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# CREEP BEHAVIOUR OF PARTICLE-BASED PANELS AND ITS RELATION TOWARDS DENSITY PROFILE

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***Abstract:***

*Wood-particle-based panels are versatile materials, which can be used for packaging, furniture and construction. Their usability ranges from non-load-bearing to load-bearing purposes. Since they are used over long periods of time, it is important to know their behaviour under load over long periods. Three different particle-based panels: Oriented Strand Board - OSB type 3, P5 and P2 grade particleboard - PB) where exposed to different bending loads. The load was applied to the upper and bottom sides of the panel for 24h. The behaviour of panels was correlated to density profile. During this experiment, it was determined that deformation in bending depends on the type of composite and the side of the panel exposed to the load. The lowest deflection was observed in OSB. At 40% of maximum load, the highest deflection was determined in P5 grade PB, while at 60% of maximum load, the highest deflection was determined in P2 grade PB. The wood particle type did not play an essential role when analysing deflection, because OSB type 3 and PB grade P2 values were about 10% lower than that of the P5 structural panel. A possible reason why the deflection was 10% higher in the case of structural PB P5 could be related to the actual load applied, namely for PB P2 the load was 176 N, whereas for PB P5 the load was almost 45% higher (253 N). The deflections increased linearly corresponding to stress levels of 40% and 60% of the maximum load.*

***Key words:*** *OSB; particleboard; deformation; creep; density profile.*

## INTRODUCTION

The usability of wood-based panels when used for load-bearing purposes is related to their viscoelastic behaviour when they are exposed to long-term loadings (Huang 2015). Creep is the time dependent deformation of a material under sustained load (Ashby & Jones 1986). If the load is large and the duration is long, failure will occur. Creep takes a leading role for the design and durability of wood structural elements (Huang 2016). The information about fundamental properties of wood particles/fibres-based products and processing method on the creep behaviour is limited (Bouafif et al. 2013). For wood structures designed to resist decades, the progressive deflections should be assumed during the service life (Zhou et al. 2000). The deflection of wood and wood-based composites has been analysed in relation with moisture content (Ranta-Maunus 1975) and air humidity (Bazant & Meiri 1985). Holzer et al. (1989) made an exhaustive study about the viscoelastic behaviour of wood. Many analyses were conducted to determine constitutive models to predict the deformation of loaded wood when moisture content changes (Huang 2015). The differences in creep behaviour of wood-based panels are related to the type of constituents and to the adhesives Since more than three decades the rheological behaviour of OSB (Pałubicki & Plenzler 2004), MDF (Zhou et al. 2000), CLT (Nguyen et al. 2019) and HDPE (Bouafif et al. 2013) have been investigated. Gressel (1972) studied the influences of climate and load on deflection of wood-based materials. Creep behaviour of particleboards was analysed by Clad & Schmidt-Hellerau (1981) and Dinwoodie et al. (1990), of I-beams was assessed by Leichti (1986) and of structural lumber by Friedly et al. (2009). Creep behaviour of wood-based panels is also related to the type of panel: (Dinwoodie et al. 1990,

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Niemz et al. 1997, Mundy et al. 1998), density (Pałubicki & Plenzler 2007), sample size (Fan & Enjily 2008), equilibrium moisture content (Pałubicki & Plenzler 2007), level and duration of load (Fan et al. 2009) etc. The acquisition of creep data and its use in analysis, prediction, and estimation are of great importance for material research and characterization.

During production of wood-based panels, some unwanted effects, like settlement of fines to the bottom of the formed mat occur. The settlement of fines leads to uneven density profile, which could have a negative impact on wood-based panel properties and form stability during the whole service life.

The creep test can last up to 72 days (Pałubicki & Plenzler 2007). In this research, short-time four-point bending tests for 24 hours were performed, in order to compare the creep behaviour of different particle-based composites, when the load was applied to the top and bottom face of the testing specimen.

## MATERIALS AND METHODS

For the purpose of this experiment, three particle-based panels were used (Table1):
- OSB type 3 for load-bearing use in humid conditions (EN300),
- PB type P5 for load bearing use in humid conditions (EN312-5) and
- PB type P2 for general purpose use (furniture) in dry conditions.

