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Bending behaviour of insulated ribbed plywood plate during drying of accumulated moisture

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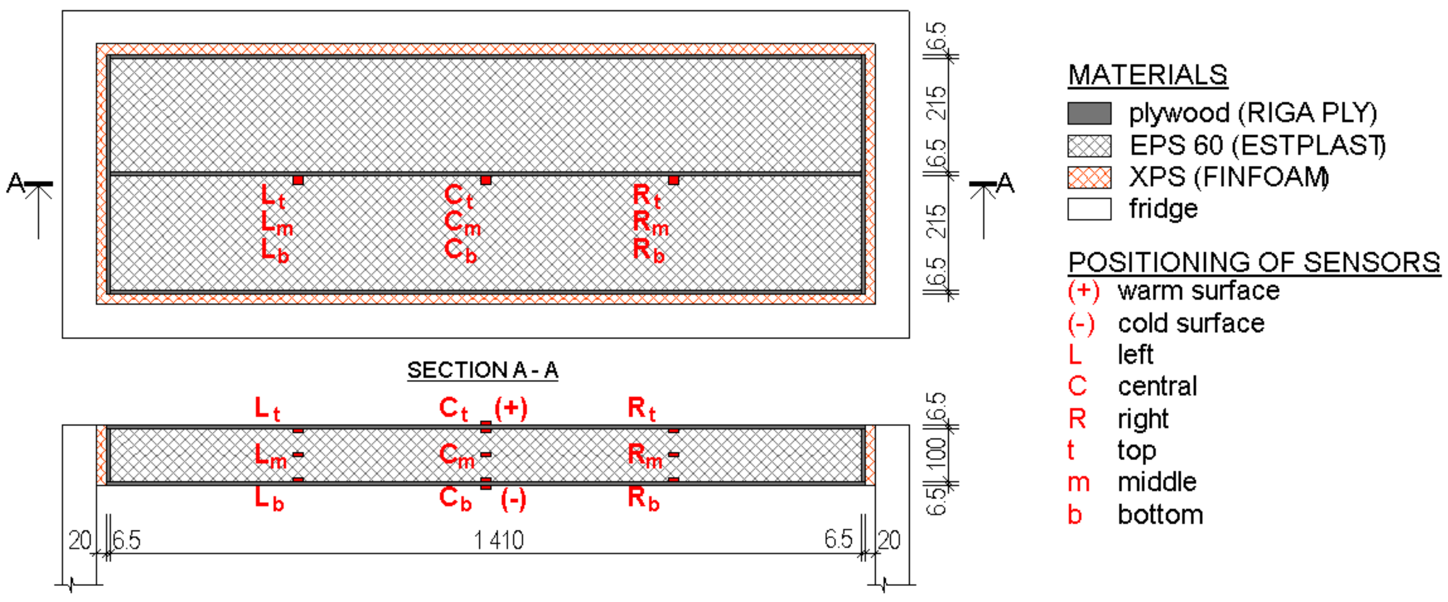
INTRODUCTION

Nowadays building designs need to fulfil with criteria of energy efficiency, minimum environmental impact and also provide healthy and safe condition for building occupants. Studies have already been carried out on hygrothermal behaviour of vertical light weight walls with an exterior air barrier and with OSB as interior vapour retarder. There is also an ongoing research of the composite plywood plates with increased specific stiffness that could be also used as building envelope. For such plates hygrothermal performance has great influence on deformation and durability.

Therefore the goal was set to verify methodology for evaluation of lasting accumulated moisture impact on ribbed plywood plate used as building envelope construction. Moisture was accumulated in the inner layers of the plate about 10 months. After that the plate was dried to its initial moisture content approximately within 3 months. The plate was loaded in 4-point bending to evaluate moisture impact on its deflection.

DIMENSIONS AND MATERIALS OF THE TEST PLATE

The dimensions of the plate are shown in figure 1. The sheetings and ribs were made of birch plywood “Riga Ply” of thickness 6.5 mm (initial moisture – 8.5%). Polystyrene insulation EPS 60 “Estplast” of thickness 100 mm was placed between the ribs. All parts of the plate were glued together with polyurethane wood adhesive “Bison PU MAX D4”. The XPS sheets around the perimeter of the plate shown in figure 1 were not components of the plate and were used only in order to ensure the temperature difference between fridge and room. Since the plate previously was used to study moisture flow through the inner layers, in order to prevent moisture flow through the side surfaces of plate they were covered with a sealant. For collecting data the plate was equipped with cables and eleven sensors.



