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FIBER REINFOCED POLYMER USED FOR FLOODING PROTECTION OF ENGINEERING STRUCTURES MADE OF RC AND BRICK MASONRY

BY

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Abstract. Urban and rural floods are becoming nowadays a frequent problem to be dealt with, by both the population and the authorities. Floods and flood related natural disasters act against the civil, industrial and agricultural structures by the hydrostatic and hydrodynamic pressures of water. A set of protective solutions based on Fiber Reinforced Polymer (FRP) composite materials, for structural elements of buildings subjected to flood loadings, is proposed and analysed. These solutions are achieved by using the hand lay-up forming technique utilizing glass, carbon or aramid fibers fabrics pre-impregnated with thermosetting epoxy, polyester or vynilester resins.

The application of these FRP composites is carried out on reinforced concrete columns and beams as well as on brick masonry works aiming to increase in the overall load bearing capacity, especially against horizontal loads. An improved protection against excessive humidity is also envisaged.

The Finite Elements Method based LUSAS software was used to simulate a partially flooded structure. The numerical modeling was carried out in both the un-strengthened and strengthened conditions of the structure in order to assess the increasing in load and deformation capacities of the structural elements. Volumetric finite elements were used for modeling the concrete and masonry members.

Key words: FRP composites, flooding, reinforced concrete members, brick masonry panels

1. Introduction

This investigation deals with the retrofitting methods applied to buildings and structures in flood hazard areas especially dry flood proofing. Retrofitting solutions intend to eliminate and reduce the possibility of flood damage. The retrofitting actions are intervention measures such as: *elevation* of building, *relocation* of structure outside of floodplain, *dry flood proofing* through strengthening of the structural elements, *wet flood proofing*, *floodwalls or levees protection*.

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An example of a flooded house exposed to hydrostatic pressure increasing with the water depth as well as the buoyancy forces is illustrated in Fig. 1.

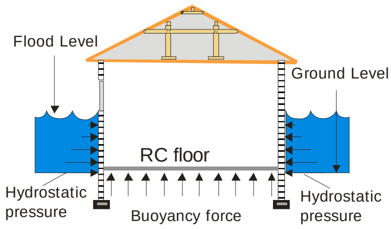

Fig. 1. – Hydrostatic pressure acting on masonry walls and reinforced concrete floor.

A suitable protection method will be analyzed in the case of structures placed in areas susceptible flooding. In fig. 2 a series of practical solutions for protection against flooding is shown.

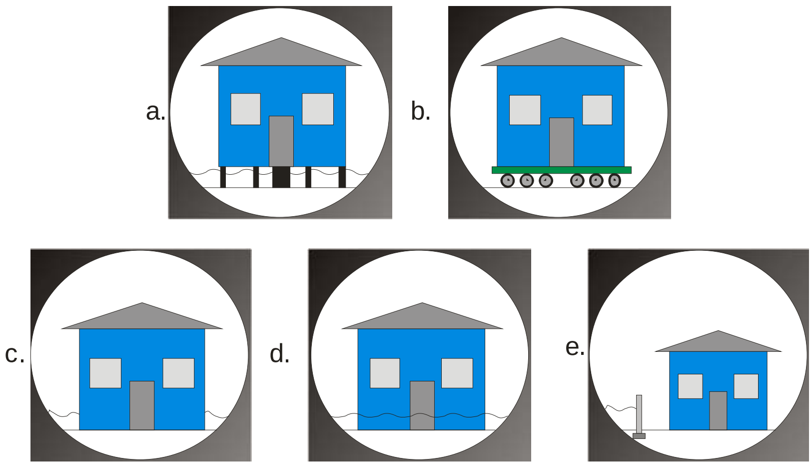

Fig. 2. – Methods of protection applied to houses in the case of flood disaster: *a* – elevation of an existing house using solid walls or columns; *b* – relocation of an existing building outside of flooded area; *c* – dry flood proofing using strengthening methods of structural elements; *d* – wet proofing where the utilities and structural elements are resistant to water during flooding; *e* – floodwalls or levees placed around the house [1].

From the analysis of these five cases, dry flood proofing using FRP has been considered since fiber reinforced polymer have particular advantages namely: *convenient specific properties* (impact absorption, damping performance, fatigue resistance), *long term durability* (corrosion resistance, environmental resistance), *design flexibility* (tailored properties, good architectural features), *weight saving* (dead load reduction), insulating properties (electrical, thermal and acoustic), *acceptable fire resistance* (low smoke and toxicity). Thus, FRPs can be used in a variety of structural applications such as: repair and strengthening of RC structures, masonry, wooden elements or connections, steel or cast iron elements, etc.

