Thünen-Institut (HF) · Leuschnerstraße 91d · 21031 Hamburg

GS Götz Schmitt GmbH

Neue Finien 2

D-28832 Achim

Institut für Holzforschung

PD Dr. habil. Gerald Koch
Wiss. Direktor

Leuschnerstraße 91d
21031 Hamburg

Fon 040 73962-410
Fax 040 73962-499

gerald.koch@ti.bund.de
www.ti.bund.de

Ihr Zeichen/Ihre Nachricht vom:	Unser Zeichen/Unsere Nachricht vom:	Datum
07.10.2013		16.12.2013

Accelerated weathering of bamboo floor boards, assessment of surface properties and color characteristics

Dear Mr Schmitt,

we received three sets of specimens of bamboo floor boards subjected to various treatments. The specimens were subsequently analyzed as to product properties (surface and color characteristics) after an accelerated weathering process. The accelerated weathering was conducted for a period of four weeks at the installations of the Thünen-Institut für Holzforschung.

Research Institution:
Thünen-Institut für Holzforschung
Leuschnerstr. 91 d,
D - 21031 Hamburg

Material for examination:

„PRIMUS“ - medium brown, dimensions: 20 x 14 x 2 cm^3 - three specimens
„ELEGANCE“ - dark, dimensions: 21 x 14 x 2 cm^3 - three specimens
„XXL“ - medium brown, dimensions: 21 x 20 x 2 cm^3 - two specimens

The various analyses comprehend the assessment of the surface properties (photographic documentation of color changes, crack formation and warp) as well as the recording of moisture uptake/release during the course of the accelerated weathering period.

Methods:
In order to determine moisture uptake/release, respectively, the specimens were weighed at the start and after each quarter (Tables 2 and 3, Figures 2 and 3) during the accelerated weathering experiment.
The accelerated weathering (simulation parameters: sprinkle irrigation (rain), irradiation (sunshine) and temperature) of the test specimens was conducted in an artificial weathering chamber TYPE GLOBAL-UV-TESTGERÄT, MODELL UV 200 RB/10 DU, SYSTEM WEISS, BAUART BAM over a period of four weeks (see Figure 1). During the four week period of weathering the chamber software is programmed to simulate the natural course of one year (spring >> summer >> fall >> winter (Table 1). At the end of each simulated season (=

quarter) digital color photographs of all test specimens were taken in order to document changes of surface properties (see annexes page 5-13).

Fig. 1: Positioning of test specimens in the weathering chamber

Table 1: Weathering cycle of a four week duration

Cycle	Day	Weather		Duration [h]
Spring	**0 - 6**	30°C	UV-irradiation	8
		20°C	Rain	16
Summer	**7 - 13**	20°C	Rain	6
		55°C	UV-irradiation	18
Fall	**14 - 20**	30°C	UV-irradiation	8
		20°C	Rain	16
Winter	**21**	20°C	Rain	17
		-15°C	Freezing	6
		20°C	UV-irradiation	1
	22	20°C	Rain	8
		20°C	UV-irradiation	16
	23	-15°C	Freezing	6
		20°C	UV-irradiation	18
	24	20°C	Rain	8
		20°C	UV-irradiation	16
	25	20°C	Rain	8
		-15°C	Freezing	6
		20°C	UV-irradiation	10
	26	20°C	Rain	8
		20°C	UV-irradiation	16
	27	-15°C	Freezing	6
		20°C	UV-irradiation	18
	28	**End**		

Evaluation of results

Assessment of surface quality of bamboo floor boards after the four week trial period
(*profiled, thermally treated bamboo floor boards*):

