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Optimum Use of Concrete Grade in Tension Zone of a Structural Member

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Abstract:
A beam is a horizontal flexural member which provides support to the slab and vertical walls. In a beam there are two zones, i.e. compression and tension zone. Compression zone is above the neutral axis and tension zone is below the neutral axis of the beam. As concrete is weak in tension, steel is provided in the tension zone to take tensile load, but as strength of concrete is ignored in tension zone with respect to compression zone. So logically concrete plays no role in tension zone. But this concrete needs to be provided on tension side to act as strain transferring media to steel and may be called as 'Ignorant concrete'. This concrete just acts as a strain transferring media, if concrete does not play any important role in tension zone, then why can't we use low grade of concrete in tension zone than compression zone concrete? This is basic question which led to the idea of concrete grade reduction in tension zone for RCC beams to reduce construction cost.

Keywords: concrete grade reduction, flexural member, ignorant concrete, strain transferring media.

I.INTRODUCTION

Generally, size of wall is large especially in load bearing structures. With the advances in the science and technology Reinforced Concrete Construction (R.C.C.) came in to picture. Initially according to Indian standard code of practice IS456-1978, M15 grade of concrete was also permitted to be use in general construction but according to new revision made in IS 456-2000, lowest grade of concrete which can be used in concreting for construction is M20 for mild environment. With the help of creative sense, imagination, understanding and keen observation of structures in nature, scientific knowledge of various aspects of the structures, many dynamic personalities in civil engineering field are coming with new concepts with the help of which there are lots of finding viz. reduction in the thickness of wall, reduction in the beam-column sizes etc. But no research or study has been made until now on replacement of sacrificial concrete in case of deep beams. This is also a research area in structural design. As concrete is weak in tension, to take this tension steel reinforcement is provided at the bottom side of the beam section. As compressive stresses are induced in the zone above the neutral axis, compressive strength of the concrete lying above neutral axis is very important parameter. This induces compressive force in the top zone at a distance of 0.42 X_U. (X_U –Neutral axis distance from top of section.).The tension force acts at centroid of steel reinforcement provided at bottom of section. The distance between the point of action of compressive force and tension force is called lever arm and it is directly proportional to moment of resistance. Generally being a structural engineer we should concentrate towards the structural as well as functional design of the structure. But while designing, economy of the project is also a major factor. Keeping economy and safety of the structure in mind, we came with the concept of "Variation Beam".

1.1 AIM: To study optimum use of concrete grade in tension zone.

1.2 OBJECTIVE: To achieve economy in construction.

1. Attainment of strength without compromising the serviceability.

Avoid cracking of concrete in tension zone, as there is reduction in heat of hydration.

II.GENERAL BEAMS

The idealized stress strain curve for concrete as prescribed by IS code is rectangular parabolic as shown in fig 1. It consist of a parabola emerging from the neutral axis with its apex lying at the point corresponding to the strain of 0.002 and a rectangular beyond that point terminating at the compression face where the maximum strain is 0.0035. Let x_u be the depth of neutral axis below the compression face.

The depth of parabolic part of stress block= $4x_u/7$

And depth of rectangular part of stress block = $3x_u/7$

Area of stress block = Area of rectangle ABCD + Area of Parabola OAD = 0.361 fckxu = 0.36 fckxu

The distance of centroid of stress block from compression face is obtained by taking moments of area about the top compression face.

$$x = \frac{\left(0.446 fck \frac{3xu}{7}\right)\left(\frac{1}{2}\frac{3xu}{7}\right) + \left(\frac{2}{3}\left[0.446 fck \frac{4xu}{7}\right]\right)\left(\frac{3}{7}xu + \frac{3}{8}\frac{4xu}{7}\right)}{0.361\ fck\ xu}$$

These parameters enable us to find total compression resisted by concrete and the moment of resistance contributed by concrete in compression

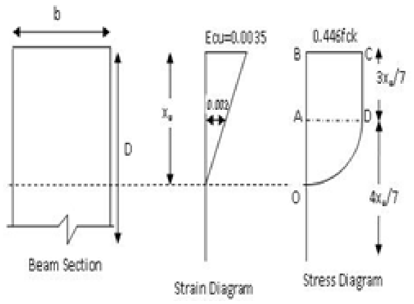


Figure.1. Stress block across beam section

III.METHODOLOGY

First part of the project is preparation of specimen i.e. preparing variation beam and conventional beams and second part is testing. The main aim of the project is to study flexural strength of both variation and normal beam and studying the crack appearance at the interfaces. The quality, properties, characteristics of concrete and its ingredients should be high. Hence pretesting of materials like cement, coarse aggregate and fine aggregate is done before the execution of the project work.

MIX DESIGN DATA FOR M25

Water	Cement	F. A.	C.A.	
180	401.75	606.58	1191.48	By mass
0.46	1	1.56	2.98	Absolute Volume

MIX DESIGN DATA FOR M20

Water	Cement	F. A.	C.A.	
180	372	615.58	1209.14	By mass
0.5	1	1.65	3.25	Absolute Volume

Design:

1) Singly Reinforced Section

Now for M25 + Fe 415 combination

Pt limit = 0.96% × b × d

= 0.96 × 150 × 225

= 324mm^2.

Now by adopting steel #3-Ø 12mm,

Ast provided = 405mm^2

We have moment of resistance as

Mu = T × L

=0.87 x 415 x 405 x (225 – 0.416 x 108)

=26.33 kN m.

