CASE STUDY ON FAILURE MECHANISM FOR REINFORCED CONCRETE FRAME STRUCTURE WITH DIFFERENT INFILL MATERIAL

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Reinforced concrete frame structures are a wide spread structural system all around the world. Considered to be flexible structures, they are strongly recommended in areas with height seismicity. Several problems may occur due to different stiffness between the infill material and the reinforced concrete frame structure. Two major failures may appear – to crack the infill material or to damage the columns from the structural system. The second one is more unfavorable, and the only solution is to demolish the entire structure. The paper aim is to present a solution for this problem. For this purpose several numerical simulation are done using traditional material for the infill wall and an innovative solution. The results show that a flexible infill material lead to a better behavior for the system.

Keywords: infill material, stiffness, polyurethane.

INTRODUCTION

Reinforced concrete (RC) frame buildings are a widely used structural system due to its fast execution and good behaviour at horizontal loading. Even so, problems may appear due to non-structural elements that are not always taken into consideration in the design process, but have a great influence on the overall behaviour of the structure. These elements bring supplementary stiffness to the structure and can cause unfavourable failure mechanisms. Some of them are cause by the stiffness differences between the infill walls and the RC frame structure – producing either the failure of the infill wall or damaging the columns at the extremities (Olteanu, 2011). Separation between masonry walls and frames is often not provided and, as a consequence, walls and frames interact during strong ground motion. This leads to structural response deviating radically from what is expected in the design, Figure 1 (Elwood *et al.*, 2000).

Experimental research on the response of RC frames with masonry infill walls subject to static and dynamic lateral cyclic loads have shown that infill walls lead to significant increases in strength and stiffness in relation to bare RC frames (Mehmet, 2011). Intense research had been conducted starting with Polyakov (1960), Stafford-Smith and Carter (1969), Klingner and Bertero (1978), Mehrabi *et al.* (1996), Stavridis and Shing (2009) to more recent research conducted by Dolsek and Fajfar (2008), Sagttar and Liel, 2010, and Pujol and Fick (2010).

Figure 1. Damaged RC frame with hollow clay tile infill masonry, Izmit 1999 (Elwood *et al.*, 2000)

It is recognized that infill materials significantly influence the seismic performance of the resulting infill frame structures. The present study focuses on the effect of different types of infill materials (commonly used and a new one) on the seismic performance of an infill RC frames compared using SAP2000 and Axis (Olteanu *et al.*, 2011).

The paper presents several comparisons between classical infill material and a new one. The innovative masonry block is based on polyurethane.

POLYURETHANE

Polyurethane is a resilient, flexible and durable manufactured material that can replace rubber, metal or wood in thousands of applications. Can be manufactured in any color, can take any shape, size or geometrical complexity. Since its invention during the 1940s, polyurethane has been used in a wide range of items.

In Romania, the polyurethane was introduced in 1978 and it is manufactured by Oltchim SA.

Polyurethane is used in construction since 1950 in the shape of insulation panels for roofs, walls, ceilings and floors. Metal-faced polyurethane sandwich panels are widely used for large industrial buildings, refrigerated and other warehouses, office blocks, exhibition halls, fair pavilions, schools and sports halls. Prefabricated sandwich wall and lightweight roofing consist of metal facings bonded tightly together by a core of rigid polyurethane foam.

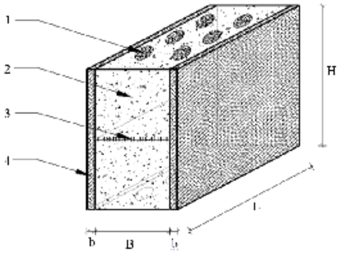


Figure 2. FlexyBrick: 1. Gaps; 2. Polyurethane; 3. Reinforcement mesh; 4. Cement plates

Polyurethane foam sandwich panels are recommended for facilities where a constant temperature or strict hygiene maintenance is required.

Polyol and isocyanate are the main components of polyurethane, which have to be mixed mechanically at a temperature of 25°C. The mixture expands and because of the limited dimensions of the mold, physical properties of the polyurethane bricks are obtained.

