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Conformation of mixed structures made of load-bearing masonry and reinforced concrete frames

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Abstract **– The objective of this paper is to study the behaviour of mixed structures made of load-bearing masonry and reinforced concrete frames. These structural systems are found in many countries located in seismic areas, including in Romania. The mixed structural system can be used for civil, industrial or agricultural constructions and is of great technical and economic importance. Although they are often found in practice, in many situations these structures are treated wrongly regarding their conformation, but also their behaviour. Load-bearing masonry develops a strong interaction with reinforced concrete frames under the action of seismic forces, and this approach can lead to a substantial inaccuracy in specifying the real seismic response of structures in terms of lateral stiffness, strength and ductility.**

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

1. INTRODUCTION

The mixed structural system is the structural system in which the gravity loads are taken by both the reinforced concrete frames and the load-bearing masonry walls, while the lateral loads are mostly taken by the reinforced concrete frames.

The system can have two versions:

- the mixed system with predominant walls represents the mixed system in which the load-bearing masonry walls largely contribute to taking over the gravity loads;
- the mixed system with predominant frames represents the mixed system in which the reinforced concrete frames mostly contribute to taking over the gravity loads.

However, the influence of the reinforced concrete frames that interact with the load-bearing masonry walls can be great and for this reason must be taken into account. The behaviour of the assembly will be similar to that of the predominant structural component.

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

Generally, in practice, mixed structures are used with load-bearing masonry walls on the outer contour of the building and reinforced concrete frames inside the building to be able to have large rooms.

But it is also possible to meet the version in which the load-bearing masonry walls are inside and the reinforced concrete frames are outside.

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2. CASE STUDY. ANALYSIS OF THE BEHAVIOR OF MIXED STRUCTURES MADE OF LOAD-BEARING MASONRY AND REINFORCED CONCRETE FRAMES

The objective is to determine the behaviour of mixed structures of load-bearing masonry and reinforced concrete frames and compare them with the results obtained for a structure only of load-bearing masonry and with a structure only of reinforced concrete frames. Two 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 on the outer contour of the building reinforced concrete frames, 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 P+2E height regime with a non-circulable terrace, with the residential destination located in the municipality of Constanta with the seismic characteristics related to the site.

The strength class of the concrete used was C20/25; Brikstone brick was used for the load-bearing masonry. After the evaluation of the loads and the pre-sizing of the resistance elements, the result was for the frames beams a section of 25x60 cm, for the corner column and the marginal column a section of 30x30 cm and for the central column a section of 40x40 cm, and for the load-bearing walls the thickness of the walls of 25 cm, the masonry pillars of 25x25 cm and the masonry belts 25x25 cm.For all four structural solutions, linear dynamic analysis was performed using the SCIA Engineer finite element program and the results obtained are presented below.

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	25.4825	0.2466	4.0557	0.0164	0.0412	0.0000	0.0029	0.0004	0.8363
2	32.1729	0.1953	5.1205	0.8927	0.0057	0.0010	0.0005	0.0335	0.0101
3	45.3457	0.1386	7.2170	0.0030	0.7856	0.0000	0.0921	0.0001	0.0430
4	69.1663	0.0908	11.0082	0.0001	0.0031	0.0004	0.0241	0.0001	0.0303
5	74.0995	0.0848	11.7933	0.0000	0.0001	0.0007	0.0067	0.0022	0.0137
6	77.7192	0.0808	12.3694	0.0003	0.0031	0.0005	0.0113	0.0141	0.0397
7	93.4973	0.0672	14.8806	0.0231	0.0006	0.0185	0.0225	0.2274	0.0001
8	95.5702	0.0657	15.2105	0.0263	0.0000	0.0259	0.0017	0.2789	0.0008
9	105.2071	0.0597	16.7442	0.0115	0.0000	0.1023	0.0451	0.0069	0.0003
10	107.5243	0.0584	17.1130	0.0026	0.0001	0.0419	0.0018	0.0015	0.0001
				0.9760	0.8397	0.1911	0.2086	0.5651	0.9744

Fig. 2 Natural vibration periods for the mixed structure with reinforced concrete frames on the external contour of the building and load-bearing masonry 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. 3 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. 4 Natural vibration periods for the structure in reinforced concrete frames