Material	Mass, kg
Plywood “Riga Ply”	8.165
Polystyrene EPS 60 “Estplast”	0.935
Sealant, cables and sensors	2.230
Total:	11.330

Figure 1. *Dimensions of ribbed plate, positioning of the sensors and initial mass of the plate and its components.*

EXPERIMENTAL SETUP

The moisture was accumulated due the temperature gradient and relative humidity gradient along the thickness of the plate during the first stage of the test which started in the spring of 2016 when behavior of building envelope was simulated. The plate was placed on the top of fridge leaving its door open like it is shown in figure 2.

Experimental conditions on the warm surface of the plate were like for realistic indoor conditions where due the heating and solar radiation the fluctuations of temperature and relative humidity can occur. The relative humidity at room was 18.6 to 90.9% and the temperature was 11.8 to 33.3 °C. The relative humidity at fridge was 16.8 to 59.3% and the temperature at the start of experiment was 14.4 °C reaching -18.6 °C about in six hours.

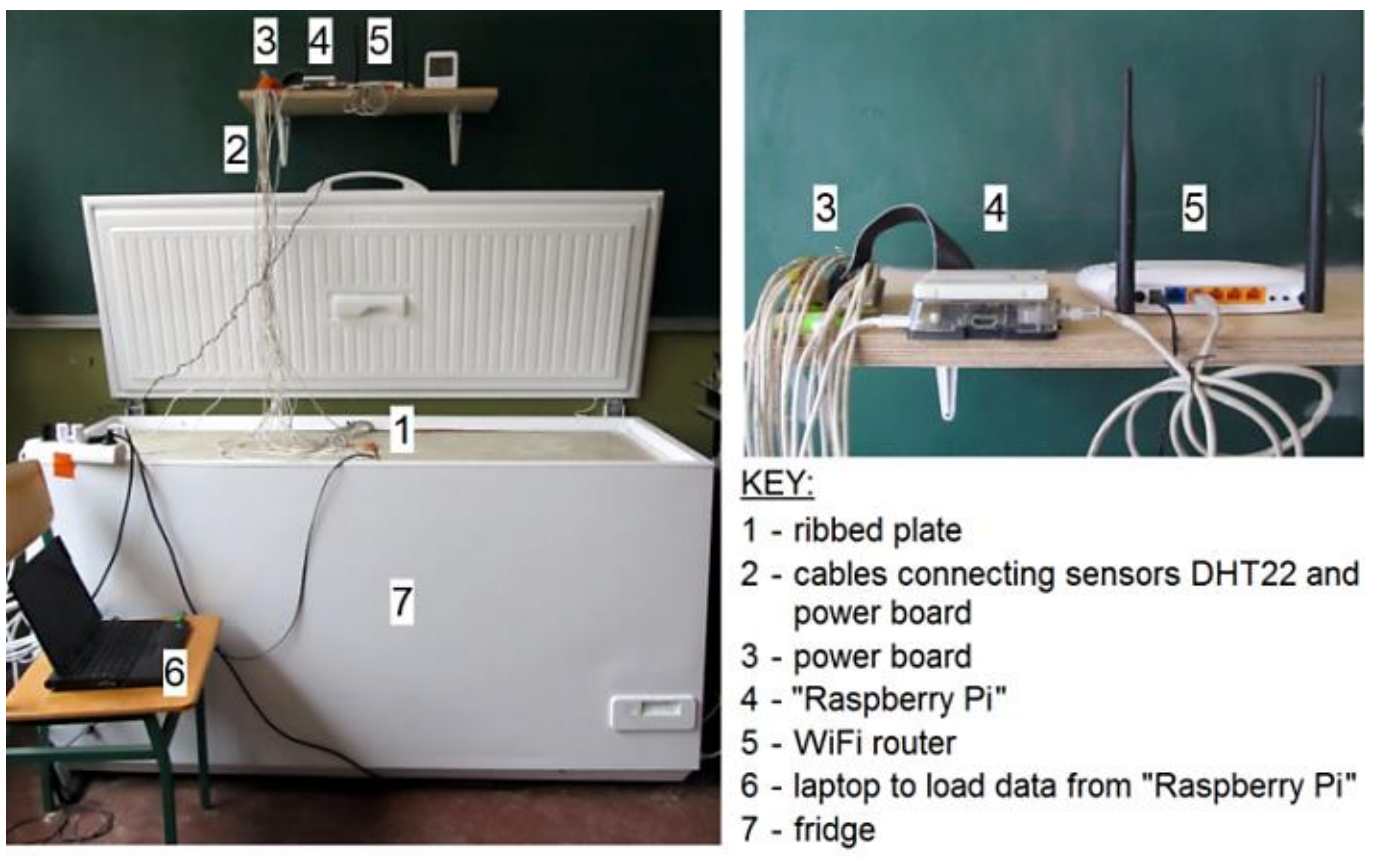


Figure 2. *Experimental setup for simulation of building envelope conditions.*

In the winter of 2017 the plate was removed from the fridge and left at room conditions to dry out for about three months. The relative humidity at room was 20.0 to 49.0% and the temperature was 13.0 to 21.0 °C. During drying the plate was placed on the stand thus ensuring free exposure of ambient air to the both sheetings of plate. During drying time the plate was weighed with an accuracy of ±0.005 kg to determine the average moisture content of plywood and to evaluate its effect on the deflection of plate in bending. The moisture content of plywood was determined assuming that plywood absorbs all moisture accumulated in plate, since polystyrene is not a hygroscopic material.

