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Effect of Change in Grade of Concrete on the Composite Members of a Framed Structure

Vidula S. Sohoni[1], M.R.Shiyekar[2]
[1]*Bharati Vidyapeeth University College of Engineering, Pune, Maharashtra -411043,India*
.[2] Sinhagad College of Engineering Pune-411052, Maharashtra, India

Abstract—The past few decades have seen outstanding advances in the use of composite materials in structural application. Composite members are widely used in structural systems to achieve additional rigidity. R.C.C.members with conventional Torsteel reinforcement may now be replaced by composite members with rolled steel sections like angle sections, galvanized iron pipe sections.Experimentally as well as analytically these members prove to be a better alternative to conventional members and are more advantageous especially at the beam-column junction and in high rise earthquake-resistant structures.The present paper aims at studying the effect of change in grade of concrete on the behavior of composite members.Beams and columns using rolled steel sections as reinforcement were cast using varying grades of concrete and tested. Results of failure loads and deformations in flexure and axial compression show that use of rolled steel sections as reinforcement proves to be advantageous even for variations in grades of concrete.

Keywords—Composite Members, Grade of Concrete, Rolled Steel Sections,Stiffness,Poisson,s Ratio

I. INTRODUCTION

In civil engineering, composite materials have revolutionized traditional design concepts and made possible an unparalleled range of new existing possibilities as viable material of construction. Numerous varied structural members may be used today to meet performance and functional requirements in structures.Composite members in which conventional torsteel reinforcement is replaced by rolled steel sections like angle sections, galvanized iron pipe sections are proving to be a better alternative for high rise structures and especially at the beam column junctions.Use of these composite members may add to the ductility of the joints and thus helps to improve the overall response of the structure for earthquake resistance.

This increase in ductility may be achieved by increasing the ductility of the brittle matrix. Addition of steel fibres to the matrix is one of the measures for this[1].Ductility may also be increased by using composite members. Ductility using ultra high strength members may be increased for compression members but for flexural members the increase is unfound[2]. Effect of compressive strength and tensile reinforcement ratio on flexural behavior of high-strength concrete beams has been investigated[3].This effect is with reference to the load-deflection behavior and displacement ductility .The results show that flexural rigidity increases as concrete compressive strength increases. Ductility may also be increased by using composite members.Use of variety of rolled steel sections proves to be advantageous for this and may be considered as a good alternative[4]. Through innumerable attempts, the elastic properties of all the structural materials have been worked out and quantified by the I.S. codes[5] and are known fairly accurately. However, it remains to be seen how concrete responds to embedding of fabricated steel sections, in view of elastic properties. This forms the core of the proposed study.In the present study , the effect of change in grade of concrete on flexural strength, deformations of flexural members and compressive strength and axial deformations of compression members is to be studied.For this study, the cross sectional dimensions of the members , percentage of tension reinforcements is kept the same and grade of concrete is varied.

II. DEFINITION OF THE STUDY

- Deciding the combinations of composite members by using rolled steel sections as reinforcement..
- Deciding the various grades of concretes to be considered .
- Investigating experimentally the behaviour of composite members for various grades.
- Comparison of the experimental results of various grades.
- Arriving at a conclusion for the properties of the composite members based on change in grade of concrete.

III. FORMULATION OF THE PROBLEM

A. **Step 1:** Identify various combinations of rolled steel sections to be used as reinforcement.Identify various grades of concrete and accordingly carrying out the mix design and thus arrive at proportions of ingredients for these grades.Casting the cubes for these grades and also casting the required number of beams and columns of every combination.

B. **Step 2:** Tesing cube specimens to arrive at the crushing strength.Testing beam specimens for flexure and arrive at failure loads and deformations.Testing column specimens for compression and arrive at failure loads and deformations.

C. **Step 3:** Compare the experimental results for various grades and thus to know the effect of change in grade of concrete on composite members. Calculation of Modulus of Elasticity for all specimens and all grades.Arriving at the conclusions to know the effect of change in grade of concrete.

