

Torsional Strain Energy of Normal Concrete and SCC with Glass and Steel fibers



Swamy H. C. M, Prince Arul Raj. G

Abstract: Concrete is a two phase material with initial internal micro cracks before loading. When the load is applied on the specimen these internal cracks propagate and material fails after reaching its maximum allowable stress. There are different force systems like tensile, compressive, shear, torsion and combination of above. The strain energy is the energy which develops internally in the material to resist deformation because of application of external load. So if the minimum energy level is reached the deformation exceeds its plastic limit and cracks start propagating from tensile zone to compressive zone. Usually the torsional strain energy is studied to define the material characteristics for taking twisting and rotational effects in the member. A study is made regarding the torsional strain energy of ordinary and SCC with glass and steel fibers. Also a comparison is made for strain energy by experimental and analytical models. To give additional strength to the concrete, steel, and glass fibers are also added to SCC and their torsional strain energy was estimated.

Key Words: Torsional strain energy, Concrete density factor, Steel fibers, Glass fibers, Torsional energy.

I. INTRODUCTION

Concrete as a composite, behaves like a homogeneous media good in compression but weak in tension. The use of concrete is enormous and an attempt to save the ingredients of concrete materials is justified. The use of SCC reduces not only the material but also in other aspects like labor, obtaining alternative building materials and so on.

In this paper a study on torsional strain energy is conducted for plain concrete beam of size 500 mm x 100mm x 100mm of ordinary concrete and self compacting concrete. Densities of ordinary concrete, with and without glass and steel fibers were calculated and their properties are enunciated. The variations in the strength and strain energy with respect to different percentages of super plasticizers with and without glass and steel fibers are studied. The control specimen is ordinary concrete without fibers and super plasticizers. Then concrete with super plasticizers (SP) dosages of 0.5%, 1%, 1.5% and 2% and glass and steel fibers with dosages of 0.2%, 0.4%, 0.8% and 1% were considered.

The cement used was OPC 53 grade .Silica fume was used as a mineral binder. As we know the cement content in the mass of concrete is 10% of the total mass of concrete, and it has adhesive and cohesive property and only the binding media, so using cement of different quantities its torsional strain energy is altered.

Its property with steel and glass fiber and there formation of matrix in the interfacial transition zones are discussed.

II. LITARATURE REVIEW

Fiber reinforced Concrete:

Romualdi and Batson¹ (1963) concluded in their paper that the first crack strength of concrete can be improved by mixing closely spaced continuous glass fibers in it. To prevent micro cracks the glass wires act as crack arresters by the mechanism of pinching forces at the crack tips Which also predicts about the propagation of cracks. These above said mechanism improves high fatigue and impact resistance. It is proved that the strength of concrete matrix is inversely proportional to the square root of the mesh wiring spacing.

Shah and Rangan² have shown that randomly distributed short steel fibers increases internal crack resistance with respect to increased in resistance based on ductility of the concrete. For concrete of aggregate 10 mm maximum size, it is observed that by increase in the volume of fibers increases the crack stress approximately first crack with minimum spacing of 2.5cm of fiber spacing or less.

Pokatiprapha et al³ have investigated that for the concrete composite, mechanical properties such as flexure, torsion, axial compression and tension can be established by the principle of law of mixture, with mortar act as a matrix and reinforcement as steel fibers. However steel fibers considerably increase the resistance of the mortar to crack propagation.

Ultimate composite axial compression strength is always lower than ultimate mortar strength. Composite ductility increases with increase in the quantity and presence of fiber. The strength of the matrix based on the diameter and length of the reinforcing wire, provided that there is no problem with bundling.

Shah and Vijay Rangan⁴ reveal the fact about randomly distributed steel fibers and their mechanical property. They predicted the different properties of the fibers like its volume, orientation length and type of steel fibers used. Comparisons are made between, ordinary reinforcement with fibers in flexure, tension and compression. The fiber effect is predicted after the production of initial cracks in the concrete matrix.

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The length, orientation, stress strain relationship are much effected in post cracking behavior. Below a certain length the spacing and orientation of the fiber have little influence. Based on composite material approach the reinforcing action of the fiber is analytically predicted considering the individual properties of the components.

Snyder and Lankard⁵ investigated the steel fiber effect on parameters of fibers and parameters of concrete mix on flexural strength of fiber reinforced concrete and matrix.

They have flexural strength (up to four fold) for steel fibers with short length (6.4 to 63.5 mm) and small diameter (0.15 to 0.79 m). A linear relationship can be developed between the first crack due to flexural strength and ultimate flexural strength with the content of fibers by 4% volume.

