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# Influence of Atmospheric Physical Effects on Static Behavior of Building Plate Components Made of Fiber-Cement-Based Materials

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***Abstract*—**The paper presents the brief information on particular results of experimental study focused to the problems of behavior of structural plated components made of fiber-cement-based materials and used in building constructions, exposed to atmospheric physical effects given by the weather changes in the summer period. Weather changes represented namely by temperature and rain cause also the changes of the temperature and moisture of the investigated structural components. This can affect their static behavior that means stresses and deformations, which have been monitored as the main outputs of tests performed. Experimental verification is based on the simulation of the influence of temperature and rain using the defined procedure of warming and water sprinkling with respect to the corresponding weather conditions during summer period in the South Moravian region at the Czech Republic, for which the application of these structural components is mainly planned. Two types of components have been tested: (i) glass-fiber-concrete panels used for building façades and (ii) fiber-cement slabs used mainly for claddings, but also as a part of floor structures or lost shuttering, and so on.

***Keywords*—**Atmospheric physical effect, building component, experiment, fiber-cement, glass-fiber-concrete, simulation, static behavior, test, warming, water sprinkling, weather.



## I. INTRODUCTION

THE paper authors' workplace deals with the experimental research of the actual behavior of civil structures very intensively in the long term. The experimental verification is mainly oriented to the loading tests of load-carrying structures and components, but also to other problems in the connection with load-carrying capacity, strength and resistance. Within the co-operation with the company of the Research Institute of Building Materials, Inc. (VUSTAH, a.s.) at Brno city the large research directed towards the experimental investigation of the behavior of building plate components based on fiber-cement materials has been realized recently. The attention has been paid to the development of these materials from the viewpoint of production technology, physical and chemical properties (see http://www.vustah.cz), to mechanical properties and load-carrying capacities (see mainly [1-7, 12-15]) and, last but not least, to the influence of atmospheric physical effects, caused by weather changes, on the static behavior of these products.

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## II. PRINCIPLES OF TEST METHOD

The procedure of the simulation of atmospheric influences on the behavior of façade panels, oriented to the verification of temperature and rain effects on stresses and deformations of the building plate component, is based on the defined cyclic mode of the test specimen warming up and sprinkling.

To simulate the behavior of the plate structural component under warming up and sprinkling caused by varying weather conditions, an experimental conventional procedure developed at the Research Institute of Building Materials, Inc. has been utilized. The method involves producing recurrent cycles composed of partial segments:

(i) water sprinkling – 170 ± 5 min.;
(ii) pause – 10 ± 1 min.;
(iii) radiant warming up – 170 ± 5 min.;
(iv) pause – 10 ± 1 min.

In common 18 those cycles represent 1 year of component operation in the summer period upon South Moravian region.

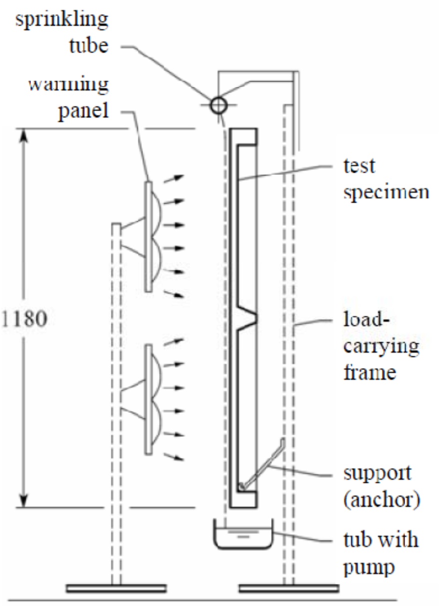


Fig. 1 Scheme of test equipment

While warming, after the time of 15 minutes the surface temperature of 60 ± 5 ºC must be reached. The difference between the temperature in the centre and near the corners of the specimen must not be more than 15 ºC. The prescribed sprinkling intensity is 1 liter / $m^2$·min. The illustrative scheme of the test equipment for the procedure of the simulation "warm – rain" described above is shown in Fig. 1. The source of radiant warming is represented by the electric warm panels; sprinkling is caused by water from the sprinkling tube as a part of the sprinkling system including the tub with a pump ensuring water circulation.

The test arrangement according to the scheme in Fig. 1 is chosen with regard to fulfill the requirements corresponding to the simulation of the sun radiation and water sprinkling acting to one side of the component, which cannot be performed, for example, by testing in the closed box.

