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 propagates 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 important 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.

Key words: 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

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Low Strength concrete (Kg/Cum )</th>
<th>Moderate Strength (Kg/Cum )</th>
<th>High Strength (Kg/Cum )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>225</td>
<td>356</td>
<td>510</td>
</tr>
<tr>
<td>Water</td>
<td>178</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>801</td>
<td>848</td>
<td>890</td>
</tr>
<tr>
<td>Course Aggregate</td>
<td>1169</td>
<td>1032</td>
<td>872</td>
</tr>
</tbody>
</table>

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)

\[ G_f = (0.75 W_o + W_i) \times A_{lig} \]

\[ W_i = 0.75 \times (S/L) m_1 + 2 m_2 \times g \times CMOD_c \]

Where

- \( G_f \) = Fracture Energy (N/mm²)
- \( W_o \) = Area below CMOD curve up to rupture of Specimen (N-mm)
- \( W_i \) = Work done by dead weight of specimen and loading jig (N-mm)
- \( A_{lig} \) = Area of broken ligament (b x h) (mm²)
- \( m_1 \) = Mass of specimen (kg)
- \( S \) = Loading Span (mm)
- \( L \) = Total length of specimen (mm)
- \( S \) = Loading Span (mm)
- \( L \) = Total length of specimen (mm)
- \( L \) = Total length of specimen (mm)
- \( g \) = Gravitational acceleration (9.81m/s²)
- \( CMOD_c \) = Crack mouth opening displacement at the point of rupture (mm)

Mathematical Model:

Fracture Energy \((G_f) = K_1^2 / E_1\) - Plane Stress Condition

\( G_f = K_1^2 / E_2 \) - Plane Strain Condition

\( K_1 \) = Stress intensity factor.

\( E_1 = 5000 \sqrt{\sigma_0} \)

\( E_2 = E_1 / (1 - \mu^2) \)

\( \mu = 0.15 \) 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

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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>
<thead>
<tr>
<th>Table 2: Strain Energy and Fractural Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Concrete</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Ordinary Concrete M18</td>
</tr>
<tr>
<td>Moderate Strength M30</td>
</tr>
<tr>
<td>High strength M60</td>
</tr>
</tbody>
</table>

Beam Size : 100 x 100 x 600 Dim in mm

**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

<table>
<thead>
<tr>
<th>Displacement (mm)</th>
<th>Load KN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.2</td>
<td>20.81</td>
</tr>
<tr>
<td>0.4</td>
<td>18.42</td>
</tr>
<tr>
<td>0.6</td>
<td>14.96</td>
</tr>
<tr>
<td>0.8</td>
<td>11.69</td>
</tr>
<tr>
<td>1.0</td>
<td>10.53</td>
</tr>
<tr>
<td>1.2</td>
<td>7.89</td>
</tr>
</tbody>
</table>

High strength concrete (28 days strength)

References