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Analysis of Areas with High Stress Concentrations in Mixed Structures

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Abstract **- This paper analyses the influence of structural conformation on the behaviour of mixed structures. Mixed structures made of load-bearing masonry and reinforced concrete frames are often found as a structural solution, both in Romania and abroad. The mixed structural system can be used for civil, industrial or agricultural constructions. Such a structural solution is frequently reached due to the need to have larger free spaces from an architectural point of view. In principle, mixed structures combine the advantages of load-bearing masonry structures and the advantages of frame structures, but in the design of these structures, great attention must be paid to the conformation of the structure and especially in the areas of interaction between the load-bearing masonry and the frame structure.**

Keywords – load-bearing masonry, mixed structures, reinforced concrete frames, structural response

1. INTRODUCTION

Mixed structures originate from load-bearing masonry structures, but due to the need for larger free spaces, the load-bearing masonry is replaced in some places inside with reinforced concrete frames.

Generally, in practice, mixed structures with load-bearing masonry walls on the exterior contour of the building and reinforced concrete frames inside the building are used in order to have large rooms, but mixed structures with load-bearing masonry walls on the interior and reinforced concrete frames on the exterior can also be created.

The correct integration of the two structural systems requires expertise in structural engineering, and the structural analysis of their behaviour under seismic conditions can be complex.

Mixed structures combine the advantages of load-bearing masonry structures and the advantages of frame structures, but in the design of these structures, great attention must be paid to the conformation of the structure and especially to the areas of interaction between the load-bearing masonry and the frame structure.

The objective of this work is to study the behaviour of mixed structures and to analyse the areas with high stress concentrations resulting from the interaction of the two structural systems.

2. ANALYSIS OF INTERACTION AREAS BETWEEN LOAD-BEARING MASONRY AND REINFORCED CONCRETE FRAMES OF MIXED STRUCTURES

The objective is to determine the behaviour of mixed structures made of load-bearing masonry and reinforced concrete frames, to highlight the areas where high concentrations of stresses and deformations occur. This will be done by analysing a building made with a mixed structure, with a structure made only of load-bearing masonry and with a structure made only of reinforced concrete frames.

2 variants of mixed structures were analysed: a variant in which load-bearing masonry was used on the outer contour of the building, and reinforced concrete frames were used inside the building, and a variant in which reinforced concrete frames were used on the outer contour of the building, and load-bearing masonry was used inside the building.

The comparative study was carried out for the 4 structural solutions on a building with a height regime of P+2E with a non-circulatory terrace having the residential destination located in the municipality of Constanta with the seismic characteristics related to the location.

The strength class of the concrete used was C20/25, Brikstone brick was used for the load-bearing masonry. Following the load evaluation and the pre-dimensioning of the resistance elements, the frames resulted in beams with a section of 25x60cm, corner and marginal pillars 30x30cm and central pillars 40x40 cm, and for the load-bearing walls, the wall thickness of 25cm, the masonry pillars 25x25cm and the masonry belts 25x25cm.

Mod	Omega [rad/s]	Perioada [s]	Frecv. [Hz]	Wxi / Wxtot	Wyi / Wytot	Wzi / Wztot	Wxi_R / Wxtot_R	Wyi_R / Wytot_R	Wzi_R / Wztot_R
1	57.0206	0.1102	9.0751	0.0003	0.8394	0.0001	0.0733	0.0000	0.0025
2	62.4737	0.1006	9.9430	0.8640	0.0004	0.0000	0.0000	0.0411	0.0017
3	74.4786	0.0844	11.8536	0.0005	0.0002	0.0736	0.0083	0.0353	0.0001
4	80.3753	0.0782	12.7921	0.0000	0.0000	0.0512	0.0047	0.0146	0.0000
5	81.8858	0.0767	13.0325	0.0001	0.0000	0.0767	0.0111	0.0292	0.0000
6	85.2502	0.0737	13.5680	0.0001	0.0002	0.0540	0.0113	0.0253	0.0000
7	90.3540	0.0695	14.3803	0.0000	0.0000	0.0324	0.0023	0.0034	0.0001
8	92.1425	0.0682	14.6649	0.0000	0.0000	0.0327	0.0066	0.0021	0.0000
9	100.6787	0.0624	16.0235	0.0016	0.0017	0.0002	0.0016	0.0011	0.8548
10	109.5690	0.0573	17.4384	0.0001	0.0000	0.0390	0.0259	0.0213	0.0001
				0.8667	0.8419	0.3598	0.1451	0.1735	0.8593

