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Case study

Creep deflection of Wood Polymer Composite profiles at demanding conditions

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ABSTRACT

Durability and low maintenance make Wood Polymer Composite (WPC) profiles popular in decking applications. EN 15534-4 specifies minimum performance levels to guarantee WPC quality. However, despite such quality specifications, occasionally high temperature creep issues are reported. This paper evaluates the creep performance of three commercial WPC decking profile grades. All three WPC grades meet the requirements specified in EN 15534-4. Nevertheless, at slightly more demanding load conditions, some WPC samples fail around the creep deflection limits specified in the standard, and which are supposed safe. Reference outdoor testing in the moderate climate of the Netherlands shows creep deflection rates which are expected to lead to fatal failure of these WPC samples in a couple of years. It is concluded that predictive testing requires insight in progressive creep strain development relative to fatal failure strain level.

1. Introduction

WPC profiles are on the US market since a few decades and in Europe since about 20 years as an alternative to solid wood in decking, fencing and siding applications [1]. One of the drivers for the use of WPC materials is their outdoor durability relative to ordinary solid wood in combination with low maintenance [2]. Whereas most solid wood grades require proper treatment or coating in order to resist outdoor exposure to fungal growth, varying humidity and UV irradiation, the encapsulation of the wood fibres or wood particles by a (UV stabilised) polymer matrix is expected to make WPC materials more or less intrinsically durable. Still, WPC durability appears to be less absolute than expected, and in particular the effect of fungal decay and UV radiation on WPC mechanical performance has been subject of several studies since the late 1990s [2–7]. Despite these issues, the market volume has increased from 0 and 150 kton in the year 2000 to 260 and 1100 kton in 2012 for Europe and North America, respectively, leaving alone China, Japan and other countries [8,9].

To allow consistent evaluation and specification of WPC materials and products, several standards are available. The European Standard EN 15534-1, being a harmonisation of several national standards, provides a wide range of standard testing methods for evaluation of physical, mechanical, thermal and other properties of WPC decking profiles like durability [10]. EN 15534-4 specifies requirement levels for particular WPC decking quality parameters [11]. Despite these testing standards and quality specifications, occasionally WPC durability issues related to, among others, high temperature creep performance are reported [12]. Apparently, the standard test method and specifications either do not account for worst case scenarios, or do not address all relevant aspects of this WPC decking profile quality parameter.

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Following EN 15534-1, WPC profile creep is tested at 20 °C under 1000 N load for 3 weeks, or, alternatively, at 50 °C under 850 N load for 1 week. These testing conditions seem in the relevant order of magnitude for everyday practice where a heavy garden table may easily weigh 200 kg without further stuff like plant pots put on it. However, there seems no reason why the maximum load applied on a WPC decking terrace is lower when temperature is higher during summer time. Moreover, WPC decking may easily reach a temperature of 50 °C. The average air temperature in large parts of Europe reaches 20–25 °C in July-August, with frequent peak air temperatures of 30–35 °C in southern Europe [13]. Considering a temperature increase of up to 25 °C in full sun [14], the WPC maximum top surface temperature may reach 45–60 °C. And although the temperature of WPC decking will not be 50 °C for a continuous period of 1 week, the cumulative period during several summer seasons may be well longer in several parts of Europe.

Therefore, in this study, the creep performance of three commercial WPC decking profiles is evaluated at conditions specified in EN 15534, as well as at slightly more demanding conditions: 50 °C under 1000 N load for 3 weeks. For reference purposes, creep deflection at outdoor conditions during summer time is evaluated as well. In order to allow evaluation of progressive creep deflection, creep is not only recorded at the times specified in EN 15534, but at several times during the creep tests.

2. Experimental

2.1. Materials

Three types of polypropylene (PP) based WPC decking profiles were supplied by European manufacturers. Specifications of the profiles are indicated in Table 1. A schematic representation of the geometries is indicated in Fig. 1. The WPC samples were conditioned for at least 7 days at 20 °C and 50% RH prior to testing.

2.2. Creep testing

Creep deflection of WPC profile samples was determined according to EN 15534-1. A specially designed loading rig was placed in a conditioned lab at 20 °C and 50% RH (Fig. 2, left) and the support span was as recommended by the supplier as indicated in Table 1. A 1000 N load was applied during 3 weeks using a spring. The required compression level of the spring to apply 1000 N was determined using a conventional balance. The displacement, a_i, of the cylindrical loading head was measured using a strain gauge with an accuracy of 0.01 mm at times specified in EN 15534-1:

a_1 = deflection before applying the load
a_2 = deflection 1 min after the load is applied
a_3 = deflection at the end of loading (before removal of the load)
a_4 = deflection 24 h after the removal of the load

Additional to measuring at these specified times, deflection was determined after several multiples of 24 h up to 3 weeks creep time. As soon as the spring visibly deviated from the required compression level due to WPC sample deflection, the spring was loaded to 1000 N again.

Similar creep tests were performed at 850 N load for 1 week according to EN 15534-1 in a Weiss SB11^{300} temperature-humidity cabinet (Weiss Umwelttechnik GmbH, Reiskirchen-Lindenstruth, Germany) at 50 °C and 50% RH (Fig. 2, right). The WPC samples were conditioned in the 50 °C conditioned cell for 1 h (without load) prior to starting the test. Similar creep tests at 50 °C were performed at 1000 N load for 3 weeks.

