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Problems in Using RCDC for Columns Under Biaxial Bending

by Vasant Kelkar, Ashish Bhangle & Prabhat Pandey

Preamble : Structural engineers are using STAADpro or ETAB for analysis of structures. RCDC is very popular for preparing the RCC drawings and bar bending schedule. Many engineers are using the software without cross checking the results which will be dangerous if there is some bug in some of the versions of software. Some engineers complained about the incorrect results of RCDC for biaxial column design in some of the versions. One such example of column design has been illustrated by Dr. V S Kelkar showing the variation in results with different versions. Structural engineers should not blindly accept the results from any software without validating it .

.... **Editor**

A large number of multistoreyed buildings are being constructed in Mumbai and other cities in India. Columns and shear walls of such buildings are subjected to moments about their major axis mainly due to wind and earthquake loads. They are also subjected to moments about their minor axis due to lateral loads plus minimum eccentricity, slenderness etc. as per IS code. Hence, the columns/walls have to be designed for biaxial bending. For such design and detailing R.C.C. columns and shear walls RCDC software of M/s. S-Cube is very useful and hence is being used by several structural consultants.

When designing columns for compression plus biaxial bending, especially rectangular columns and shear walls having one cross sectional dimension small, it was noticed that reinforcement percentages obtained by RCDC V5 or V6.3a were far too less than those obtained by ETABS and other softwares. However, earlier Version 4 of RCDC did not give such low values of reinforcement percentages. To check this discrepancy and to decide procedure for a safe design of rectangular columns/walls the authors developed their own software for columns with biaxial bending and compared the results with those obtained by other softwares.

Discussions were also held with S-Cube on this subject wherein this discrepancy and the reasons for the same were pointed out to them. But they came out with a new Version 6.3 which gives two options viz: Version 6.3a which apparently still follows same procedure as V5 and Version 6.3b which apparently follows the same procedure as V4. Surprisingly for the same rectangular columns, steel percentages obtained by Version 6.3a are much less than those by Version 6.3b – although they are from two options given in the same software. It is the authors' opinion that results obtained from RCDC V5 and V6.3a especially for shear walls or rectangular columns are apparently incorrect and should be used with caution. This is explained in the following pages.

1) Column is subjected to axial load Pu and moments Mux and Muy about X and Y axis respectively. Refer Fig. 1

   Cl. 39.6 of IS 456 states:
   "The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in 39.1 and 39.2 with neutral axis so chosen as to satisfy the equilibrium of load and moments **about two axes**".

Exact solution of this problem becomes very complex. Hence, code also gives a method wherein max. capacities of Mux with Pu and of Muy with Pu are calculated separately treating each case as of axial load with uniaxial bending moment and then satisfying the interaction formula given in Clause 39.6 of IS 456.

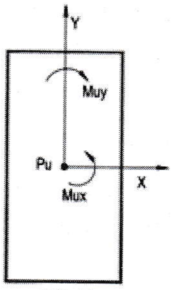

FIG. 1A
COLUMN SUBJECTED TO BIAXIAL BENDING

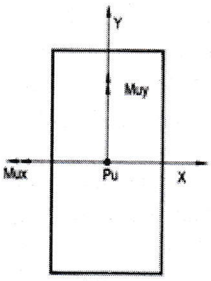

FIG. 1B
VECTOR REPRESENTATION OF Mux, Muy

2) In RCDC Version 4 apparently this interaction formula procedure of code is followed to design columns with biaxial bending.

RCDC Version 6.3 gives in 'Design Settings' under 'Design methods" two alternatives for design:

a) Resultant M (combined action)
b) Interaction Principle (Discrete action)

Version 6.3 b) apparently considers uniaxial moment capacities in each direction and then uses interaction formula of IS code – a procedure similar to V4.

Version 6.3 a) apparently considers resultant of both moments to obtain exact solution.

