

## Ductile design, strong columns

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**Abstract:** In a lot of cases in the structural design for civil structures, the architectural design gives the shape of the structure. The same case is when the structure has the circular columns with frames on both directions. We are in a seismic zone, where are necessary to analyze the structure having a ductile design and the structure shall provide an adequate energy dissipation capacity. The structure must respect the conditions from P100-2006 Norm, point 5.2.3.3.2, for a ductile behavior.

**Keywords:** ductile, energy dissipation, circular columns, moment capacity.

### I. INTRODUCTION

In many cases, the architectural design gives the shape of the structure for civil buildings. In this case for a building with 5 levels, having commercial space at ground floor, the architectural design gives the section of the columns, which are circular. This case it's happened also for civil building having parking area at ground floor or at the underground floors. It is known that the circular shape of the columns is not very liked by the structural engineer, because it has less advantages than rectangular columns.

Because of the seismic zone, it is really necessary to have a ductile behavior of the structure. From this reason the frame nodes must respect the condition from the P100-2006 Norm, point 5.2.3.3.2, which is

$$\sum M_{Rc} \geq \gamma_{RD} \cdot \sum M_{Rb}$$

The  $\gamma_{RD}$  is the high resistance factor, which is equal to 1.3 for the high ductile buildings, and 1.2 for medium ductile buildings.

To have this behavior of the structure it is necessary to compute the Moment capacity for beams and columns. After that, for each node it's necessary to verify the condition. There are more methods to do this:

One is to make static calculation (with a software like ETABS), to obtain the forces and then to design the reinforcement from beams and columns. The condition for ductile behavior will be made by

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computing for each node the moment capacity, using formulas and tables.

Another method is to use computer software for static calculation and also for the moment capacity, such as BetonExpress which we have in our company.

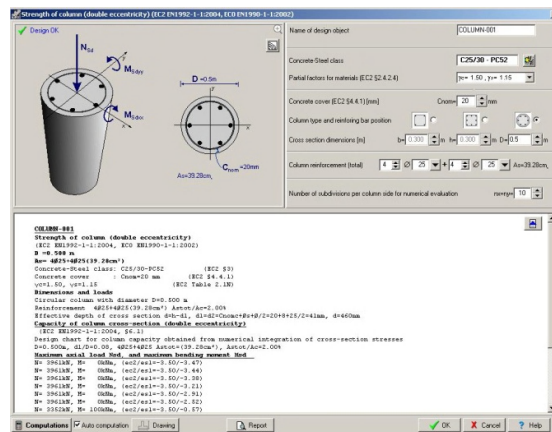


Fig.1.1 Moment capacity – in BetonExpress

The condition will be established using formulas for each node and compare to the factor  $\gamma_{RD}$ .

Also, a ductile design can be done, by using Etabs software, which offers important facilities for a simplified calculation. It has to follow the next few steps to analyze the model: a) define the structural model; b) calculation of moment capacity; c) “pushing” the structure until we will obtain the values of the asking strains; d) verifying the plastic hinge; In this case it will be a pushover analysis.

Another method, which will be developed in this technical paper, is to use proper software, what will determine the ductile behavior using the resistance factor, of a structure.

It is known that for each floor, the columns capacity it's decreasing with height and it's necessary to have strong columns and weak beams for each level.

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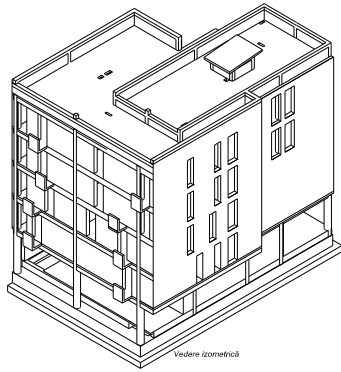


Fig.1.2 Isometric view of structure

## II. MODEL ANALYSIS

The model which has been used is of a structure of 5 levels, located in Timisoara. City of Timisoara is in seismic zone having ground acceleration  $a_g=0.16g$ ,  $T_c=0.7\text{sec}$ .