IV. METHODOLOGY

A. Identified Combinations of Composite Members

Following three types of members are considered for experimental work.

1)Type'N'members: Members with *Normal* i.e. conventional torsteel reinforcements.

***2)Type 'A' members*:** Members with rolled steel *Angle* sections as reinforcements.

***3)Type 'P' members*:** Members with *Pipe* sections as reinforcements.

In preparing these member specimens, cross sectional area , percentage steel is kept same.Following grades of concrete are considered.Grade M 20 ,Grade M 25I,Grade M 30.

Following number of specimens were cast and cured for 28 days before testing.

Table I: *No.of specimens cast*

Member	Type of Member	Grade of Concrete			Total
		M 20	M 25	M 30	
Cubes	-	03	03	03	09
Beams	Type 'N'	03	03	03	09
	Type 'A'	03	03	03	09
	Type 'P'	03	03	03	09
Columns	Type 'N'	03	03	03	09
	Type 'A'	03	03	03	09
	Type 'P'	03	03	03	09

B. Testing the specimens

1) Cubes:Cubes were tested under compression testing machine to know and verify the grade of concrete used.Average of the strength was taken as the crushing strength of cubes and hence the grade of concrete used.

2) Beams:The beams were tested on UTM for two point loads under middle third loading arrangement.The load was applied gradually.The deflection under the two point loads were recorded with the help of dial gauge.Maximum deflection and ultimate load were noted down.

***3) Columns*:**The columns were tested under UTM for axial compression.The load was applied gradually. The deformation under the axial load was recorded. Maximum failure load and corresponding deformation was recorded.

C. Comparing the Results for Various Grades ,Calculation of Modulus of Elasticity and Conclusions: Results obtained for various grades were compared and percentage variation is compared .For this comparison, Type'N' members are considered as the basis and grade-M 25 is considered as the basis. For beams , Modulus of Elasticity is found out from the value of deflection for middle third Loading and corresponding failure load.For columns, Modulus of Elasticity is found out from the value of axial deformations and corresponding failure load in axial compression. Based on the results of comparative study, conclusions may be arrived at about the effect of change in grade of concrete on behavior of composite members.

V. SUMMARY OF THE BEAM SECTIONS

Size of the beam: 150mm x150mm x750mm

Table II: *Summary of the Beam Sections*

Details	I) Type 'N' sections	II) Type'A' sections	III)TYPE 'P'sections
Main Reinforcement	2 #12	2 ISA 20x20x3	2 pipes 25mm outer diameter, thickness 1.5mm
Percentage Steel (pt)	**1.32%**	**1.31%**	**1.28%**
Hanger Bars	2 # 8mm	2 #8 mm	2#8mm
Stirrups	2legged#8mm @200mmc/c	2legged #8mm@200c/c.	2legged #8mm@200mmc/c

VI. COLUMN SPECIMENS

Column specimens were cast by considering the three types of reinforcements as vertical bars by keeping the sizes and percentage of steel ,the same. Summary of column specimens is as follows.Size of the column: 230 mm x230 mm x850mm

Table III: *Summary of the Column Sections*

Details	I) Type 'N' sections	II) Type'A'sections	III) Type 'P' sections
Main Reinforcement	5 #12	4ISA 25x25x3	Pipe 90mm od 2mm thick
Percentage Steel (pt)	1.06%	1.06%	1.04%
Links	2legged#8mm@180 mmc/c.	2legged#8mm@ 180mmc//c.	No links

VII. CONCRETE MIX DESIGN AND PROPORTIONING THE INGREDIENTS

Design of the mix was carried out to achieve the required characteristic strength for various grades .Mix design referring to I.S.10262 -1970 was carried out for following design data.