The plate was loaded in 4-point bending. The loading scheme of the plate is shown in figure 3. Load and reaction forces were applied by rollers of diameter 30 mm. Since it was planned to carry out a series of loading, the load was chosen such that only elastic deformations would occur in the most stressed areas of the plate. Load of 2.0 kN was chosen for testing and was applied to plate in four steps – 0.5, 1.0, 1.5 and 2.0 kN – reaching maximum value in 20 to 30 minutes. The deflection of the midpoint of the plate was determined as average value of measurements with deflection gauges at midpoint of each side of the plate. Accuracy of deflection gauges was 0.01 mm.

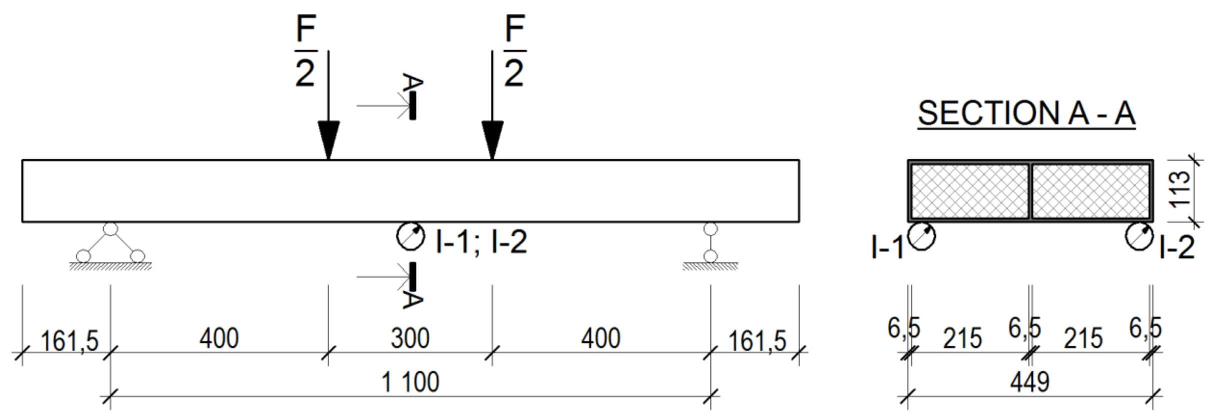


Figure 3. *Loading scheme and displacement of deflection gauges (I-1 and I-2).*

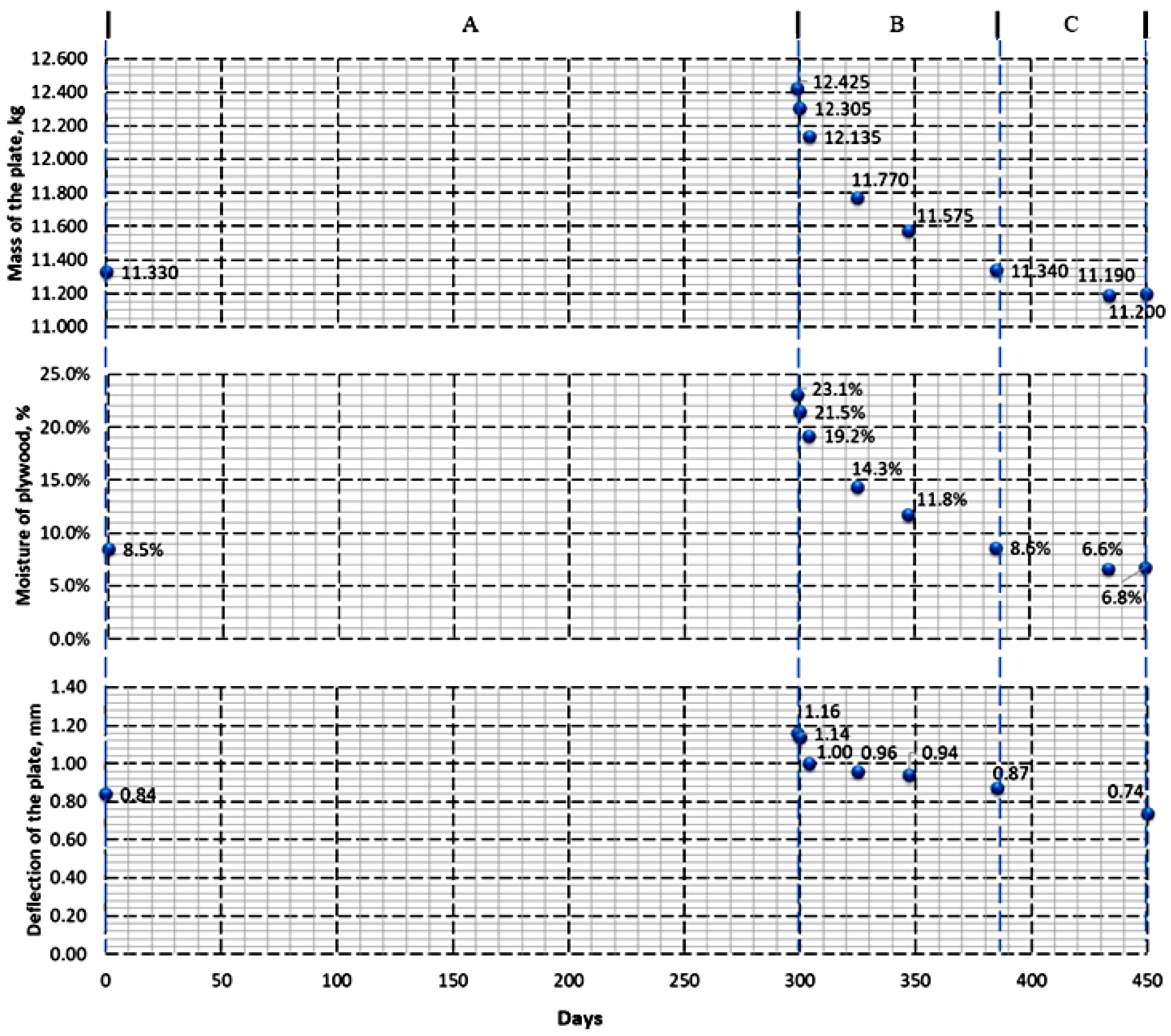
RESULTS

The results are shown in figure 4. Generally the test can be divided into three stages:
A – the plate is placed on the top of fridge as shown in figure 2, moisture is accumulated due the temperature gradient and relative humidity gradient along the thickness of the plate (299 days);
B – the plate is removed from the fridge and left at room conditions to dry out to its initial mass, the plate is loaded in 4-point bending periodically to measure its deflection (86 days);
C – the plate is dried to equilibrium moisture corresponding to the room conditions (66 days).

First time the plate was weighed and loaded in 4-point bending before it was placed on top of the fridge. Initial mass of the plate was 11.330 kg. During the stage “A” additional moisture of 1.095 kg was accumulated that is 9.7% of initial mass of the plate. Average moisture of plywood changed from 8.5% to 23.1%. The deflection before and after accumulation of moisture was 0.84 and 1.16 mm respectively.