Fig. 1 Natural vibration periods for the mixed structure with load-bearing masonry on the external contour of the building and reinforced concrete frames inside the building

Mod	Omega [rad/s]	Perioada [s]	Frecv. [Hz]	Wxi / Wxtot	Wyi / Wytot	Wzi / Wztot	Wxi_R / Wxtot_R	Wyi_R / Wytot_R	Wzi_R / Wztot_R
1	73.8422	0.0851	11.7523	0.1906	0.5973	0.0000	0.0773	0.0124	0.0222
2	75.5981	0.0831	12.0318	0.6376	0.1889	0.0000	0.0230	0.0420	0.0000
3	102.2893	0.0614	16.2798	0.0047	0.0144	0.0000	0.0040	0.0008	0.8321
4	131.0308	0.0480	20.8542	0.0004	0.0000	0.0661	0.0004	0.0456	0.0000
5	133.0748	0.0472	21.1795	0.0004	0.0001	0.0002	0.0425	0.0001	0.0000
6	144.3926	0.0435	22.9808	0.0002	0.0000	0.0383	0.0002	0.0252	0.0000
7	146.9559	0.0428	23.3888	0.0002	0.0000	0.0000	0.0197	0.0000	0.0000
8	147.8840	0.0425	23.5365	0.0001	0.0000	0.0681	0.0002	0.0470	0.0000
9	150.0735	0.0419	23.8849	0.0001	0.0000	0.0016	0.0268	0.0013	0.0000
10	176.5145	0.0356	28.0932	0.0008	0.0000	0.0967	0.0002	0.0989	0.0000
				0.8350	0.8007	0.2712	0.1943	0.2734	0.8544

Fig. 2 Natural vibration periods for the load-bearing masonry structure

Mod	Omega [rad/s]	Perioada [s]	Frecv. [Hz]	Wxi / Wxtot	Wyi / Wytot	Wzi / Wztot	Wxi_R / Wxtot_R	Wyi_R / Wytot_R	Wzi_R / Wztot_R
1	13.1724	0.4770	2.0965	0.2365	0.5097	0.0000	0.0240	0.0061	0.1411
2	13.6080	0.4617	2.1658	0.5855	0.2985	0.0000	0.0146	0.0157	0.0025
3	15.5101	0.4051	2.4685	0.0650	0.0773	0.0000	0.0043	0.0024	0.7425
4	38.7771	0.1620	6.1716	0.0277	0.0458	0.0000	0.1543	0.0542	0.0162
5	40.2575	0.1561	6.4072	0.0541	0.0361	0.0000	0.1217	0.1052	0.0001
6	46.0264	0.1365	7.3253	0.0080	0.0092	0.0000	0.0302	0.0159	0.0726
7	59.4416	0.1057	9.4604	0.0059	0.0074	0.0000	0.0080	0.0039	0.0034
8	62.0667	0.1012	9.8782	0.0092	0.0077	0.0001	0.0080	0.0054	0.0000
9	65.4528	0.0960	10.4171	0.0000	0.0000	0.1682	0.0328	0.1153	0.0000
10	70.5148	0.0891	11.2228	0.0000	0.0000	0.0271	0.0056	0.0167	0.0000
				0.9919	0.9917	0.1954	0.4036	0.3408	0.9784

Fig. 3 Natural vibration periods for the structure in reinforced concrete frames

In the figures above, it can be seen that the natural periods are larger for reinforced concrete frame structures, meaning they have a more flexible behaviour. Load-bearing masonry structures have the smallest natural periods, so they have a more rigid behaviour. Mixed structures are more rigid than reinforced concrete frame structures, but more flexible than load-bearing masonry structures. In mixed structures, when reinforced concrete frames are used inside the building, they have a more rigid behaviour than when reinforced concrete frames are used on the exterior contour of the building.

