Comparison of Fracture Parameters of Medium Strength Concrete and High Strength Concrete

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***Abstract*—The main aim to perform this experimental study on different grades of concrete medium strength and concrete of high strength (M-25 and M-60) is to predict fracture criteria and behaviour of concrete specimen on application of load. The test was performed on concrete beams to calculate and analyze the behaviour of fracture variables of given concrete for various size and these variables fracture energy and zone length of fracture process. The dependency of these variables on concrete size is predicted by using the Bazant's size effect method. Beams of different grades of concrete are made and tested. Notch to depth ratio for beam specimen which is adopted for crack generation is $(a_0 / d = 0.15, 0.30, 0.45)$ 27 beams, 3 cubes and 3 prisms were also tested to find out the different mechanical properties of concrete strength and modulus of elasticity of concrete is also determined.**

***Keywords*—Brittleness number, Characteristic length, Fracture process zone, Size effect, Stress intensity factor.**

I. INTRODUCTION

The strength of concrete structures is generally size dependent and the impact of size on the strength of structure is important. Generally all concrete structures are constructed which are dependent on the strength of standard sizes specimen larger the concrete structures lower is the strength from standard specimen size. The increase in specimen size also increases the load on failure, but the nominal stresses decreases. The load carrying values which are less traditional as the size of the members increase.

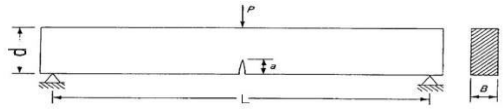

Fig. 1. Magnetization Representation of three point bending test of beam specimen (Courtsey A. Bordelon)

The effect of size of concrete structures can be measured by correlating the stress at the ultimate load of failure in geometrically identical specimens of various sizes with identical notch ratios.

A. Medium Strength Concrete Material Details

Cement conforming to with specific gravity of 2.9 (PPC) is generally used for design mix fine aggregate (sand) of specific gravity of 2.60 passing sieve size of 2.36 mm coarse aggregate used having specific gravity 2.70 is used passing 20 mm sieve coarse aggregate of 10 mm is used. Maximum aggregate (coarse) which is used is limited upto10 mm normal water is used for casting.

TABLE I: DETAIL OF MIX PROPORTION

Grade of concrete – M 25

Beam series	Notch-depth ratio a_0 / d	Mix Proportions (Kg/m^3) of concrete			
-	-	Fine Agg	Coarse Agg	Cement	Water
Series A	0.15	740.4	860.8	489.7	220.4
Series A	0.15	740.4	860.8	489.7	220.4
Series A	0.15	740.4	860.8	489.7	220.4
Series B	0.30	740.4	860.8	489.7	220.4
Series B	0.30	740.4	860.8	489.7	220.4
Series B	0.30	740.4	860.8	489.7	220.4
Series C	0.45	740.4	860.8	489.7	220.4
Series C	0.45	740.4	860.8	489.7	220.4
Series C	0.45	740.4	860.8	489.7	220.4

TABLE II: MECHANICAL PROPERTIES FOR M.S.C

Beam Series	**Series A**	**Series B**	**Series C**
Wet Density (KN/m^3)	24.083	22.763	23.832
Cube Comp strength (fck) Mpa	30.45	30.06	29.08
Modulus of Rupture(fbt) Mpa	3.03	2.77	3.06
Modulus Of Elasticity (E) Mpa	27590.75	27694.54	26962.9

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TABLE III: LINEAR REGRESSION DATA AND CORRESPONDING GRAPH

Beam Size(d) mm	100 mm	140 mm	160 mm
Series A	30.86	54.02	74.77
	30.52	51.05	72.04
	28.09	50.04	71.66
Series B	36.86	58.54	69.46
	39.66	54.06	70.86
	31.45	57.86	71.98
Series C	41.64	51.54	76.87
	40.32	55.58	78.86
	39.02	60.42	78.44

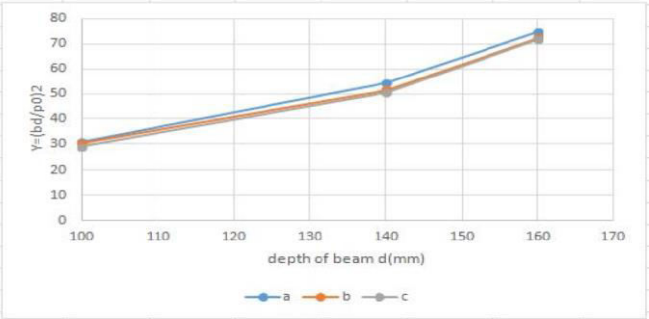

Fig. 2. Linear Regression Data & Corresponding Graph

TABLE IV: FRACTURE VARIABLES FROM SIZE EFFECT METHOD FOR M.S.C

Beam Series	$\frac{a}{d}$	G_f	C_f
Series A	0.15	69.96	70.10
Series B	0.30	54.65	61.62
Series C	0.45	49.86	52.50

