight drop is the easiest, most common and desirable method recommended by ACI Committee 544 [1]. Moreover, a wider variation can be found in the results of the drop weight test and this may be due to the interpretation of the test results based on the validation of first crack by visual implies and this crack may occur in any direction. It is difficult to control the drop hammer, drop height precisely as it is done manually. The impact resistance of concrete is determined by the impact which occurs at a single point, that may be either on a tough coarse aggregate, or fibre or matrix. The varying design of the mix may lead to changes in impact resistance, including aggregate shape, fibre geometry and fibre dispersal. [2-7]. They made the

comparison between impact load results obtained from numerical modeling and that of the experimental research data [8]. In his experimental work, the best performance under impact loading has been given by the concrete having 2.0% volume fraction of fibers reported by Farnam et al. [11]. Rao et al. [12] studied the performance of energy-absorption capacity of SIFCON slabs increases with increased volume of fibre, and absorb more energy as compared with FRC and RCC slabs.

From1990 to 2020 lot of work performed on the behaviour SIFCON under various mechanical properties using various substitution, substitute of cement and fine aggregate [13]-[17]. In the current study, an attempt has been made to develop expression, to predict the impact energy from the compressive strength of slurry-infiltrated fibre concrete. In recent times, concrete impact resistance is recognized as an essential property in an infrastructure construction.

2. Experiments

2.1 Material properties

For this research throughout the work, 53 grades OPC used which procured from the locally available market. River sand used as a fine aggregate which confirming to as per IS 383-1970. A commercial high-performance superplasticizer (polycarboxylic ether) was used as a high-range water-reducing agent to produce a workable slurry infiltrated fibre concrete. The dosage of superplasticizer 1.0 % of the cement content. The hook ended steel fibre with an aspect ratio 60, length of 35 mm and equivalent diameter of 0.6 mm was used. The density of the fibre was 7800 Kg/m3 and tensile strength of fibre was 1100 MPa.

*Corresponding author. Tel: +919822935983; E-mail address: shelorkar@gmail.com

Proceedings of the 12th Structural Engineering Convention (SEC 2022), NCDMM, MNIT Jaipur, India| 19-22 December, 2022

Published online: December 19, 2022
doi:10.38208/acp.v1.640

2.2 *Mix proportions*

In this study, water-cement ratio of 0.4 was adopted and hook steel fibres of 0%, 2%, 3% and 4% volume fraction were used. To investigate the compressive strength and an impact strength property on slurry infiltrated fibre concrete, each of three mixes were employed to study MK and FA with cement replacement of 5, 7.5, and 10 %. The mass ratio of mortar composition was 1:1 (water: cementitious material and sand). About 1 % of superplasticizer is added for each replacement of SIFCON to maintain suitable consistency.

2.3 *Mixing procedure and specimens preparation*

The process of making SIFCON is different, because of high steel fibre content. While in SFRC the steel fibres are mixed intimately with wet (or) dry mix of concrete, previous to mix being poured into forms. SIFCON made by infiltrating low viscosity cement slurry into a bed of steel fibres “pre-packed” in forms (or)molds. Typical casting procedure of SIFCON specimen as shown in Figure 3.Mix design of SIFCON performed by fundamental of packing density approach. Each mix of freshly mixed concrete was then cast into cubes (100 mm) which were used in the compressive strength tests. Cylindrical (100×64 mm) discs which were cut from the cylindrical specimen were used for the impact test.

2.4 *Impact test*

The Impact or toughness strength of the specimens was determined in accordance with the procedure proposed by American Concrete Institute committee 544.2R-89. For this purpose, from each mix, six discs of size 100 x 64 mm were cut from 100 x 200 mm cylindrical specimens using a masonry cutter.