Some possible application solutions for strengthening of structures or structural elements with FRP composites are the following:

a) *Visible* from outside intervention using plate bonding, hand lay-up techniques, confining with FRP fabrics, etc;

b) *Hidden* using glass FRP glued sheets or rods inserted in preformed slots or FRP profiles or bars.

2. Proposed Model

An in filled masonry construction with reinforced concrete columns and beams was analysed in the event of a major flood. The hydrostatical water loading was modeled according to the ASCE/SEI 7 code [2], using the following load combinations:

$$\begin{aligned}
&1.\ 1.4(D+F);\\
&2.\ 1.2(D+F+T)+1.6(L+H)+0.5(L_r \text{ or } S \text{ or } R);\\
&3.\ 1.2D+1.6W+2.0F_a+L+0.5(L_r \text{ or } S \text{ or } R);\\
&4.\ 0.9D+1.6W+2.0F_a+1.6H,
\end{aligned} \tag{1}$$

where: D is the dead load, F – the load due to fluids with well-defined pressures and maximum depths, T – the self-straining force, L – the live load, H – the load due to lateral soil pressure or ground water pressure, L_r – the roof live load, S – the snow load, R – the rain load, W – the wind load and F_a – the flood load.

3. The Analyzed Model

The first step in the performed analysis was to identify the most severe loaded panel of the considered structure. A typical Romanian masonry structure was modeled together with the reinforced concrete framing elements specified by recent design codes (tie-beams and columns – Fig.3).

After this step, the frontal panel was considered independently further on in order to decrease the number of finite elements and reduce the computation time to a reasonable period. Fig. 5 and 6 illustrate the bending moment distribution on the tension face of the panel together with the displacements in the acting direction of the pressing water

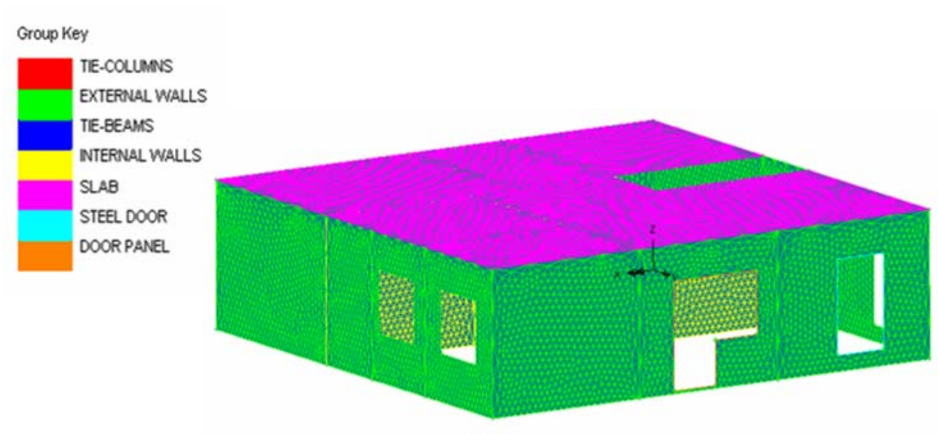

Fig. 3. – Finite Elements Mesh in the structural model.

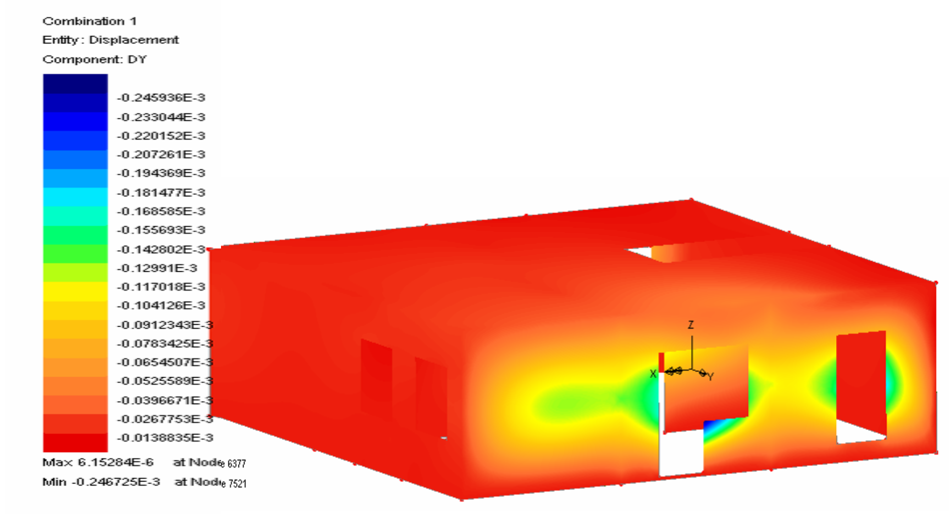

Fig. 4. – Displacements map on the model (water action considered in the load combination)