## III. Glass-Fiber-Concrete Panels

### A. Test Specimens

The first type of the test specimens is the building façade panel made of glass-fiber-concrete (Fig. 2) based on cement matrix reinforced by dispersed glass fibers. This material is highly resistant to the most of physical, chemical and mechanical influences (see e.g. [3, 4, 6, 8, 9, 12, 13]), but in dependence on its usage in the particular structural component the influence of moisture and temperature changes caused by atmospheric physical effects of the weather can be significant.

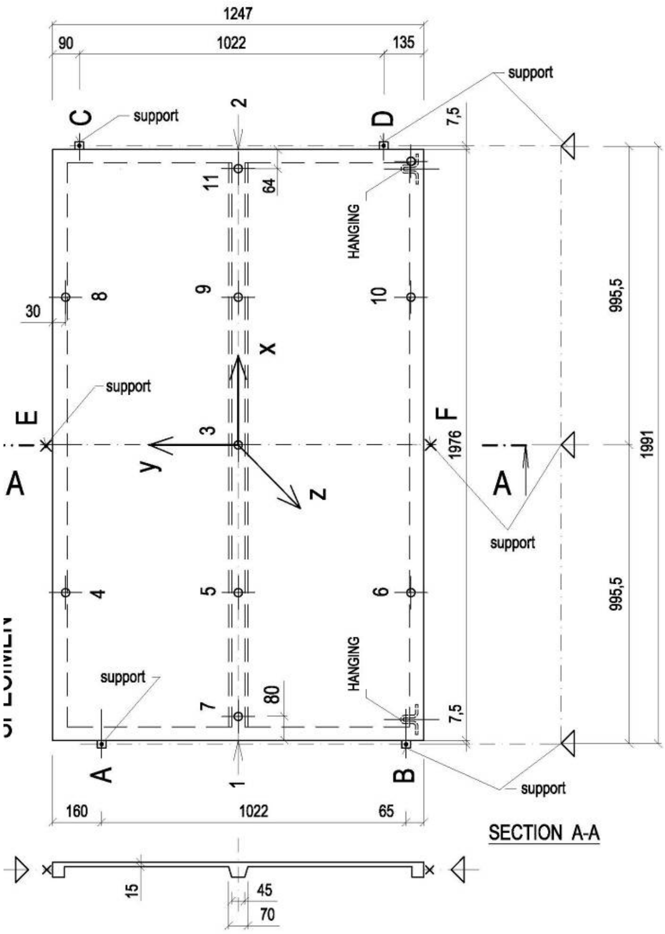


Fig. 2 Scheme of test specimen: glass-fiber-concrete façade panel (rotated 90º counterclockwise related to real position in construction)

In this case, in connection with atmospheric effects on the static behavior, i.a. the influence of two types of the panel anchorage to the load-carrying structure has been investigated – for anchorage detailing see e.g. Figs. 5, 6, more in [3, 4].

### B. Test Arrangement and Realization

The panel warming has been realized using the system of eight electric warm sources. Sprinkling panel surface by water has been realized by the hole sprinkling tube located above the top edge of the panel and connected to the submersible pump in the tub of the testing frame. Figs. 3 to 6 illustrating test arrangement and realization demonstrate test method principle but mainly, clearly the test procedure practical application.

In total 35 cycles has been executed. The specimen surface temperature was controlled by infrared remote detectors and verified by thermo-camera (see illustration in Figs. 7 and 8).

Fig. 3 Warming glass-fiber-concrete façade panel: view to electric warm sources and water tub

Fig. 4 Warming glass-fiber-concrete façade panel: view to panel backside with installed detectors

Fig. 5 Sprinkling glass-fiber-concrete façade panel: view to indicators of deformations on the side of specimen

Fig. 6 Sprinkling glass-fiber-concrete façade panel: view to water simulating rain effects

### *C. Test Results*

The specimen has been tested 28 days after its production. At support points A, B, C, D and E, F (see scheme in Fig. 2) the characteristic forces and displacements caused by warming and water sprinkling have been measured. The basic test results are presented in Fig. 9 to 12, which show forces and deformations caused by panel shrinking or expanding as a result of temperature and moisture changes in the interaction with marginal conditions given by actual panel supporting.