Krishna Raju et al.⁶ have reported about three different grades of concrete with varying steel percentage between 0 to 3 percent. In this article it is reported about the compressive strength and bearing strength of concrete. It also indicates that the compressive strength and bearing strength increases with increase in fiber content. They also predicted about the bearing strength and compressive strength of fiber reinforced concrete.

Hughes and Fattuhi⁷ have concluded that workability of the fresh fibrous concrete mix depends on the properties of the constituent ingredients of the mixture. Workability increases with increasing sand content, gravel content, aspect ratio, volume content and length of fibers. It also predicts that workability decreases with water cement ratio and diameter of the fiber. The maximum size of the coarse aggregate has no much effect on workability effect in fiber reinforced concrete. The slump cone test and ve-be consistometer gives a single parameter about the rehology of the matrix.

Swamy and Stavrides⁸ have reported that the properties of fiber reinforced concrete depends on two states fresh state and hard state. In the first state the workability of the matrix mainly depends on the size, orientation and volume of the fibers. In hardened state the property depends on its orientation, compact ability and consolidation property of the matrix.

Mangat⁹ has concluded that the strength of the matrix follows the standard law of mixture. It also includes the dimensions of the fibers and its orientation. It predicts about the rectangular and circular fibers. It concludes that by increasing the effective spacing decreases the tensile strength non linearly.

Kukreja, C.B. et al,¹⁰ have reported that tests are conducted to compare the direct tensile strength, indirect tensile strength and flexural tensile strength of fiber reinforced concrete with plain concrete. They used fibers obtained by cutting the wires on a hand operated machine. It reported that the direct tensile strength of the fiber reinforced matrix is directly proportional to the aspect ratio.

Maximum increase of 46.33 percent of direct tensile strength was obtained by fibers of aspect ratio 80 with 0.5% volume concentration. Maximum increase of indirect tensile strength is 40% for aspect ratio 80 and steel fibers percentage of 1%.. Flexural strength increased by 46.15% for aspect ratio 80 with 1.5% steel fibers. Indirect tensile strength is an inverse function of fiber spacing. It improves post cracking strength than first cracking strength. . They have further added that the energy absorption capacity of the

fibrous composite in flexure increases by 14.98 times due to addition of fibers of aspect ratio 80 and volume concentration 1.5% over plain concrete composite.

Walkus et al.¹¹ reported that cracking behavior of strength properties and deformation behavior are improved with the use of short steel fibers. It also indicates that the addition of micro reinforcement (i.e 1.2% to 1.8% by volume). A volume of steel fibers of about 1.2% seems to be the best. It gives an idea that the crack position depends on the orientation and % of reinforcement in the cross section of the specimen.

ACI committee 544 12 published a report on the measurement of properties of fiber reinforced concrete. This report predicts about existing testing methods for (1) toughness energy absorption (2)workability (3) Impact strength. The available test methods can be used for other tests like air content, yield unit weight, compressive strength, split tensile strength, shrinkage, creep, modulus of elasticity, cavitations, corrosion and abrasion resistance.

Swamy and Al Taan¹³ have presented on the flexural and deformation characteristic for beams with 20 mm aggregate size and reinforced with steel bars Fibers are added in addition to the reinforcing bars at the tension zone which improves the crack arresting resistance of the concrete member. It indicates only a marginal increase in the post cracking strength. The test gives that the maximum compressive strain reached a value of 0.005 to 0.006 and reinforcing bars attain stresses well in excess of their yield strengths. They further proposed an ultimate strength theory which shows good agreement with the experimental data.

Siddique¹⁴ has reported the compaction method to improve the strength properties of steel fiber reinforced concrete. Different methods like rodding and external vibrations are used. Test results indicated that external vibration increases the compressive strength, split tensile strength and flexural strength of concrete over that of rodding.

M.Vijayanand,et al¹⁵ (2010) reported that, tests on SCC beams with steel fibers of (0%, 0.5% and 1%) are conducted and tensile steel ratio (0.99%,1.77%and 2.51%) for flexural strength. By addition of fibers improves both flexural strength and tensional strength of the matrix.

III. DISCUSSIONS

From table: 1 it is evident that by increasing the volume of SP from 0.5% to 1% improves the workability (Slump)⁷ from 115 to 150 mm. But with the further increase of SP from 1.5 to 2 %, with increase of GF from 0.8 to 1% has no effect on slump. Indicates that SP has no effect.The same effect is shown in other tables also indicating the action of SP with fibers. The mechanism is to be established with study of micro-structure of concrete with and without GF and SF. From Table: 5, by using glass fibers and steel fibers¹ the torsional strength of concrete will be improved because of crack arresting by applying pinching forces at the crack tips. The transition zone of concrete matrix also indicates that the increase in strength inversely proportional to spacing of fibers. The torsional strain energy improves with quantities of GF and SF.