2.3. Outdoor creep testing

Creep was also evaluated for WPC-1 and WPC-2 at outdoor conditions at 1000 N load on top of a roof in Wageningen (Netherlands) in the periods 17 July – 9 August 2016 (3 weeks + 1 day for relaxation) and 23 August – 21 September 2016 (4 weeks + 1 day for relaxation) (Fig. 3). An overview of all creep test conditions used in this study are presented in Table 2.

2.4. Static flexural testing

Flexural properties of WPC profile samples were measured (n = 3) on a Zwick Z010 instrument (Zwick GmbH & Co. KG, Ulm, Germany) using a specially designed testing rig (Fig. 4), the cylindrical supports and loading head having a diameter of

Table 1
WPC types, main dimensions and support span recommended by supplier.

Grade	Type	Width, B (mm)	Height, H (mm)	Support span, L (mm)
WPC 1	Hollow	140	26.75/26.15	400
WPC 2	Hollow	144	37.23/37.30	600
WPC 3	Solid	137	21.30	500

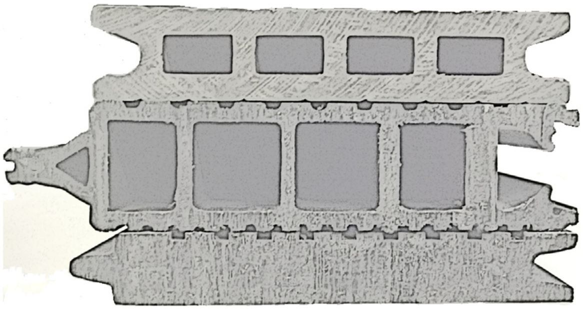


Fig. 1. Schematic representation of the WPC profile geometries: WPC-1 (top), WPC-2 (middle), WPC-3 (bottom).

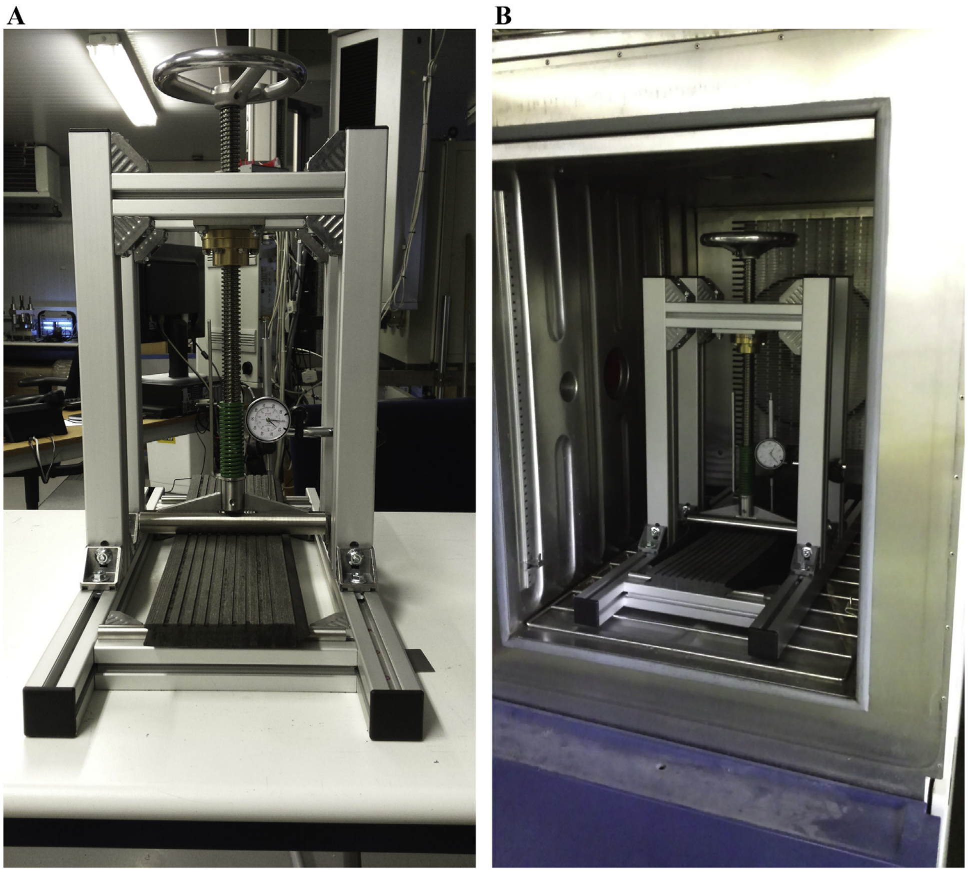


Fig. 2. Testing rig for analysis of creep behaviour of WPC decking profiles: in a conditioned lab at 20 °C and 50% RH (A) and in a temperature-humidity cabinet at 50 °C and 50% RH (B).

