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The Influence of the Conformation and Arrangement of the Structural Walls on the Seismic Response of the Dual Structures

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Abstract – **In practice, dual structural systems are frequently encountered, consisting of structural walls and reinforced concrete frames. The main problem when designing dual systems is to correctly notice the contribution of each component.**

As structural engineers, we can control and improve the behaviour of constructions subject to seismic action by the way we design, conform and realize the structural system. This is also the objective of the present paper, namely, the analysis of the influence of the conformation and arrangement of the structural walls on the seismic response of buildings with a dual structural system.

Keywords – dual structures, seismic response, structural walls

1. INTRODUCTION

The entire territory of Romania is exposed to a significant seismic hazard. The notable particularity is the long period of ground oscillations, embodied in a large value of the corner period Tc from the spectrum of the seismic acceleration response.

The anti-seismic design performance is directly related to the level of the design codes. The most recent codes for the design of buildings in our country are: P100-1/2013 [3], for seismic design of buildings and CR 2-1-1.1/2013 [1], design for constructions with reinforced concrete structural walls, and less complete for dual structural systems design.

Predicting the seismic response of structures to future earthquakes contains a large dose of uncertainty, a fact due primarily to the impossibility of accurately knowing the characteristics of future earthquakes, and secondly to the simplifying assumptions used to calculate the structural response. That is why it is very important to have a good conceptual design of the structures located in seismic areas, which ensures a suitable seismic behaviour.

2. CASE STUDY. ANALYSIS OF THE DUAL STRUCTURES WITH DIFFERENT CONFORMATIONS

The structure that is the object of the case study has the ground floor and eight floors, with a level height of 3.00m. In plan, the structure has a rectangular shape, with seven 6.00m spans and five 6.00m openings. The location of the structure was made in the Bucharest city area, characterized by an acceleration of the ground for design ag=0.30g for seismic events with an average recurrence interval of 225 years, according to the Seismic Design Code P100-1/2013 [1] and a ground corner period Tc=1.60s. The present case study aims to analyse the influence of the conformation and arrangement of the structural walls on the seismic response of buildings with a dual structural system.

For this purpose, the following characteristics will be analysed:

- the structure's own dynamic characteristics;

-verification of relative level displacements (drifts);

-the percentage of taking over the shear force of the frame subsystem and the wall subsystem on each individual level.

The case study started from the analysis of a classical system in reinforced concrete frames. The structure was entered into the finite element analysis program ETABS. Following pre-dimensioning, a square section of 65x65cm was obtained for the central pillars, and a section of 55x55cm for the marginal and corner pillars. For the beams, a section of 30x60cm was obtained, both for the transverse and for the longitudinal direction, and the thickness of the slab was established at 15cm.

Analysing the obtained results, a large fundamental period of the building (0.975s) is found, resulting in large displacements that exceed the admissible values.

Given the fact that the structure in reinforced concrete frames proved to be much too flexible, far exceeding the values of admissible displacements, it was stiffened by adding structural walls along the contour, turning it into a dual structure.

For the analysis, three variants of different conformation were proposed by changing the position of the structural walls, their arrangement in the plan.

The dual structure, named variant B1 (Figure 1), will take over the geometry of the structure in frames and will be stiffened by adding walls with a length of 3.00m interaxial, on the contour.

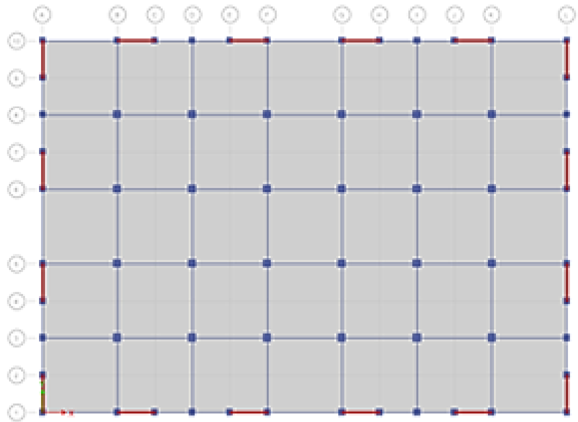

Fig. 1 Plan view of dual structure - B1

It can be observed that following the changes made, the dual structure has a favourable response to seismic action, a fact due to the respect of fundamental design principles/concepts such as regular sections in the plan, symmetry, resistance and torsional stiffness. A significant decrease in the fundamental period of the structure is noted (Table 1), as a result of the addition of structural walls on the contour. The influence of the structural walls on the lateral stiffness of the construction was also analysed, quantified by the relative level displacement (Figure 2).