They were placed on the base plate of the impact testing machine and was then struck with repeated blows. The impact load was applied with a 13.5 Hammer dropped repeatedly from a 300mm height onto a 63.5 mm steel ball, which was located at the Centre of the top surface of the disc. The drop hammer was then placed with its base upon the steel ball and held vertically. The hammer was dropped repeatedly. The base plate held rigidly on to the concrete platform to perform the test effectively. The drop hammer was placed at a convenient height to operate manually. The energy absorbed by the specimen was evaluated using equation (1):

$$E_1 = \frac{1}{2}M(v_1)^2N \qquad (1)$$

where E1 is the impact energy (Nm), M is mass of the drop hammer in kg (13.5 kg), V1 is impact speed(m/s), N is a number of blows required for failure of the specimen, and h, is the drop height in meters (0.30 m). During the impact, the speed of the drop hammer (V1) is measured, and it was calculated as 2.422 m/s (impact energy per blow = 39.53 Joules).

3. Results and discussion

The average compressive, tensile, flexural and impact or toughness strength test results are graphically illustrated in (Fig.1). The following Table 1 gives a summary of mechanical properties of plain concrete.

Table-1. Mechanical properties of plain concrete

Mix	Compressive strength (MPa)	Splitting tensile strength (MPa)	Flexural strength (MPa)	Impact strength (N-m)
CON	56.28	7.68	8.84	1368.02

3.1 *Compressive strength*

The increase in compressive strength at 28 days was 51.56 %, 69.68 % and 75.19 % for a 2.0%, 3.0% and 4.0% volume fraction of fibre and 10% metakaolin respectively. The results suggest that the higher volume fraction of fibre incorporation into the concrete increases the strength of the concrete. For fly ash 27.93%,44.45% and 60.98% for a 2.0%, 3.0% and 4.0% volume fraction of fibre and 10% fly ash respectively. Fig.1 shows that an illustration of various mix and with regarding compressive strength and its clearly shows that effect of increasing in percentage of fibre increase the compressive strength.

3.2 *Flexural tensile and splitting tensile strength test results*

The effect of volume fraction of fibres on slurry infiltrated fibrous concrete tensile strength and flexural strength is shown in (Fig. 2). It is clear from (Fig. 2) that the flexural strength is improved in general as the volume fraction of the fibre is increased. Flexural strength increased by 139.14 %, 173.98 % and 207.69 % when fibre volume fractions were 2.0 %, 3.0 %, 4.0 % respectively, and partial replacement of met by 10 % partial replacement of metakaolin for cement. The test results indicate that the high tensile strength, possessed by the steel fibre improved the flexural strength of slurry infiltrated fibrous concrete specimen 207.69%. Also (Fig.3) presents the results of various mix fibre volume fraction testing carried out on six different mixtures versus splitting tensile strength after 28 days. As expected, a higher splitting tensile strength was obtained in 4.0% volume fraction of steel fibre. Introducing steel fibre into the concrete mixtures has led to significant increases in the splitting tensile strength. For instance, the splitting tensile strength increased by 89.45 %, 114.84 % and 132.55 % when fibre volume fractions were 2.0%, 3.0% and 4.0 % respectively.