25 mm. The support span, L, was as indicated in Table 1 and the loading rate, v, was according to Annex A of EN 15534-1:

$$v = \frac{0.00185 * L^2}{H} \quad (1)$$

resulting in cross head speeds of 11.1, 17.9 and 21.7 mm/min for WPC-1, WPC-2 and WPC-3, respectively. Samples tested at 50 °C were conditioned in the 50 °C climate chamber for 1 h prior to starting the test.

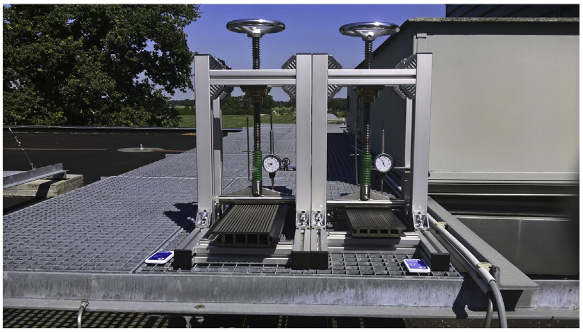


Fig. 3. Outdoor testing of creep behaviour of WPC decking profiles on top of roof in Wageningen (NL).

Table 2
Testing conditions applied for creep testing in this study.

	Conditioned lab	Temperature-humidity cabinet		Outdoor, on top of roof
Temperature (°C)	20	50	50	As is
Relative humidity (%)	50	50	50	As is
Load force (N)	1000	850	1000	1000
Time (weeks)	3	1	3	3 & 4
According to standard	EN 15534-1	EN 15534-1	–	–

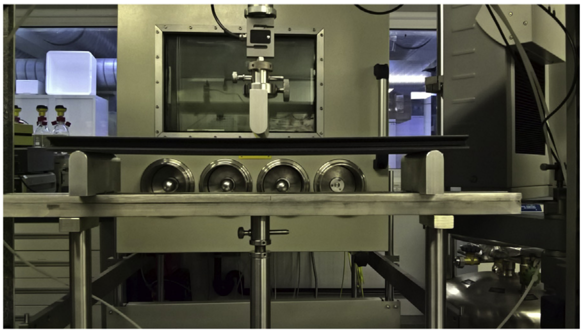


Fig. 4. Testing rig for analysis of flexural testing of WPC decking profiles in a conditioned lab chamber at 20 °C and 50% RH (door open) and at 50 °C and 50% RH (door closed).

3. Results and discussion

3.1. Creep deflection in mm according to EN 15534 standard

Fig. 5 presents the creep deflection in mm of the 3 WPC grades at temperature-load-time conditions as specified in EN 15534-1 (Table 2). The difference in creep response for duplicates indicates variation in WPC material quality. However, after applying 1000 N load for 3 weeks at 20 °C, all creep deflections keep well within the requirement levels specified in Table 4 of EN 15534-4: the creep deflections, $\Delta_s = a_3 - a_2$, remain smaller than 10 mm and the residual (plastic) deflections after load removal, $\Delta_{sr} = a_4 - a_1$, remain smaller than 5 mm. Creep deflection progresses steadily but slowly and creep deflection rate decreases with time proceeding, which is in particular visible for WPC-3.

Also after applying 850 N load at 50 °C for 1 week, the creep deflections keep within the specified requirement levels. Although, the residual deflections Δ_{sr} for WPC-1 and WPC-3 come close to the 5 mm limit.

The point load of 1000 N may be considered high for practical situations. However, a 3 cm thick granite garden table top of 2 x 1 m including a metal supporting frame weighs about 200 kg, giving 50 kg load per table leg [15,16]. Putting a heavy flower pot in a corner could add 25 kg. So 1000 N may be a worst case scenario, but not an unrealistic scenario.

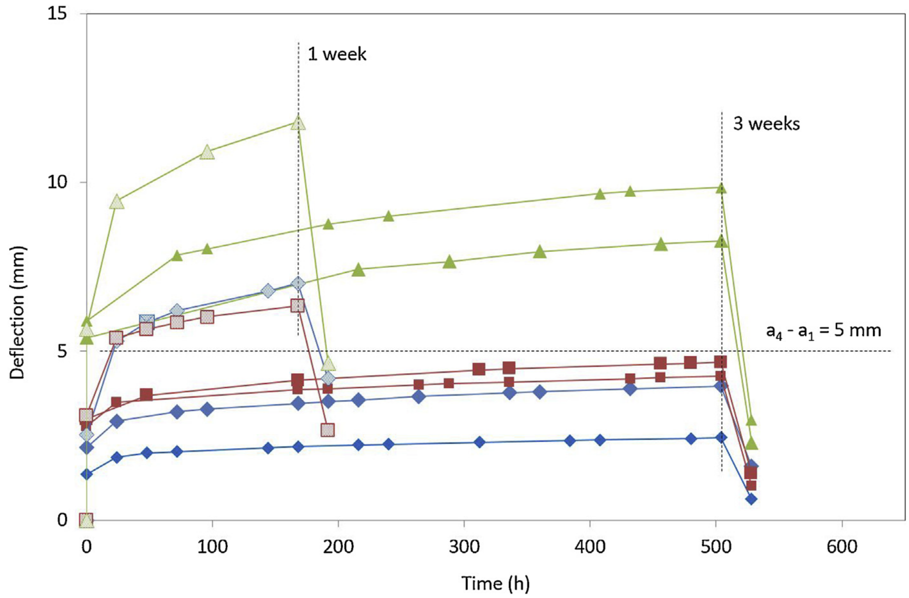


Fig. 5. Deflection (mm) of WPC decking profiles versus creep time at 20 °C and 1000 N load (solid symbols) and at 50 °C and 850 N load (mottled symbols): WPC-1 (◆), WPC-2 (■), WPC-3 (▲). Lines are included to guide the eye. '$a_4 - a_1 = 5$ mm' indicates the maximum residual deflection level specified in EN 15534-4.