As can be seen, the choice of introducing the structural walls that stiffened the structure also led to the verification of displacements, the drift falling below the admissible limit.

Table. 1 The magnitudes of the dual structure vibration modes - B1

Mode	Period (s)	UX	UY	Sum UX	Sum UY	RZ	Sum RZ
1	0.628	0	0.7472	0	0.7472	0	0
2	0.611	0.7515	0	0.7515	0.7472	0	0
3	0.444	0	0	0.7515	0.7472	0.7366	0.7366
4	0.179	0	0.1413	0.7515	0.8884	0	0.7366
5	0.176	0.138	0	0.8895	0.8884	0	0.7366
6	0.123	0	0	0.8895	0.8884	0.1492	0.8858
7	0.088	0	0.0559	0.8895	0.9444	0	0.8858
8	0.087	0.0553	0	0.9448	0.9444	0	0.8858
9	0.06	0	0	0.9448	0.9444	0.0586	0.9445
10	0.055	0	0.0267	0.9448	0.9711	0	0.9445

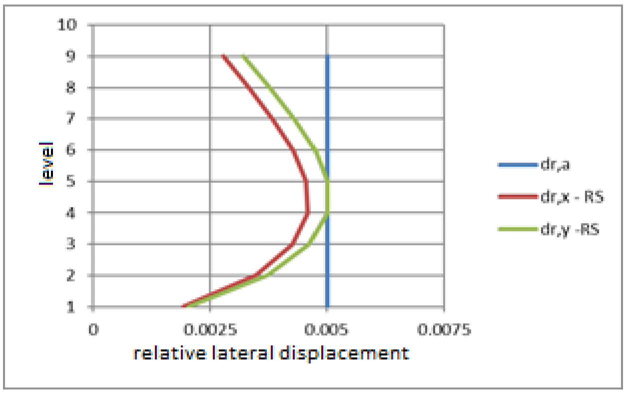

Fig. 2 Comparative graph: relative level displacement and admissible displacement (SLS)

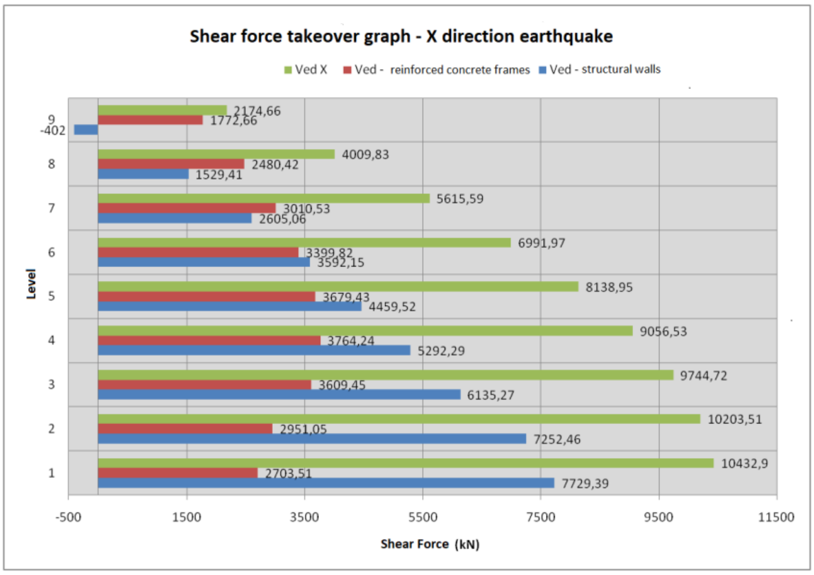

Fig. 3 Comparative graph of shear force takeover by the wall subsystem and the frame subsystem in the longitudinal direction – structure B1

Another important characteristic is the verification of the percentage of taking over the shear force of the frame subsystem and the wall subsystem on each individual level.

The graph presented above (Figure 3) describes how the cutting force is taken over by the two subsystems, walls and frames. Percentage wise, walls subsystem is responsible for taking over 74% of the shear force at the base of the structure, the frames remaining with 26%. The high percentage of taking over the shear force, over 50%, is maintained until level 6, from where frames become predominant.

After the analysis, it was observed (Figure2) that the structure is more flexible in the transverse direction than in the longitudinal direction, a fact that we will try to remedy through a new proposal for the positioning of the structural walls, another conformation of the dual structure, called variant B2.

