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A Comparative Study on Fracture Energy of Concrete Beams by Experimental and Analytical Model Study

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Abstract: ***Concrete is a brittle material. It contains micro cracks at the transition zone before loading. The failure of almost all concrete except light weight concrete is by fracture in transition zone which propagates towards plastic zone. When the tensile strength of concrete reaches its maximum value cracks will start propagating from the extreme tensile fiber in the tension zone of the concrete beam. Here an attempt is made to evaluate for its maximum fracture energy, also a comparative study is proposed between experimental and analytical model for rectangular concrete beam of same size but with different concrete grades. Grade of concrete is the prime importance criteria which defines the compressive strength of the concrete. This related to other strength parameters of the concrete elements. This study helps to develop rectangular beam models for analysis of concrete beams by fracture method of analysis and design. It is the next coming method after limit state method of concrete design.***

Keywords: Fracture Energy in Concrete Beams, Concrete Beam Models for Fracture, Analytical fracture Models for Concrete Beams

1. Introduction

Concrete is versatile used building material throughout the world. It is the next to water, used material in the human life. So this indicates its amount of utilization, by in turn indicates its component materials using and availability requirement. So the ingredients of concrete should be optimized. This can be only done by using economical design philosophies. Now we are using limit state method to proportionate the concrete elements. In this method the concrete is loaded beyond its elastic limit. But even after that plenty of material strength is available before complete collapse of the structure. Now here we are calculating the maximum fractural energy, which gives an indication that to what extent the concrete members can be stressed beyond the elastic limit.

Here the total strain energy is calculated and it is compared with fractural energy, which is less than its elastic strain energy. Now codes provide limitation of crack widths for other than water retaining and gas containers. Here Experiment is conducted for maximum fractural energy for a Particular displacement which occurs at maximum loading condition.

2. Methodology

Mix Design

Table 1: From P.K. Mehatha

Type of Concrete	Low Strength concrete (Kg/Cum)	Moderate Strength (Kg/Cum)	High Strength (Kg/Cum)
Cement	225	356	510
Water	178	178	178
Fine Aggregate	801	848	890
Course Aggregate	1169	1032	872
Water/ Cement ratio	0.7	0.5	0.35
Strength in Mpa	18	30	60

3. Analytical Model

Fracture Energy: (Standard Model)(Published in Japan Concrete Institute standard JCI-S-001-2003)

$G_F = (0.75\, W_0 + W_1)/ A_{lig}$

$W_1 = 0.75\, ((S/L)\, m_1 + 2\, m_2)\, g * CMOD_c$

Where

G_F = Fracture Energy (N/mm^2)

W_0 = Area below CMOD curve up to rupture of Specimen (N-mm)

W_1 = Work done by dead weight of specimen and loading jig (N-mm)

A_{lig} = Area of broken ligament (b x h) (mm^2)

.m_1 = Mass of specimen (kg)

S = Loading Span (mm)

L = Total length of specimen (mm)

.m_2 = Mass of jig not attached to testing machine but placed on specimen until rupture (kg)

.g = Gravitational acceleration ($9.81 m/s^2$)

$CMOD_c$ = Crack mouth opening displacement at the point of rupture (mm)

Mathematical Model:

Fracture Energy (G_F) = K_I^2 / E_1 - Plane Stress Condition

$G_F = K_I^2 / E_2$ - Plane Strain Condition

K_I = Stress intensity factor.

$E_1 = 5000 \sqrt{f_{ck}}$

$E_2 = E_1 / (1 - \mu^2)$ μ = 0.15 to 0.2

Total Strain Energy for beams (U)(Compression)

$U = 1/2 * (P^2 L / A E)$

P = Load in Newton

L= Length in mm

A= Area of cross section of beam

E= Modulus of Elasticity

Objectives of this study

1) What is the total strain energy of concrete beam which is subjected to compression.
2) How the Fractural energy behavior is experimented
3) What is the variation of total fractural energy in experimental analysis for different concrete graded beams.
4) What is the behavior of different graded concrete beam for fractural energy with plane stress and plane strain condition.