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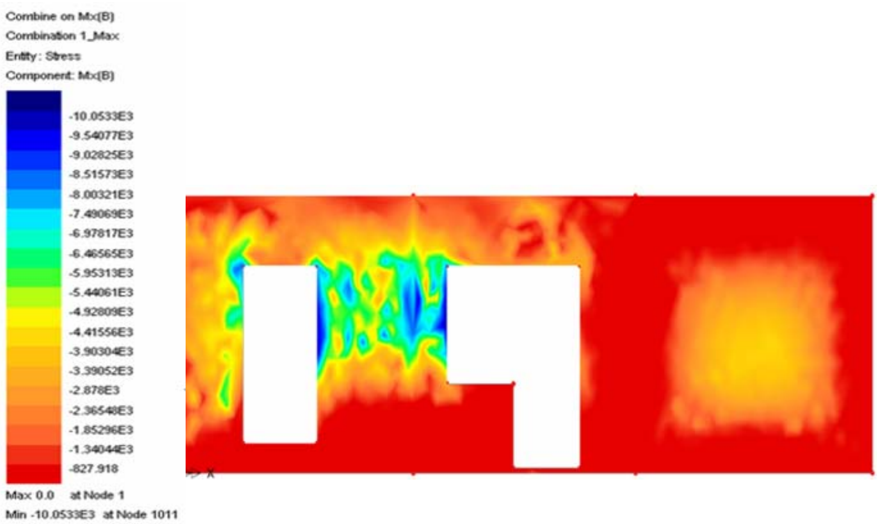

Fig. 5. – Bending moment distribution on the interior face of the individual panel

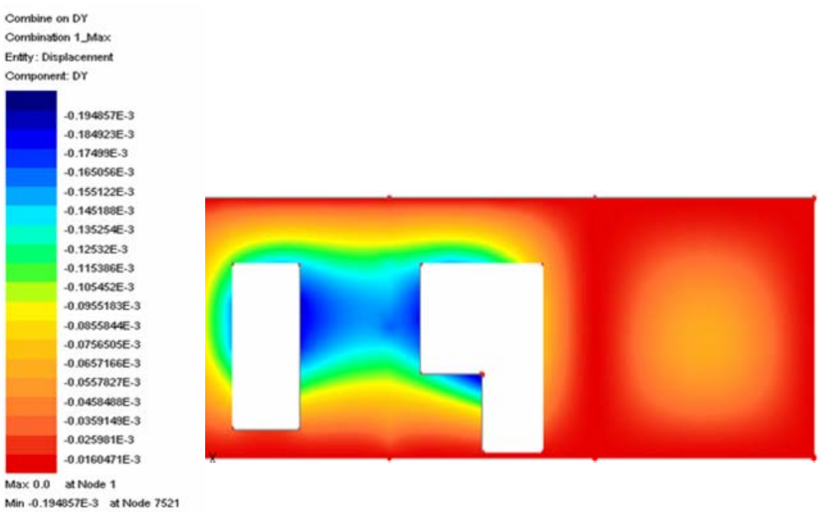

Fig. 6. – Displacements in the direction of water pressure action

The strengthening effect exerted by the fibre reinforced composite material was modeled considering a continuous membrane attached on the interior face of the panel.

A substantial increase in the deformation capacity of the panel was observed. Figs. 7 and 8 show the behavioural differences between the two considered situations (unreinforced and reinforced masonry panels).

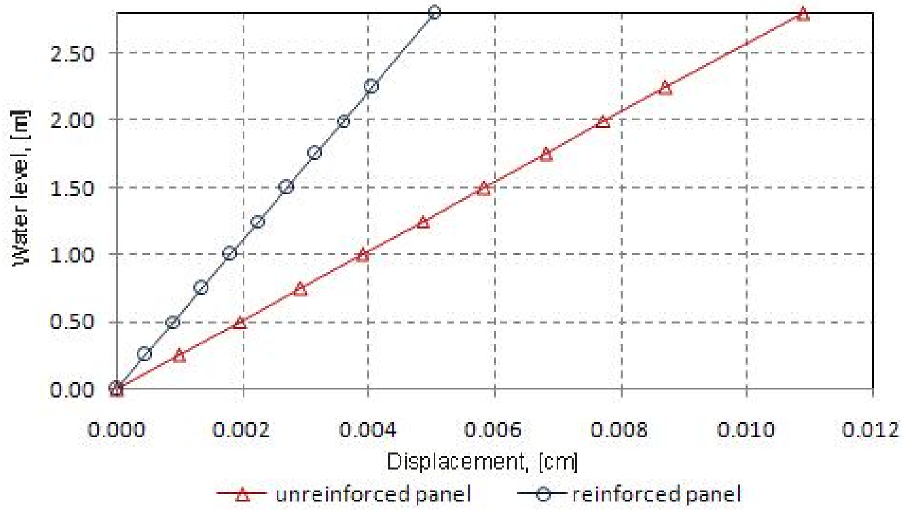

Fig. 7. – Water level *vs*. displacement (centre point of the panel).