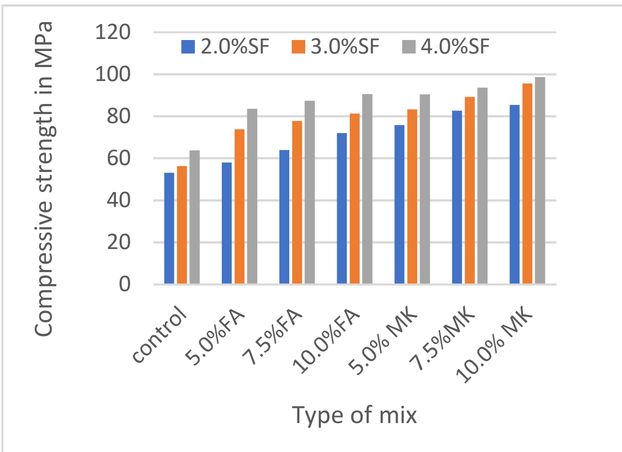

Fig. 1. Compressive strength of slurry infiltrated fibre concrete

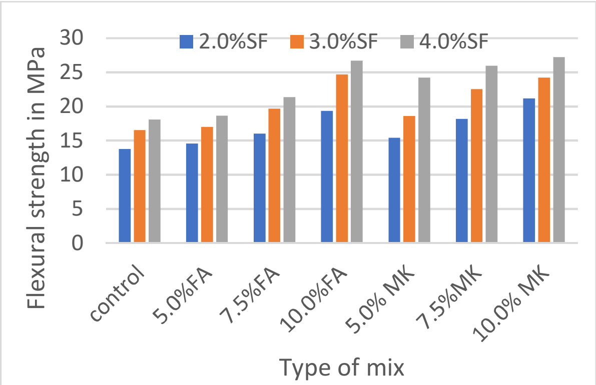

Fig. 2. Flexural tensile strength of slurry infiltrated fibre concrete

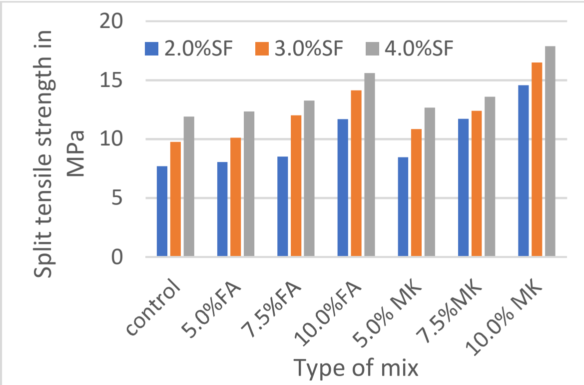

Fig. 3. Splitting tensile strength of slurry infiltrated fibre concrete

3.3 Impact test results

The impact energy of plain concrete, as well as the slurry infiltrated fibre concrete with the different volume fraction of fibre content and the impact resistance performance is shown in (Table 2). The impact resistance given in the table is the average values of three-disc specimens. From the results, it was noted that by using hook ended steel fibre along with fly ash and metakaolin in the mixtures, there was a considerable increase in impact energy, when compared to plain concrete.

It is obvious that, by the incorporation of steel fibres into the mixture, a definitive increase in a impact energy was observed. At 28 days, the mix that contains 4 % steel fibre along with 10 % fly ash and metakaolin showed an increase impact energy as compared with plain and other mix. These results reveal that the use of steel fibre can exclusively increase impact resistance or ductility performance of the concrete [9-12].

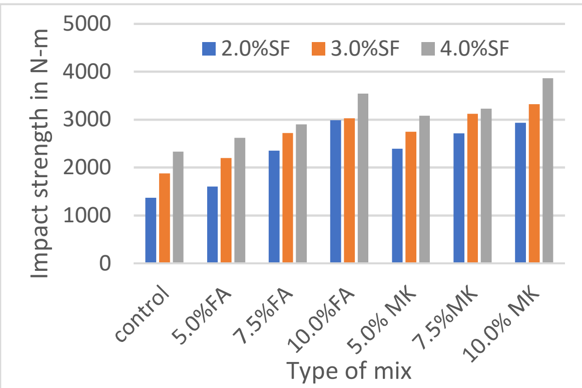

Fig. 4. Impact strength of slurry infiltrated fibre concrete

Table-1. Test results and predicted value of impact energy (N-m)

