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Shake table test of a structural model made of glass fiber reinforced mineral matrix composite

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Abstract

The paper presents the results regarding the behaviour of a structural model made of Glass Fibre Reinforced Mineral Matrix Composite tested to various seismic actions on the shaking table. The model dimensions are 3.40 m x 3.40 m x 3.00 m meaning width x length x height. The structure was made of multiple prefabricated panels pre-assembled directly on the shaking table. The final shape of the panel bearing structure is a ribbed thin plate type in both vertical and horizontal directions. These were obtained by casting the mineral matrix on the glass fibre reinforced prefabricated panels. The recorded results show the maximum relative displacements and the maximum accelerations revealing the structure's stiff behaviour.

Key words: composite material, seismic action, structural behaviour

1 Introduction

The use of glass fibre reinforced mesh as structural material in the construction industry has significantly increased in recent years. Various mixtures for mineral matrix required for composite structural elements were developed. Cementitious materials, such as mortar and concrete, are brittle materials, very weak in tension. This weakness is conventionally overcome by reinforcing concrete with steel, either in the form of traditional reinforcement or as fibre reinforcement. Additionally, in case of conventionally reinforced concrete structures, a certain minimum cover thickness is required in order to protect the reinforcement from the deleterious effects of environmental factors. This only adds to the weight of the structure, which is quite significant in the case of reinforced concrete. Hence, the need to develop a lighter material and structural elements based on inexpensive cements with high structural and impact strength has grown in recent years both for engineering and architectural reasons [1, 2].

Shaking table tests have many advantages. They help researchers to observe the seismic damage mechanisms and to evaluate the maximum capacity as well as how the seismic forces are distributed. Moreover, locating the weak points in the structure and verifying the dynamic analytical models for the new structural systems are very important aspects [3, 4]. This study investigates the behaviour of a full-scale one-storey building made of structural composite panels. One of the objectives of making the structural model was to obtain a resistant, rigid and light-weight construction. Low weight means lower seismic forces that need to be borne by the structure.

2 Materials and model testing

The mineral matrix is a combination of super sulphated cement in addition with Portland cement and sand in proportion of 1:1:2, 2 % calcium stearate, 1 % setting retardant, 2 % superplasticizer and 20 % water. After the components had been mixed, the fluid mixture was cast in place in the assembled glass fibre reinforced panels (Fig. 1). The layer thickness was 20 mm. The panels were modulated to 60 cm length and 3.00 m height. The structural model was built in a week. After the panels had been positioned in their places next to each other, the binder was cast in the rib network. The distance between the ribs was 30 cm and 60 cm in horizontal and vertical directions, respectively. A more detailed description of the model layout and dimensions can be found in [5].

Table 1. Structural materials properties

MATERIALS	**Tensile E - modulus** [MPa]	**Compressive E – modulus** [MPa]	**Tensile Strength** [MPa]	**Compressive Strength** [MPa]
Mineral matrix	1460	6320	1.7	25
E-Glass fibre reinforcement	72413	-	1950	-
Composite material	51240	7120	8.7	27.6

Figure 1. a) Building model assembly; b) Glass fibre reinforced polystyrene wall panels

