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SEISMIC RESISTANCE OF HIGH-STRENGTH R/C MEMEBERS

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SUMMARY

Presented in this paper are be some of the results from the analytical investigations performed within the frames of the scientific-research project "Development of a Methodology for High-Strength Concrete", financed by the Ministry of Science of Republic of Macedonia and realised in co-operation with the construction company "Beton" - Skopje, "Ading" - Skopje and IZIIS - Skopje. The results on the strength and deformability characteristics of three cross-sections with different dimensions and five different concrete strengths as well as the results for construction of an optimal cross-section with high-strength materials are given.

INTRODUCTION

Following the modern world trends in the field of using of high-strength materials, the first part of the scientific-research project by which a technology for obtaining of concrete with compressive strength of up to 120 MPa exclusively from domestic resources was defined, was carried out in IZIIS at the period between 1992-1996.

To define the ultimate bearing capacity and deformability of RC elements constructed of high strength concrete and steel, three different elements with proportions 40/40, 60/60 and 80/80 and length 3.0 m were considered. The first part of the investigations involved analyses of a constructed cross-section with constant proportions and identical percentage of reinforcement, but different concrete strength (MB 30, MB 50, MB 60, MB 75 and MB 90). Then, analyses of bearing capacity and deformability (i.e., ductility) were done for the newly designed cross-section (of smaller proportions), constructed of ultra high-strength concrete and steel in respect to a corresponding element constructed by using concrete MB30 and ribbed reinforcement RA 400/500. σ-ε diagram for each type of concrete which was used for building the cross-section is shown on the figure 1 and table1.

Table 1- Strength and deformation characteristics for different class of concrete

MB (class of concrete)	30	50	60	75	90
Eb, (Ec) [GPa]	31.5	36.0	38.0	40.6	42.9
fb, (fc) [MPa]	20.5	30.0	33.0	37.5	45.0
εc,max [‰]	3.5	3.2	3.0	2.5	2.2

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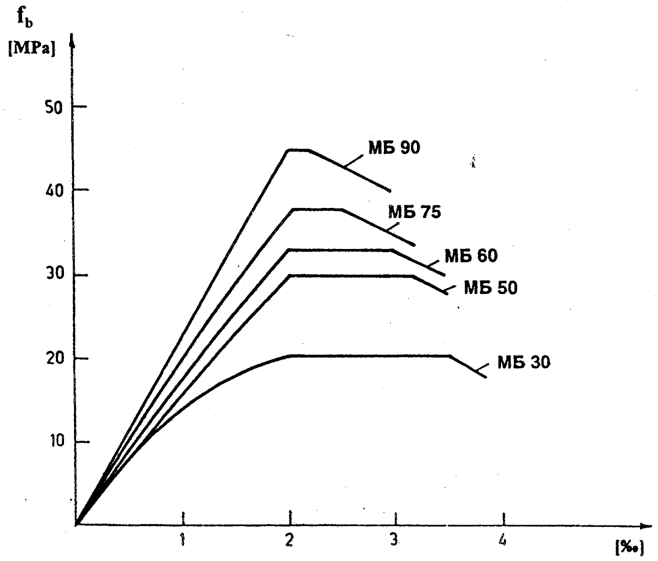

Figure 1. σ-ε diagram for different class of concrete

The second phase of the project will involve experimental tests on models of RC elements, (beams and columns) and will be logical continuation from the first phase.

Presented further are the results from the analytical investigations. All the analyses have been performed by using computer programmes developed at IZIIS - Skopje.

STRENGTH AND DEFORMABILITY (DUCTILITY) CAPACITY

The analysis was carried out on three elements of different proportions 40/40, 60/60 and 80/80 cm. For different level of axial load, these cross-sections were constructed and proportioned for MB 30 and RA 400/500 (Fig. 2). In all these elements, the percentage of vertical reinforcement was approximately 1% with use of 8Rϕ16, 12Rϕ 19 and 16Rϕ22, for each cross-section, respectively.