3.2. Creep deflection at slightly more demanding conditions

A third series of creep tests has been performed at 50 °C while applying the same load during the same time as applied at 20 °C, namely 1000 N of load for 3 weeks. At these conditions the creep deflections increase significantly for all three WPCs (Fig. 6). WPC-3 shows high deflection rate during the first days, followed by much slower rate during the next period. WPC-1 shows high progressive creep deflection for 2 samples during the entire test period. Most striking is that 3 out of 4 WPC-1 samples break. Remarkably, the WPC-1 grade performs close to best at load conditions specified in EN 15534-1 at 50 °C.

The moment of discovery of the breaking is indicated in the graph with a cross. Actual breaking, however, has occurred somewhere in between the moment of discovering the profile failure and the moment of the previous measurement. Also

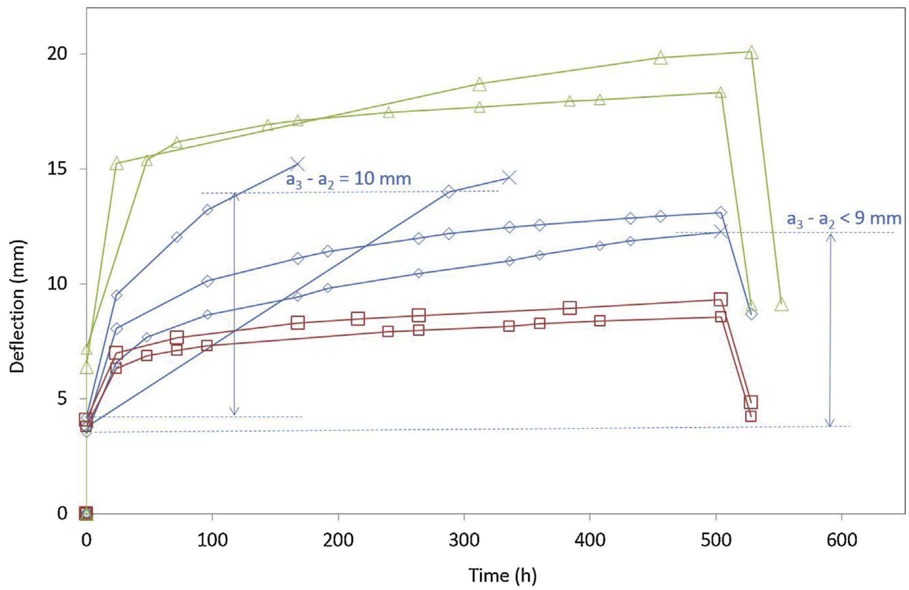


Fig. 6. Deflection (mm) of WPC decking profiles versus creep time at 50 °C and 1000 N load: WPC-1 (◇), WPC-2 (□), WPC-3 (△). The × indicates the moment in time at which fatal break of WPC samples was discovered. Lines through the symbols are included to guide the eye. '$a_3 - a_2 = 10$ mm' indicates the maximum creep deflection level specified in EN 15534-4.

the deformations indicated with the × are estimates only. Still it can be concluded that the three WPC-1 samples break around 10 mm deflection, which is the requirement level for creep deflection specified in EN 15534-4 and therefore considered to be a safe level for creep deflection of WPC profiles, independent of the load applied.

3.3. Creep strain in %

The maximum deflection in mm is a commonly understood indicator for WPC decking profile performance, both for industry, installers and for consumers. However, for understanding the deformation and fracture of composite materials the strain in % is a more clear parameter. The strain (%) in a WPC profile loaded in 3-point bending mode is maximum in the outer layers, and can be calculated as follows [17]:

$$\varepsilon = \frac{600 * d * H}{L^2} \quad (2)$$

where d is the displacement recorded at the centre of the profile (mm), H is the thickness of the profile (mm) and L is the applied support span of the profile (mm).

At the same time, the creep strain development of WPC materials can be modelled using the Findley power law model as shown by several researchers [18–21]:

$$\varepsilon(t) = \varepsilon_0 + at^b \quad (3)$$

where ε(t) is the creep strain (%) at time t (h), ε_0 is the instantaneous strain (%), and a and b are material constants (a is the amplitude of transient creep strain, b is the time exponent). The creep strain values of WPCs tested in this research are fitted using this Findley model by plotting log (ε − ε_0) versus log (t) (Fig. 7). The model parameters are listed in Table 3.