4. Discussions

From the table 2 below it is evident that the strain energy of the concrete beam is higher as it is the total energy stored which is resisting the deformation or the fracture. This energy increases

With grade of concrete, as it indicates that from M18 to M30 increase in energy is approximately one third but from M30 to M60 it is almost 2 times. This is also in the case of fracture energy both in analytical and experimental findings. Fracture energy strength increase with increase in grade of concrete. It indicates that high strength concrete can be used for highly critical stress conditions without any damage or problem.

Table 2: Strain Energy and Fractural Energy

Type of Concrete Mpa	G_F (Experimental) Mpa	G_F (plane Stress) Mpa	G_F (plane Strain) Mpa	U (Strain Energy) Mpa
Ordinary Concrete M18	248.8	256.47	250.669	341.96
Moderate Strength M30	360.7	355.49	363.99	474.39
High strength M60	648.6	654.69	639.96	872.92

Beam Size : 100 x 100 x 600 Dim in mm

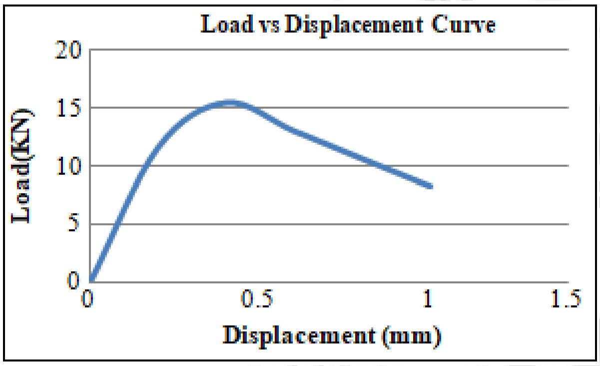

Figure 1: Ordinary Concrete

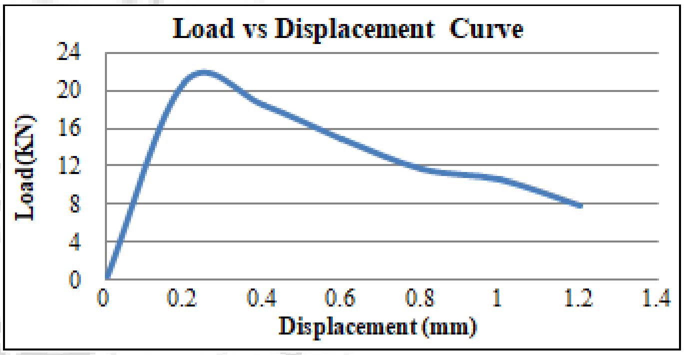

Figure 2: Moderate Strength Concrete

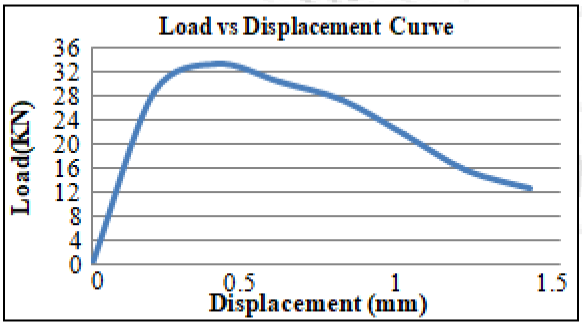

Figure 3: High strength Concrete

Table 3: Load Displacement Values

Displacement (mm)	Load KN
0	0
0.2	28.62
0.4	33.57
0.6	30.45
0.8	27.5
1.0	21.7
1.2	15.8
1.4	12.9

Low Strength Concrete (28 day strength)

Table 4: Load Displacement Values

Displacement (mm)	Load KN
0	0
0.2	11.65
0.4	15.55
0.6	13.09
0.8	10.69
1.0	8.32

Moderate Strength Concrete (28 day strength)

5. Conclusion

Fractural energy indicates the ultimate energy which the beam can take with maximum displacement. It is the indicator for maximum stress condition with maximum strain. Here an attempt is made to compare the fracture energy by analytical and experimental models which clearly indicates that the grade of concrete will be the factor which depicts the strength of the concrete beam. So in addition to fractural energy the crack propagation can also be studied.

Table 4: Load Displacement Values

Displacement (mm)	Load KN
0	0
0.2	20.81
0.4	18.42
0.6	14.96
0.8	11.69
1.0	10.53
1.2	7.89

High strength concrete (28 days strength)

References

[1] I.S – 456 – 2000
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