Moisture uptake and dimensional changes:
Weight changes due to moisture uptake or loss (equilibrium moisture content) during accelerated weathering are shown in Tables 2 and 3 as well as in Figures 2 and 3. The analysis of weight changes of the specimens belonging to the three submitted collectives **PRIMUS, ELEGANCE** and **XXL** reveal a moderate moisture uptake. The difference between the highest moisture content attained after the fall/rain cycle and

the initial moisture content amounted to a maximum of **6,1% and 6,3%** for the collectives **PRIMUS** and **ELEGANCE**, respectively. This relatively modest moisture uptake of the two collectives can be attributed to the careful thermal treatment (causes thermal decomposition and modification of hydroxyl groups) and the glue bonding of the bamboo strands.
The **XXL** specimens, however, showed a significantly higher moisture uptake (maximum difference between fall/rain cycle and initial moisture content of **12,8%**; see also Figures 2 and 3). At the end of the weathering period the mean moisture content of the XXL collective was 7,0% higher than the initial moisture content compared to a low of 1,5% (**ELEGANCE**) and 2,2% (**PRIMUS**).

Table 2: Specimen weight before and after each weathering cycle

Weight in gr: Specimen	before weathering*	after 1st week Spring		after 2nd Woche Summer		after 3rd week Fall		after 4th week Winter	
		Rain	Sun	Rain	Sun	Rain	Sun	Rain	Sun
P1	630,1	658,6	652,8	642,1	631,9	667,9	660,4	654,4	644,1
P2	624,4	654,5	648,3	637,2	626,4	663,9	656,0	649,5	638,7
P3	638,6	666,3	660,6	651,7	641,4	676,5	669,2	662,5	652,7
E1	687,4	711,1	705,9	696,4	685,5	718,5	711,7	709,0	697,0
E2	625,7	663,0	657,8	634,7	621,9	669,1	660,2	646,2	634,7
E3	646,1	687,2	682,4	656,4	643,0	693,2	684,8	670,8	657,0
X1	795,0	856,8	846,1	837,9	821,2	888,4	876,3	860,2	844,2
X2	791,4	858,1	848,2	847,9	830,6	901,0	888,6	869,6	853,5

* Initial moisture content in equilibrium with surrounding room climate

Table 3: Moisture content (MC) change in % after each weathering cycle

Course of MC in %: Probe	Starting point	Spring		Summer		Fall		Winter	
		Rain	Sun	Rain	Sun	Rain	Sun	Rain	Sun
P1		4,5	3,6	1,9	0,3	6,0	4,8	3,9	2,2
P2		4,8	3,8	2,0	0,3	6,3	5,0	4,0	2,3
P3		4,3	3,4	2,0	0,4	5,9	4,8	3,7	2,2
Mean PRIMUS	**0**	**4,5**	**3,6**	**2,0**	**0,3**	**6,1**	**4,9**	**3,9**	**2,2**
E1		3,4	2,7	1,3	-0,3	4,5	3,5	3,1	1,4
E2		6,0	5,1	1,5	-0,6	6,9	5,5	3,3	1,4
E3		6,4	5,6	1,6	-0,5	7,3	6,0	3,8	1,7
Mean ELEGANCE	**0**	**5,3**	**4,5**	**1,5**	**-0,4**	**6,3**	**5,0**	**3,4**	**1,5**
X1		7,8	6,4	5,4	3,3	11,8	10,2	8,2	6,2
X2		8,4	7,2	7,1	5,0	13,9	12,3	9,9	7,9
Mean XXL	**0**	**8,1**	**6,8**	**6,3**	**4,1**	**12,8**	**11,3**	**9,0**	**7,0**

Due to the modest moisture uptake specimens of the collectives **PRIMUS** and **ELEGANCE** possess a very good dimensional stability during and at the end of artificial weathering. No significant dimensional changes were observed for the individual specimens of both collectives. Again, this superior dimensional stability must be attributed the tempering effect the thermal treatment had on the processed bamboo strands.
Neither did the two **XXL** specimens show significant dimensional changes despite the much higher moisture uptake during the course of artificial weathering. Evidently, the thermal modification of the woody tissue (decomposition of the hydrophilic hydroxyl groups) prevented the higher moisture uptake from causing appreciable dimensional changes.