A. Degree of Quality Control = Good
Type of Exposure = Mild,
B . Type of Cement = O.P.C.
Specific Gravity of Cement = 3.15,
C. Type of Aggregates = Crushed Stones.
Max.Size of Aggregates = 20 mm
Grading of Aggregates-Coarse Aggregates = Zone II
Fine Aggregates = Zone I

Considering above mentioned data and assuming the characteristic strength as per the grade to be designed, mix design was carried out. The decided proportions as obtained by mix design were used while preparing the concrete of respective grade during casting.

Table IV: *Proportions of Ingredients obtained*

	Grade of Concrete		
	M 20	M 25	M 30
Target Strength In N/mm^2	20	25	30
Water	0.4	0.426	0.5
Cement	1.0	1.0	1.0
Fine Aggregates	1.25	1.41	1.507
Coarse Aggregates	2.3	2.82	3.15

VIII. LOADING ARRANGEMENT FOR BEAMS

The beams were tested on Universal Testing Machine(UTM) for middle third loading by applying two point loads.

IX. TESTING OF CUBES

Age at Time of Testing =28 Days

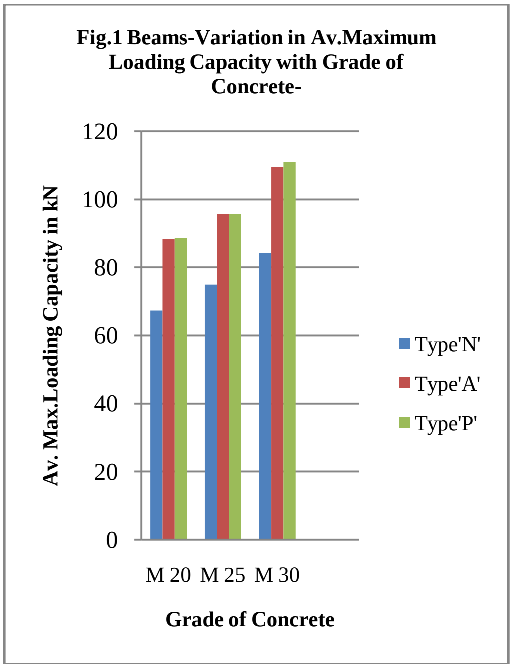
Table V: *Cube Test Results*

Specimen No.	**Grade Of Concrete**		
	M 20	**M 25**	**M 30**
1	24.8	28.77	33.572
2	25.34	28.55	32.264
3	27.03	28.25	33.136
Average Compressive strength in N/mm^{2s}	25.72	28.52	32.99

X. TESTING OF BEAMS

Table 6: Test Results for Beams

Grade of Concrete	Type of Beam	Av. Maximum Load Capacity In kN	Av.Maximum Deflection In mm
M 20	Type'N'	67.36	1.61
	Type'A'	88.34	1.953
	Type'P'	88.7	1.13
M 25	Type'N'	75	1,45
	Type'A'	95.66	1.756
	Type'P'	95.66	1.0
M 30	Type'N'	84.2	1.27
	Type'A'	109.6	1.6
	Type'P'	111	0.896



XI. TESTING OF COLUMNS

Table 7: Test Results for Columns

Grade of Concrete	Type of Column	Av. Maximum Load Capacity In kN	Av.Maximum Axial Deformation In mm
M 20	Type'N'	976.58	0.433
	Type'A'	976.58	0.426
	Type'P'	1065.36	0.31
M 25	Type'N'	1242.92	0.443
	Type'A'	1242.92	0.42
	Type'P'	1176.44	0.303
M 30	Type'N'	1242.92	0.386
	Type'A'	1242.92	0.35
	Type'P'	1154.14	0.203