With the increase of fibers in the concrete improves the Torsional strain energy. It also indicates that the presence of fibers also improves strength and durability(Table-7) values also.

The concept of Total Strain Energy is the basic equation for calculations of deformation in all structural mechanics. So literature review shows less details regarding strain energy, especially regarding torsional strain energy and it clearly indicates the minimum energy related to fracture. Here comparison is made and conclusions are clearly given for ordinary concrete, SCC with and without GF and SF. It also indicates that glass fibers are superior and more eco-friendly than steel fibers.

IV. CONCLUSIONS

V. TABULATIONS

Table: 1 Slump Cone Test for Ordinary concrete with G F

Mix	0.5 SP, 0.2GF	1.0 SP, 0.4GF	1.5 SP, 0.8GF	2.0 SP, 1.0GF
Slump	115	150	130	120

Table: 2 Slump Cone Test for Ordinary concrete with S F

Mix	0.5 SP, 0.2SF	1.0 SP, 0.4SF	1.5 SP, 0.8SF	2.0 SP, 1.0SF
Slump	102	130	112	108

Table: 3 Slump Cone Test for SCC with S F

Mix	0.5 SP, 0.2SF	1.0 SP, 0.4SF	1.5 SP, 0.8SF	2.0 SP, 1.0SF
Slump	85	142	132	112

Table: 4 Slump Cone Test for SCC with G F

Mix	0.5 SP, 0.2SF	1.0 SP, 0.4SF	1.5 SP, 0.8SF	2.0 SP, 1.0SF
Slump	90	170	150	120

Note: G F - Glass Fibers S.F – Steel Fibers S P – Super Plasticizers.

Table: 5 Comparison of Strain Energy for (M30)

Type of concrete	Torsion Strain Energy By Experiment N-mm	Torsion Strain Energy By Formula N-mm	
		Strength	Serviceability
Ordinary Concrete	3.1348	1.96	2.05
0 .C (0.5 SP& 0.2 GF)	6.3	5.56	4.182
0 .C (1.0 SP& 0.4 GF)	18.4275	21.86	22.81
0 .C (1.5 SP& 0.8 GF)	13.896	23.01	24.04
0 .C (2.0 SP& 1 GF)	7.326	13.57	14.76
SCC (0.5% SP)	4.544	2.94	3.072
SCC (1% SP)	5.48	5.6	5.8
SCC (1.5% SP)	11.913	6.8	7.12
SCC (2% SP)	0.5	0.37	0.39
SCC (0.5 SP & 0.2 GF)	6.672	14.35	14.97
SCC (1 SP & 0.4 GF)	6.426	9.79	10.21
SCC (1.5 SP & 0.8 GF)	4.67	6.73	7.058
SCC (2 SP & 1 GF)	1.354	8.3	8.67
SCC (0.5 SP & 0.2 SF)	4.992	5.824	6.1
SCC (1 SP & 0.4 SF)	1.8876	1.12	1.17
SCC (1.5 SP & 0.8 SF)	3.459	3.53	3.69
SCC (2 SP & 1 SF)	11.004	14.17	14.79

Table:6 Values of flexural tensile strength for M30

Type of concrete	Flexural tensile strength f_{cr}	
	By Experiment	By Formula
Ordinary Concrete	2.87	4.88
0 .C (0.5 SP& 0.2 GF)	3.33	3.73
0 .C (1.0 SP& 0.4 GF)	3.26	3.61
0 .C (1.5 SP& 0.8 GF)	3.058	2.92
0 .C (2.0 SP& 1 GF)	2.63	2.66

SCC (0.5% SP)	3.56	2.87
SCC (1% SP)	3.62	3.7
SCC (1.5% SP)	3.92	3.959
SCC (2% SP)	2.97	3.21
SCC (0.5 & 0.2 GF)	2.15	3.7
SCC (1 SP & 0.4 GF)	1.61	3.365
SCC (1.5 SP & 0.8 GF)	1.12	2.97
SCC (2 SP & 1 GF)	0.68	0.41
SCC (0.5 SP & 0.2 SF)	3.8	3.852
SCC (1 SP & 0.4 SF)	3.62	3.6
SCC (1.5 SP & 0.8 SF)	3.25	3.32
SCC (2 SP & 1 SF)	2.8	2.87