3) For exact solution of column with biaxial moments the following procedure satisfying equilibrium of axial forces and moments about the two axes, can be followed:

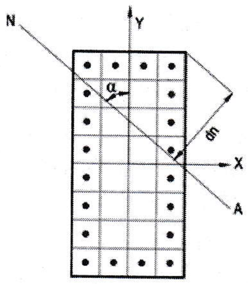

FIG. 2
DIVISION OF COLUMN SECTION INTO ELEMENTS (OR STRIPS)

a) The column section is divided into a no. of strips or elements each of area ΔAi. Refer Fig. 2

b) Under Pu, Mux, Muy, angle 'α' of inclination of N.A. and its depth 'dn' are unknown.

c) Steel percentage 'pt' is assumed and corresponding bar areas calculated – for bars on two or four faces.

d) Then for assumed 'pt', various values angle 'α', and N. A. depth 'dn', values of strains and hence internal stresses σ_i in each element and bar are determined in each case and corresponding capacity Pu, Mux, Muy calculated from the equilibrium equations:

$$Pu - \sum(\sigma_i)(\Delta Ai) = 0$$
$$Mux - \sum(\sigma_i)(\Delta Ai)(Yi) = 0$$
$$Muy - \sum(\sigma_i)(\Delta Ai)(Xi) = 0$$

This is repeated for various values of 'dn' and then of 'α' and then of 'pt'.

e) The lowest steel percentage 'pt' for which the above equations are satisfied gives the correct solution.
This procedure is used in our own software program 1 and also in ETABS.

4) Instead of the above procedure, RCDC Version 5 and version 6.3 a) apparently consider the resultant of the moments Mux and Muy. This resultant moment Muy_1 is about Y_1 axis where Y_1 makes an angle 'Θ' with Y axis. Refer Fig. 3. Moment Mux_1 about X_1 axis is obviously zero. The problem is then considered as of a column subjected to Pu and a uniaxial moment Muy1.

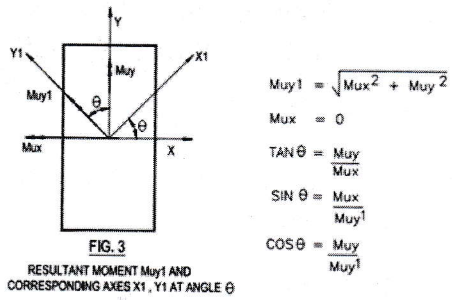

FIG. 3
RESULTANT MOMENT Muy1 AND CORRESPONDING AXES X1, Y1 AT ANGLE θ

For various assumed values of 'pt', various depths 'dn' of N. A. (Parallel to Y_1) are considered and for each case strains and internal stresses in concrete and reinforcement are calculated in each element or strip. Refer Fig. 4.

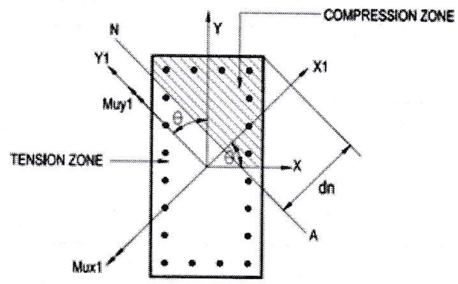

FIG. 4
ASSUMED N.A POSITION AND COMPRESSION / TENSION ZONES

Final location of NA is taken as the one, which satisfies the following equilibrium equations of internal and external forces for the lowest 'pt' value.

$$Pu - \Sigma(\sigma i)(\Delta A_i) = 0 \quad ...1$$
$$Muy_1 - \Sigma(\sigma i)(\Delta A_i)(X_{1i}) = 0 \quad ...2$$

The third equilibrium equation of moments about X1 axis viz:

$$Mux_1 - \Sigma(\sigma i)(\Delta A_i)(Y_{1i}) = 0 \quad ...3$$

is not checked at all – although it should be also satisfied.

5) It is obvious that internal stresses in concrete and steel will also give non zero moment about X_1 axis = $\Sigma(\sigma_i)(\Delta A_i)(Y_{1i})$

Hence, the solution obtained is valid only if an external moment Mux_1 is also present along with Pu and Muy1, to satisfy equilibrium with moments of internal stresses about X_1 axis.

Thus, the solution obtained by satisfying only two equilibrium equations is actually for external loads Pu, Muy1 and Mux1.

Mux1 direction will be generally as shown in the figure. Then resolving Muy_1 and Mux_1 back to X and Y axis we get

$Muxa = Muy_1 \sin\Theta + Mux_1 \cos\Theta = Mux + Mux_1 \cos\Theta$
and $Muya = Muy_1 \cos\Theta - Mux_1 \sin\Theta = Muy - Mux_1 \sin\Theta$

The first two terms in the above equations are the original design moments Mux and Muy. But the solution obtained is for these moments plus components of Mux_1. It is seen from the above equations that these components increase original Mux but decrease original Muy.

Increase in Mux does not give much higher steel since it is about the major axis of column.