The high values for the regression coefficient, R^2, indicate that the Findley model provides a good description of creep strain development of the WPC profile samples. This also indicates that these full size commercial WPC profile samples respond in a similar way to creep loading as small specimens used for flexural testing according to ISO 178 and ASTM D790, typically in the order of 80*10*4 mm^3 [18–21]. Variation in Findley model parameters is high for WPC-1 at both 20 and 50 °C, corresponding to what has been discussed for creep response in Figs. 5 and 6 already. Also WPC-2 and WPC-3 show large differences for parameters a and b at 20 °C, although this is less easy to see from Fig. 5. Despite this variation, several trends are clear. The initial strain ε_0 is higher for WPC-3 than for the other 2 WPC grades, which is due to the higher stress as a result of the same load applied at similar support span but at much lower profile thickness (Table 1). Further, the initial creep strain increases with increasing temperature for all three WPC grades, in particular for WPC-1. This relates to a decrease of the material stiffness with increasing temperature. Also the creep parameter ‘a’ increases with increased temperature for all three WPCs. An increases of ‘a’ with increasing temperature is expected considering that the parameter ‘a’ mathematically relates to early stage creep mainly, and since early stage creep is related to molecular chain relaxations [19]. The creep parameters ‘b’, being the slopes in Fig. 7 and mathematically relating to long-term creep, shows a different trend. It decreases

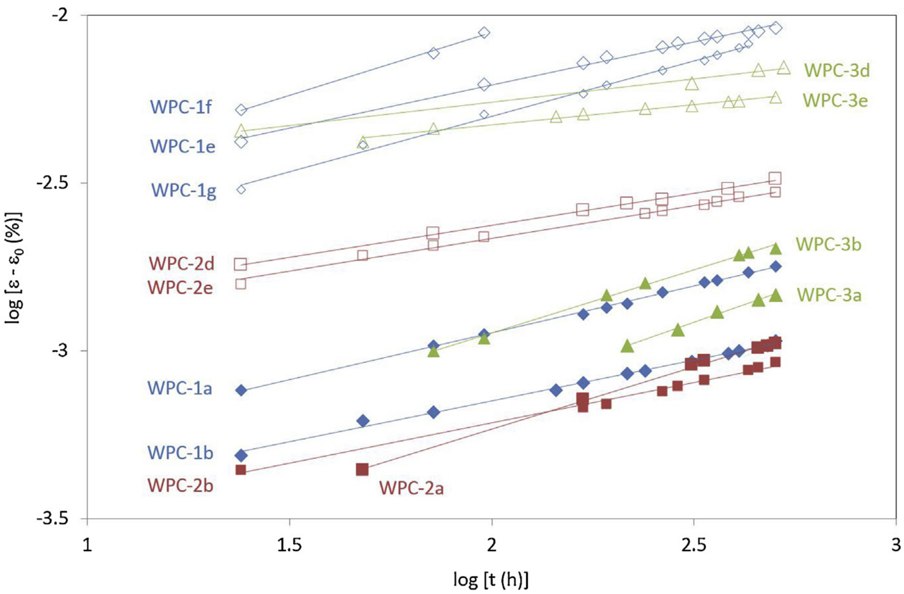


Fig. 7. Plot of the logarithm of creep strain data of WPC-1 (◆), WPC-2 (■), WPC-3 (▲) versus the logarithm of time: at 20 °C and 1000 N load (solid symbols); at 50 °C and 1000 N (open symbols). Lines are the regression lines, thus presenting the Findley correlation. Coding refers to individual creep tests performed; Findley parameter details presented in Table 3.

Table 3
Findley power law fitting parameters for WPC creep strains at different temperatures and 1000 N load.

Sample code	Temp (°C)	ε_0 (%)	a	b	R^2
WPC-1a	20	0.21	0.00031	0.2792	0.999
WPC-1b	20	0.13	0.00023	0.2436	0.996
WPC-2a	20	0.19	0.00011	0.3703	0.998
WPC-2b	20	0.17	0.00020	0.2411	0.993
WPC-3a	20	0.28	0.00010	0.4322	0.992
WPC-3b	20	0.30	0.00020	0.3751	0.997
WPC-1d*	50	0.37	0.00153	0.3335	–
WPC-1e	50	0.37	0.00190	0.2567	0.994
WPC-1f	50	0.41	0.00158	0.3737	0.996
WPC-1g	50	0.34	0.00109	0.3299	0.995
WPC-2d	50	0.25	0.00099	0.1894	0.999
WPC-2e	50	0.24	0.00088	0.1963	0.994
WPC-3d	50	0.33	0.00290	0.139	0.993
WPC-3e	50	0.37	0.00269	0.1214	0.981

* Findley parameters could not be fitted because only 1 measuring point was available. Parameters have been estimated as the average parameters for the other WPC-1 samples tested, while double counting the values for WPC-1f because creep strain development of WPC-1d resembles WPC-1f more than WPC-1e and WPC-1 g.

with increasing temperature for WPC-2 and WPC-3, while it increases for WPC-1. The trend for WPC-2 and WPC-3 may be explained by considering that molecular chain relaxation times decrease with increasing temperature. Whereas at 20 °C molecular chain relaxation may tend to continue in the long-term creep region, thus causing higher apparent long-term creep, while at higher temperature chain relaxation times are becoming shorter, tending to be completed already during the early stage creep time. The long-term creep then only consists of slippage of molecular chains [19]. The increasing value for 'b' for WPC-1 indicates that at 50 °C slippage of molecular chains occurs at higher rate than for WPC-2 and WPC-3.