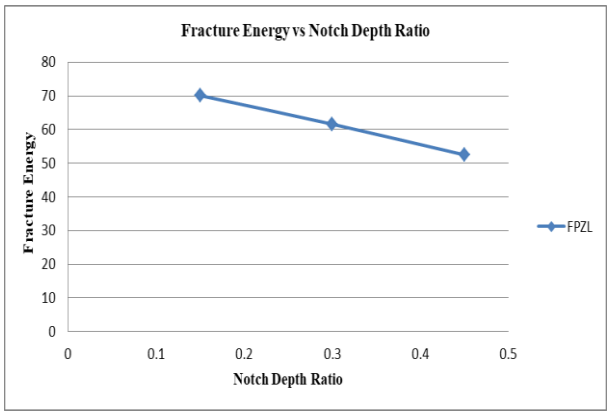

Fig. 3. Fracture energy vs. Notch Depth Ratio

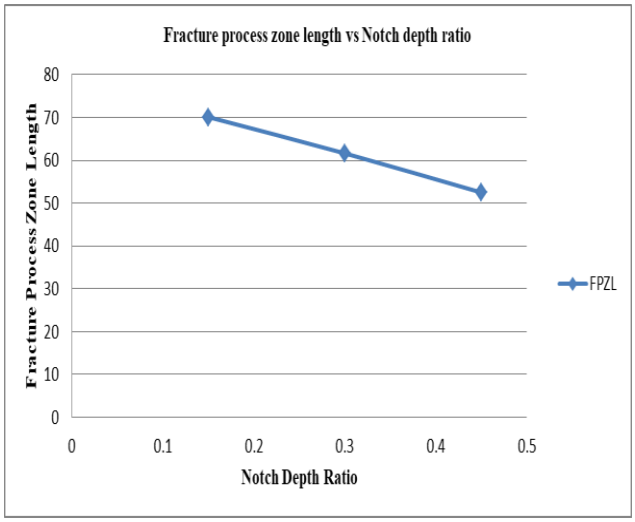

Fig. 4. FPZL vs. Notch Depth Ratio

B. Fracture Variables of High Strength Concrete

100mm size cubes were prepared to determine compressive strength of concrete used. Cylinders with 150mm diameter and length of cylinder are 300mm were used to calculate elasticity modulus of concrete used for experimental study. Prisms of size (500mmx100mmx100mm) were taken to find modulus of fracture of concrete different mould sizes was used for different beam size. A fracture parameters variation of prepared concrete specimen is studied. Three point bend test is generally performed on geometrically similar notch beams to calculate fracture toughness and process zone length. Beams in each batch (ao/d = 0.15, 0.30 and 0.45).

TABLE V: HIGH STRENGTH CONCRETE MECHANICAL PROPERTIES

Beam Series	Series A	Series B	Series C
Wet Density (KN/m^3)	26.87	25.04	25.88
Cube Comp strength (fck) Mpa	65.84	70.43	69.86
Modulus of Rupture(fbt) Mpa	5.56	6.62	5.96
Modulus Of Elasticity (E) Mpa	32750	32350	31755

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TABLE VI: MIX PROPORTION OF HIGH STRENGTH CONCRETE (GRADE OF CONCRETE – M 60)

Beams series	Notch-depth ratio	Mix Proportions (Kg/m^{3}of Concrete)			
-	-	Fine Agg	Coarse Agg	Cement	Water
Series A	0.15	664.4	1130.6	530.5	162.2
Series A	0.15	664.4	1130.6	530.5	162.2
Series A	0.15	664.4	1130.6	530.5	162.2
Series B	0.3	664.4	1130.6	530.5	162.2
Series B	0.3	664.4	1130.6	530.5	162.2
Series B	0.3	664.4	1130.6	530.5	162.2
Series C	0.45	664.4	1130.6	530.5	162.2
Series C	0.45	664.4	1130.6	530.5	162.2
Series C	0.45	664.4	1130.6	530.5	162.2

TABLE VII: LINEAR REGRESSION DATA AND CORRESPONDING GRAPH FOR HIGH STRENGTH CONCRETE

Beam Size(d) mm	100 mm	140 mm	160 mm
	40.32	50.62	54.87
Series A	38.32	48.45	60.54
	41.19	53.44	61.26
	46.86	53.24	61.46
Series B	43.62	53.06	72.46
	50.45	65.86	74.78
	40.4	41.54	67.87
Series C	44.32	57.28	70.06
	49.33	61.22	75.64