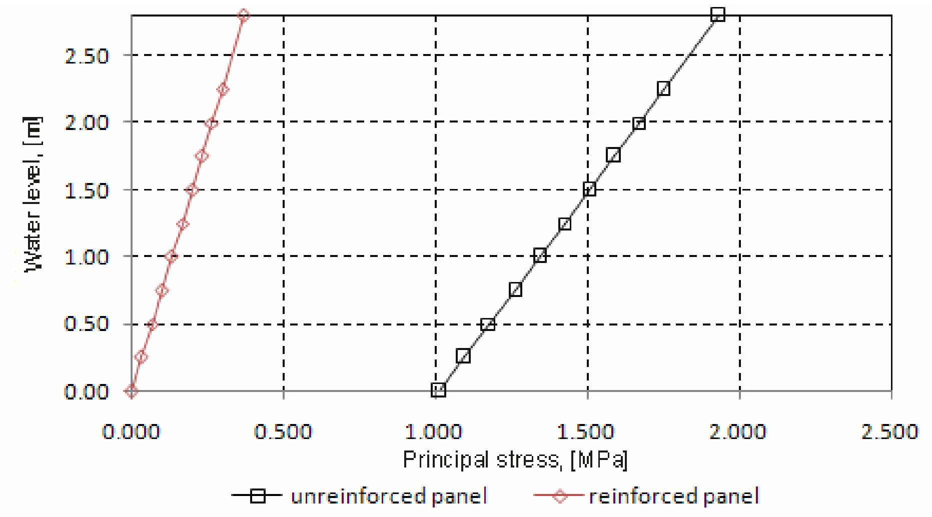

Fig. 8. – Water level *vs*. principal stress (centre point of the panel)

3. Conclusions

The following conclusions can be formulated after performing the finite elements analysis:

a) Fibre reinforced polymer composites can be successfully utilized to improve the load–carrying capacity of the construction members and structures made of traditional materials, when they are subjected to loading from flooding.

b) Finite element analysis and modeling are suitable tools for analysis of masonry structures strengthened with FRP composite membranes.

c) An important increase in the flexural capacity and stiffness improvement of reinforced masonry panel is possible when FRP composites strengthening systems are used;

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REFERENCES

1. * * * *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures*, F.E.M.A. (Federal Emergency Management Agency) January 1995.
2. * * * *Minimum Design Loads for Buildings and other Structures*, American Society of Civil Engineers, ASCE 7-05, 2006.
3. * * * *LUSAS Modeller User Manual" for Civil, Structural and Bridge Engineering*, Version 13.6, 2004-2005, Surrey, UK.

UTILIZAREA COMPOZITELOR POLIMERICE ARMATE CU FIBRE PENTRU PROTECTIA LA INUNDATII A STRUCTURILOR INGINERESTI DIN BETON ARMAT SI ZIDARIE

(Rezumat)

Inundațiile din mediul urban şi rural sunt probleme frecvente cu care se confruntă Romania la ora actuală. Dezastrele naturale de tip inundații afectează structural construcțiile civile, industriale şi agricole datorită presiunii hidrostatice şi hidrodinamice a apelor. Autorii propun o serie de măsuri de protecție a elementelor structurale a unei construcții folosind compozite polimerice armate cu fibre (CPAF). Măsurile de protecție au la bază metoda formării prin contact şi folosesc țesături din fibre de sticlă, carbon, aramid preimpregnate cu răşini epoxidice, poliesterice sau vinilesterice.

Aplicarea acestor CPAF se realizează la stâlpi din beton armat, grinzi din beton armat şi zidării de cărămidă în vederea creşterii capacității portante, rezistenței la încărcări orizontale şi a protecției la umiditate excesivă.

Programul de analiză cu elemente finite LUSAS a fost folosit pentru generarea unei structuri parţial inundată în fază neconsolidată şi în fază consolidată, cu CPAF, în vederea realizării studiului comparativ al sporurilor de tensiuni şi deformaţii din elementele structurale. Au fost folosite elemente de volum pentru modelarea elementelor din beton şi zidărie. S-a constatat că aplicarea soluţiilor compozite de consolidare conduce la îmbunătăţirea comportării la încovoiere normală pe planul elementelor şi la sporirea rigidităţii structurale.