*Table 1*

***Characteristics of wood-based panels used in the investigation***

| | Mark | Type of resin | Thickness in mm | Density in g/cm$^3$ |
|---|---|---|---|---|
| OSB type 3 for load-bearing use in humid conditions | OSB 3 | Melamine-urea formaldehyde | 17.44 (0.32) | 0.587 (0.51) |
| PB type P5 for load bearing use in humid conditions | PB P5 | Melamine-urea formaldehyde | 18.08 (0.28) | 0.709 (0.45) |
| PB type P2 for general purpose use in dry conditions | PB P2 | Urea-formaldehyde | 18.07 (0.36) | 0.700 (0.67) |

Samples (240mm×25mm×18mm) were conditioned at 20°C and 65% relative air humidity until constant mass was achieved. After completed climatization (30 days), 6 test specimens for each face were tested on universal testing machine Zwickl Roell Z 250 (Ulm, Germany), according to combined tests ASTM 04.10 Wood D143-09 for bending strength and EN 1195:1998. The EN 310:1993 describes the method of short-time strength determination in three-point bending test. In this study a four-point bending scheme was chosen, because it ensures constant bending moment and absence of shear between middle bearings (Pałubicki & Plenzler 2007). The density profile was determined with Dense Lab X (Hameln, Germany). The maximum force of loading and the creep behaviour were determined with four-point bending test (it will be referred from now on as bending test). On half of the samples, the load was applied on top, and on the other half – on the bottom face of the sample (Fig. 1). It has to be mentioned that OSB samples were cut out in such manner that the orientation of the strands was parallel to the length of the sample.

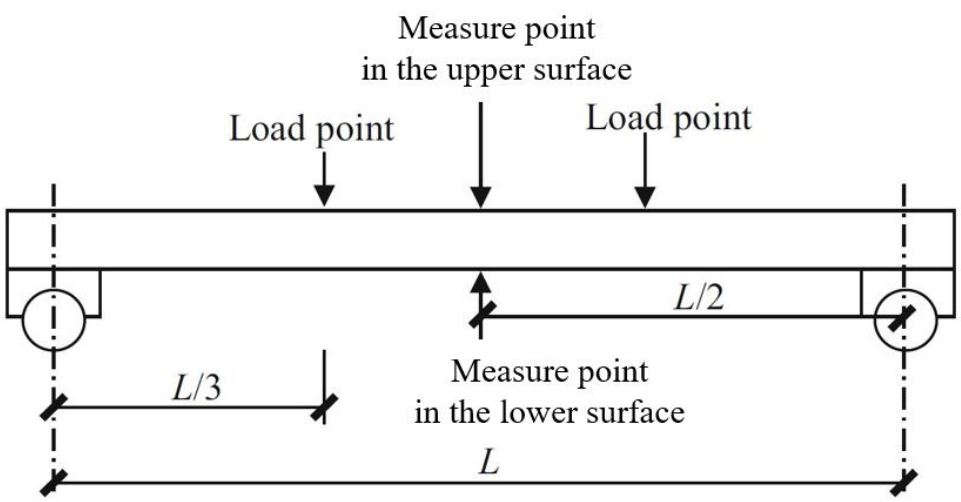



***Fig. 1.***
***Testing method for maximum load and creep behaviour (after Huang 2016) (L=240mm).***

Creep behaviour was determined at 40% and 60% of the average maximum load determined during the bending strength test. For half of the samples, the load was applied on top, and for the other half – on the bottom face of the panel. The duration of the test was 24 hours. Determined deformations were compared to the density of the top and bottom faces, which was analyzed by means of density profile measurement device with 50x50mm testing samples. The density of the surface layer was calculated as the average of the first and last 2mm of the panel.

**RESULTS AND DISCUSSION**

The typical density profiles of the panels used in the experiment are shown on Figs 2 to 4.