The plan view of the structure is shown in the next figure:

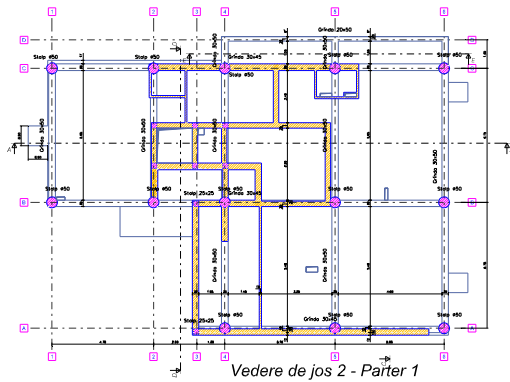


Fig.2.1 Plan view of the structure

The column, as shown, has 50cm in diameter, and the beams are 30x50cm on y direction and 30x45 cm by x direction. The plate has a thickness of 15cm. The foundation is beams network, in a shape of rotate T. First time the structure has been compute with Etabs software, to determine the forces in columns and beams. The elements have been designed to these forces. This software was also used for control the software which was used to analyze the ductile behavior.

For the ductile behavior, we used software named MidasGen 2010, developed by a Korean company, which had implements the ECs. The model has been drawn in AutoCAD 3d, and imported as dxf file in MidasGen. The sections of frame elements has been input in the program, also the material was given. Seismic properties have been given, and the structure was loaded with dead and live loads. Midas software has included EC8 Response Spectrum Function. Next figure shows us how looks the window with RSP function:

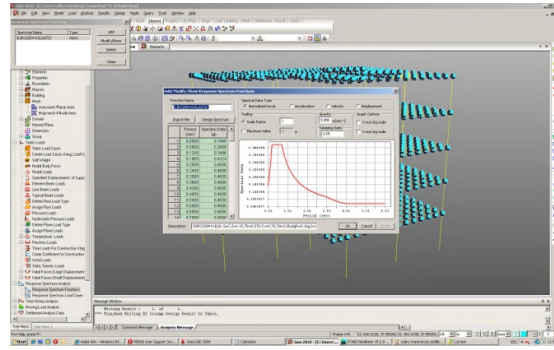


Fig.2.2 EC8 RSP Function

The structure was meshed by auto function using triangle and quadrics elements. The combinations have been given by software based on EC0 Norm.

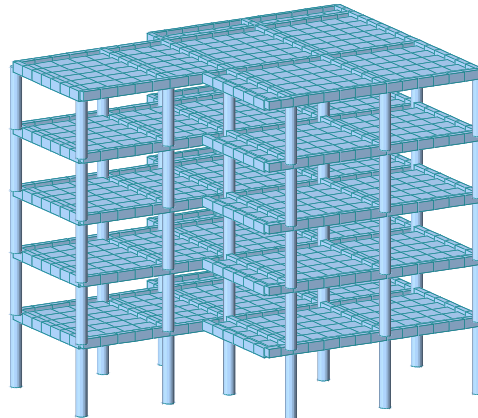


Fig.2.3. 3D Model View

Using this software we'll obtain results as deformations, forces, stresses, which are usual for this kind of software. We present in the following picture some of them:

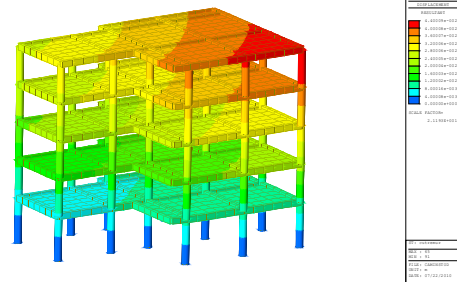


Fig.2.4. Seismic strains

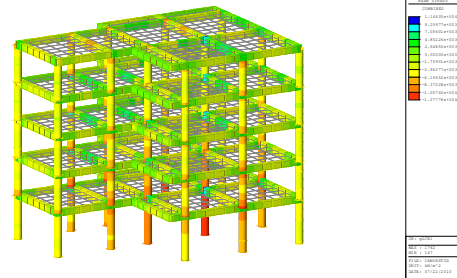


Fig.2.5. SLU Eqv Stress

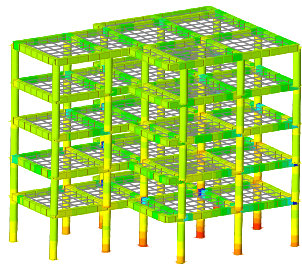


Fig.2.6. SLS Eqv Stress

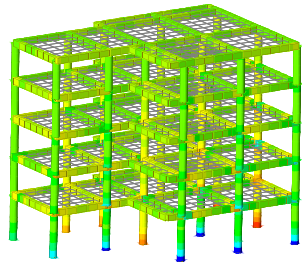


Fig.2.7. Eqv Stress for quake loads

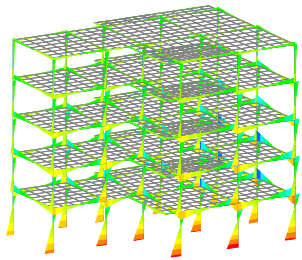


Fig.2.8. Moments diagrams for quake loads

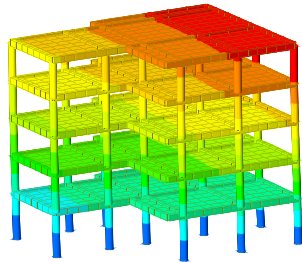


Fig.2.9. Mode 1 of vibration

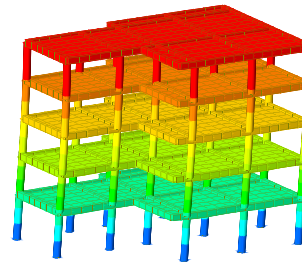


Fig.2.10. Mode 2 of vibration

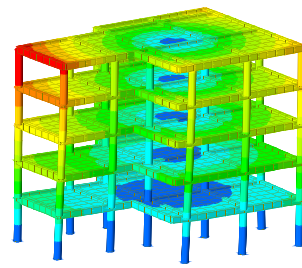


Fig.2.11. Mode 3 of vibration

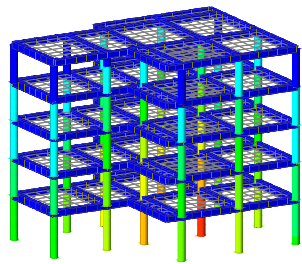


Fig.2.12. Mode 3 of vibration



The most useful part its start from here. You can design beams and columns, having a window in which can control the number of reinforcement and diameter of them, the cover concrete and the stirrups. The beams and columns can be checked, but also can be made a ductile design. Next figure will show the resistance factor on both directions on the middle frame, for the columns with 5 bars of 25mm.

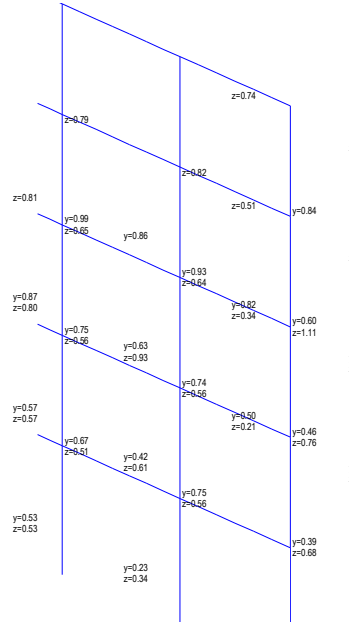


Fig.2.13. Middle transversal frame -  $\gamma_{RD}$  factor

It can be seen that the  $\gamma_{RD}$  factor it's under the value of 1.3, which means that the structure doesn't have a ductile behavior. In this case, the reinforcement column must be increased. After increasing the reinforcement to 10Ø25, the columns must be checked, but first you have to design or checked the reinforcement, this is necessary to do before the ductile design. We checked the columns with this reinforcement and we found that the column it's OK, looking also to the interaction curve, like in the next figure:

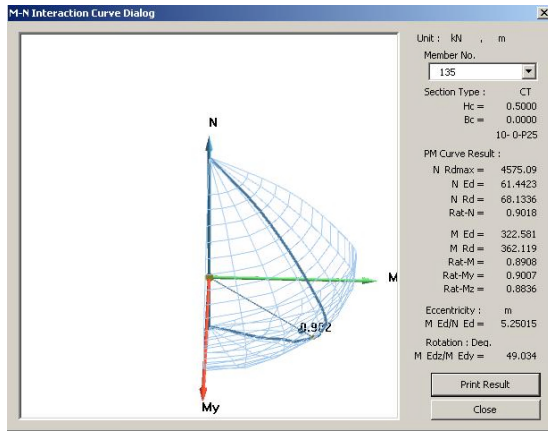


Fig.2.14. Interaction curve

To control this value, to be sure if the results are good, we will compare with Etabs. We checked the same column and the result is appropriate (90%-97%). We verified also the column section with 10Ø25 bars, for the stresses in reinforcement, which are different in a circular section. Fig. 2.13

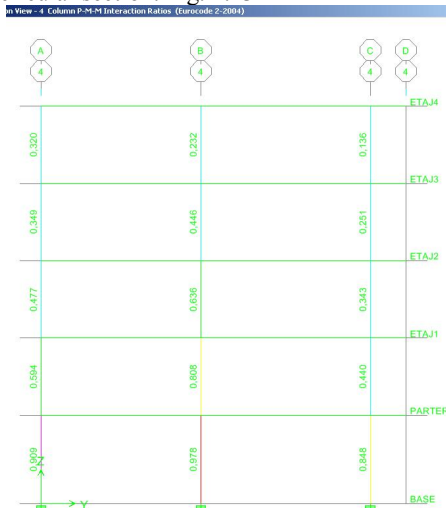


Fig.2.15. Columns checked by Etabs

After the ductile design, the beams have been checked, the columns have been also checked, and for the transversal frame we found that the  $\gamma_{RD}$  factor is greater than 1.3

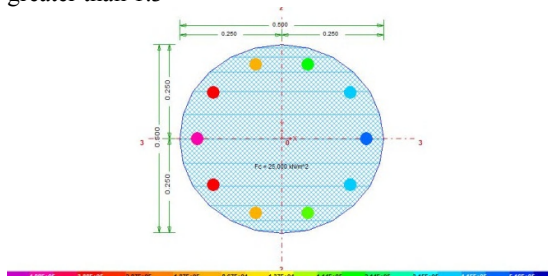


Fig.2.16. Column section and reinforcements checked

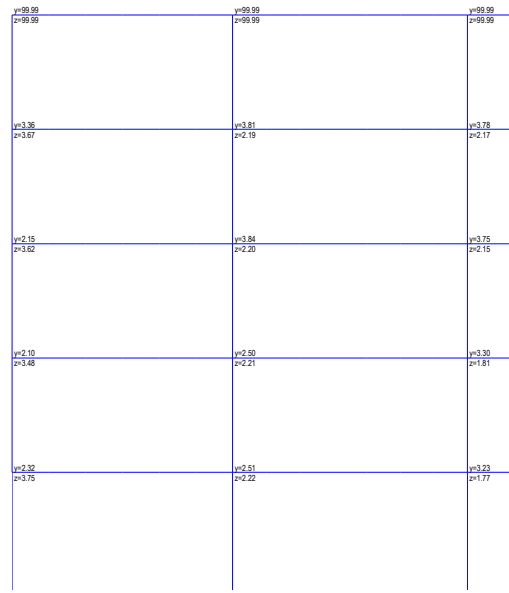


Fig.2.17. Middle transversal frame -  $\gamma_{RD}$  factor

In the upper figure, it's shown the  $\gamma_{RD}$  factor, which is greater than 1.3. The minimum value is 1.77 > 1.3. The resistance factor can be controlled by the user, modifying the value. So, if you need a medium ductile structure you can put another value of the factor.

### III. CONCLUSIONS

After this analyses and comparing these two types of software, we can conclude: that, to a structure where the moment capacity, and the node verification takes time, using different methods, calculating with formulas and tables, also using design software, but which need a different types of analyze, it's more easy to adopt such analysis presented in this paper, which will helps you to do from the first time a ductile design to a structure. Verifying each node to establish the resistance factor, takes time, but in this case it's easy to control the factor and you can also optimize the structure using beams and columns design (or check) together with ductile design, after which, the behavior of the structure is ductile. In the same time it is necessary to have a hand calculation, to compare the results, in case of being a new user of the software.

### V. REFERENCES

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