The Findley parameters found in this study are very comparable to values presented by Jiang et al. for a 59 wt.% Wood flour filled PP composite profile [21]. Data presented for injection moulded specimens by Park and Balatinecz show the same increasing trend for ε_0 and a with increasing temperature. Their values are higher, though, due to both lower fibre content in their WPC material as well as higher stress applied in their creep tests [20]. Their work also shows the significant effect of fibre content on creep strain development. Xu et al. [19] have evaluated PVC and HDPE based profiles, so direct comparison is not possible, although parameters for PVC are in the same order of magnitude as those found for the PP based materials in the present study.

Fig. 8 presents the creep strain (%) in the outer WPC layer of the 3 WPC decking grades versus creep time as well as the Findley fitting lines. At 20 °C the curves show steady but slow creep rate, whereas at 50 °C creep rates are higher, in particular for WPC-1 and WPC-3. WPC-3 shows high creep rate during early stage, but strain rate levels off at longer term, as discussed

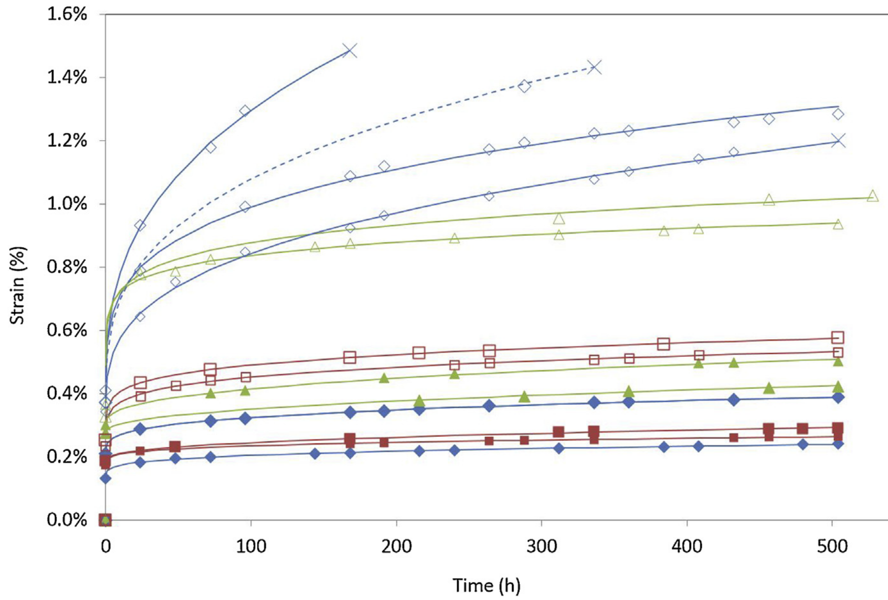


Fig. 8. Strain (%) at the outer layer of WPC decking profiles versus creep time at 20 °C and 1000 N load (solid symbols), and at 50 °C and 1000 N load (open symbols): WPC-1 (◆), WPC-2 (■), WPC-3 (▲). Lines are Findley power law model fitting lines.

before. WPC-2 shows relatively low rate for both short and long term creep. Clearly, WPC-1 shows high creep strain rates both at short and long term. The strains at the moment of break discovery, indicated by ×, have been calculated using the Findley model parameters for each sample.

When comparing these creep strain data in % to the deflection in mm (Figs. 5 and 6), it is noted that WPC-1 exhibits highest creep strain in % while WPC-3 shows highest deflection in mm. This shift is related to the ratio of L^2/H, as presented in Eq. (2). As a result of the lower L and higher H for WPC-1 compared to WPC-3, the ratio L^2/H for WPC-1 is only about half that of WPC-3, being 400*400/26.8 mm = 5970 mm and 11,737 mm for WPC-1 and WPC-3, respectively. This factor of 2 more than compensates the about 30% lower deflection in mm for WPC-1.

Another feature occurs when decreasing L. The EN 15534-1 testing standard requires that L for creep deflection testing is equal to the support span recommended by the supplier for actual application (nominal installation distance). By decreasing L, the deflection of the profile in mm at a given load will decrease. In this way the performance of a relatively flexible WPC material may be compensated for, and the WPC profile may still meet the 10 mm maximum deflection requirement specified in EN 15534-4. However, as ε is proportional to the inverse of L^2 (Eq. (2)), the material strain in % increases by 50% when decreasing support span by 25% to reach the same deflection in mm. In other words, when decreasing L, deflection in mm may stay within the requirement levels, however, at the same time the strain in % may approach fatal failure strain. Since EN 15534-4 does not address the failure strain of profiles, either in mm or %, this key performance limit is not automatically in sight of the evaluator.