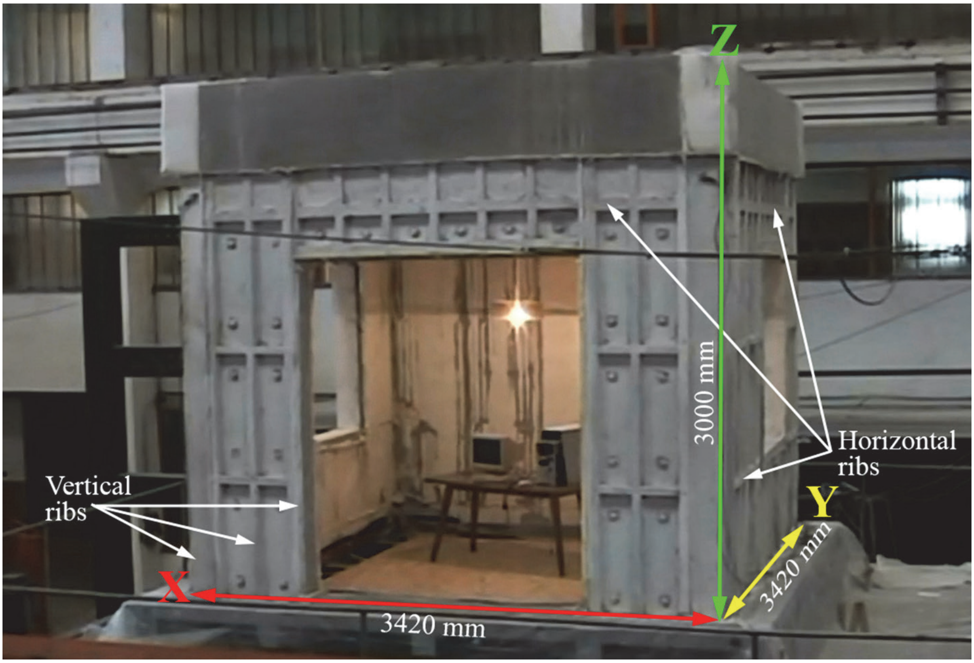

Figure 2. Structural model mounted on the shaking table

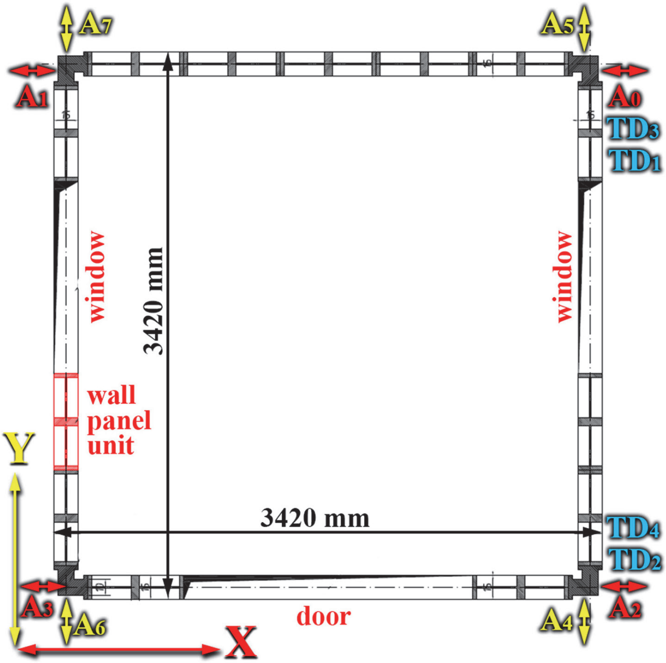

Figure 3. Position of the transducers A- accelerometers; TD-Displacement transducers

Table 2. Seismic action applied

Name	**Frequency** [Hz]	**Duration** [s]	**X - direction**	
			PGA [g]	**PGD**[mm]
SB 7	7	10	0.40	45
SB 10	10	15	0.40	42
Vrancea 1986 (ELC)	-	25	0.29	50
El Centro 1940 (VN)	-	30	0.31	65

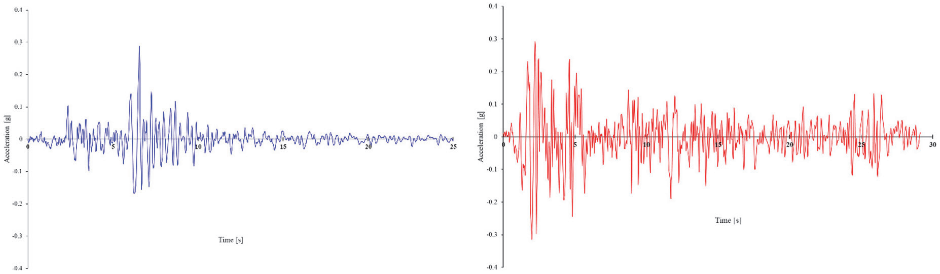

Figure 4. The seismic records for Vrancea 1986 (left) and El Centro 1940 (right) earthquakes

In Fig. 3 the displacement transducers TD1 and TD2 are located at the base of the model, whereas TD3 and TD4 were set to measure the displacements at the top of the structure which is the base of the attic. The acquisition of the test data has been done digitally by simultaneously recording signals from two types of transducers: Dytran 3202A1 LIVM (accelerometer) and PT5AV (displacement transducer).

The experiment on the shaking table started from a set of diagnostic low-level tests on intact specimen including impulse loading and white noise excitation. The base motion records were applied to the building progressively. The applied ground motion data is shown in Table 2. The loading scenarios taken into consideration were two sine-beat motions (SB) of different frequencies and duration as well as two earthquake records for Vrancea 1986 earthquake and El Centro 1940 earthquake. The seismic records used in the research are shown in Fig. 4.

3 Experimental results and discussions

The model was excited progressively with PGA ranging from 0.1 to 0.4g. At each level of acceleration, the specimen behaved completely linearly and no visible cracks were observed in any of the walls. Figures 5 to 7 present the graphs with comparative results. In the case of Vrancea 1986 seismic motion, the maximum relative displacement produced was 5.00 mm while the maximum acceleration, as recorded by the accelerometers, was 0.72g. Visible damages during the tests were not observed.

The initial fundamental frequency of the test building was 7 Hz and 7.85 Hz in the X and Y directions, respectively. At the 0.3g and 0.5g levels of acceleration in cases of sine-beat dynamic actions, no visible cracks occurred. At the 0.32g and 0.72g, the maximum level of acceleration in the case of El Centro 1940 and Vrancea 1986 seismic actions, no visible damages occurred. The structure remained stable and stiff.