For the same P+2E building, it was proposed to determine the results of 3 structural systems: mixed structure, load-bearing masonry structure and reinforced concrete frame structure. Several variants of mixed structures were analysed in which the masonry pillar at the intersection of the load-bearing masonry with the reinforced concrete frame is enlarged in the direction of the frame. One variant has the masonry pillar dimensions of 25x25 cm. In the other variants, the masonry pillar dimensions are 25x40 cm, 25x50 cm and 25x60 cm.

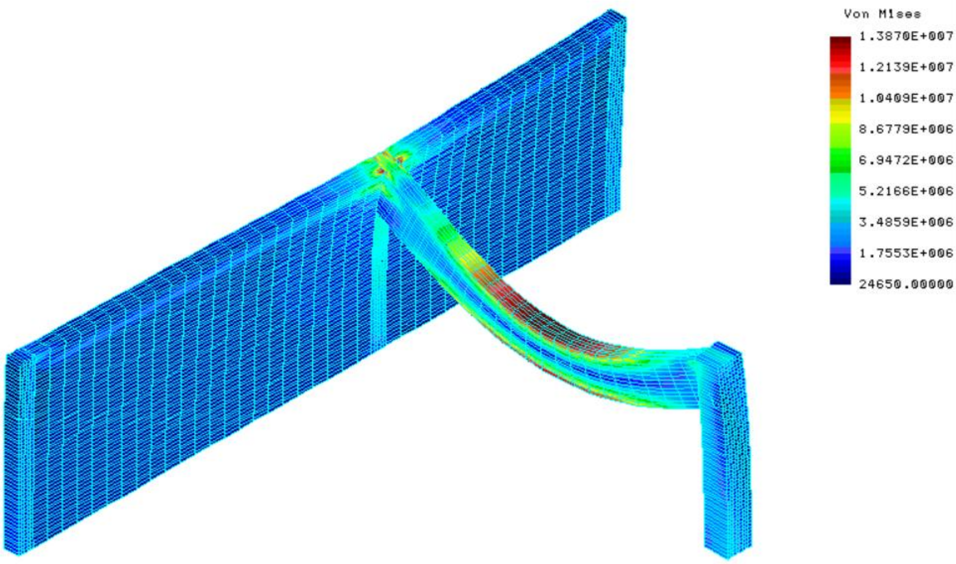

Fig. 4 Stress diagram for the mixed structure with the masonry pillar of 25x25 cm

After analysing the results, it can be seen that it is enough for the size of the masonry pillar to be increased to 40 cm in the direction of the frame so that high stress concentrations do not occur anymore.

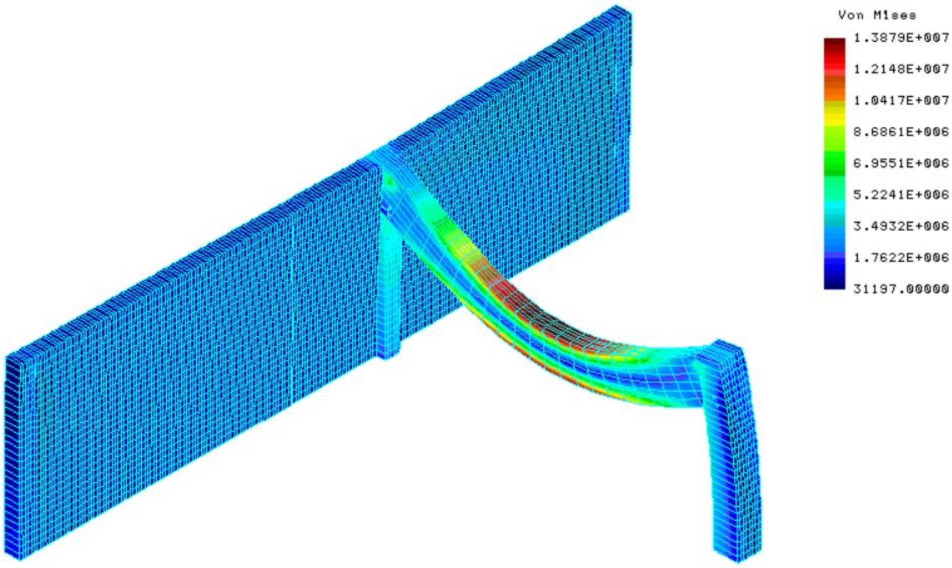

Fig. 5 Stress diagram for the mixed structure with the masonry pillar of 25x40 cm