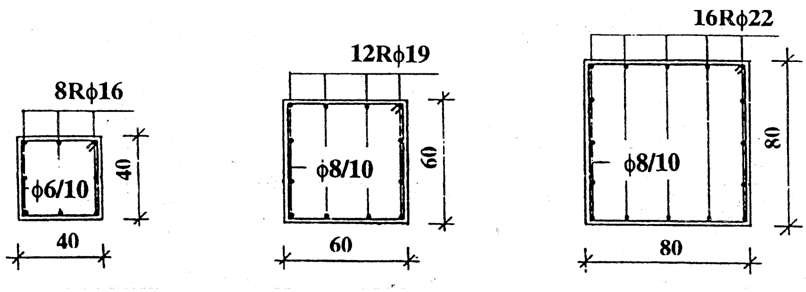

Figure 2. Characteristics of the cross-sections

For each cross-section, tables 2, 3, 4, 5 and 6 display the bearing capacity at yielding point - My, the ultimate bearing capacity Mu, the cross-section rotation at yielding point fy, the ultimate rotation fu, the rotation ductility Dϕ and the displacement capacity at yielding point Δy of a corresponding element with length 3.0 m, ultimate displacement Δu and ductility of the element DΔ.

Table 2- Strength-deformability characteristics of RC cross-sections made of concrete MB30

Section	b/d [cm]	P [kN]	My [kNm]	Mu [kNm]	ϕy [x 10 -3]	ϕu [x 10 -3]	Dϕ [ϕu/ϕy]	DΔ [Δu/Δy]
1	40/40	762.	182.	187.	0.098	0.628	6.41	3.03
2	60/60	1724.	524.	535.	0.065	0.340	5.23	3.00
3	80/80	3048.	1304.	1340.	0.049	0.228	4.65	3.07

Table 3- Strength-deformability characteristics of RC cross-sections made of concrete MB50

Section	b/d [cm]	P [kN]	My [kNm]	Mu [kNm]	ϕy [x 10 -3]	ϕu [x 10 -3]	Dϕ [ϕu/ϕy]	DΔ [Δu/Δy]
1	40/40	762.	190.	203.	0.087	0.548	6.30	3.00
2	60/60	1724.	555.	589.	0.058	0.303	5.22	2.99
3	80/80	3048.	1375.	1462.	0.043	0.198	4.60	3.01

Table 4-Strength-deformability characteristics of RC cross-sections made of concrete MB60

Section	b/d [cm]	P [kN]	My [kNm]	Mu [kNm]	ϕy [x 10 -3]	ϕu [x 10 -3]	Dϕ [ϕu/ϕy]	DΔ [Δu/Δy]
1	40/40	762.	194.	213.	0.086	0.541	6.29	2.89
2	60/60	1724.	560.	624.	0.056	0.292	5.21	2.78
3	80/80	3048.	1403.	1549.	0.043	0.194	4.51	2.97

Table 5- Strength-deformability characteristics of RC cross-sections made of concrete MB75

Section	b/d [cm]	P [kN]	My [kNm]	Mu [kNm]	ϕy [x 10 -3]	ϕu [x 10 -3]	Dϕ [ϕu/ϕy]	DΔ [Δu/Δy]
1	40/40	762.	195.	224.	0.083	0.456	5.49	2.70
2	60/60	1724.	572.	660.	0.055	0.239	4.35	2.56
3	80/80	3048.	1414.	1630.	0.041	0.155	3.78	2.55

Table 6- Strength-deformability characteristics of RC cross-sections made of concrete MB90

Section	b/d [cm]	P [kN]	My [kNm]	Mu [kNm]	ϕy [x 10 -3]	ϕu [x 10 -3]	Dϕ [ϕu/ϕy]	DΔ [Δu/Δy]
1	40/40	762.	198.	229.	0.079	0.319	4.04	2.13
2	60/60	1724.	581.	674.	0.052	0.173	3.33	2.07
3	80/80	3048.	1436.	1674.	0.039	0.114	2.92	2.04

Figure 3 shows the results of all the three cross-sections separately, including the moment-rotation diagrams for five different concrete strengths MB30, MB50, MB60, MB75 and MB90.

