Strain Energy Release Rate and Yield Strength for Normal and SCC with and without Glass and Steel Fibres

Swamy H. C. M & Prince Arul Raj G

ABSTRACT

Concrete is versatilely used building material. Its use in economical way is justified. Usually, torsion is predominant in water tank ring beam, canopy beams and cantilever retaining wall. Usually, failure in the structure is acceptable only after proper yielding of the material. According to limit state design philosophy balanced section is preferred. So here an attempt is made to identify yield strength of normal concrete and SCC with and without glass and steel fibres. Its torsional strain energy release is identified and in which concrete it is low and rate of taking the strength is discussed. Here plain concrete are considered. The performance is measured with respect to energy release and yield strength.

Keywords: strain energy release, yield strength, torsional strain energy.

Classification: DDC Code: 620.112 LCC Code: TA407.4

Language: English

London Journals Press

LJP Copyright ID: 392945
Print ISSN: 2631-8474
Online ISSN: 2631-8482

London Journal of Engineering Research

Volume 22 | Issue 3 | Compilation 1.0

Strain Energy Release Rate and Yield Strength for Normal and SCC with and without Glass and Steel Fibres

Swamy H. C. M[α] & Prince Arul Raj G[σ]

ABSTRACT

Concrete is versatilely used building material. Its use in economical way is justified. Usually, torsion is predominant in water tank ring beam, canopy beams and cantilever retaining wall. Usually, failure in the structure is acceptable only after proper yielding of the material. According to limit state design philosophy balanced section is preferred. So here an attempt is made to identify yield strength of normal concrete and SCC with and without glass and steel fibres. Its torsional strain energy release is identified and in which concrete it is low and rate of taking the strength is discussed. Here plain concrete are considered. The performance is measured with respect to energy release and yield strength.

Keywords: strain energy release, yield strength, torsional strain energy.

Author α: Part time research scholar at Karunya Institute of Science and Technology, Coimbatore, Tamil Nadu.
σ: Professor and Dean at Karunya Institute of science and Technology, Coimbatore, Tamil Nadu.

I. INTRODUCTION

Concrete and its use as a building material is well known fact. Its design, construction and maintenance are well justified. Before designing a structure, we have to select proper building material for its construction. Its behaviour under different loading condition has to be studied and the proper design philosophy has been selected and strength, serviceability and form should be satisfied. Here an attempt has been made to evolve a simple method to test a beam specimen subjected to torsion. Its strain energy is calculated and its rate of taking strain energy is evaluated for normal and self-compacted concrete with and with out glass and steel fibre is conducted.

As we know we have three design philosophy namely working stress, ultimate method and limit state method. In the limit state method, the strength and its serviceability are justified. The study on torsional strength is limited because it is included in compression, tension, flexure and shear. But here an attempt is made to study torsional behaviour completely by using fracture mechanics.

Fracture mechanics especially post fracture behaviour talks about material property and type of fracture either brittle fracture or elastic fracture. Fracture mechanics distinguish between brittle and other than brittle fracture. Linear elastic fracture mechanics (LEFM) talks about the difference between brittle fracture and elastic fracture.

The material toughness at the on set of fracture at plane-strain is denoted by K_{IC}. The plain -Strain K_{IC} is based on the lowest load at which crack occurs. Strain energy release rate at fracture is given by G_{IC} and its relation ship with K_{IC} is related as follows:

$G_{IC} = K^2_{IC} / E$ --------- For Plane Stress

$G_{IC} = K^2_{IC} / (E (1-V^2))$---- For Plane strain

E = Modulus of elasticity of concrete

V = Poisson ratio

II. LITERATURE REVIEW

Application of fracture mechanics to study the improved behaviour of concrete under tensile loads was first adopted by Romualdi and Baston. Griffith suggest that the fracture of a brittle material is due to the presence of small cracks and proposed a theory of fracture strength based on the changes in the strain energy and surface energy as the crack extends. The Griffith approach was extended to ductile material by Orowan[3] and Irwin. The strain energy release rate which Irwin denoted by G_{IC} , may generally, be less than that is required to cause unstable crack propagation. The strain energy release rate at the on set of the unstable crack propagation was referred to as the critical strain-energy release rate G_{IC}. G_{IC} is regarded as a material property where as G_{IC} is primarily a function of loading and geometry of the system.

Not much work is conducted on, to relate the yield strength and strain energy release rate. A simple procedure with relating the material property and load has been established in this work.

Objectives of the study

1. To evaluate Yield strength for normal and SCC with and without glass and steel fibres.
2. To calculate strain energy release rate for plane stress and plane strain conditions.
3. To discuss the material property based on yield strength criteria.
4. To develop the relation between Youngs modulus and yield strength.
5. To develop the poisons ratio relation with strain energy release rate.
6. To explain failure criteria of the material for normal and SCC with and with out glass and steel fibres.
7. To explain how the fibres and microstructures behaviour for the torsional strain energy.
8. Compare the normal concrete, SCC and its behaviour with and with out glass and steel fibres.