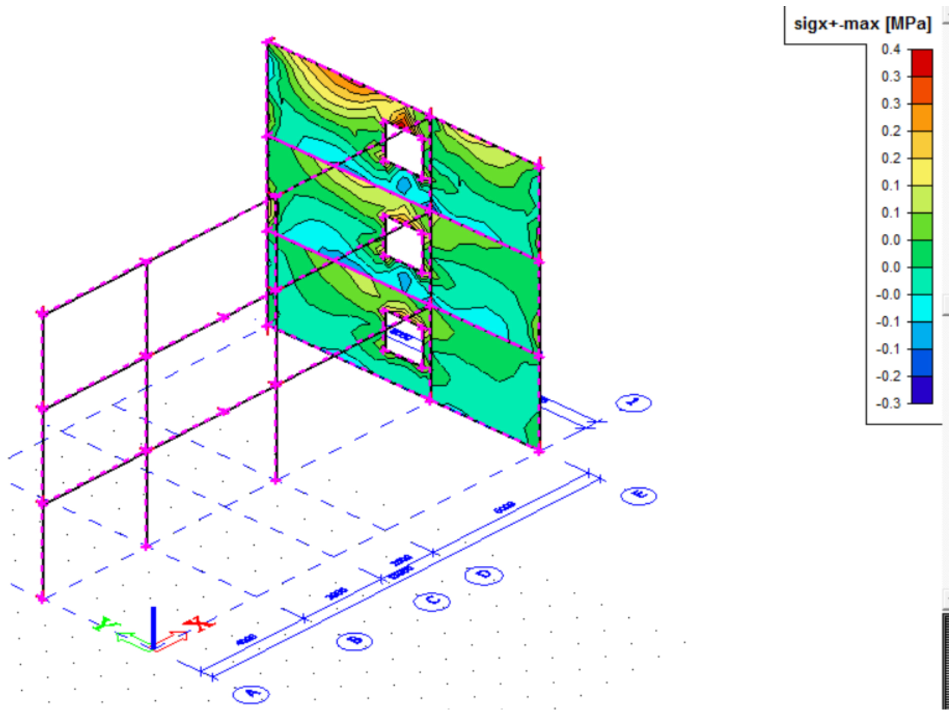

Fig. 5 Masonry stress diagram for the mixed structure with reinforced concrete frames on the external contour of the building and load-bearing masonry inside the building

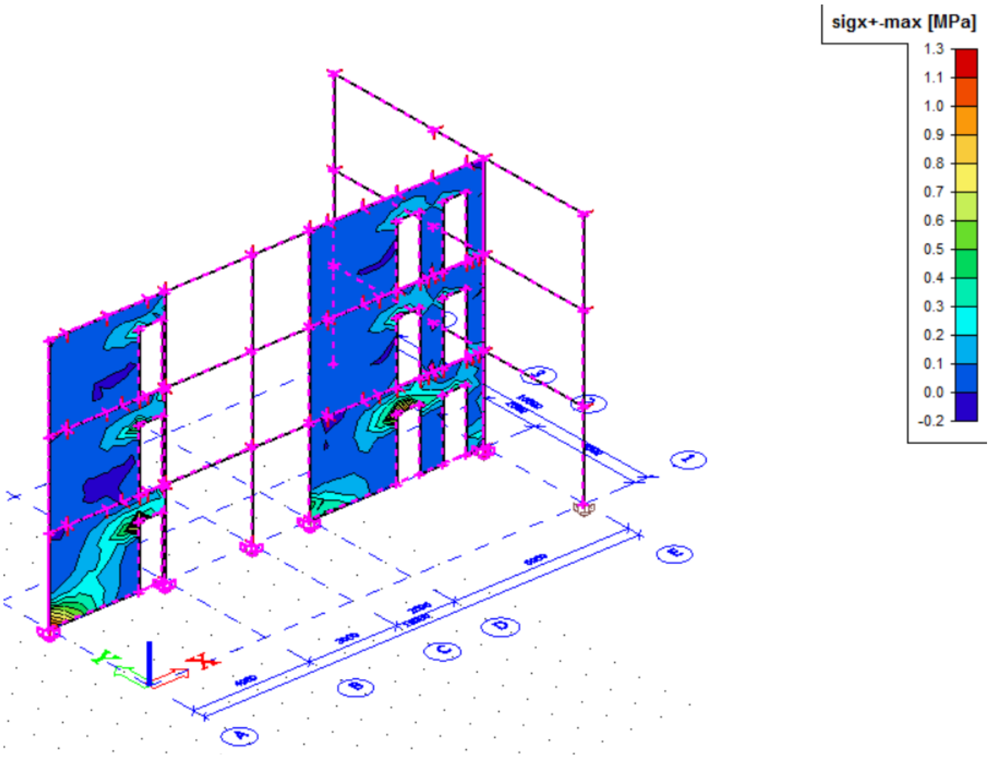

Fig. 6 Masonry stress diagram for the mixed structure with reinforced concrete frames on the external contour of the building and load-bearing masonry inside the building