Although the maximum level of response acceleration, 0.72g, was recorded for Vrancea earthquake, the maximum displacement was recorded for El Centro earthquake, 47 mm at the top of the model. However, the relative displacements between the top and the base of the structure were maximum for the two seismic scenarios based on real records, as it can be seen in Fig. 7. The maximum value of the lateral displacement at the top of the structure did not exceed the limits prescribed in the seismic design codes [6, 7].

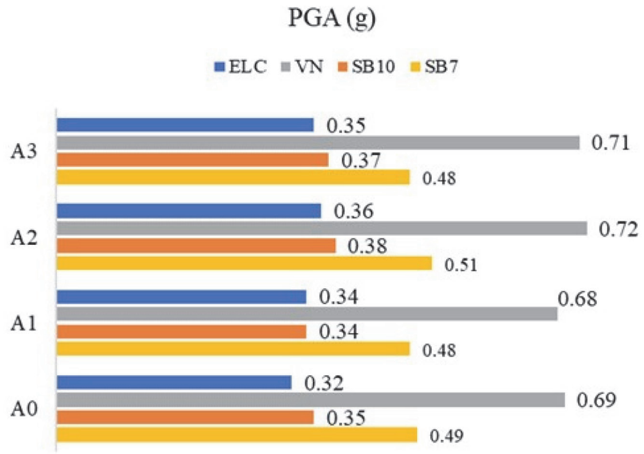

Figure 5. Comparative results of the maximum accelerations in the longitudinal direction

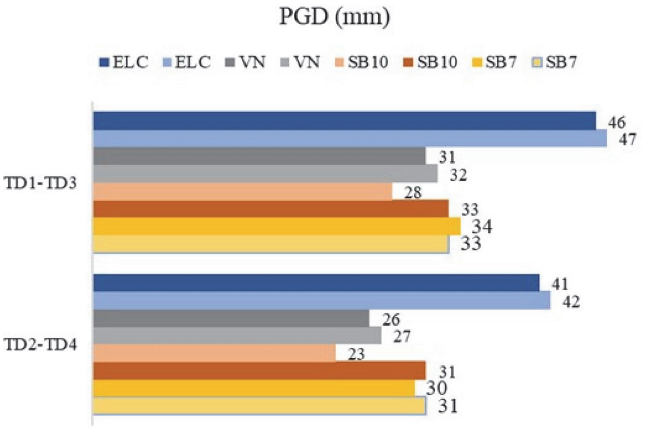

Figure 6. Comparative results of the maximum absolute displacements in the longitudinal direction

The relatively high values of the response accelerations in the model, Fig. 5, compared to the PGA of the input motion, Table 2, as well as the small values of the relative displacements between the top and the base of the model, Fig. 7, suggest that the building was very stiff from the beginning to the end of the experimental program. No visible degradations could be detected in the ribbed wall panels or at the corners of openings, one of the most vulnerable points in terms of stress concentrations [8, 9].

The model was subsequently subjected to additional shake table tests in order to assess its behaviour under repeated seismic motions of different amplitudes and frequency content [5[.

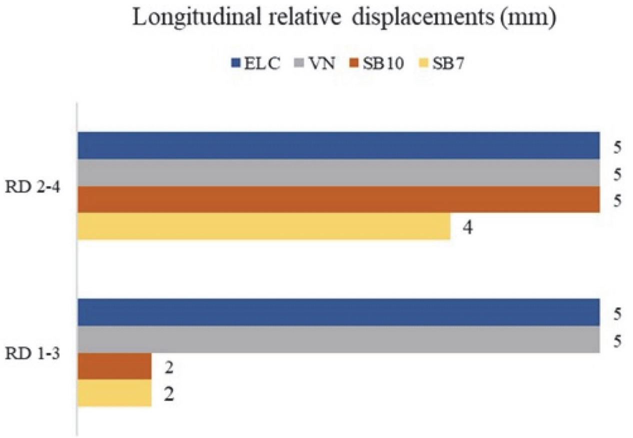

Figure 7. Comparative results of the relative displacements in longitudinal direction

4 Conclusions

This paper presents the results of an experimental programme with different dynamic actions on the shaking table. The structural model is at a natural scale and is made of a mineral composite material reinforced with fiberglass mesh. The model was fixed to the base and instrumented with displacement transducers and accelerometer. The model has low weight due to the reduced sections and very high rigidity due to the fiberglass reinforcement and the ribbed walls respectively.

Following the tests performed, records of accelerations and absolute displacements were recorded for the post-processing stage. According to these records, the structural model has a good seismic behaviour in all the considered seismic scenarios. Regarding the damages of the construction, it did not show visible structural degradation as it remained intact after all tests. The maximum relative displacement between the top and the base of the model is 5 mm, which means 0.17 % of the construction height. The different values of the displacements recorded on the longitudinal walls show that the wall with the door opening had larger flexibility compared to the opposite longitudinal wall without any openings.

From a structural point of view, the solution can be considered successful in the case of constructions with a level or maximum two storeys and, therefore, regarded as an alternative to traditional materials like masonry, wood or reinforced concrete when building houses.

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