Color changes and color stability:
At the end of the weathering experiment (simulation of the four annual seasons) the weathered surfaces of **PRIMUS** and **ELEGANCE** floor boards evinced a very good "color stability" without the typical "greying" effect due to the (natural) UV-induced photo-degradation of lignin and extractives. Likewise, the **XXL**

specimens also showed a good "color stability" during the course of artificial weathering, however with a (slight) increase in intensity of brown tints (see annexes for photo documentation). None of the **XXL** specimens showed any appreciable "greying" during the artificial weathering experiment (simulation of the four annual seasons).

Crack formation and warp:
Towards the end of the artificial weathering experiment none of the specimens belonging to the three collectives **PRIMUS, ELEGANCE** and **XXL** produced any perceptible deformation/warp; only a slight scaling off of fiber bundles (macerated fibers) was evident, particularly with the **XXL** specimens**.**
When observing the directly weathered cross-sectional surfaces it became evident that some specimens of the **ELEGANCE** collective had developed clearly visible cracks. This phenomenon was even more pronounced with specimens of the **XXL** collective. In both instances the cracks invariably developed during the simulated summer season (sunshine), presumably due to drying stresses induced by the exposure to the high (55°C) temperature. To analyze the intensity (depth of penetration) of the crack formation the specimens were trimmed by 2 cm after the weathering experiment had come to a close. The assessment of the newly exposed cross-sectional areas revealed no cracks (prolongation of earlier formed cracks) in the woody tissue (see annexes for photo documentation). Hence, crack formation during artificial weathering took place "only" in the directly exposed (outermost) region of the transverse end surfaces.

Conclusions:
The results of the artificial weathering experiment reveal a good to very good color stability of thermally treated bamboo floor boards pertaining to the three collectives **PRIMUS, ELEGANCE** and **XXL.** Dimensional stability can also be rated good. Localized formation of cracks and scaled-off fiber bundles are not likely to jeopardize the in-use performance of the material tested under conditions of a simulated exposure to one year of weathering. As regards the assessment of the material's performance in service (after one year of simulated weathering) the tested bamboo floor board collectives **PRIMUS, ELEGANCE and XXL** are considered suitable for terrace decking.

Further indications:
Concerning the interpretation of the results for color characteristics during the artificial weathering experiment it has to be stated explicitly that an infestation by mold or bue stain fungi cannot be simulated in the weathering chamber (sterile environment due to intensive UV-radiation). Such organisms which develop on moist and badly ventilated surfaces tend to cause more or less intensive discoloration due to metabolic reactions and even slight decomposition of the woody tissue. In order to simulate such discolorations*, often the prime reason of complaints by dissatisfied customers*, field and further laboratory tests are required.
The above results do not allow any "general" conclusion with respect to the service life of the artificially weathered bamboo floor boards because long-term outdoor (GK* 3 – 4) performance does not only depend on material properties but rather on quality of workmanship, maintenance as well as positioning of and load on individual components.
* *hazard class according to DIN EN 350-1*

According to the pertinent institutional schedule of regulations we are obliged to charge a fee for the work conducted. Please effect payment according to the attached invoice noting the accompanying transaction number.

Sincerely

i.A.
PD Dr. habil. G. Koch
Wiss. Direktor

M.-T. Lenz
Techn. Assistentin

Annexes:

Figure 2: Moisture content changes in %, individual values
Figure 3: Moisture content changes in %, collective means
page 5-13: Photo documentation of weathered specimens