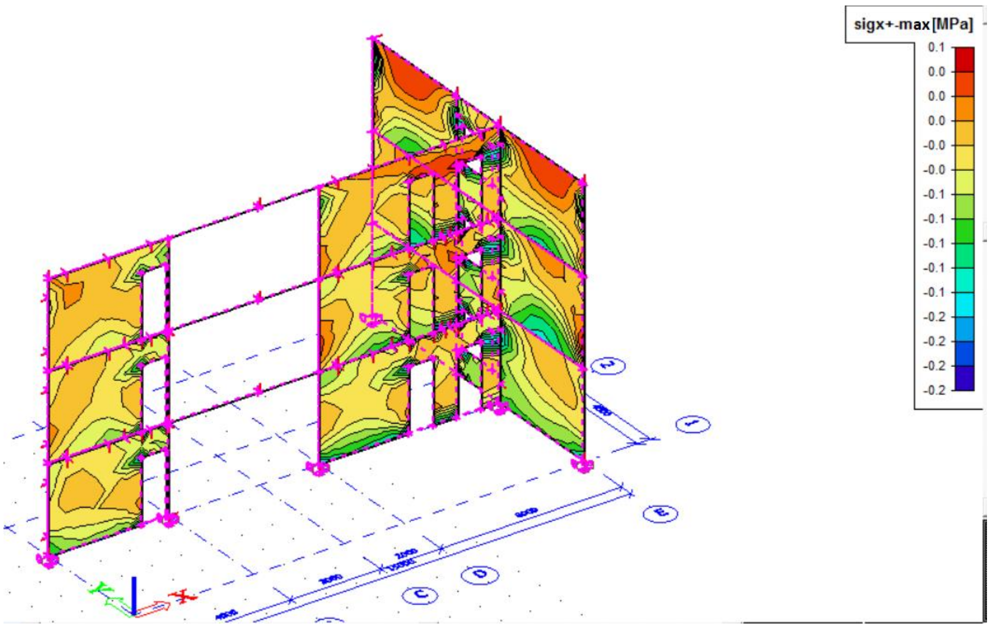

Fig. 7 Stress diagram for the load-bearing masonry structure

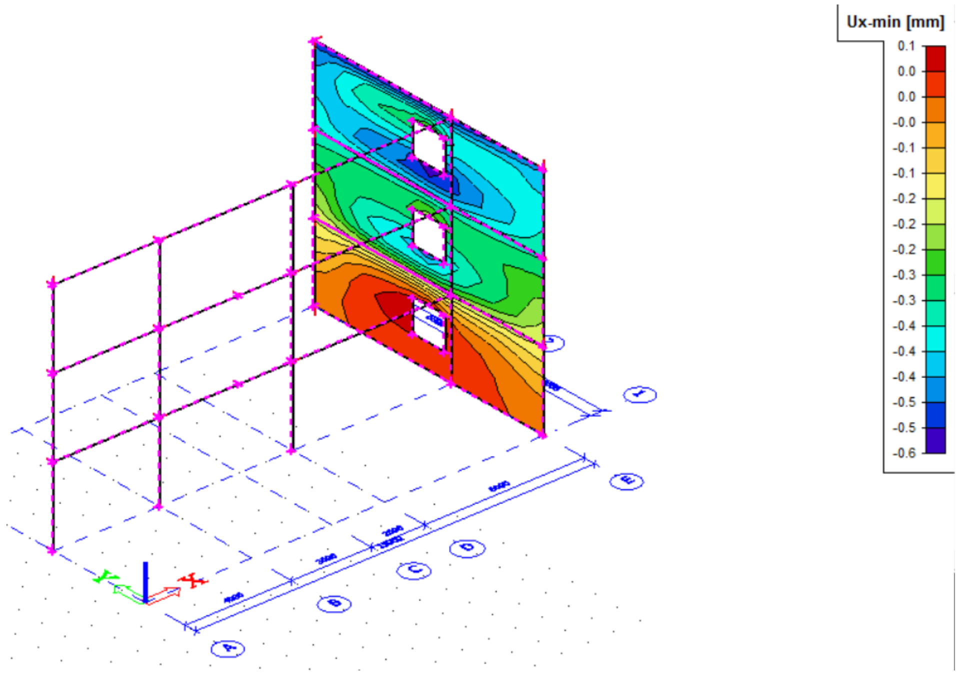

Fig. 8 Diagram of masonry wall displacements for the mixed structure with load-bearing masonry on the external contour of the building and reinforced concrete frames inside the building