FlexyBricks, as the masonry blocks are called, can be produced in a variety of shapes and sizes. In Figure 2 a prototype is shown for a polyurethane masonry a block that has fibre cement boards on both faces, in order to increase the mechanical strength.

By creating an appropriate mold, FlexyBrick can be produced with circular cross section, similar with the branch of a tree. In this way, polyurethane concrete block can replace logs used for constructions in the country-house.

SOFTWARE ANALYSES

In order to compare the behaviour of bare RC frame with that having infill of different materials, static and modal analysis were performed, using computer software AxisVM and SAP2000. Both of them are based on the finite element method (Pastia *et al.*, 2013).

A 3 stories 2D RC frame structure was considered, each level of 3 m high and opening of 6 m. The dimensions of the columns are 50x50 cmxcm, and for the beam are 30x50 cmxcm. The structure was loaded only with self weight. Four cases were considered: the bare RC frame and 3 cases with different infill material –clay tile, aerated light weight concrete (A.A.C) and FlexyBrick. The considered material characteristics are presented in Table 1.

Table 1. Materials characteristics

Material	Modulus of elasticity, E (N/mm^2)	Poisson coefficient, υ	Unit weight (kg/m^3)
Concrete, C20/25	29000	0.2	2500
Clay tile	1210	0.2	2700
A.A.C.	2500	0.1	1100
FlexyBrick	100	0.2	180

Results for Static Analysis

In the static analysis the total internal efforts were evaluated. These values determine the structural system elements dimensions for the cross section and for the reinforcement. The values for the axial force and shear force at the base of the frame are shown in Figure 3 and Figure 4.

These results are directly proportional with the weight of the considered structures, which are shown in Figure 5. The values for the weight were extracted from SAP2000. The main conclusion from this analysis is that the proposed brick, FlexyBrick, brings the smallest load to the structural system.

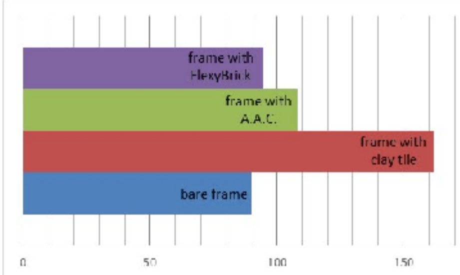


Figure 3. Axial force reactions results

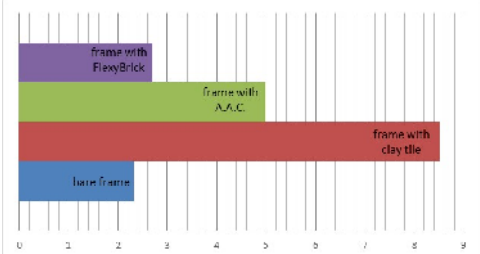


Figure 4. Shear force reactions results

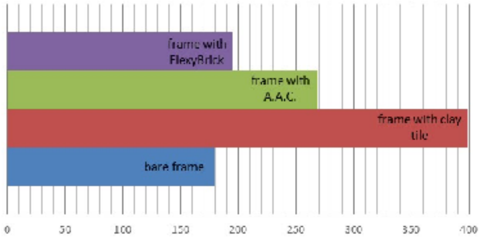


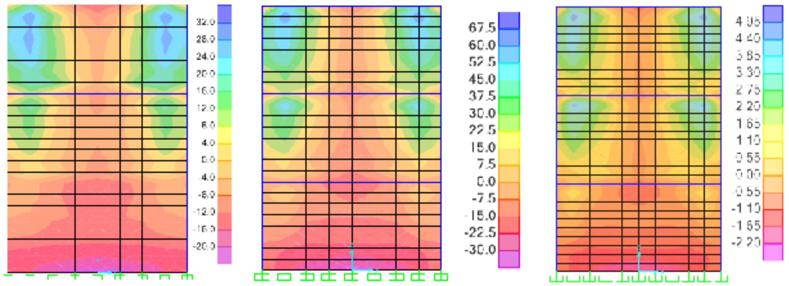
Figure 5. Structure weight, G (kN)

If the maximum stresses that appears in the masonry are compared, it can be noticed in Figure 6 that even though the distribution is similar in all 3 cases, the maximum values for the clay infill is 13 times higher than the values obtained for FlexyBrick and the case in which we consider A.A.C. infill, the values are only 6 times higher.