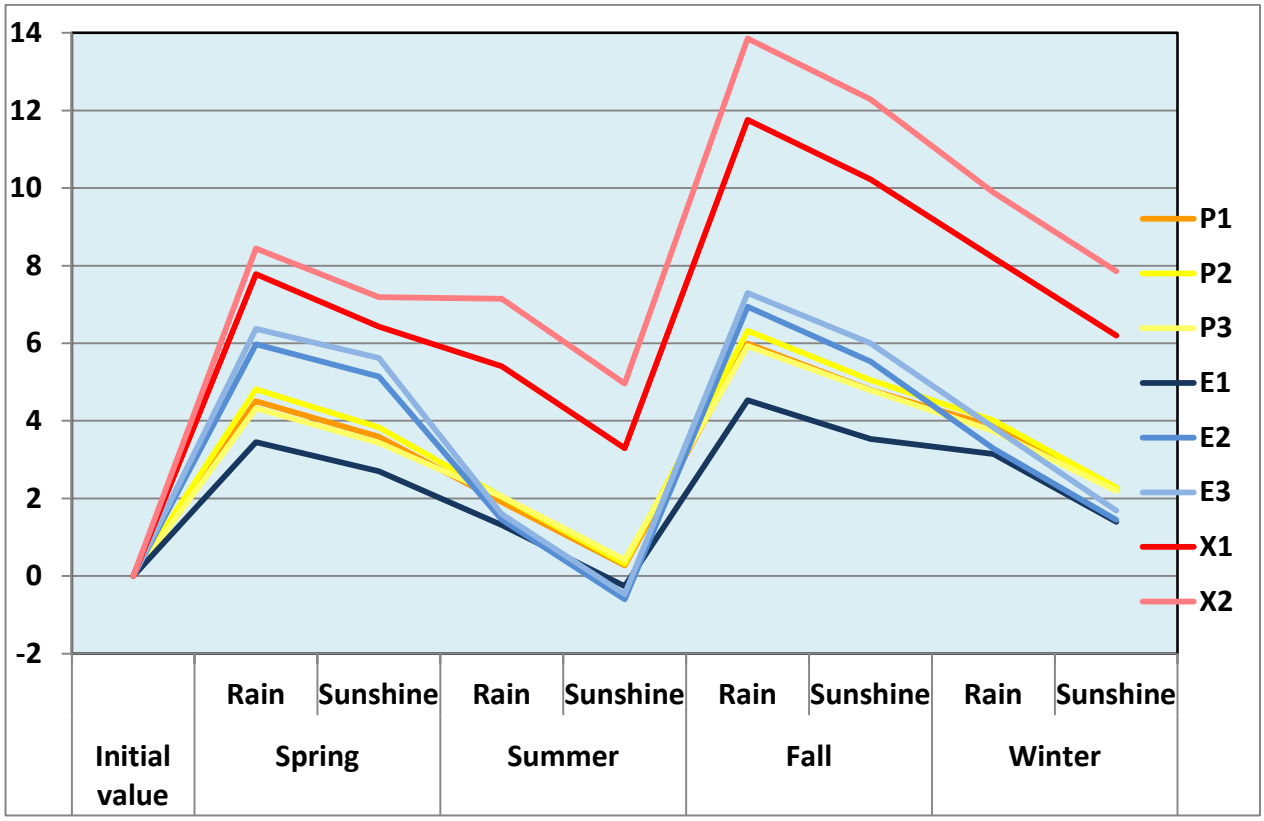


Fig. 2: Moisture content changes in %, individual specimens