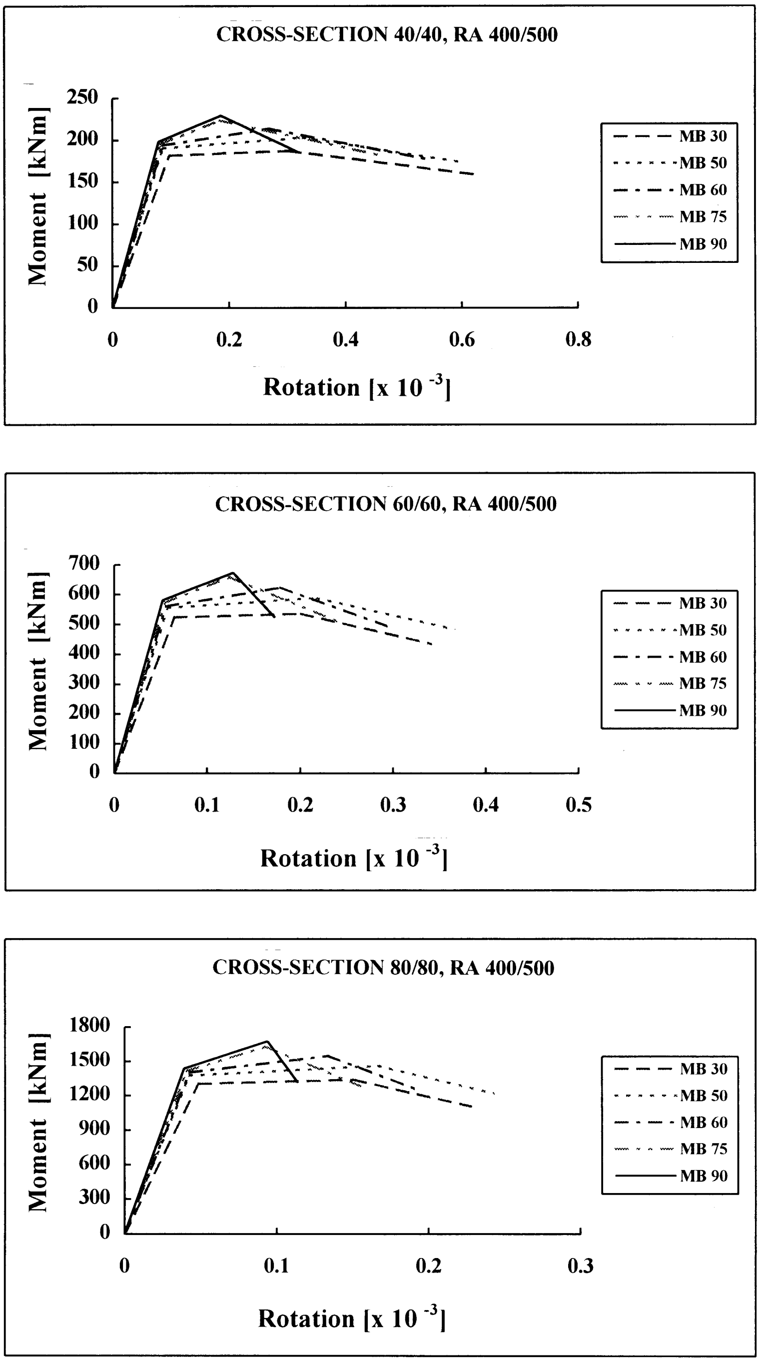

Figure 3. Moment-rotation relationship for differrent cross-section

CONSTRUCTION OF AN OPTIMAL CROSS-SECTION

After each cross-section and element have been analyzed in details, steps were taken to define an optimal cross-section constructed of high strength material that will have similar characteristics to those of a cross-section of larger proportions constructed with MB30 and RA 400/500. For this purpose, for each cross section (40/40, 60/60 and 80/80) defined were the corresponding decreased cross-sections 30/30, 45/45 and 55/55 for MB90 and the same level of axial load. Figure 4 grapchically shows the results from the analysis.