During stage “B” the plate was dried to mass of 11.340 kg. The difference of this and initial mass is 0.010 kg that is within the range of measurement error. Average moisture of plywood changed from 23.1% to 8.6%. The deflection after drying to initial mass of the plate was 0.87 mm. As the precision of the deflection gauges was 0.01 mm and the difference between deflections corresponding to initial mass (11.330 kg) and mass after drying (11.340 kg) did not exceed 0.03 mm, it can be assumed that difference of deflections also is within the range of measurement error.

During stage “C” the plate was dried to equilibrium moisture corresponding to the room conditions. Between the last two measurements 17 days elapsed.



KEY:
A – accumulation of moisture (299 days);
B – drying to the initial moisture content (86 days);
C – drying to the equilibrium moisture content corresponding to the room conditions (66 days).

Figure 4. *Mass of the plate, moisture of the plywood and deflection of the plate.*

CONCLUSIONS

A method to evaluate lasting impact of moisture on ribbed plywood plate used as building envelope was verified. To achieve this goal the plate was loaded in four-point bending before accumulation of moisture due the surface exposure to different temperatures and ambient air humidity, after accumulation of this moisture and after drying out. After reaching initial mass of plate no substantial changes of the plywood properties were detected. Also test results shows that the deflection under loading before accumulation of moisture and after drying out to the initial mass practically has the same value and the difference of deflection is almost within the range of measurement error. The experimental verification confirms applicability of the methodology to evaluate lasting moisture impact on ribbed plywood plates.

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