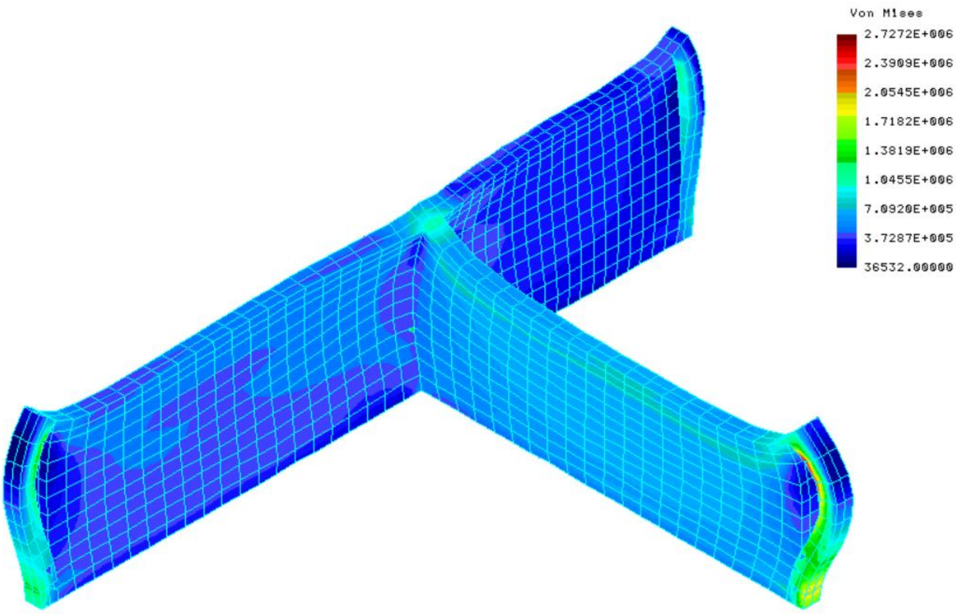

Fig. 6 Stress diagram for load-bearing masonry structure

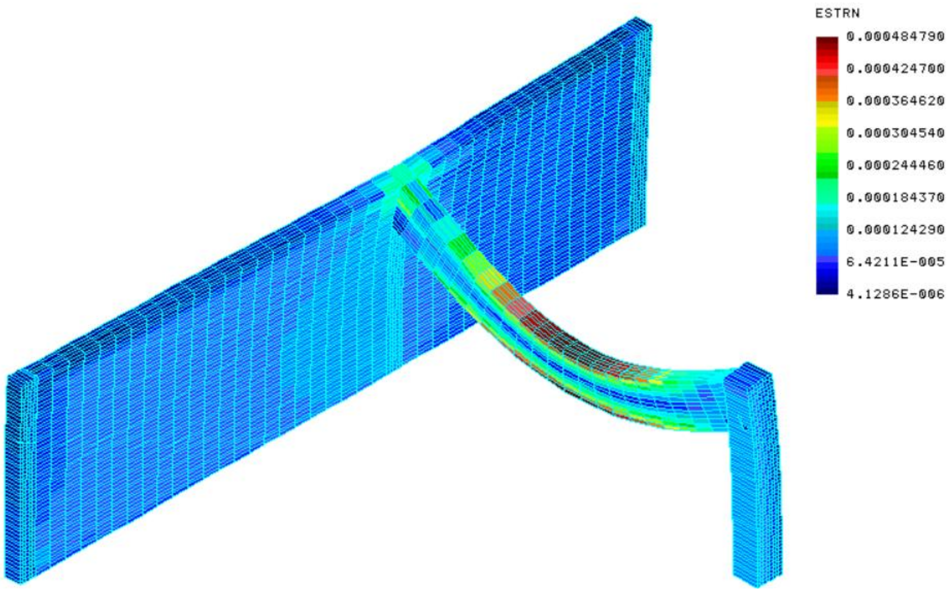

Fig. 7 Deformation diagram for the mixed structure with the 25x25 cm masonry pillar