REFERENCES

- Romualdi, J.P. and Batson, G.B., "Mechanics of crack arrest in concrete," Journal of Engg. Mechanics Division Proceedings, ASCE, Vol. 89, EM 3, June 1963, pp.147-160
- Romualdi, J.P. and Batson, G.B., "Behaviour of reinforced cement concrete beams with closely spaced reinforcement", Journal of the American Concrete Institute, Proceedings Vol.60, No.6, June 1963, pp.775-789.
- Romualdi, J.P. and Mandel, J.A., "Tensile strength of concrete affected by uniformly distributed and closely spaced short lengths of wire reinforcement", Journal of the American Concrete Institute, Proceedings, Vol.61, No.6, June 1964, pp.657-670
- Shah, S.P. and Rangan, B.V., "Effects of reinforcements on ductility of concrete", Journal of the Structural Division Proc., ASCE, Vol.96, ST 6, June 1970, pp.1167-1184
- Rajagopalan, K. Parameswaran, V.S. and Ramaswamy, G.S., "Strength of steel fibre reinforced concrete beam", The Indian concrete Journal, Vol. 48, No.1, Jan 1974, pp.17-25
- Pakotiparapha, B., Pama, R.P. and Lee, S.L., "Mechanical properties of cement mortar with randomly oriented short steel wires" Magazine of Concrete Research, Vol.26, No.86, March 1974, pp.3-15
- Tattersall, G.H. and Urbanowicz, C.R., "Bond strength in steel fibre reinforced concrete", Magazine of concrete research, Vol.26, No.87, June 1974, pp.105-113
- Kar, J.N. and Pal, A.K., "Strength of fibre reinforced concrete", Journal of the Structural Division, Proc. ASCE, Vol.98, (ST-5), May 1972 pp-1053-1068
- Ramey, M.R., "Compression fatigue of fibre reinforced concrete", Journal of Engineering Mechanics Division, ASCE, Vol.100, EM 2, April 1974, pp.139-149
- Shah, S.P. and Vijayarangan, B., "Fibre reinforced concrete properties", Journal of American Concrete Institute Proceeding Vol.68, No.2, Feb 1971, pp.126-135.
- Chen, Klal-Fah and Carson, J.L., "Stress-Strain properties of random wire reinforced concrete", Journal of American Concrete Institute, Proceedings Vol.68, No. Dec 1971, pp-933-936
- Snyder, M.J. and Lankard, D.R., "Factors affecting the flexural strength of steel fibrous concrete", Journal of American Concrete Institute, Proceedings Vol.69, No.2, Feb 1972 pp-96-100
- "Fibre Reinforced Concrete", Proceedings of the International Symposium Ottawa, Oct 1973 publication of ACI, SP-44, 1974, pp.554
- Krishna Raju, N. et al., "Compressive Strength and Bearing Strength of steel fibre reinforced concrete", Indian Concrete Journal, Vol.51, No.6, June 1977, pp.103-108
- Swamy, R.N. and Mangat, P.S., "Flexural Strength of Steel fibre reinforced Concrete", Institution of Civil Engineers Proceedings Part 2, Research and Theory, Vol.57, Dec. 1974, pp.701-707
- Hughes, B.P. and Fattuhi, N.I., "The workability of steel fibres reinforced concrete", Magazine of Concrete Research, Vol.28, No.96, Sept 1976, pp.157-161
- Swamy, R.N. and Stavrides, H., "Influence of the method of fabrication on strength properties of steel fibre concrete." Materiaux Et constructions, Vol.19, No.52, pp.243-252.
- Mangat, P.S., "Tensile Strength of steel fibre reinforced concrete", Cement and Concrete Research, March 1976, Vol.4, pp.245-252
- Kukreja, C.B, Kaushik, S.K., Kanchi, M.B and Jain, O. P., "Flexural characteristics of steel fibre reinforced concrete", Indian concrete Journal, July 1980, pp.184-188.
- Walkus, B.R., Januszkiewicz, A and Jeuzal, J., "Concrete compositions with Steel fibre reinforcement subjected to uniaxial tension", Journal of the American Concrete Institute. Vol.76, Oct. 1979, pp.1079-1092.
- "Measurement of properties of fibre reinforced concrete", Reported by ACI Committee 544. American Concrete Institute Journal, July 1978, pp.283-289
- Swamy, R.N. and Al-Ta'an, S.A., "Deformation and ultimate strength in flexure of reinforced concrete beams made with steel fibre concrete", Journal of the American Concrete Institute, Vol.78, No.5, Sep-Oct 1981, pp.395-405
- Sabapathi, P. and Achyutha, H., "Analysis of steel fibre reinforced concrete beams", ICI, May 1989, pp.246-252.
- Siddique, R., "Effect of method of Compaction on strength properties of steel fibre reinforced concrete", Journal of Ferrocement, Vol.27, No.4, October 1997, pp.311-320.
- Zdenek P. Bazant. "Concrete fracture models: testing and practice" Engineering Fracture Mechanics 69 (2002) 165-205.

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