Xu = 0.87 fyAst/ 0.36 fckb

= 0.87 x 415 x 405 / 0.36 x 25 x 150

= 108.31 mm< 125 mm

The given section is Under Reinforced

Mulim=0.87x415x405(225-0.416×120.988) =25.54 kNm.

2) Doubly Reinforced Section

Assume 1 bar of 12mm dia.

For Doubly reinforced section

Ast2=Asc

Ast2= 1 bar of 12mm Ø

= π ÷ 4 × (12^2)

=113.097mm^2

Asc=Ast2

Assume 10mm dia bar for Asc

Asc≅120mm^2.

∴ 120 = N × π ÷ 4 ×(10^2)

∴No of bars = 1.52 ≅ 2 Nos.

3) Summary

Section Size = 150 x 250 x 700mm

Effective depth= 225mm

Clear cover = 25 mm

Steel (tension) = 4 – ø 12

Anchor Bar = 2 -8 ø

Stirrups= 6Ø @ 150mm c/c

Side cover=20mm

IV. EXPERIMENTALPROGRAM

The formwork prepared and ingredients are weighed accurately with weight balance. Ingredients are mixed with the help of concrete mixer. Concrete was placed in the formwork in layers of approximately 15 cm and compact.

Similarly, the layers were successively placed one above the other and compacted. End faces were properly compacted to get smooth finish

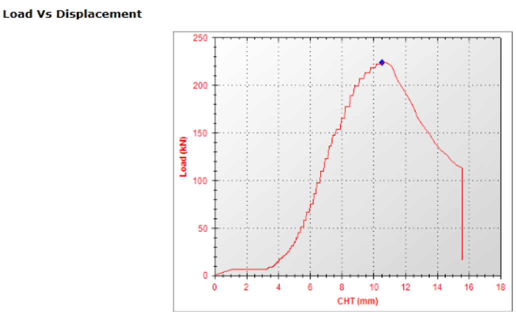
After completion of about 12 hours, Beams where placed in a water tank for curing for about 28 days and cured using ponding method. Neutral axis is marked with the help of a string stretched between two end plates. Concrete in the tension zone was placed in the formwork in layers of approximately 15 cm and compacted firstly for M20 grade of concrete. Similarly, the layers were successively placed one above the other and compacted. After the level of string was reached, the concreting operation was stopped with M20 grade of concrete. The Universal Testing Machine was used for testing the beams after 28 days. First of all, normal rectangular beam was placed on the UTM. Load was then applied gradually and uniformly. Simultaneously deflection was noted down carefully. For each deflection corresponding load was observed and noted down.

V.RESULT ANALYSIS

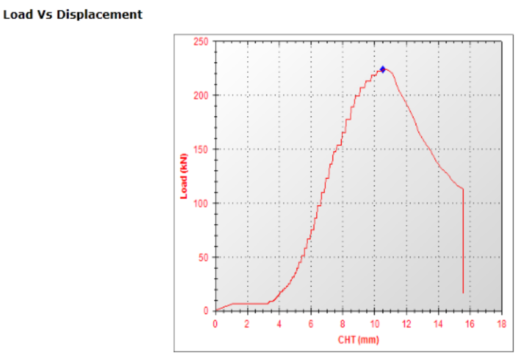
It is observed that all the four beams have achieved more strength than the design strength. The variation beam has deflection but more crack resistant than conventional beam.

CRACK PROPAGATION AND FAILURE LOAD

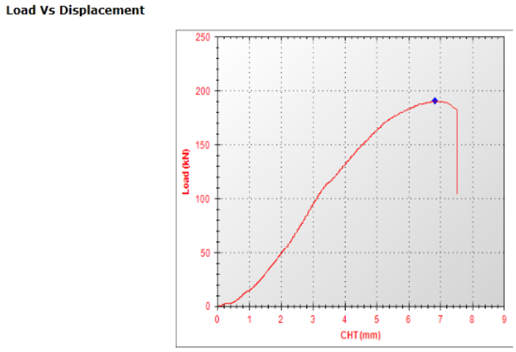
Sr. No	Beam Type	Grade of concrete	Load carried before cracking	Depth of crack in tension zone
1.	Conventional Beam 1	M25	223.520 kN	10.740mm
2.	Conventional Beam 2	M25	209.220 kN	6.320mm
3.	Variation Beam 1	M25+M20	190.200 kN	6.860mm
4.	Variation Beam 2	M25+M20	221.00 kN	4.630mm



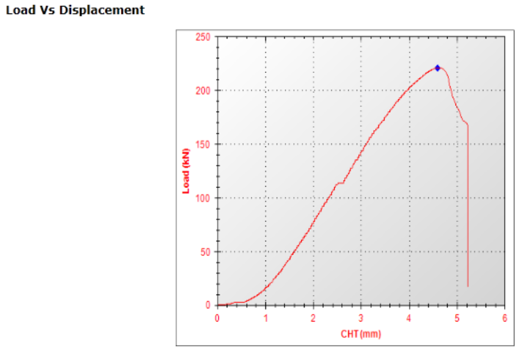
Conventional Beam 1



Conventional Beam 2



Variation Beam 1



Variation Beam 2

VI. CONCLUSIONS

I) Variation beam can be used for construction of large depth slabs, beams and other tension members having large depth.
II) The cost of construction is reduced up to 5-6%.
III) Strength and serviceability of tension member is not affected.
IV) Tension zone is more cracks resistive.

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