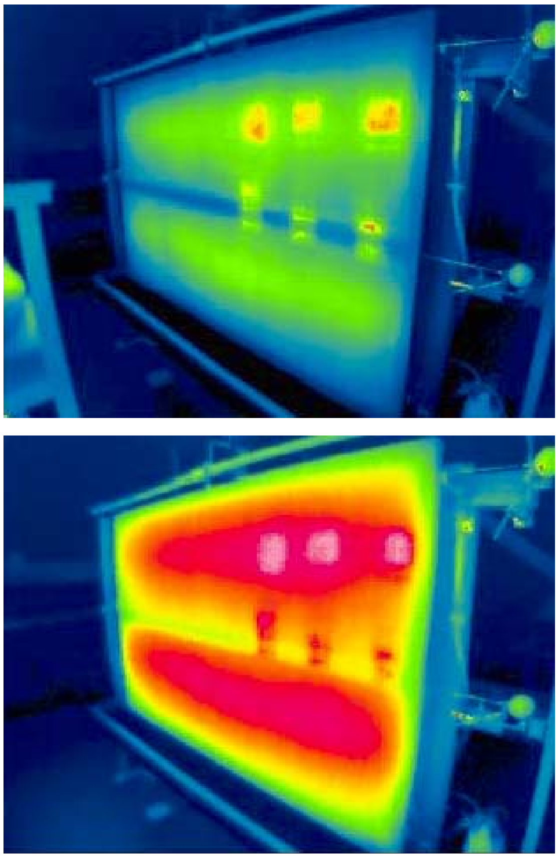

Fig. 7 Illustration of thermo-camera monitoring: warming

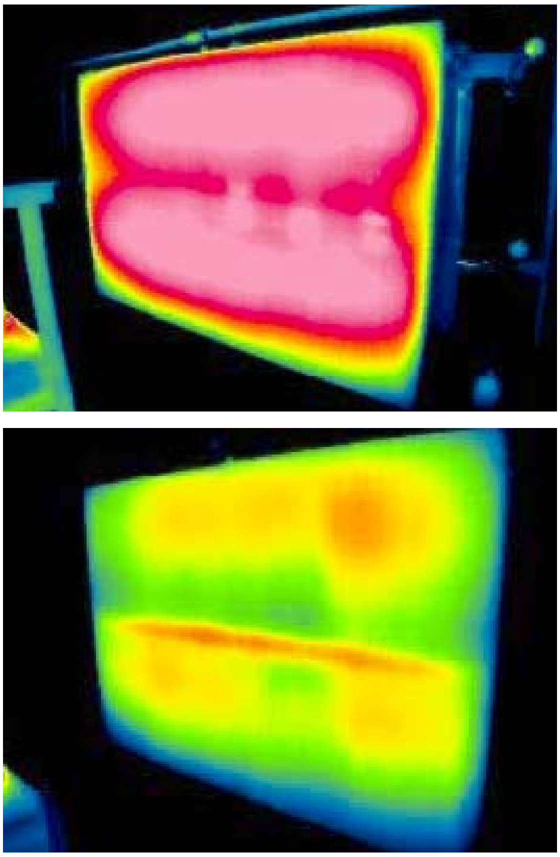

Fig. 8 llustration of thermo-camera monitoring: coolingI

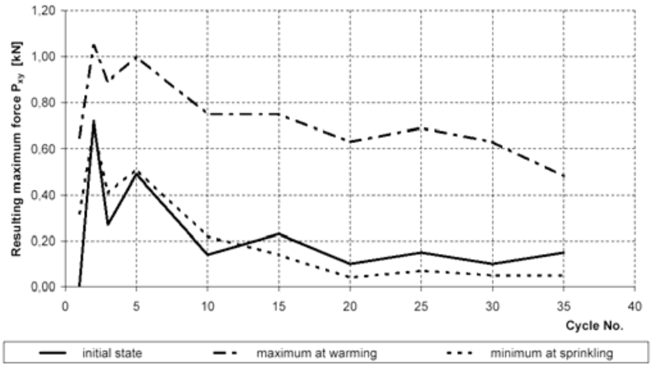


Fig. 9 Resulting maximum forces in x-y plane at points A, B, C, D

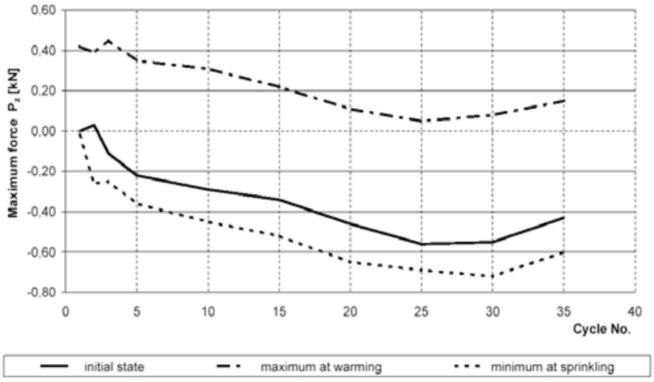


Fig. 10 Maximum force at points E, F, along the z-axis

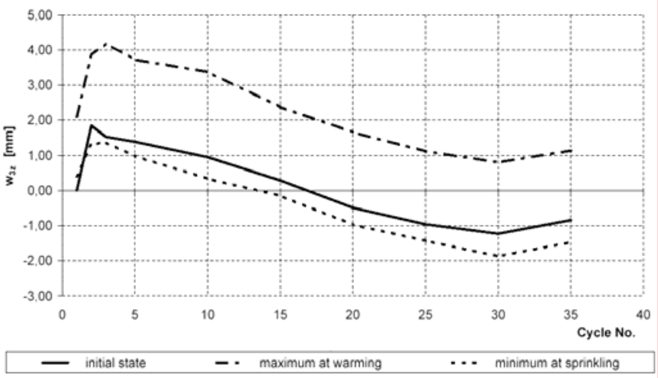


Fig. 11 Deflection at central point 3 along z-axis

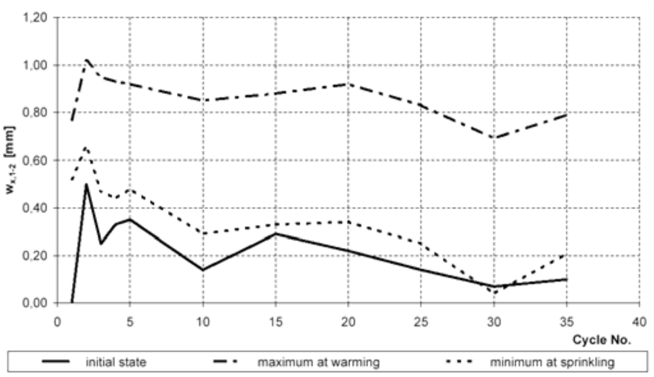


Fig. 12 Entire elongation between points 1 and 2

Presented test results give verified and useful information on actual support forces and specimen displacements caused by simulated weather conditions characterized by defined procedure of warming and sprinkling of structural façade component made of glass-fiber-concrete.

## IV. Fiber-Cement Slabs

### *A. Test Specimens*

The second type of tested component is the flat slab made of fibre-cement based on cement matrix with polypropylene and cellulose fibres in a mutual combination. In comparison with glass-fibre-concrete, products