Next, we will turn our attention to the modification of the conformation of the structural walls. The dual structure B2 kept from the B1 structure the conformation of the internal frames and on the contour, and the walls on the contour will be two on each side of the building instead of four, but having double length, that is, it has a length of 6.00m interax. Also, due to the fact that the transverse direction of the structure is more flexible, the central pillars of 65x65cm will become 60x70cm, and will be oriented with the long side parallel to the transverse direction of the building increasing the moment of inertia (Figure 4). The results for the new conformation of the structure will be extracted and analysed, observing what influence they will have on the seismic response.

We observe from the presented figures and graphs, a series of changes in the response of the structure. The first of them is the decrease of the fundamental period (Table 2) and in the comparative graph presented below (Figure 5) it can be seen how the lines defining the movements in the two directions are almost overlapping, a fact that indicates an almost identical behaviour on the two directions, behaviour recommended by the design code.

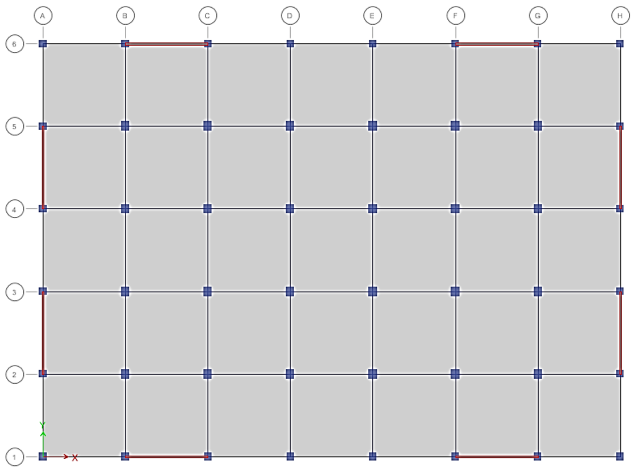

Fig. 4 Plan view of dual structure – B2

It should also be mentioned that the improvement of the overall response of the structure was achieved only by changes in the geometry and orientation of the vertical structural elements.

Particular attention was also paid to the percentage of shear force take over (Figure 6) of the frame subsystem and the wall subsystem in order to capture the influence of the changes made and to make a comparison with the results of the previous structure.

Table. 2 The magnitudes of the dual structure vibration modes – B2

Mode	Period (s)	UX	UY	Sum UX	Sum UY	RZ	Sum RZ
1	0.613	0.7267	0	0.7267	0	0	0
2	0.608	0	0.7272	0.7267	0.7272	0	0
3	0.438	0	0	0.7267	0.7272	0.7107	0.7107
4	0.165	0.1707	0	0.8973	0.7272	0	0.7107
5	0.164	0	0.1695	0.8973	0.8968	0	0.7107
6	0.111	0	0	0.8973	0.8968	0.1849	0.8956
7	0.08	0.055	0	0.9524	0.8968	0	0.8956
8	0.08	0	0.0549	0.9524	0.9516	0	0.8956
9	0.053	0	0	0.9524	0.9516	0.0575	0.9531
10	0.052	0.0233	0	0.9757	0.9516	0	0.9531

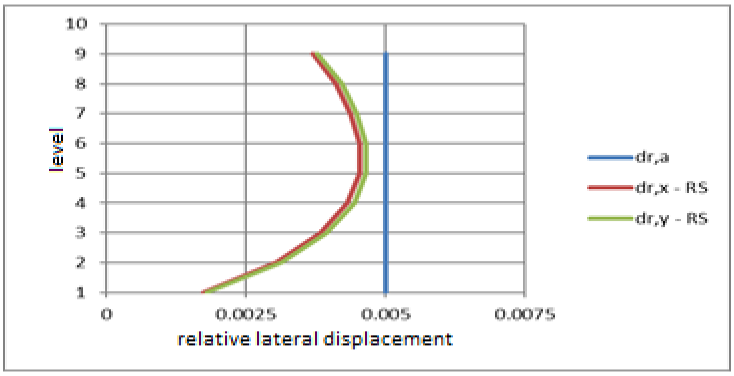

Fig. 5 Comparative graph: relative level displacement and admissible displacement (SLS)