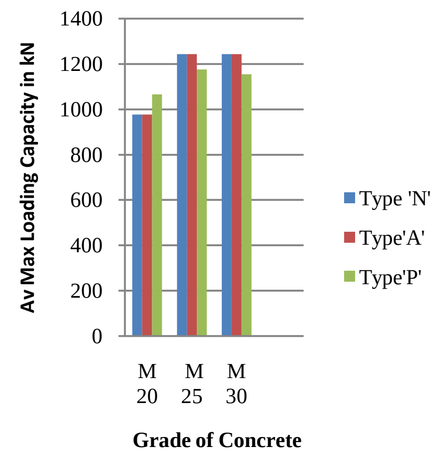


Fig.2 Columns-Variations in Av.Max.Loading Capacity with Grade of Concrete

XII. COMPARISON OF TEST RESULTS

For the comparison of maximum load capacity and deflection, grade M 25 is taken as the basic grade. Also Type 'A' and Type'P' members are compared By considering Type 'N' members as the basic members.Following table gives the comparison of beam test results.

Table 8: *Comparison of Beam Test Results*

Grade of Concrete	Ratio of Characteristic Strengths	Ratio of Actual Crushing Strengths	Ratio of Maximum Load Capacity for Beams		Ratio of Max Deflections for Beams
M 20	20/25 = 0.8	25.72/28.52 = **0.901**	N-Type	67.36/75= **0.89**	1.61/1.45=**1.11**
			A -Type	88.4/98.66=**0.896**	1.953/1.756=**1.11**
	1/0.8=1.25	1/0.901=**1.11**	P-Type	88.7/98.95=**0.896**	1.13/1.0=**1.13**
M 25	25/25 =1	28.52/28.52 =1	N-Type	75/75=1	1.45/1.45=1
			A -Type	98.66/98.66=1	1.756/1.756=1
			P-Type	98.95/98.95=1	1.0/1.0=1
M 30	30/25 =1.2	32.99/28.52 =**1.156**	N-Type	84.2/75=**1.122**	1.27/1.45=**0.87**
			A -Type	109.6/98.66=**1.111**	1.6/1.756=**0.911**
	1/1.2=0.833	1/1.156=**0.865**	P-Type	111/98.95=**1.121**	0.896/1.0=**0.896**

On the same basis, test results for columns are also compared.Following table gives the comparison of column test results.

Table 9 : Comparison of Column Test Results

Grade of Concrete	Ratio of Characteristic Strengths	Ratio of Actual Crushing Strengths	Ratio of Maximum Load Capacity for Columns		Ratio of Maximum Axial Deformations for Columns
M 20	20/25 = 0.8	25.72/28.52 = **0.901**	N-Type	976.58/1242.92 =**0.786**	0.443/0.443=**1**
	1/0.8=1.25	1/0.901=**1.11**	A -Type	976.58/1242.92 =**0.786**	0.426/0.42=**1.019**
			P-Type	1065.36/1176.44 =**0.905**	0.31/0.303=**1.023**
M 25	25/25 =1	28.52/28.52 =1	N-Type	1242.92/1242.92 =1	0.443/0.443=1
			A -Type	1242.92/1242.92 =1	0.42/0.42=1
			P-Type	1176.44/1176.44 = 1	0.303/0.303=1
M 30	30/25 =1.2	32.99/28.52 =**1.156**	N-Type	1242.92/1242.92 =**1**	0.386/0.443=**0.87**
	1/1.2=0.833	1/1.156=**0.865**	A -Type	1242.92/1242.92 =**1**	0.35/0.42=**0.833**
			P-Type	1154.14/1176.44 **= 0.98**	0.202/0.303=**0.67**

XIII. DETERMINATION OF MODULUS OF ELASTICITY FOR BEAMS AND COLUMNS

A. Beams

For the third point loading , the deflection values below the point load are measured. Analytically, this deflection can also be obtained as

$\delta = (11/972) \times (w l^4 /EI) + (23/648) \times (W l^3 /EI)$

Using this equation, and values of δ obtained experimentally, modulus of elasticity for R.C.C. for all the three grades and all the three types can be found out. For all the cases,

Self- weight of the beam (w) = 25 × 0.15 ×0.15 =0.5625 kN/m

Moment of Inertia (I) = $(0.15) \times (0.15)^3 /12 = 4.218 \times 10^7 \text{ mm}^4$

B. Columns

*M*odulus of Elasticity E for R.C.C.for the column section is calculated .Axial Deformation δ = P L /A E.