Results for the Modal Analysis

The results of this analysis are: characteristics of the models considered – periods of vibration, frequencies, eigenvalues, percentage of participation of the masses, adding modal participation rates and structural modal participation factors.

The first comparison realized was for horizontal displacement at the top of the structure, Figure 7. The maximum value is for the bare frame, 0.36 mm, and the minimum one is for the case in which the infill material is clay. In this case the displacement reaches 0.23 mm. It can be observed that the displacements for the first mode of vibration in case of a frame with FlexyBrick infill and a bare frame, are similar, differing only with 5%.



(a) (b) (c)

Figure 6. Maximum stresses in the infill material for: (a). A.A.C., (b) clay tile and (c) FlexyBrick

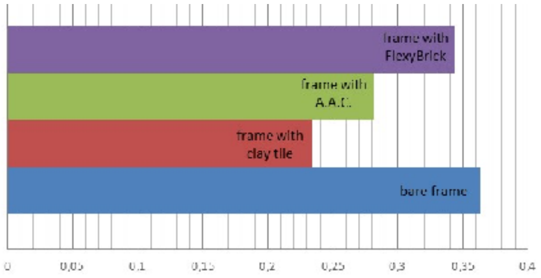


Figure 7. Horizontal displacement at the top of the structure, (mm)

The modal analysis was performed in SAP200 and Axis software. It appears that differences in values between the two computer programs vary between 0.24% and 5%, differences that may be considered negligible, Figure 8. The model with FlexyBrick infill has the closed fundamental period with the bare frame case.

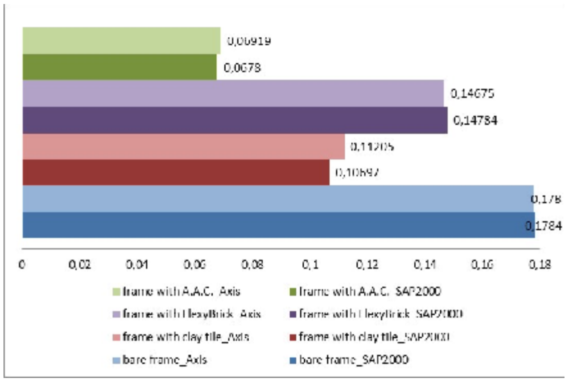


Figure 8. Period for first mode of vibration in SAP200 and Axis (s)

Comparing the stiffnesses for the four considered cases, Figure 9, it is observed that the A.A.C. has the higher value, and the FlexyBrick has the lowest one. This is in accordance with the initial hypothesis that the proposed infill material will bring for the structural system sufficient stiffness without changing the failure mechanism. Beside this the FlexyBrick infill is recommended for the envelope because of its thermal insulating properties.

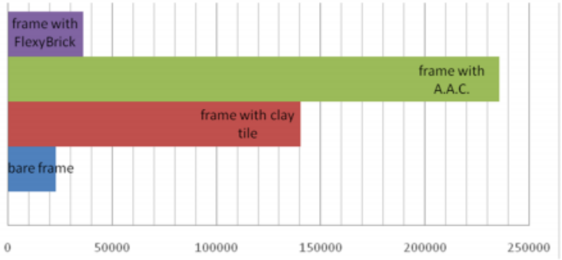


Figure 9. Assembly stiffness comparison, k (kN/m)

CONCLUSION

The main conclusion is that the behavior of reinforced concrete frame structures can be improved by changing the material characteristics of the infill. The proposed polyurethane masonry block have a flexible behavior, with good properties for thermal insulation and mechanical ones. The main advantage is the low self weight, respectively the low load that is transmited to the structural system.

Further analyses will be made in order to determine physical properties, costs and detailed behavior with nonlinear analysis for the FlexyBrick product.

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