Experimental Set Up and Procedure

Fig 1: Showing the Torsional Strain Energy Experiment in KIT lab

The experimental set up to conduct the torsional strain energy is shown in the above Fig 1. and the procedure for testing and conducting the experiments are listed in the table 1. below. The Concrete considered for the test is M30 and cement used is ACC and Chemicals used is AS chemicals with silica fume as mineral admixture.

Table 1: Experimental Details

Name of Experiment	Total Number of Specimens	Remarks
Slump Cone Test	51	Free fall
Spread Test	51	Free flow
V- Funnel - Test	51	Time in Sec
L-Box Test	51	Ratio
Compression Test	51 Cubes 150 x 150 x150 mm	Strength
Split Tensile Strength	51 Cylinders 150 mm Diameter and 300mm height	Tensile strength
Concrete Mix Design	154 Cubes 150 x 150 x 150 mm	Characteristic Strength
Flexural Strength	51 beams of 100 x 100 x 500 mm	Two-point Bending Test Load- deflection
Torsional Strength	51 beams of 100 x 100 x 500 mm	Measurement of Torque
Total No of Specimen Tested	562	

Experimental Results:

Table 2: Values of Density for ordinary concrete and SCC with and without GF and SF

Type of Concrete	Density Experimental Kg/m^3
Normal Concrete	2292
SCC (S.P-0.5%)	2150
SCC (S.P-1.0%)	2230
SCC (SP-1.50%)	2169
SCC (SP-2.0%)	2050
SCC (SP-0.5%, GF-0.2%)	2166
SCC (SP-0.1%, GF-0.4%)	2150
SCC (SP-1.5%, GF-0.8%)	2128
SCC (SP-2%, GF-1%)	2342
Normal Concrete (S.P-0.5%, GF-0.2%)	2150
Normal Concrete (S.P-1.0%, GF-0.4%)	2339
Normal Concrete (S.P-1.5%, GF-0.8%)	2158
Normal Concrete (S.P-2.0%, GF-1%)	2087
SCC (SP-0.5%, SF-0.2%)	2150
SCC (SP-1.0%, SF-0.4%)	2128
SCC (SP-1.5%, SF-0.8%)	2342
SCC (SP-2.0%, SF-1.0%)	2303

Table 3: Values of Youngs Modulus (E)for Different Types of M30 Concrete. Theoretical Value of E = 27386MPa

Type of Concrete	Youngs Modulus Experimental
Normal Concrete	34800 MPa
SCC (S.P-0.5%)	20616MPa
SCC (S.P-1.0%)	26458MPa
SCC (SP-1.50%)	28285MPa
SCC (SP-2.0%)	22913MPa
SCC (SP-0.5%, GF-0.2%)	264397MPa
SCC (SP-0.1%, GF-0.4%)	24036MPa
SCC (SP-1.5%, GF-0.8%)	21131 MPa
SCC (SP-2%, GF-1%)	92600 MPa
Normal Concrete (S.P-0.5%, GF-0.2%)	25778 MPa
Normal Concrete (S.P-1.0%, GF-0.4%)	26665 MPa
Normal Concrete (S.P-1.5%, GF-0.8%)	20869 MPa
Normal Concrete (S.P-2.0%, GF-1%)	19033 MPa
SCC (SP-0.5%, SF-0.2%)	27514 MPa
SCC (SP-1.0%, SF-0.4%)	25691 MPa
SCC (SP-1.5%, SF-0.8%)	23717 MPa
SCC (SP-2.0%, SF-1.0%)	20494 MPa