made of fibre-cement do not reach such high-quality physical, chemical and mechanical properties as well as load-carrying capacity (for more see e.g. [1, 2]), but they very good complies with strict environmental and ecologic requirements.

Because of its properties, fibre-cement is usually used for the production of flat slabs applied in load-carrying structures of building and technological constructions that means, for example, lost shuttering of bridge constructions, load-carrying structures of timber ceilings and dry floors, building claddings or shuttering panels and components in the manufactures of precast concrete products.

The test specimen subjected to the sprinkling and warming up mode is made up of fiber-cement slab bolted to the vertical wooden battens of the cross-section of 80 x 50 mm (see Fig. 13), which represents, for example, the structural composition of the external wall of timber building construction.

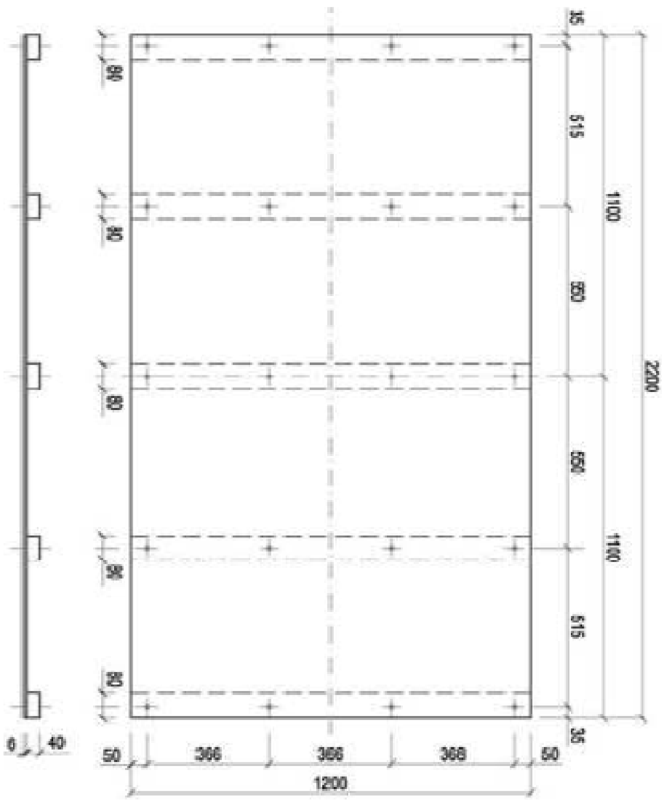


Fig. 13 Scheme of test specimen: fiber-cement slab
(rotated 90º clockwise related to the real position in construction)