Sr.No.	Mix name	Actual value	Predicted value	Standard residual
1	Control	1368.02	1402.66	-0.20
2		1875.50	1557.67	-1.09
3		2329.35	1926.55	-0.29
4	5%FA	1604.50	1642.04	-0.22
5		2200.00	1933.91	1.53
6		2620.30	2328.79	1.68
7	7.5% FA	2348.50	2414.64	-0.38
8		2718.20	2613.30	0.60
9		2900.00	2784.99	0.66
10	10 % FA	2985.00	2892.91	0.53
11		3025.85	3081.76	-0.32
12		3540.40	3241.19	1.72
13	5%MK	2390.65	2514.22	-0.71
14		2748.14	2846.80	-0.57
15		3078.43	2981.20	0.56
16	7.5%MK	2713.55	2883.10	-0.98
17		3120.16	3168.59	-0.28
18		3229.56	3481.55	-1.45
19	10 %MK	2930.96	3229.42	-1.72
20		3318.37	3388.35	-0.40
21		3863.26	3633.62	1.32

3.4 Comparison between impact energy versus compressive strength

The empirical relationship between the impact energy and compressive strength of slurry infiltrated fibre concrete has been evaluated by regression analysis as shown in (Fig.5), as the volume fraction of fibre increased; both compressive strength and impact energy were increased. It can be seen in (Fig 4) that an impact energy is obtained from the experimental work for various mix of slurry infiltrated fibre concrete. These predicted values are in good agreement with the experimental observations as illustrated in Table 2. Moreover, the maximum standard residual between the experimental and predicted value was 1.72 % and higher accuracy is being achieved. In the view of convenience and generality, the empirical relationship is accurate and preferable to evaluate the impact energy by using compressive strength of slurry infiltrated fibrous concrete without carrying out the drop weight test.

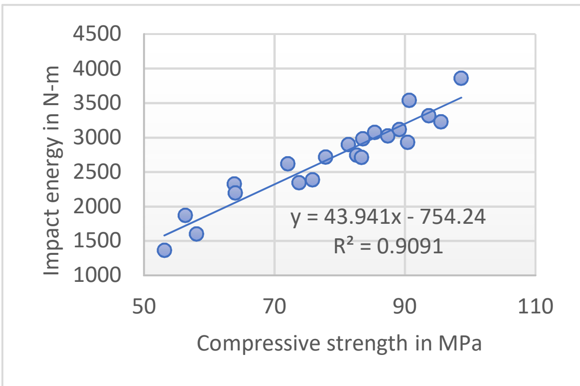

Fig. 5. Relation between compressive strength and impact strength

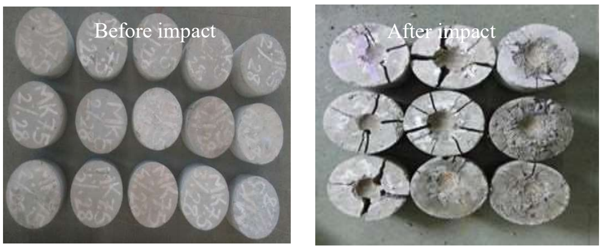

Fig. 6. Sample before and after impact strength test

3.5 Fracture pattern

It is observed that the incorporation of fibre into concrete changed the failure pattern from single large crack to a group of narrow cracks, which displays the beneficial effects of slurry infiltrated fibrous concrete when subjected to impact loading and this is consistent with the previous studies [9-12].Fig 6 shows that failure of slurry infiltrated fibrous concrete sample after impact.

4. Conclusions

Based on the experimental work, the relationship between impact energy and com-pressive strength is derived.

1.Incorporation of steel fibres in concrete enhanced its mechanical properties such as compressive, tensile and flexural strength. By adding 4 % of steel fibre with 10% metakaolin increased compressive strength by 75.19%. And also, the flexural and tensile strength were increased by 207.69 % and 132.55 % respectively. Further, the impact resistance also increased fracture; which meant the energy absorption capacity in concrete with fibres increased.

2.By incorporating steel fibre into the concrete, the failure mode was changed from brittle to ductile behaviour; since the failure crack pattern was turned from a single large crack to a group of narrow cracks demonstrating the positive effects of slurry infiltrated fibrous concrete.