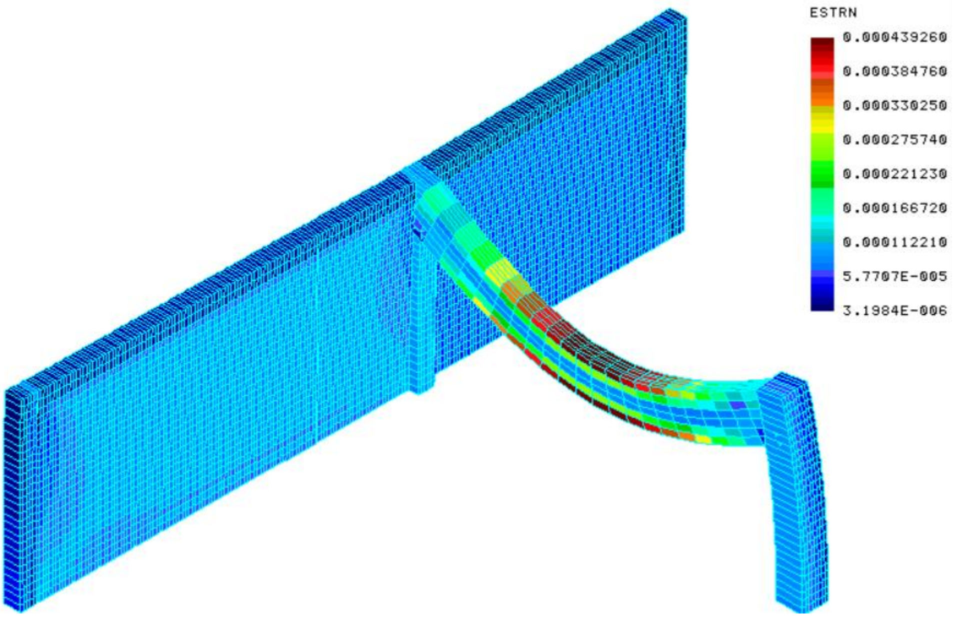

Fig. 8 Deformation diagram for the mixed structure with the 25x40 cm masonry pillar

In the figures above, it can be seen that in mixed structures, high stress concentrations appear in the beam and in the masonry pillar with dimensions of 25x25 cm at the intersection of the masonry with the reinforced concrete frame. This is not beneficial for the structure because the masonry pillar is very stressed. It can also be seen that if the size of the masonry pillar is increased in the direction of the reinforced concrete frame, the stresses decrease, they become uniform on the surface of the structural node, and the effect of stress concentration no longer appears in this case. In load-bearing masonry structures, high stress values appear in the masonry pillars, in the area where the masonry pillars intersect with the masonry and at the base of the masonry pillars.