Creep strain may be considered as the sum of instantaneous strain, early stage creep due to e.g. molecular chain relaxations and extensions and long-term creep due to e.g. viscous slippage of molecular chains [19]. In order to find a simplified reference for creep failure strain, static flexural failure strain of the WPC profiles is determined at the same support spans as used for the creep tests. The results are presented in Table 4, together with the range of strains reached after 3 weeks of creep testing. WPC-1 profiles show a static failure strain of only 0.7% at 20 °C and 1.0% at 50 °C, while the strain range at which the three WPC-1 samples have broken is 1.16–1.49%. This indicates that the failure of 3 out of 4 WPC-1 samples during creep testing is not the result of an artefact, but relates to material characteristics. Hamel et al. have extensively studied WPCs creep and conclude that tensile creep failure strain of specimens cut and machined from full-size commercially produced WPC products is only 60–85% of static failure strain [22].

The initial creep strain for WPC-3 is also high, however, after a couple of days creep strain proceeds much slower when compared to the WPC-1 profile. This low creep strain development and the relatively high static failure strain at 50 °C suggest that the WPC-3 profiles will not fail for a significantly prolonged creep time.

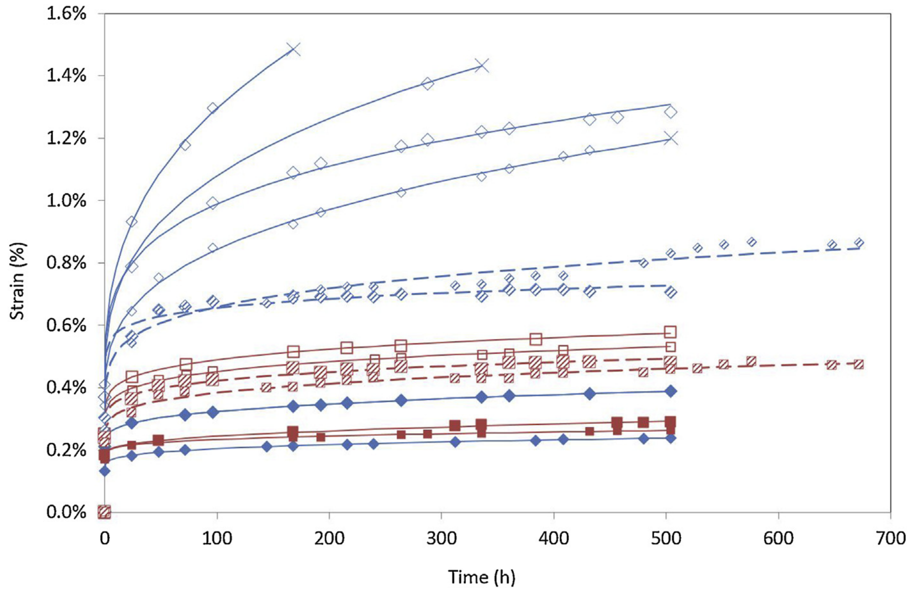
3.4. Creep strain at outdoor conditions

Creep strain curves determined at outdoor conditions during the summer of 2016 in Wageningen (Netherlands) are presented in Fig. 9. The air temperature logged during the testing period is presented in Fig. 10A and B. The air temperature is measured in the shadow, except for the period after about 17:30 o'clock each day, which can be seen from the spikes on the curves. As expected from the temperature levels, the deflection curves fall in between those at 20 and 50 °C. The creep strain of the WPC-1 profiles at outdoor conditions, however, is significantly lower than at 50 °C, while for the WPC-2 profiles creep strain comes close to that at the 50 °C trial. Differences may be the result of a feature known as heat build-up, which is the temperature increase of a material resulting from irradiation and which depends on type of material, in particular its colour. The surface temperatures of the WPC anthracite profile as measured with a contact thermometer and a laser thermometer around 13:30 o'clock during working days is also indicated in Fig. 10A and B. The level of temperature values obtained from the laser and contact thermometer show significant differences, and it is difficult to conclude which of the 2 methods provides the best indication for the temperature of the top side of the WPCs. Results indicate that the top side of the WPCs reaches at least 40 °C or more during several days in the Dutch summer, while the bottom side likely reaches the air temperature of over 30 °C during several days. The measured temperature values, however, are very similar for WPC-1 and WPC-2, so this does not explain the different positions of the outdoor creep strain curves for WPC-1 and WPC-2 relative to those at 20 and 50 °C. Although the temperature measurements do not provide an unambiguous explanation for the different creep responses of the WPC-1 and WPC-2 profiles, the outdoor creep strains confirm that even in the Netherlands significant creep deformation may be expected.

Table 4
Static failure strain and strain range after 3 weeks creep testing of WPC decking profiles in flexural loading mode at the support span length as used for the creep tests (as recommended by the supplier).

WPC grade	Static failure strain (%)		Strain after 3 weeks of creep testing (%)	
	20 °C	50 °C	20 °C, 1000 N	50 °C, 1000 N
WPC-1	0.7 (0.1)	1.0 (0.2)	0.24 – 0.39	1.16 – 1.49*
WPC-2	1.6 (0.2)	2.1 (0.3)	0.27 – 0.29	0.53 – 0.58
WPC-3	1.9 (0.2)	2.1 (0.1)	0.42 – 0.50	0.94 – 1.03

* Lowest and highest strain value at which the three WPC-1 samples have broken. The unbroken sample had a strain of 1.28% after 3 weeks.