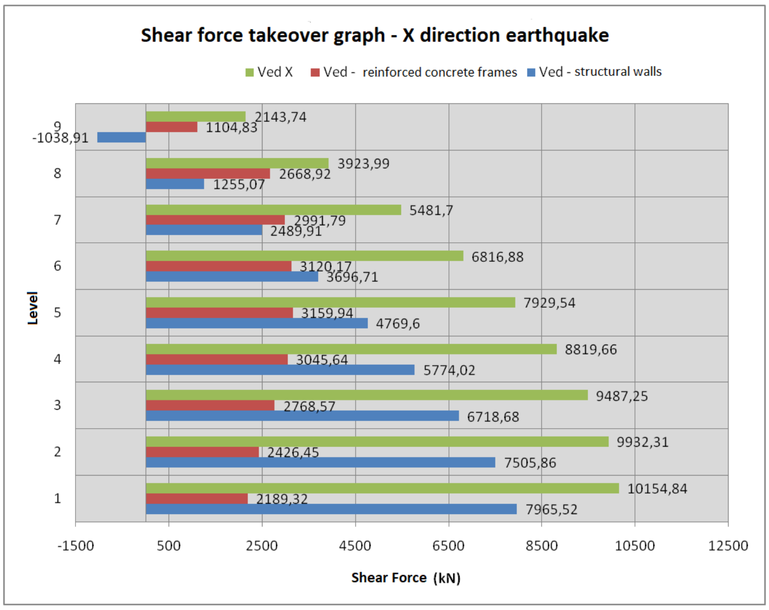

Fig. 6 Comparative graph of shear force takeover by the wall subsystem and the frame subsystem in the longitudinal direction – structure B2

Making a comparison between the dual structures B1 and B2, both having the same area of the walls in the plane, a slight increase of the walls in taking over the shear force is observed, especially at the first level of the structure, and frame subsystem starts to take over 50% of the shear force only at level 7.

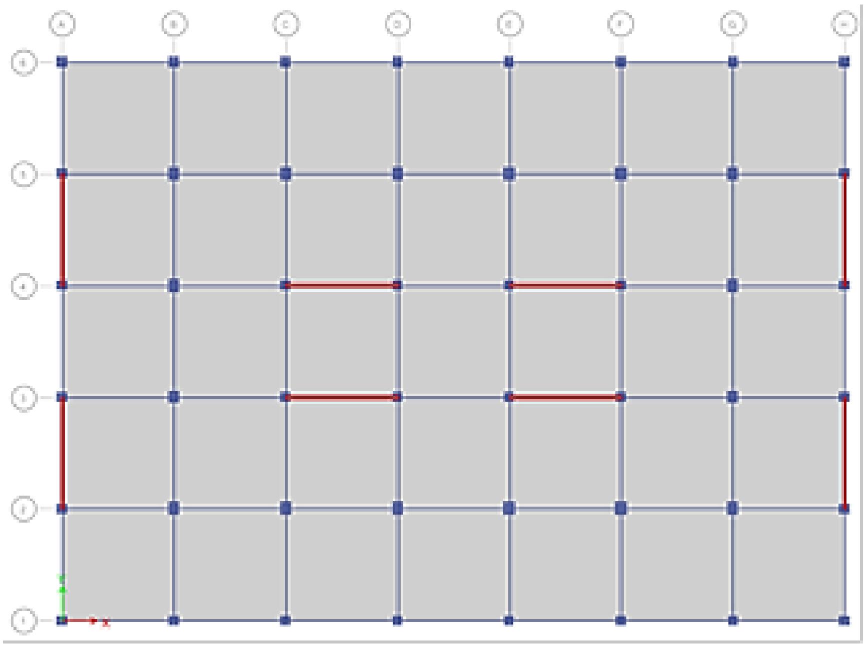

Fig. 7 Plan view of dual structure – B3

Next, we analysed a new dual structure, B3, and analysed the effect of translating the walls from the contour to the center of rigidity.

It is observed that the changes in the position of the walls towards the inside (toward the neutral axis) have an unfavorable effect, leading to a decrease in rigidity in the transverse direction, the displacements reaching close to the limit allowed by the standard (0.0487 < 0.005 - SLS). (Figure 8)

Table. 3. The magnitudes of the dual structure vibration modes – B3

Mode	Period (s)	UX	UY	Sum UX	Sum UY	RZ	Sum RZ
1	0.609	0	0.7258	0	0.7258	0	0
2	0.604	0.7281	0	0.7281	0.7258	0	0
3	0.489	0	0	0.7281	0.7258	0.7186	0.7186
4	0.163	0	0.1712	0.7281	0.897	0	0.7186
5	0.163	0.1696	0	0.8977	0.897	0	0.7186
6	0.128	0	0	0.8977	0.897	0.1784	0.897
7	0.08	0.055	0	0.9527	0.897	0	0.897
8	0.079	0	0.055	0.9527	0.9521	0	0.897
9	0.062	0	0	0.9527	0.9521	0.0564	0.9534
10	0.052	0.0233	0	0.976	0.9521	0	0.9534

All three dual structures brought improvements to the initial conformation, but the best structural response was obtained for structure B2, with walls of 6.00m interaxial length, arranged on the contour of the building, as far as possible from the neutral axis.