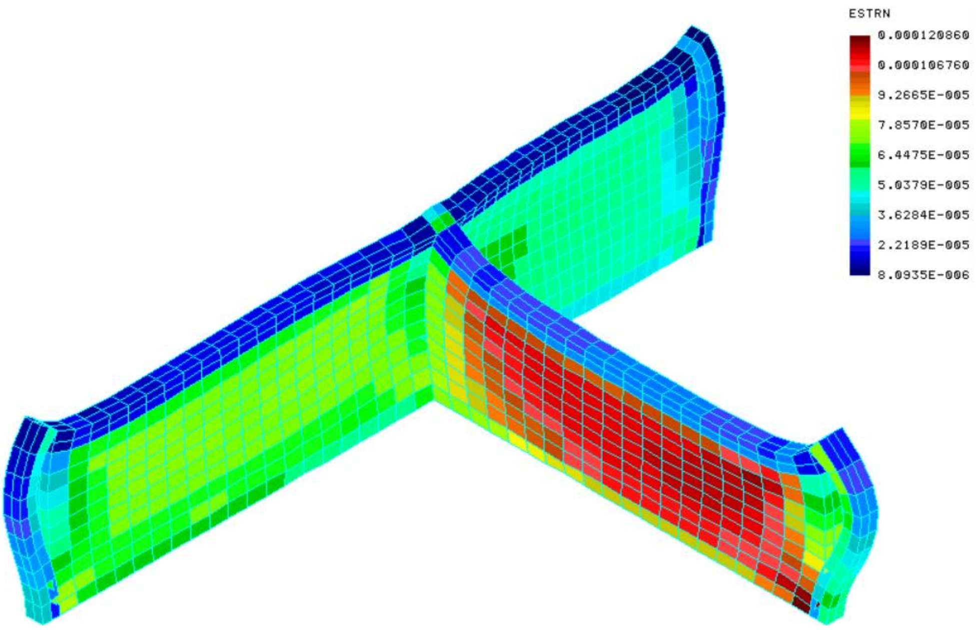

Fig. 9 Deformation diagram for load-bearing masonry structure

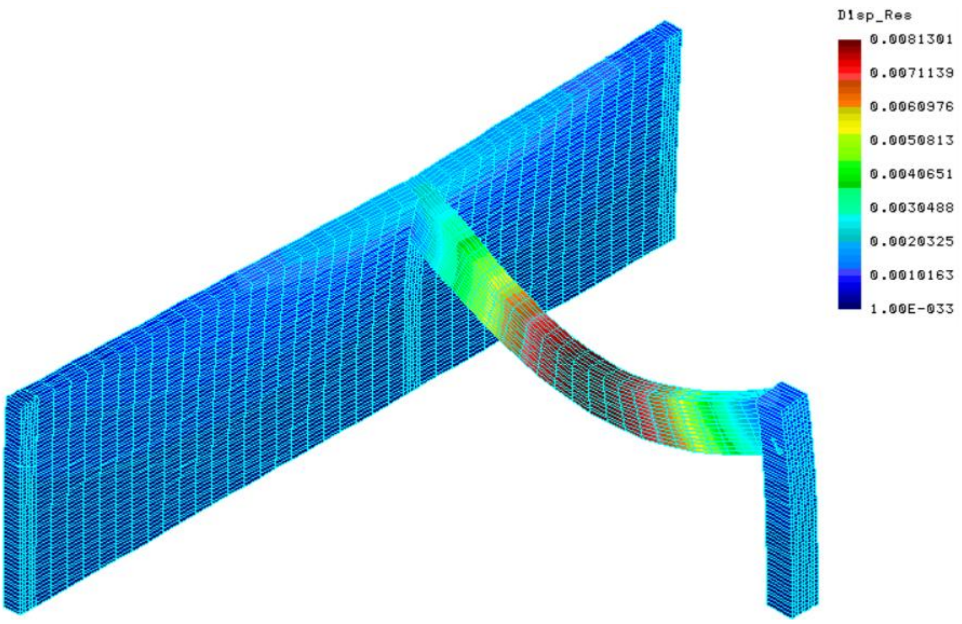

Fig. 10 Diagram of the displacements for the mixed structure with the 25x25 cm masonry pillar

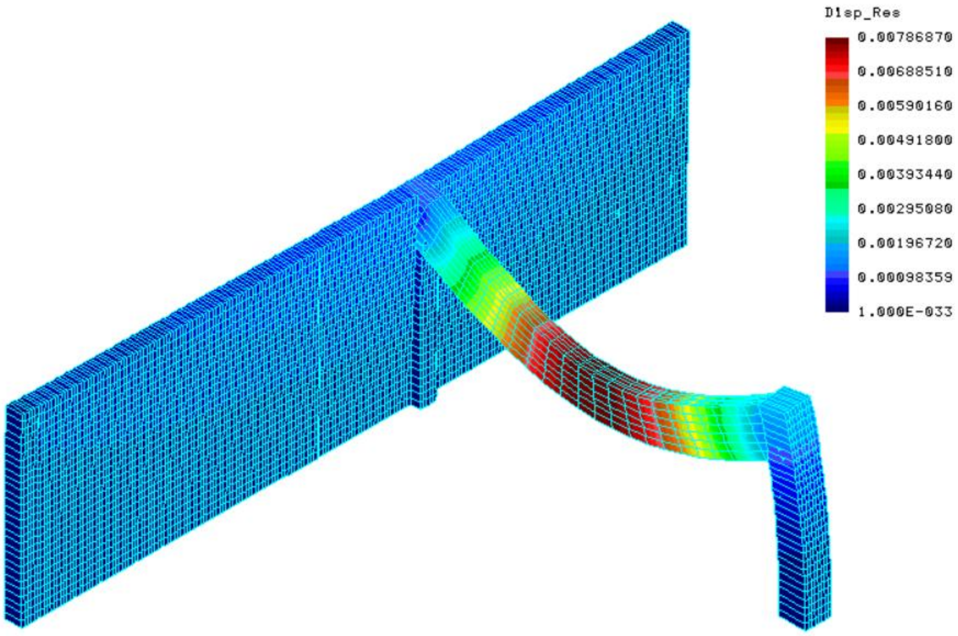

Fig. 11 Diagram of the displacements for the mixed structure with the 25x40 cm masonry pillar