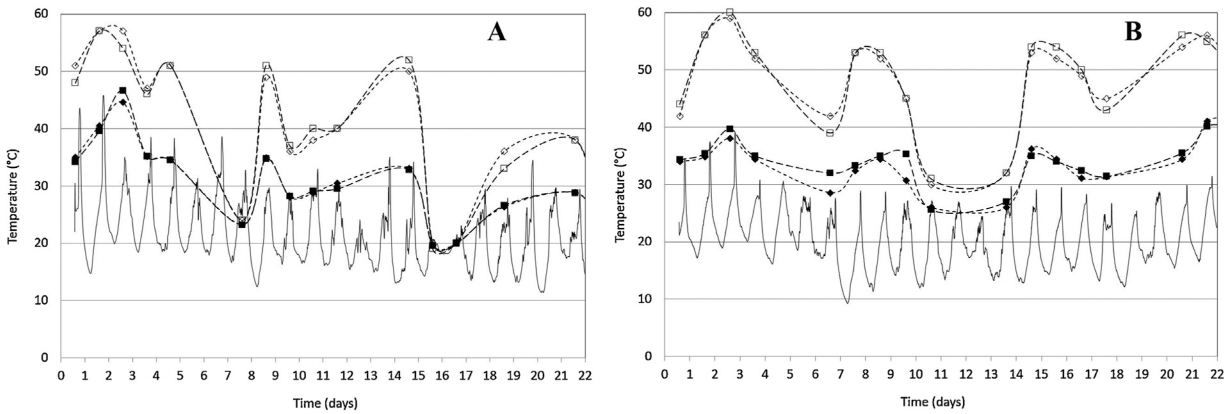


Fig. 10. Temperature measured during outdoor testing during the period 18 July – 9 August (A) and during the period 23 August – 14 September (B) in the shadow near the building in the shadow except from about 17:30 o'clock to sunset (solid line). The symbols show the contact temperature (solid symbols) and the temperature measured with laser (open symbols) on the profiles at 13:30 o'clock for WPC-1 (◆) and WPC-2 (■). Dashed lines are included to guide the eye. Rainfall during these periods was 24 mm and 8 mm, respectively.

The outdoor creep strain data have been fitted using the Findley power law model of Eq. (3) and the Findley parameters are presented in Table 5. Extrapolation to the estimated failure strain of the 3 broken profiles at 50 °C allows to estimate service life at similar conditions as during the outdoor testing period. The creep failure strain of WPC-1 profiles can be calculated from the 3 profiles broken at 50 °C. The failure strain is maximum when the profiles have broken just before discovering their failure, and minimum when the profiles have broken immediately after the last measurement before failure. These average failure strains are 1.28% and 1.37%, respectively. The creep times calculated to reach these average

Table 5
Findley power law fitting parameters for WPC creep strains at 1000 N load and outdoor conditions in Wageningen, the Netherlands.

Sample code	ε_0 (%)	a	b	R^2
WPC-1 h	0.30	0.0021	0.1143	0.81
WPC-1 i	0.27	0.0015	0.2049	0.90
WPC-2 h	0.24	0.0007	0.2017	0.93
WPC-2 i	0.22	0.0005	0.2451	0.92

minimum and maximum strains for WPC-1i are 305 and 491 days, respectively. This is a long period, but this temperature-time load may be reached accumulated over several years in the Netherlands with its moderate sea climate, especially when considering additional deteriorating influences like UV irradiation, moisture absorption/desorption cycles and freezing. In southern Europe, temperatures are at least 5–10 °C higher over a long period in summer [13], so shorter failure times may be expected there for this particular WPC grade.

4. Conclusions

This study evaluates the creep behaviour of three commercially available WPC decking profile grades according to the method specified in EN 15534-1. The creep deflections of all three WPC grades meet the requirement levels specified in EN 15534-4, both at 20 and 50 °C. However, at a slightly higher but still realistic load at 50 °C, some WPC samples break at a deflection very close to the 10 mm limit specified in EN 15534-4, which is considered to be a safe level for creep deflection of WPC profiles, independent of the load applied. The limit suffices for strong WPC materials, but not for weak materials. The deflection performance of a WPC profile can be compensated for by decreasing the support span. At the same time, when decreasing the support span and keeping the maximum deflection constant at the 10 mm requirement level, the material strain in % increases, eventually up to fatal failure strain for weak WPC profiles. Results also show that even in the moderate climate of the Netherlands the temperature-time load accumulated over a couple of years may cause creep failure of the weakest WPC grade tested. A more clear insight in safe performance of WPC materials can be obtained by correlation of progressive creep strain behaviour and (static) failure strain. A creep testing time of 1 week at 50 °C is short considering the number of days with tropical temperature even in the moderate sea climate of the Netherlands, and the surface temperatures that e.g. anthracite WPCs reach on such days.

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Glossary

a_i: Deflection at time i
B: Width of WPC profile
d: Displacement at centre of WPC profile
EN: European Norm
F: Force applied at centre of WPC profile
H: Thickness of WPC profile
HDPE: High density polyethylene
ISO: International Standard Organisation
L: Support span
PP: Polypropylene
PVC: Polyvinylchloride
RH: Relative humidity
t: time
v: Loading rate (static flexural test)
WPC: Wood Polymer Composite
ε: Strain