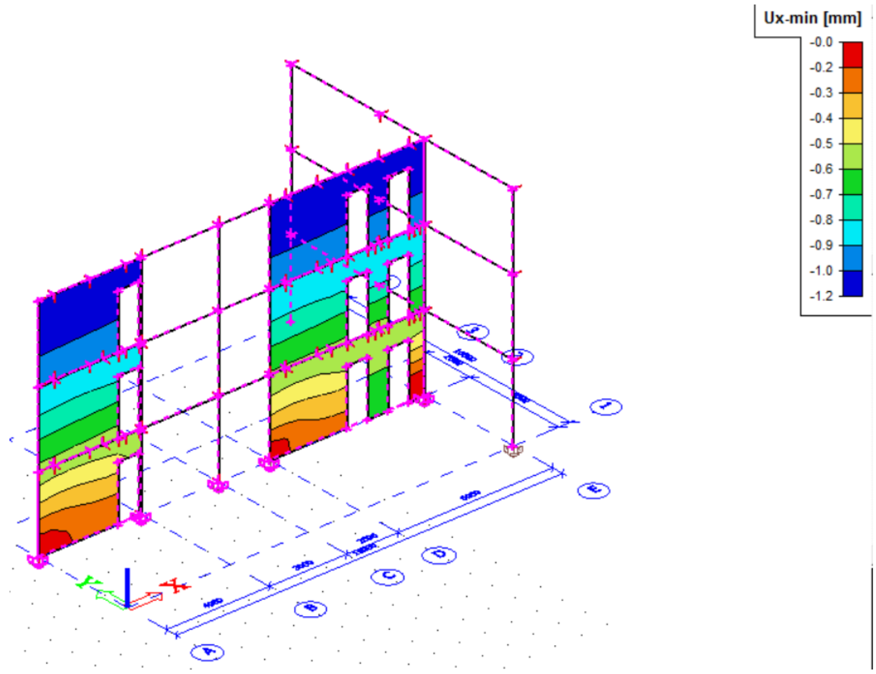

Fig. 9 Diagram of masonry wall displacements for mixed structure with reinforced concrete frames on the external contour of the building and load-bearing masonry inside the building