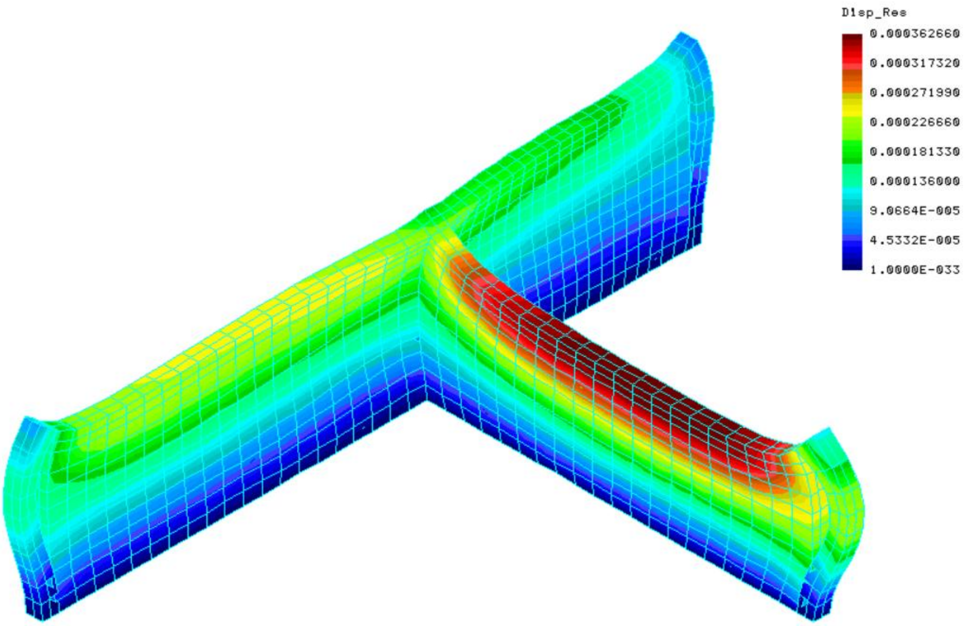

Fig. 12 Diagram of displacements for the load-bearing masonry structure

Analysing the figures above, it can be seen that in mixed structures, larger deformations appear in the same area where we had the stress concentrations, in the intersection area between the reinforced concrete frame beam and the load-bearing masonry pillar with dimensions of 25x25 cm. It can also be seen that if the side of the masonry pillar is increased in the direction of the frame, the deformations decrease and this effect of concentration of stresses and deformations disappears.

3. CONCLUSIONS

Following the analysis of the results obtained regarding the behaviour of mixed structures, made with the help of calculation programs, several conclusions and recommendations can be drawn.

The combination of the two structural systems allows for the optimization of the materials used and the reduction of costs compared to a reinforced concrete frame structure.

The integration of reinforced concrete frames improves the behaviour of the load-bearing masonry structure, especially in taking over the seismic action, this being essential in areas with high seismic risk.

Analysing the natural periods of vibration resulting for the two types of mixed structures in comparison with the frame structure and the load-bearing masonry structure, it is observed that the mixed structures are not as rigid as the load-bearing masonry structures, but not as flexible as the reinforced concrete frame structures, this being an advantage in the behaviour of these structures. (*Fig. 1, Fig. 2, Fig. 3*)

The structural systems of load-bearing masonry and reinforced concrete frames have different stiffness and structural behaviour in the case of seismic actions or other loads. This can lead to stress concentrations and deformations in certain areas of interaction between the two systems. (*Fig.4, Fig. 5, Fig.6, Fig.7, Fig.8, Fig.9*)

A solution to counteract the appearance of these areas with high stress concentrations is to achieve a better conformation of the structure in these areas.

It is recommended that the cores be more developed in the direction of the reinforced concrete frames, this aspect leading to an increase in the modulus of resistance of the masonry pillar resulting in a decrease in the stress values.

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