This gives E = PL/A δ = (P/A) / (δ/ L)

Using this expression for Modulus of Elasticity E for R.C.C., calculations are done for all the grades and all the types of columns .The obtained values of E for columns are then compared with the values of E obtained for same types of beam sections.

Table 10: Values of Modulus of Elasticity obtained

Type of Member	Grade of Concrete	Modulus of Elasticity From Beam Sections E_{RCC} in N/mm²	Modulus of Elasticity From Column Sections E_{RCC} in N/mm²
Type'N'	M 20	3.56×10^4	3.542×10^4
	M 25	4.72×10^4	4.51×10^4
	M 30	5.61×10^4	5.174×10^4
Type'A'	M 20	3.85×10^4	3.683×10^4
	M 25	4.94×10^4	4.75×10^4
	M 30	5.79×10^4	5.70×10^4
Type'P'	M 20	6.64×10^4	5.522×10^4
	M 25	7.43×10^4	6.24×10^4
	M 30	10.54×10^4	9.135×10^4

XIV. INFERENCES

A. Load Carrying capacity and Deformations

It is observed that both for beams and columns, with the change in grade of concrete, there is a proportionate increase or decrease in the values of maximum load carrying capacity and corresponding deformations. This amount of increase or decrease is same for all the types of members.

B.Modulus of Elasticity

It is observed that the value of Modulus of Elasticity for all the members also vary in proportion with the grade of concrete.

C. Comparison of Beam Sections

It is observed that the load carrying capacity for beam sections is more in Type'A' and Type'P'beams when compared with Type'N' beams. The percentage increase is almost the same for all the grades of concrete.This indicates that use of Type'A' and Type'P' beams is advantageous with the same proportion irrespective of the grade of concrete.Following table shows the percentage increase in load carrying capacity and corresponding percentage reduction in deflection and percentage change in the value of Modulus of Elasticity.

Table 11 : Comparison of various grades and types of beams

Grade of Concrete	M 20	M 25	M 30
I)Percentage Increase in Load Carrying Capacity As compared with Type 'N' Beams			
i)Type'A' Beams	+31.23	+31.54	+30.17
ii)Type 'P'Beams	+31.68	+31.93	+31.83
II)Percentage Change in Maximum Deflection As Compared with Type 'N'Beams			
i)Type'A' Beams	+21.30	+21.10	+20.62
ii)Type 'P'Beams	-29.81	-31.03	-29.45

D. Comparison of Column Sections

For column sections , for variation in the grade of concrete, Type 'A' and Type 'P' sections prove to be more suitable because though there is a reduction in load carrying capacity, it is at a much higher value of axial deformation. Following table shows the details.

Table 12: *Comparison of Various Grades and Types of Columns*

Grade of Concrete	M 20	M 25	M 30
I)Percentage Increase in Load Carrying Capacity As compared with Type 'N' Columns			
i)Type'A' Columns	0	0	0
ii)Type 'P'Columns	+9.09	-5.34	-7.14
II)Percentage Change in Maximum Deflection As Compared with Type 'N'Beams			
i)Type'A' Columns	-3.84	-5.19	-9.32
ii)Type 'P'Columns	-30.02	-31.6	-47.66

XIII. CONCLUSIONS

Composite sections with rolled steel angle sections as the reinforcement in place of conventional tor steel reinforcement may prove to be more effective in terms of -

a). Load carrying capacity in flexure .
b). Deflection and hence stiffness properties.
c) Increased value of Modulus of Elasticity E_{RCC} indicates increase in ductility and hence more suitability for earthquake resistant constructions.
d). Though the grade of concrete is changed, use of rolled steel sections in place of conventional torsteel reinforcement proves to be more suitable for multistoried buildings and earthquake resistant construction.

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