3.Empirical relationship between impact energy and compressive strength obtained from regression analysis showed that the expected values were in strong agreement with the experimental data.

4. The empirical interaction would help to develop preliminary structure designs in which impact resistance is particularly important and further decrease the number of experimentations.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

References

1. ACI Committee 544, "State-of-the-art report on fibre reinforced concrete (544.1R-96)," American concrete institute (1996).
2. Nataraja M C, Nagaraj T S & Basavaraja S B, Reproportioning of steel fibre reinforced concrete mixes and their impact resistance, Cem Concr Res, 35 (20 05) 2350 -2359.
3. Song P, Hwang S & Sheu B, Statistical evaluation for impact resistance of steel-fibre reinforced concrete, Mag Concr Res, 56(8) (2004) 437−442.
4. Song P, Wu J & Hwang S, Assessment of statistical variations in impact resistance of high-strength steel-fibre-reinforced concrete, Cem Concr Res, 35(2) (2005) 393-399.
5. Song P, Wu J, Hwang S & Sheu B, Statistical analysis of impact strength and strength reliability of steel–polypropylene hybrid fibre-reinforced concrete, Construct & Bldg. Mater, 19 (2005) 1-9.
6. Marar K, Eren O & Celik T, Relationship between impact energy and compression toughness energy of high-strength fibre-reinforced concrete, Mater Lett, 47(2001) 297-304.
7. Atef B, Ashraf F & Andrew K, Statistical variations in impact resistance of polypropylene fibre-reinforced concrete, Int J impact Engg, 32 (2006) 1907-1920.
8. Alavi Nia A, Hedayatian M & Mahmoud Nili V, an experimental and numerical study on how steel and polypropylene fibres affect the impact resistance in fibre-reinforced concrete, Int J impact Engg, 46 (2012) 62-73.
9. Ilker Bekir Topcu & Mehmet Canbaz, Effect of different fibres on the mechanical properties of concrete containing fly ash, Construct & Bldg. Mater, 21 (2007) 1486-1491.
10. Mahmoud Nili V & Afrough Sabet, Combined effect of silica fume and steel fibres on the impact resistance and mechanical properties of concrete, Int J impact Engg, 37(2010) 879-886.
11. Farnam Y, Mohammadi S & Shekarchi M. "Experimental and numerical investigations of low-velocity impact behavior of high-performance fiber-reinforced cement-based composite", International Journal of Impact Engineering, (2010),37, 220-229.
12. Rao HS, Ghorphade VG, Ramana NV & Gnaneswar, K. "Response of SIFCON two-way slabs under impact loading", International Journal of Impact Engineering, (2010)37, 452–458
13. A. P. Shelorkar, P.D. Jadhao., "Determination of Mechanical Properties of Slurry Infiltrated Steel Fiber Concrete Using Fly Ash and Metakaolin" International Journal of Engineering and Technology,7, (2018)262-267
14. A. P. Shelorkar, P.D. Jadhao., "Durability assessment of slurry infiltrated fiber concrete by using various pozzolanic materials" Indian Concrete Journals,92, (2018), 56-61.
15. A. P. Shelorkar, P.D. Jadhao., "Statistical analysis for effect of mix-parameters on properties of Slurry Infiltrated Fiber Concrete Using Various Pozzolanic Materials" SEC18: Proceedings of the 11th Structural Engineering Convention - 2018 Jadavpur University, Kolkata, India, December 19 -21, 2018.
16. A. P. Shelorkar, P.D. Jadhao, "Sorptivity of Slurry Infiltrated Fiber Concrete Containing Fly Ash and Metakaolin" UKIERI Concrete Congress Concrete: The Global Builder Jalandhar Punjab India,5 -8 March 2019.
17. A. P. Shelorkar, P.D. Jadhao., "Effects of Steel Slag on Durability Properties of Slurry Infiltrated Fibrous Concrete" International Journal of Engineering and Advanced Technology (IJEAT),8-6, (2019),143-148.