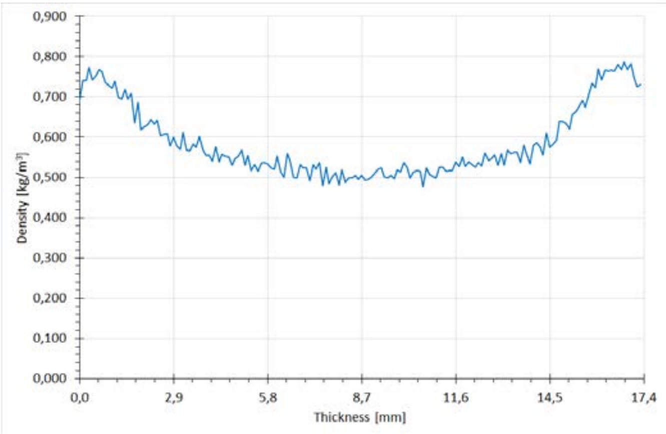



***Fig. 1.***
***Density profile of OSB 3 (top face side is left).***

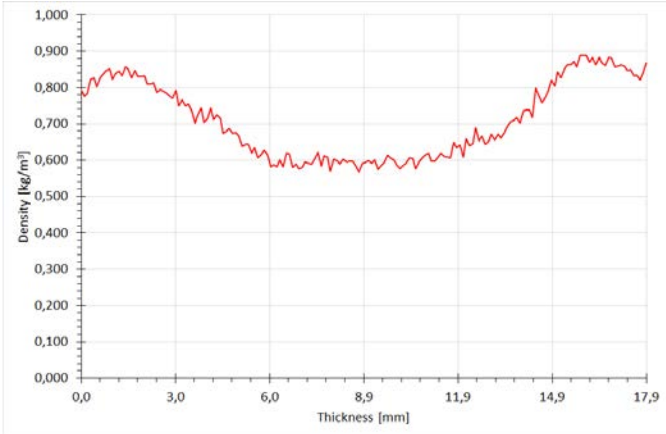



***Fig. 2.***
***Density profile of PB P5 (top face side is left).***

The density profile of OSB 3 (Fig. 2) shows a minimum density of 0.5g/cm³ at 8.7mm, in the core of the panel; the densities of the face layers range from 0.6 up to 0.8g/cm³. In the case of P5 particleboard (Fig. 3), the minimum density of 0.6g/cm³ was measured at 8.9mm. The density of the face layers can reach 0.9g/cm³. The same trend of density profile showed the P2 particleboard (Fig. 4), with a minimum of 0.6g/cm³ at 8.9mm and maximum values in the faces of 0.9g/cm³.

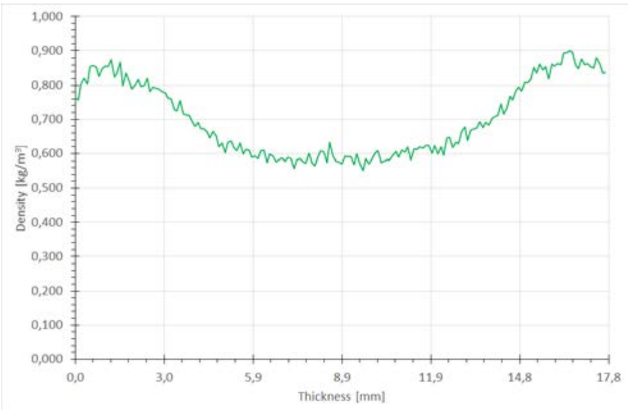



***Fig. 3.***
***Density profile of PB P2 (top face side is left).***

As results from figures 2 to 4, the highest differences between the top and bottom sides are less evident for OSB, whereas for both types of particleboard, the differences are more pronounced, due to the accumulation of fine-grained wood particles in the bottom layer of PB, that confers a slightly increased density due to agglomeration of ground material. The difference in the densities of the top and bottom 2mm from the surfaces of the panels, as well as the top and bottom halves of the panel are shown in Table 2. The densities of particleboards P2 and P5 are 13% higher than that of OSB.

*Table 2*

***Differences in top and bottom density (g/cm³) of the OSB and PB (SL=surface layer)***

| | Mark | Top SL average density | Bottom SL average density | Top half average density | Bottom half average density |
|---|---|---|---|---|---|
| OSB for load-bearing use in humid conditions | OSB 3 | 0.713 | 0.739 | 0.586 | 0.589 |
| PB for load bearing use in humid conditions | PB P5 | 0.827 | 0.862 | 0.703 | 0.719 |
| PB for general purpose use in dry conditions | PB P2 | 0.826 | 0.866 | 0.693 | 0.709 |

The bending strength test (Table 3) shows that the value of MOR for P5 is with 17% higher than that of OSB 3 and 31% higher than that of P2.

*Table 3*

***Bending strength and deflection at maximum force with regard to panel type***

| | Mark | Maximum force in N | Bending strength in $N/mm^2$ | Deflection at maximum force in mm |
|---|---|---|---|---|
| OSB for load-bearing use in humid conditions | OSB 3 | 500 (456/543) | 18.25 | 2.72 |
| PB for load bearing use in humid conditions | PB P5 | 634 (675/592) | 21.98 | 3.03 |
| PB for general purpose use in dry conditions | PB P2 | 439 (448/430) | 15.12 | 2.67 |

The numbers in brackets at maximum force represent the maximum force determined when the load was applied to the top face and to the bottom face.

The highest average deflection at of 40% of the maximum load was determined for the PB P5, that should undertake long-term loadings in humid conditions. This property is essential in such applications (Fig. 5).