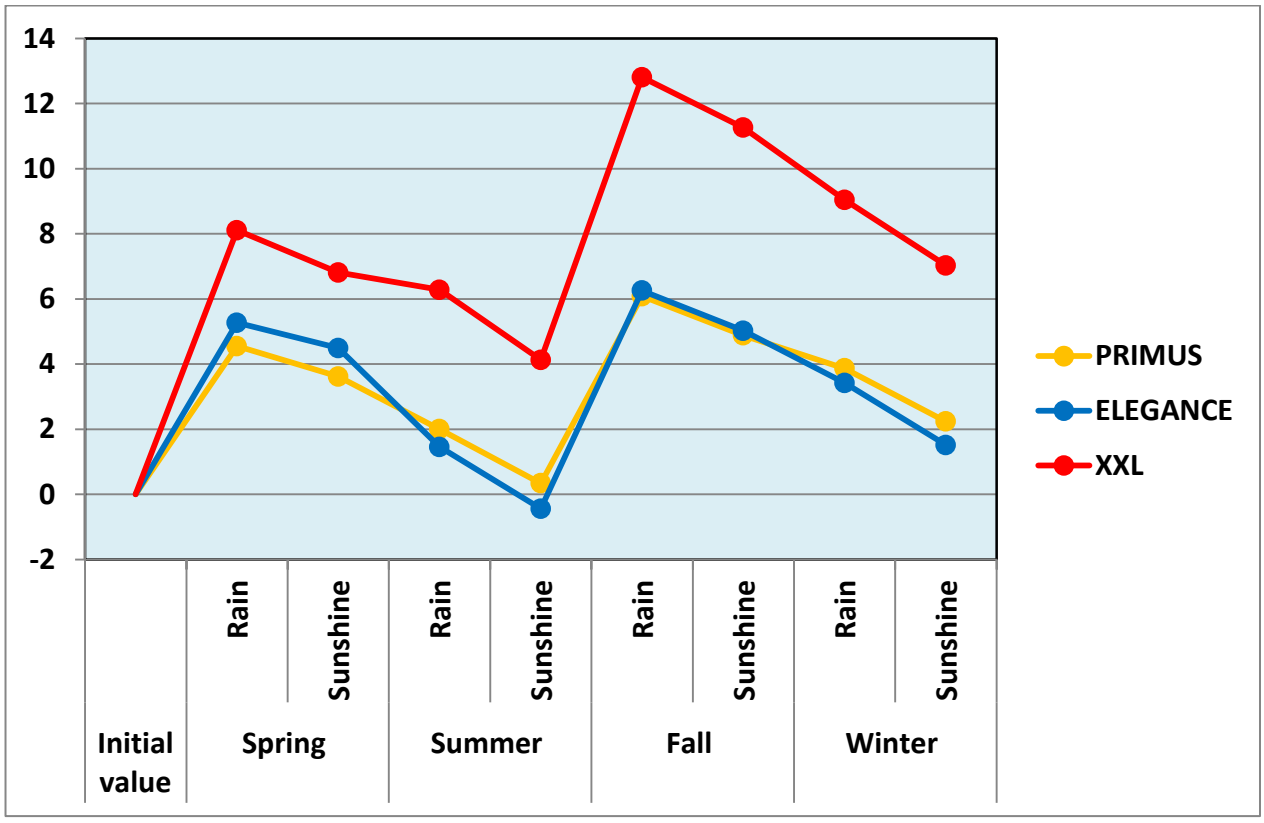
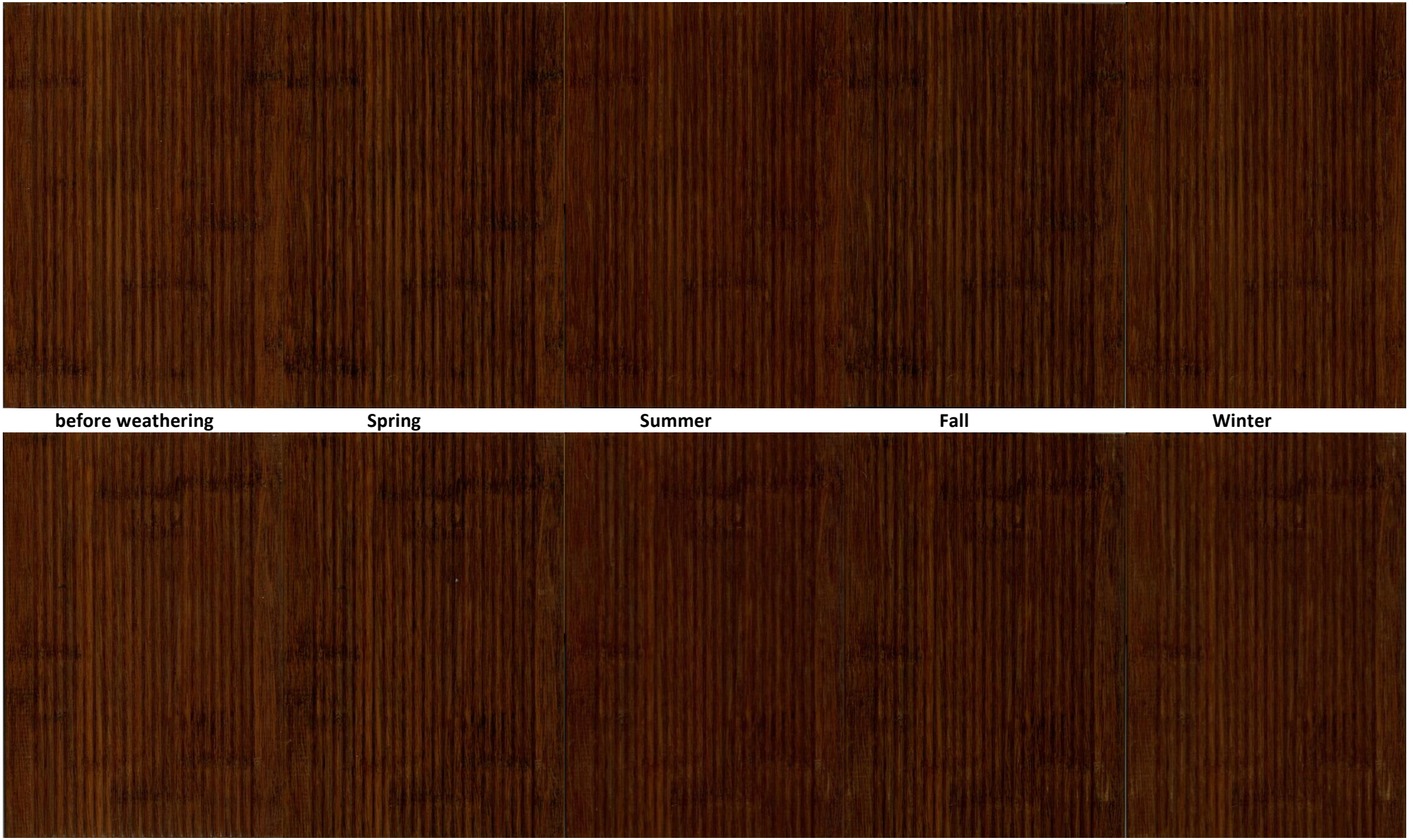