For each cross-section, four curves are given. The first curve is the cross-section (40/40 or 60/60 or 80/80) constructed with MB 30 and RA 400/500 and μv = 1.0% and a corresponding percentage of transverse reinforcement, whereas the curves 2, 3 and 4 present the results on the moments and rotation for MB90, but with different percentage of vertical and transverse reinforcement and different characteristics of reinforcement, tables 7, 8 and 9.

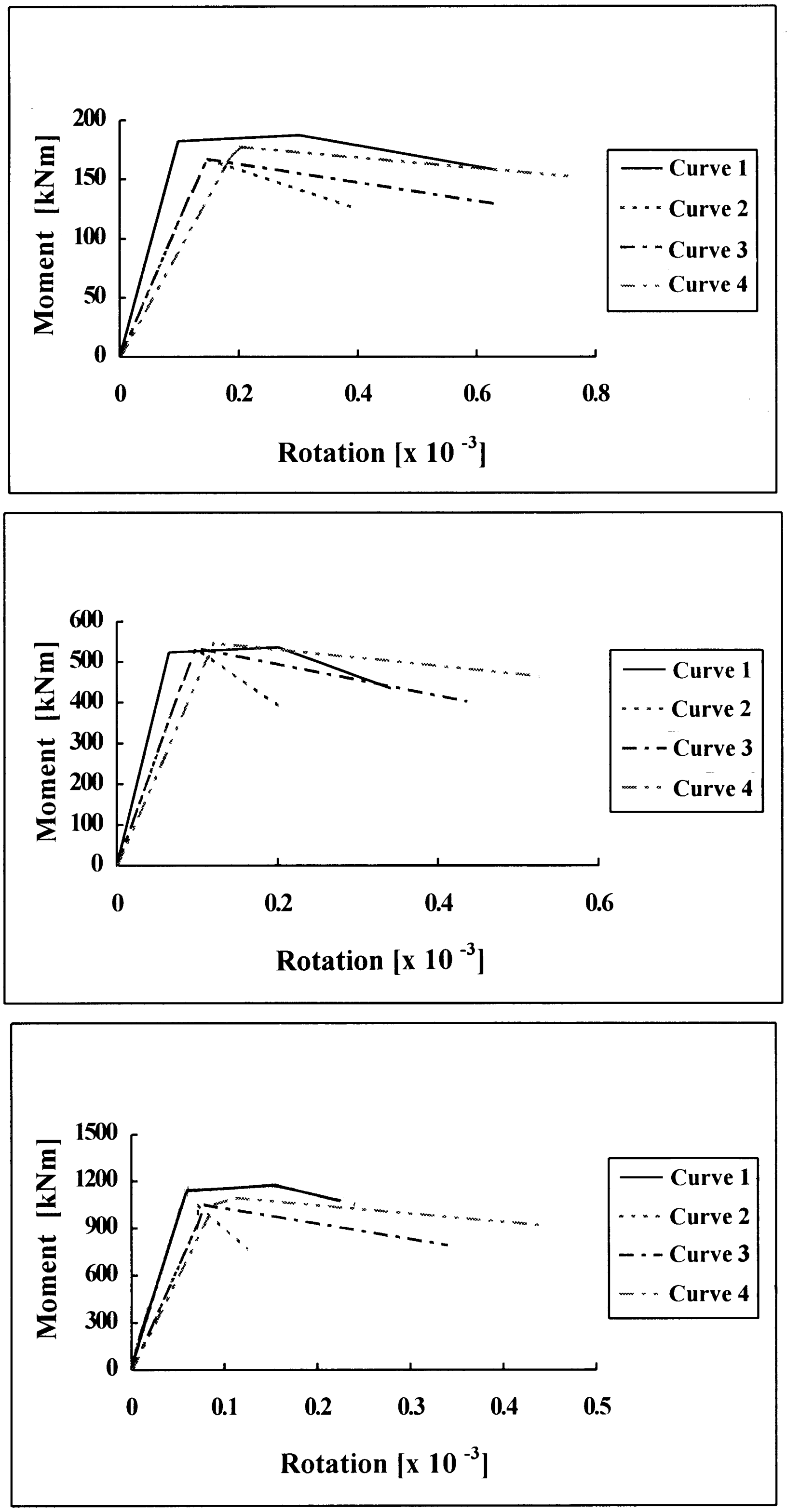

Figure 4. Moment -rotation relationship for comparative analysis of cross-sections

Table 7 - Geometrical and material characteristics for cross-section 40/40cm

	b/d [cm]	MB	Reinforcement	μv [%]	μh [%]
Curve 1	40/40	30	RA 400/500	1.00	0.350
Curve 2	30/30	90	RA 400/500	1.78	0.470
Curve 3	30/30	90	RA 400/500	1.78	0.625
Curve 4	30/30	90	BiA 680/800	0.89	0.625

Table 8 - Geometrical and material characteristics for cross-section 60/60cm

	b/d [cm]	MB	Reinforcement	μv [%]	μh [%]
Curve 1	60/60	30	RA 400/500	0.95	0.230
Curve 2	45/45	90	RA 400/500	1.68	0.310
Curve 3	45/45	90	RA 400/500	1.68	0.560
Curve 4	45/45	90	BiA 680/800	1.10	0.560

Table 9 - Geometrical and material characteristics for cross-section 80/80cm

	b/d [cm]	MB	Reinforcement	μv [%]	μh [%]
Curve 1	80/80	30	RA 400/500	0.95	0.175
Curve 2	55/55	90	RA 400/500	2.01	0.250
Curve 3	55/55	90	RA 400/500	2.01	0.450
Curve 4	55/55	90	BiA 680/800	1.12	0.450

The newly constructed cross-sections are presented in figure 5.

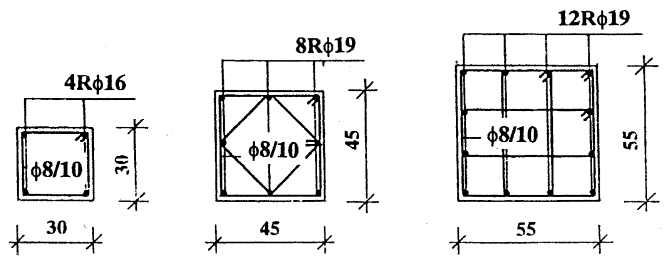

Figure 5. Charactersitics of adopted cross-sections

CONCLUSIONS

Taking into account the results from the investigations, the following conclusions are drawn:

- Cross-sections constructed of the same proportions, the same reinforcement percentage but different concrete strength have different characteristics regarding bearing capacity and deformability. The increase in concrete strength leads to an increased strength, while the rotation capacity, i.e., deformability capacity is decreased and hence is decreased the ductility capacity of the cross-section, i.e., the element. So the rotation ductility capacity of 4.65 for MB30 for cross-section 80/80 drops to 2.92 for MB90, i.e., the displacement ductility of 3.03 drops to 2.04.

- The results presented in Figure 4 show that in the fourth curves presenting the cross-section constructed with MB90 and steel BiA 680/800, the obtained strengths are different from those of the cross-section previously constructed by use of ordinary materials (curve 1) from 2.1 to 10%, while the ductility capacity of the cross-sections is different for 1.5 to 5.7%.

- The results have shown that the application of high-strength concrete in design of modern RC structures is possible only in combination of high-strength steel, whereas the deformability capacity could be provided only by appropriate construction and increase of the percentage of transverse reinforcement.

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