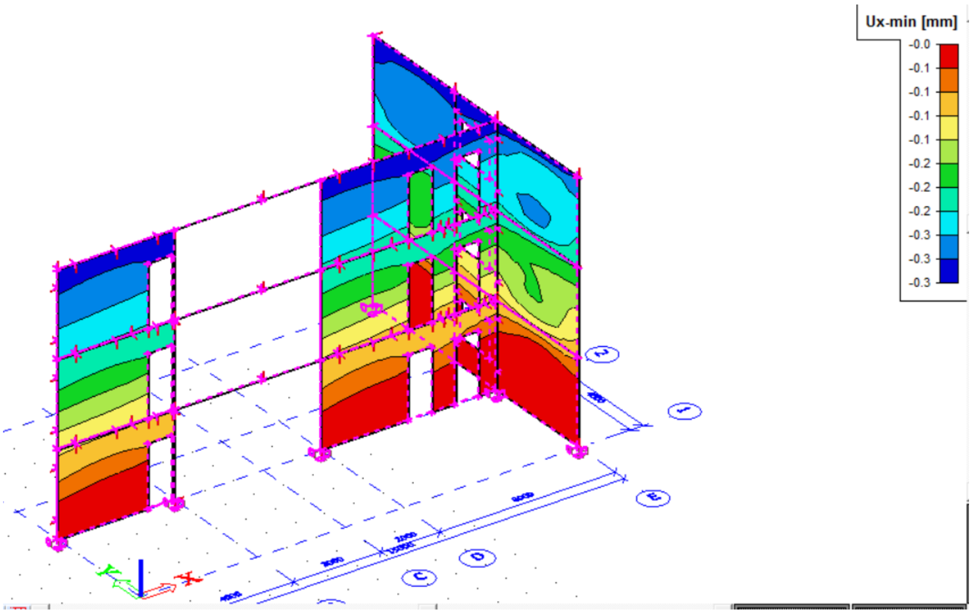

Fig. 10 Diagram of displacements for the load-bearing masonry structure

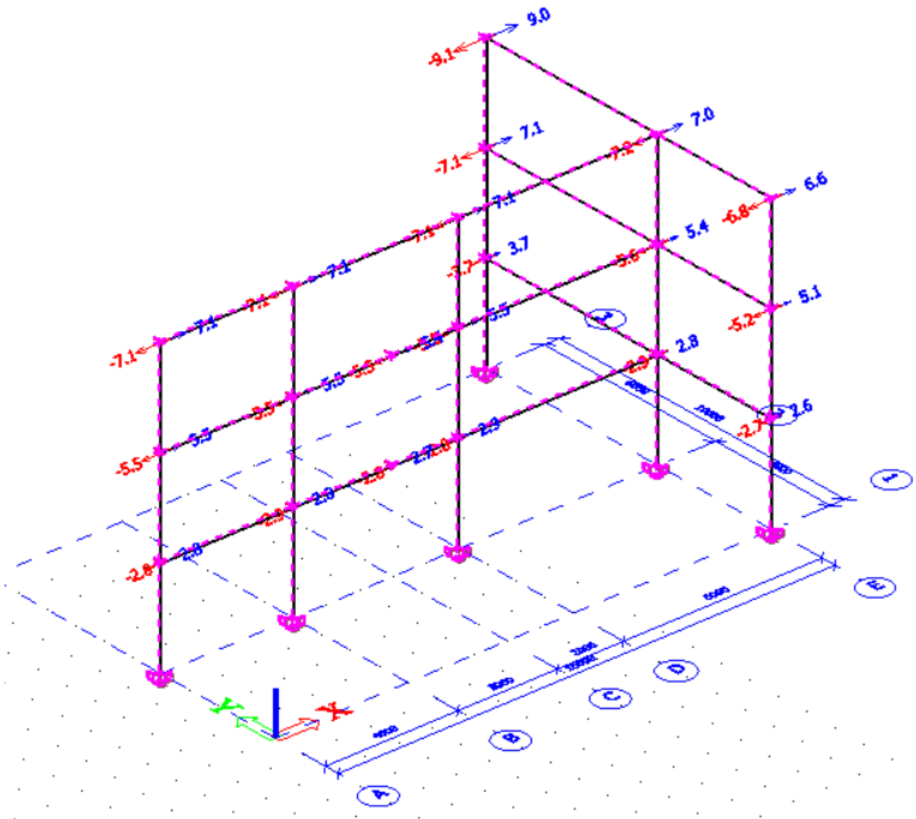

Fig. 11 Diagram of displacements for the structure in reinforced concrete frames

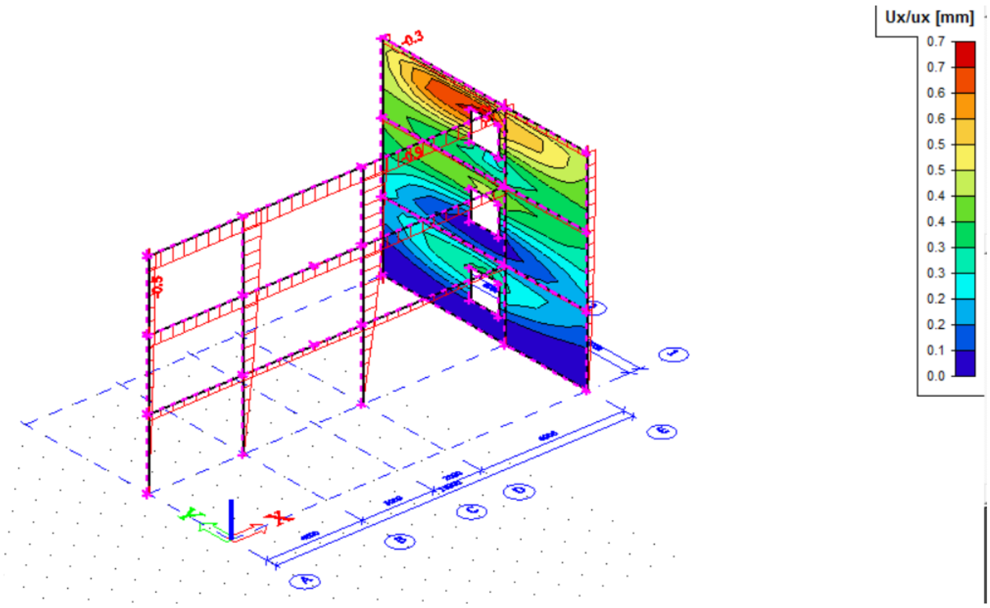

Fig. 12 Strain diagram for mixed structure with load-bearing masonry on the external contour of the building and reinforced concrete frames inside the building