It has been demonstrated that by using the same volume of concrete, by judiciously positioning and conforming the elements, the behaviour of the structure during seismic action can be improved.

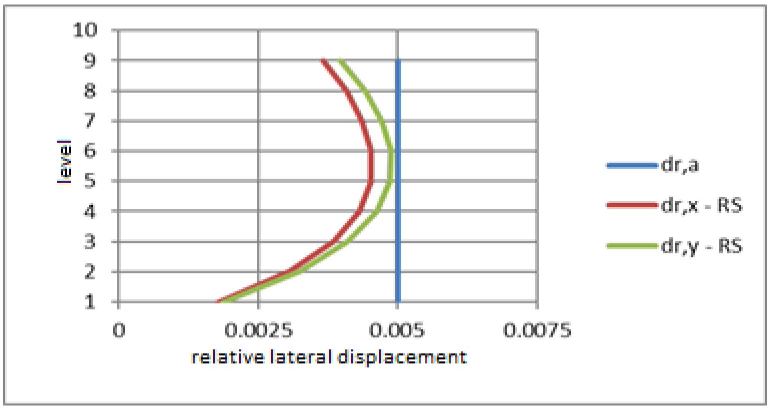

Fig. 8 Comparative graph: relative level displacement and admissible displacement (SLS)

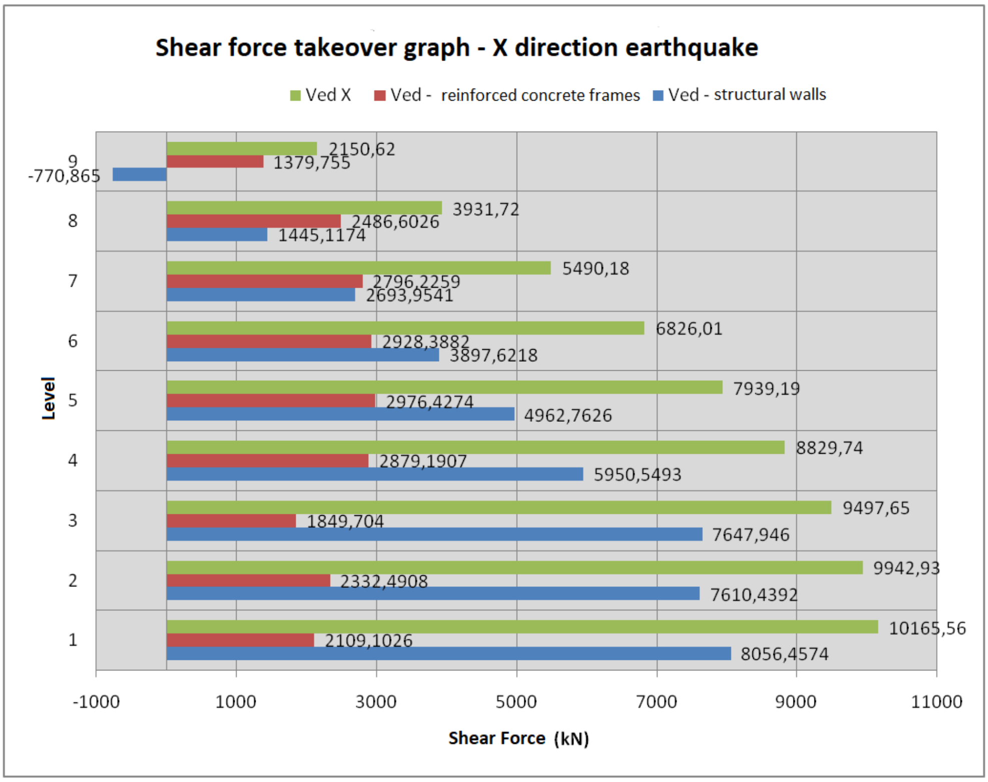

Fig. 9 Comparative graph of shear force takeover by the wall subsystem and the frame subsystem in the longitudinal direction – structure B3

3. CONCLUSIONS

As a general conclusion of the case study, we can point out the fact that the behaviour of the dual structures is greatly influenced by the orientation and arrangement of the walls section in plan and not necessarily by their total area. This could be seen from the analysis of the results of the three dual structures studied, where the improvement of the structure's behaviour was observed only from changes in the conformation and arrangement of the structural walls, without any change in the volume of concrete.

Therefore, the seismic response of a structure can be greatly improved from the design phase, if the design engineer gives the necessary time to the conformation and the most advantageous arrangement of the resistance elements of the structure, obtaining a structure with an optimal behaviour.

4. REFERENCES

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