But decrease in moment Muy (which is about the minor axis) reduces steel significantly in rectangular columns and walls.

Thus, solution by RCDC version 5 or 6.3 a) for columns/walls is actually for a slightly higher Mux and much smaller value of Muy and not for given Mux and Muy. This results in substantial reduction of required steel.

6) We ourselves developed a software for columns with biaxial bending by using the exact method above satisfying all three equations of equilibrium (called Program 1) and checked the required reinforcement percentage. We also checked the reinforcement with our own earlier software which is based on interaction formula of IS456 (called Program 2). Given below are reinforcement required for walls of size 1800 x 250 mm, with M30 grade concrete obtained with various softwares.

In all the four examples considered, Pu and Mux were kept the same while Muy was varied. In calculations with ETABS and RCDC the additional moments due to minimum eccentricity and slenderness were not included for comparison with results of other softwares. Reinforcement was considered to be equally placed on two long faces of the column cross section.

Column	Pu KN	Mux KNM	Muy KNM	Required Reinforcement %								STAAD Pro With RDACE 3 option*
				Etabs		RCDC V4	RCDC V5	RCDC V6.3a	RCDC V6.3b	Our Own Program		
				UFL 0.95	UFL 1.0					Program 1	Program 2	
C1	3000	1500	0	0.8 (min)	0.8 (min)	0.34	0.34	0.34	0.34	0.29	0.275	0.65
C2	3000	1500	100	1.07	0.88	0.83	0.34	0.34	0.83	0.86	0.85	0.85
C3	3000	1500	200	2.14	1.89	1.84	0.34	0.34	1.64	1.81	1.7	1.8
C4	3000	1500	300	3.09	2.85	3.19	0.36	0.36	2.88	2.61	2.65	2.9

* STAAD Pro results – Courtesy Mr. Hemant Vadalkar

Notes: Methodology used in the above softwares

- **Our Program 1 and Etabs** – Uses inclined N.A. and satisfies 3 equilibrium equations as per first alternative of Cl. 39.6 of IS456
- **RCDC V4, V6.3b and our Program 2** – Uses the 2nd approximate alternative of Cl.39.6 of IS456 calculating uniaxial capacities separately in two directions and using the interaction formula of code.
- **RCDC V5 and V6.3a** – Apparently considers uniaxial bending in the direction of resultant moment and satisfies only two equilibrium equations.
- The results of ETABS were also obtained considering Utilization Factor Limit (UFL) = 1.0 for comparison with results of other softwares. Otherwise ETABS considers this factor by default = 0.95 (i.e. it restricts ratio of required capacity to actual capacity to max. 0.95) which results in somewhat higher percentage of steel as seen in table above.
- ETABS gives min. steel as 0.8% irrespective of actual required steel. Hence, ETABS results for C1 show higher steel.

It is seen that reinforcement obtained in our Programs 1 & 2, RCDC V4, and RCDC V6.3b are similar while those obtained by RCDC V5 and RCDC V6.3a are substantially less. This difference is much higher when moment about weak axis Muy is higher for reasons mentioned in 5) above.

Results of ETABS with UFL = 1.0 also match very well with those of our programs 1 and 2, RCDC V4, V 6.3b. ETABS on its own restricts UFL to 0.95 which is not a requirement of IS code and hence shows somewhat higher steel in that case.

Even steel obtained from RCDC V6.3a is much less than that from RCDC V6.3b. How can two alternative options of solution given in Version 6.3 give such completely different results? The reason is obviously as discussed above that RCDC V6.3a (and also V5) apparently gives reinforcement for Pu + a slightly bigger value of Mux + much reduced value of Muy and not for Pu + Mux + Muy and this gives much less steel especially where one dimension of column cross section is small as in shear walls and rectangular columns.

Hence, in our opinion reinforcement obtained from RCDC V5, RCDC V6.3a, is substantially lower than actually required and if so provided can make the column/wall unsafe and hence should be used with caution

NOTE:

Recently version 7.0 of RCDC has been released which also has two options V7.0a and V7.0b similar to the two options V6.3a and V6.3b. They give similar results as those of V6.3a and V6.3b in the above table. So there will be no change in the results and conclusions discussed above even when V7.0 is used.

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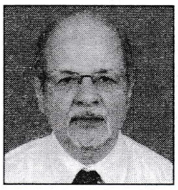

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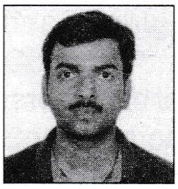

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