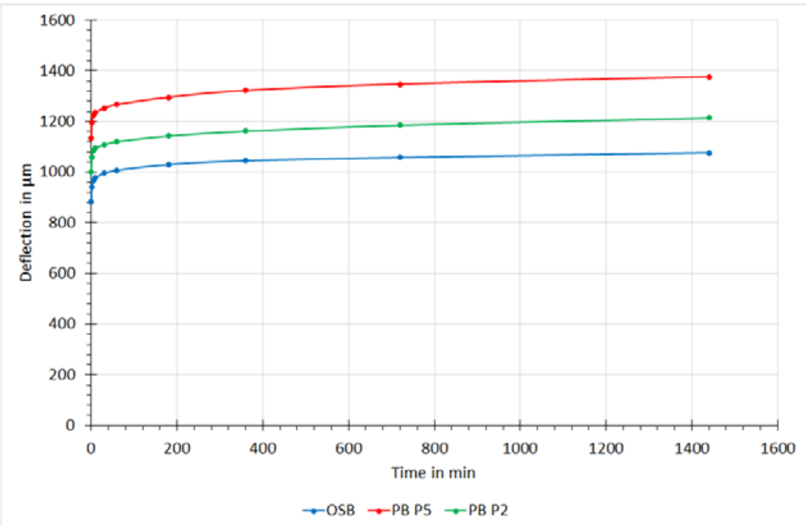



***Fig. 4.***
***Average deflection at at 40% of the maximum load of OSB 3, PB P5 and P2.***

Comparing the average values between P5 and P2 grade particleboards, an interesting behaviour can be observed, namely the deflection was higher for load bearing use in humid conditions panel (PB P5). A possible reason for such behaviour could be related to the actual load applied, namely for PB P2 the load was 176 N, whereas for PB P5 the load was almost 45% higher (253 N). When the load level was 60%, the difference between P2 and P5 grade particleboards was lower (Fig. 6).

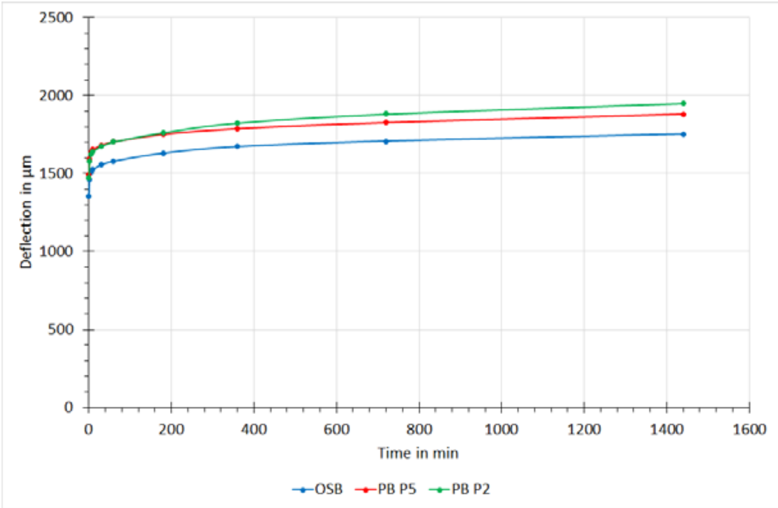
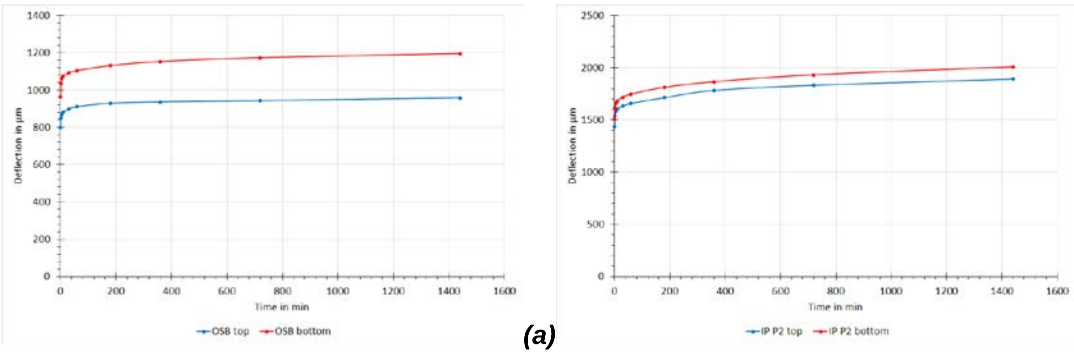