Table 4: Strain Energy Release Rate (G_{IC}) and Yield Strength

Type of Concrete	Yield Strength MPa	G_{IC} – Plane Stress MPa	G_{IC} – Plane strain MPa
Normal Concrete	40.44	6.942 x 10^{-9}	7.15 x 10^{-9}
SCC (S.P-0.5%)	46.154	3.9 x 10^{-9}	4.03 x10^{-9}
SCC (S.P-1%)	56.73	1.26 x 10^{-8}	1.29 x 10^{-8}
SCC (S.P-1.5%)	52.91	4.20 x 10^{-9}	4.30 x 10^{-9}
SCC (S.P-2%)	45.71	5.644 x 10^{-8}	5.77 x 10^{-8}
SCC (SP-0.5%, GF-0.2%)	48.09	2.62 x 10^{-8}	2.68 x 10^{-8}
SCC (SP-1%, GF-0.4%)	52.87	5.57 x 10^{-8}	5.70 x 10^{-8}
SCC (SP-1.5%, GF-0.8%)	42.06	4.59 x 10^{-9}	4.60 x 10^{-9}
SCC (SP-2%, GF-1%)	18.56	1.02 x 10^{-8}	1.04 x 10^{-8}
Normal Concrete (SP-0.5%, GF-0.2%)	51.59	3.78 x 10^{-8}	3.87 x 10^{-8}
Normal Concrete (SP-1%, GF-0.4%)	53.33	1.06 x 10^{-6}	1.10 x 10^{-7}
Normal Concrete (SP-1.5%, GF-0.8%)	41.74	6.79 x 10^{-9}	6.94 x 10^{-9}
Normal Concrete (SP-2%, GF-1%)	38.15	8.43 x 10^{-7}	1.39 x 10^{-8}
SCC (SP-0.5%, SF-0.2%)	51.39	2.07 x 10^{-8}	1.93 x 10^{-8}
SCC (SP-1%, SF-0.4%)	55.03	8.81 x 10^{-7}	1.63 x 10^{-8}
SCC (SP-1.5%, SF-0.8%)	47.54	7.52 x 10^{-9}	7.72 x 10^{-9}
SCC (SP-2%, SF-1%)	40.96	9.34 x 10^{-9}	9.56 x 10^{-9}

III. DISCUSSIONS

Yield strength of SCC with super plasticizer dosage of 1% is having maximum value of 56.73(Table-3) indicating that the super plasticiser improves the workability at normal W/C ratio of 0.4. The mix also gives an idea that the micro structure contains less pores and developed good gel -pores which filled the pores and making concrete more attaining ultimate strength before fracture. This mix is costly because super plasticiser dosage is 1% and the industry permits 0.5% as maximum dosage for big works.

Similarly, with the normal concrete with super plasticizer 1% and Glass fibre 0.4% (Table1) which is the mix which is economical and gives maximum yield strength. This mix having good strain energy release rate and we can recommend it as design mix. The density (Table2) and modulus of elasticity of the mix is dominating comparing with the other mixes. So, from the (Table 3) gives that it is having good modulus of elasticity. The glass fibre is having good modulus of elasticity and ultimate strength compared to steel fibres. The reason for its good property is that it develops good bond between the aggregate phase, cement mortar phase and interfacial transition zone. The applied load creates a system in this matrix in such a mode that the yield strength and E values and its density giving a good torsional strain energy release value.

The poisons ratio for strength can be taken as 0.15 and for serviceability it is 0.2. The yield strength, modulus of elasticity and strain energy release rate all are maximum in normal concrete with 0.4% glass fibres with 1% super plasticizer. This mix in this paper is the deciding mix . Even other mixes may give little high or low values of yield strength, modulus of elasticity and torsional strain energy release.

The failure criteria indicates that the strain energy release which is having good yield strength and at plane strain or plane stress condition is considered, it is elastic plastic failure. The material which is having glass fibre with good super plasticizer gives good strength and serviceability conditions. The normal concrete mix with fibres gives good yield strength and strain energy release rate.

The material behaviour is different at different loading conditions and here we are evaluating a very sensitive term torsional strain energy which describes the material property at microscopic level. The study of the concrete with different types of fibres with different dosages for normal and SCC gives a clear idea about the physical, mechanical and microstructural behaviour of concrete.

mechanical and microstructural behaviour of concrete.

Conclusions and remarks

Torsional strain energy release and yield strength criteria gives two types of material property evaluation and checking the micro structure of concrete mechanically. This work clearly indicates thar the modulus of elasticity, density, yield strength and strain energy release are maximum for normal concrete with 0.4% glass fibres and 1% super plasticizer gives very good result. But by decreasing the dosage of superplasticizer indicates that the workability decreases and requires high W/C ratio which reduces the strength drastically.

SCC can be used with different dosages of superplasticizer and fibres with proper mix design criteria.

REFERENCES

1. 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
2. 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.
3. 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, Proceedigs, Vol.61,No.6, June 1964, pp.657-670
4. 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
5. 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
6. 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
7. 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
8. Kar.J.N. and Pal.AK,"Strength of fibre reinforced concrete", Journal of the Structural Division, Proc.ASCE, Vol.98,(ST-5), May 1972 pp-1053-1068
9. Ramey, M.R.,"Compression fatigue of fibre reinforced concrete", Journal of Engineering Mechanics Division, ASCE, Vol.100, EM 2, April 1974, pp.139-149
10. 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
11. Chen, Klal-Fah and Carson, J.L.,"Stress-Strain properties of random wire reinforced concrete", Journal of American Concrete Institute, Proceedings Vol.68, No, Dec1971. pp-933-936.
12. Snyder, M.J and Lankard, D.R. "Factors affecting the flexural strength of steel fibrous concrete", Journal of American Concrete Institute, Proceedings Vol.69, No2, Feb 1972 pp-96-100
13. "Fibre Reinforced Concrete", Proceedings of the International Symposium Ottawa, oct 1973 publication of ACI, SP-44,1974,pp.554
14. 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