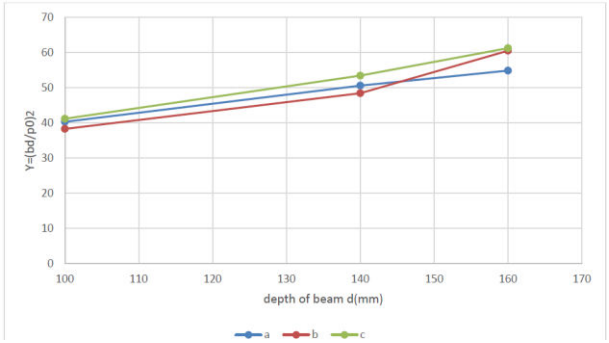

Fig. 5. Linear Regression Data & Corresponding Graph

TABLE VIII: FRACTURE VARIABLES FROM SIZE EFFECT METHOD FOR H.S.C

Beam Series	$\frac{a}{d}$	G_f	C_f
Series A	0.15	84.20	75.89
Series B	0.30	67.52	64.65
Series C	0.45	59.80	56.26

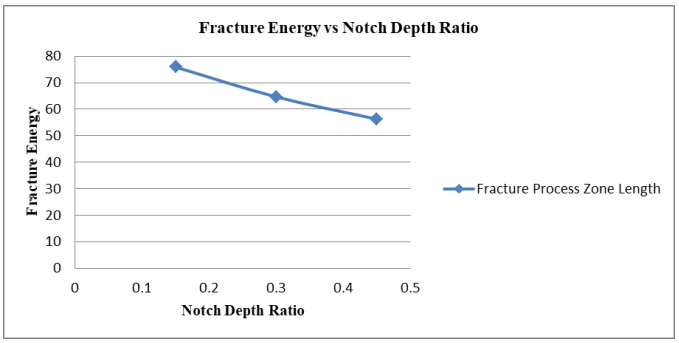

Fig. 6. Fracture Energy vs Notch Depth Ratio for High Strength Concrete

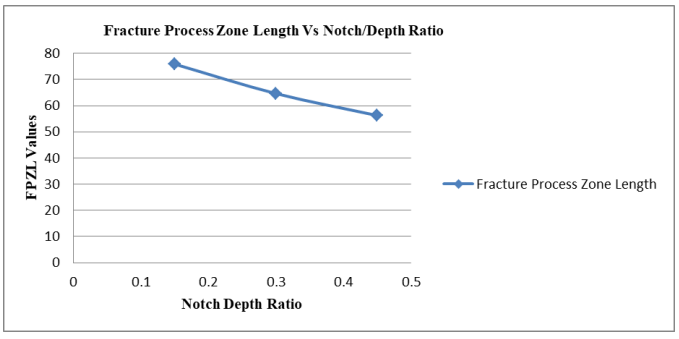

Fig. 7. Fracture Process Zone Length Values vs Notch Depth Ratio for HSC

C. Comparison of Fracture Variables of High Strength Concrete and Medium Strength Concrete

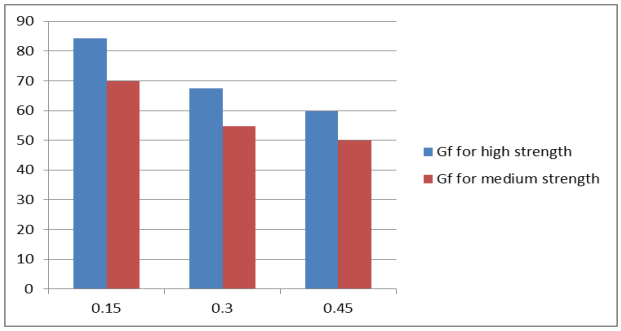

Fig. 8. Average values of fracture energy for H.S.C and M.S.C for various notch depth ratio

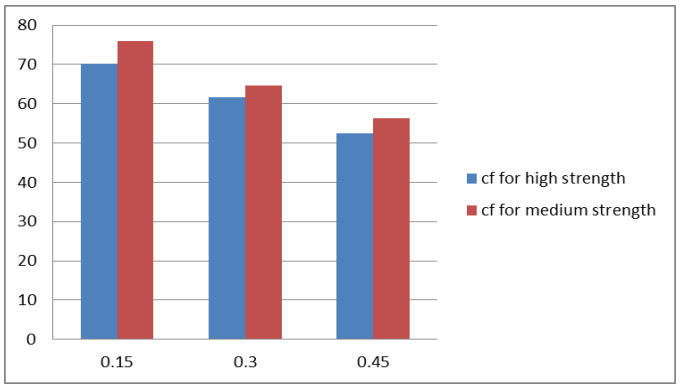

Fig. 9. Comparative values of F.P.Z.L for H.S.C and M.S.C for different notch depth ratio

II. CONCLUSION

As we increase the notch depth ratio the fracture criteria (energy) value in concrete of medium strength is found to be decreasing.

Increasing the notch to depth ratio or size of the beam the fracture process zone length value is found to be decreasing. The reduction in values of fracture criteria of concrete indicates that it will have a brittle failure.

These two conditions also arises in concrete of high strength both values fracture energy and length of fracture process zone decreases as the notch to depth ratio of beam increases. Stress concentration at the crack tip region is also increases resulting in the values of both the fracture parameters

Comparison of fracture variables for MSC and that of HSC is shown in figure (8, 9) for different notch depth ratio.

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