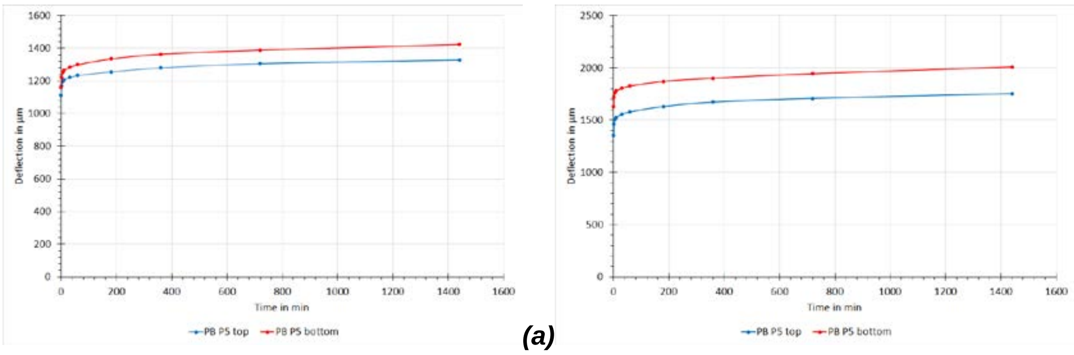

***Fig. 5.***
***Average deflection at 40% of the maximum load of OSB 3, PB P5 and P2.***

At the beginning of the test, the deflection of the PB P5 was higher than that of P2. Under constant load, after 24 hours, the average deflection of P2 increased, recording a value higher with 3% compared to P5.

Deflection of samples at 40% and 60% of the maximum load with regard to the panel and side of the load application is shown in Figs 7 to 9.




***(a)*** ***(b)***
***Fig. 6.***
***Deflection of OSB 3: (a) at 40% of the maximum load and (b) at 60% of the maximum load.***




***(a)*** ***(b)***
***Fig. 7.***
***Deflection of PB P5: (a) at 40% of the maximum load and (b) at 60% of the maximum load.***

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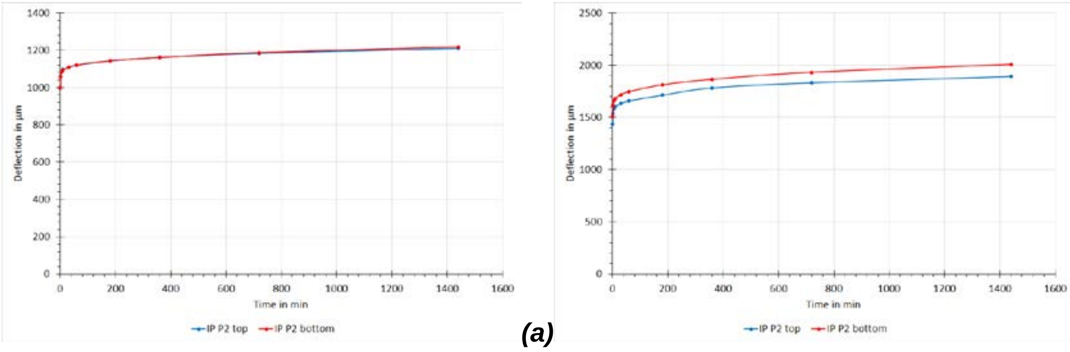


*(a)* *(b)*

***Fig. 8.***

***Deflection of PB P2: (a) at 40% of the maximum load and (b) at 60% of the maximum load.***

Comparing the deflection values with regard to the load application side, density of surface layer and load level, an interesting behaviour can be observed. At 40% of the maximum load, the low deformation was reported when the load was applied on the top panel side, meaning that the denser surface layer was under tension and creating higher resistance against deflection (hence lower deflection). At 60% of the maximum load, a positive effect of the high density of the bottom side can only be observed for particleboards, whereas for OSB, the relation changed. For OSB and a high level of load, the orientation of the strands was more important than the surface layer density, hence lower deflection was observed when the load was applied on the bottom side of the panel.

## CONCLUSIONS

Density and bending strength have a close compatibility with other properties which are of main importance in successful utilization of engineered wood products. The wood particle type did not play an essential role when analysing deflection, because OSB 3 and P2 values were about 10% lower than that of the P5 particleboard.

According to the results obtained in this experiment, it can be concluded that the creep behaviour is related to: the panel type and its application, the load level and the side of the panel to which the load was applied. The deflections increased linearly corresponding to stress levels of 40% and 60% of the maximum load. This behaviour of the selected panels will be completely different when environment conditions of the tests are changed from dry (indoor) to humid (outdoor).

Further investigations with different thicknesses, panel qualities, moisture content and test durations in different climate conditions should be conducted.

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