Fig. 14 Installation of test specimen and test equipment for warming and sprinkling fiber-cement slab

Fig. 15 Warming fiber-cement slab: preparation of equipment

Fig. 16 Warming fiber-cement slab: view to electric warm sources

Fig. 17 Sprinkling fiber-cement slabs: view to water simulating rain effects

Fig. 18 Sprinkling fiber-cement slabs: view to water out flowing from sprinkling tube

### *A. Test Arrangement and Realization*

The specimen warming has been realized, as in the case of glass-fiber-concrete façade panel, also by eight electric warm sources. The temperature of the specimen surface has been controlled using contactless infra-thermo-detector. For the verification of the uniform distribution and intensity of the warming upon the panel area the use of the thermo-camera can be practicable and effective.

The shots of the test arrangement and realization verifying the influence of sprinkling and warming on the structural system using fiber-cement slabs are in Figs. 13 to 18.

### *B. Test Results*

Fig. 19 illustrates the resulting deformation of the slab (the deflection perpendicular to the centre plane [mm]) of given dimensions (see Fig. 12) after 50 cycles of the "warm-rain" mode. After the finishing total number of 50 cycles in the mode of repeated warming and water sprinkling, no obvious failures or cracks have been monitored on the surface of the tested specimen.

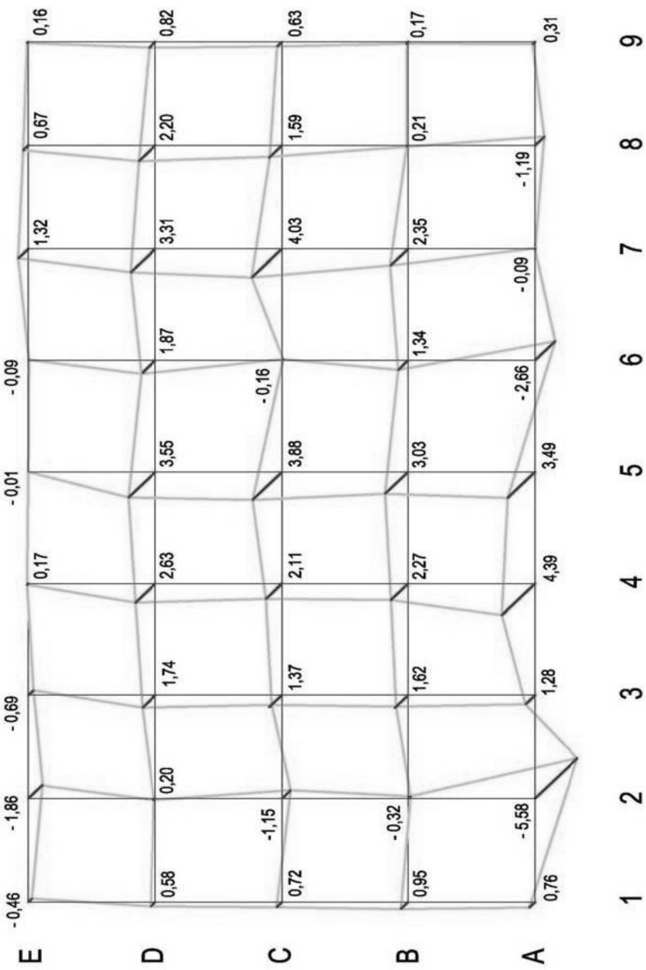


Fig. 19 Deformations of fiber-cement slab: distribution of deflections perpendicular to centre plane (rotated 90º counter-clockwise related to the real position in construction)

## V. Conclusion

Presented test results give verified and useful information on actual forces and displacements caused by simulated weather conditions characterized by defined procedure of warming and sprinkling of building structural components made of materials based on cement matrix with dispersed reinforcing fibers.

The obtained results cannot be generalized, because from particular examples mentioned above it is evident, that the results are, case by case, very different in dependence on the variability of the physical, chemical and mechanical material properties and diversity of structural detailing and supporting the components, which altogether significantly influence the component behavior caused by atmospheric effects given by weather changes.

## Acknowledgment

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