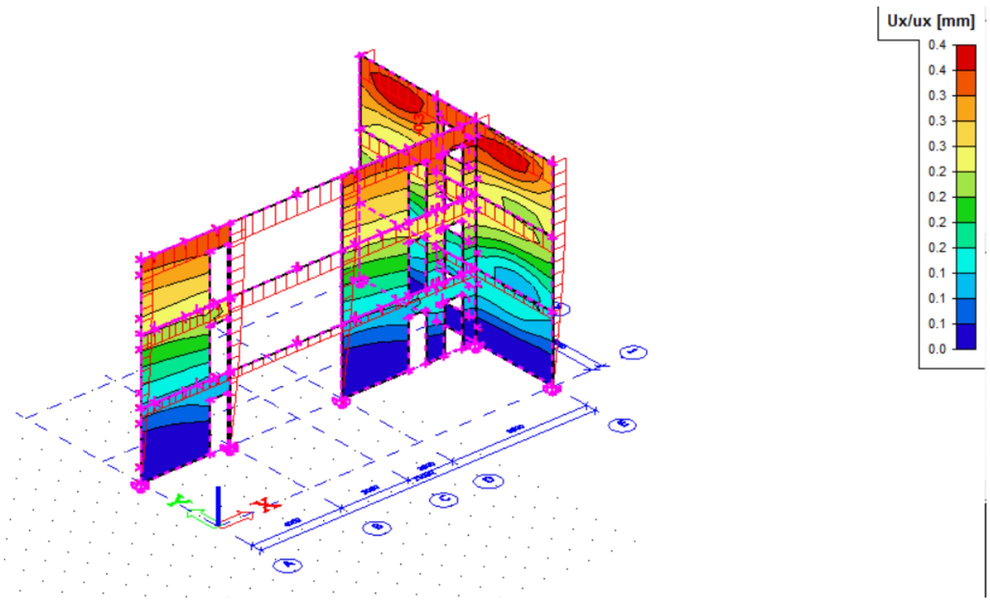

Fig. 13 Strain diagram for the load-bearing masonry structure

3. CONCLUSION

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

First of all, it can be seen that the mixed structures took from the advantages of the two structural systems that we referred to.

Reinforced concrete frame structures are flexible structures, and load-bearing masonry structures are rigid structures. Analysing the natural vibration periods resulting for the two types of mixed structures in comparison with the structure in reinforced concrete frames and the load-bearing masonry structure, it can be seen that the mixed structures are not as rigid as the load-bearing masonry structures, but not very flexible as the frame structures from reinforced concrete, this being an advantage in the behaviour of these structures. (Fig. 1, Fig.2, Fig.3, Fig.4)

Mixed structures with load-bearing masonry on the external contour of the building and reinforced concrete frames inside the building are more rigid than mixed structures with load-bearing masonry on the inside of the building and reinforced concrete frames on the external contour of the building. (Fig. 1, Fig.2)

It is observed that in mixed structures, the behaviour of the structure in taking over the seismic force is better than that of the load-bearing masonry structure, this is due especially to the reinforced concrete frames.

But in addition to these advantages, it is also noticeable that in the case of mixed structures, areas of high stress concentrations appear at the intersection of the masonry with the reinforced concrete frames and at the base of the load-bearing masonry walls due to the fact that the eccentricity of the forces on the masonry wall increases. (Fig. 5, Fig.6, Fig.7)

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 these masonry pillars be more developed in the direction of the reinforced concrete frames, this aspect leading to the increase of the resistance module of the masonry pillars resulting in a reduction of the stress values.

To reduce the stresses at the base of load-bearing masonry walls, it is recommended to increase the thickness of the wall, in this way, by increasing the surface of the transmission of the stresses, their values decrease, as a result, the load-bearing masonry would no longer be so stressed and would not suffer too much deformation. (Fig. 12, Fig.13)

Another solution to improve the load-bearing capacity of masonry walls is to choose a brick with a higher compressive strength.

4. REFERENCES

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