Fig. 3: Moisture content changes in %, collective means



before weathering **Spring** **Summer** **Fall** **Winter**

Specimens P1 (top) and P2 (bottom)

before weathering **Spring** **Summer** **Fall** **Winter**

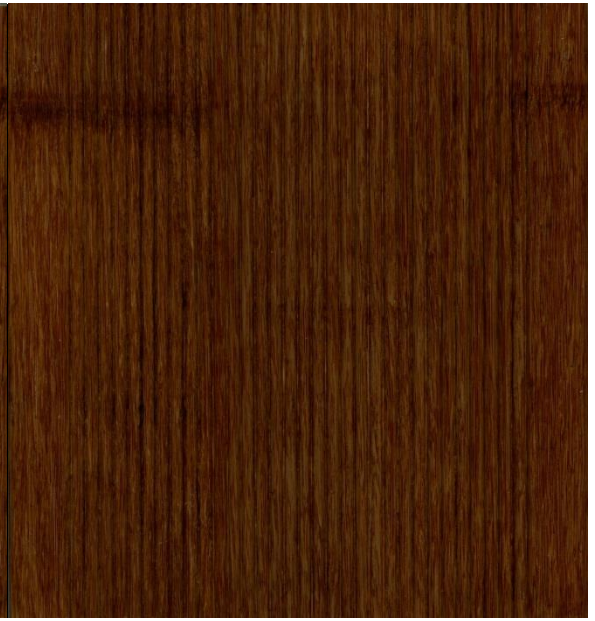
Specimens P3 (top) and E1 (bottom)

before weathering **Spring** **Summer** **Fall** **Winter**

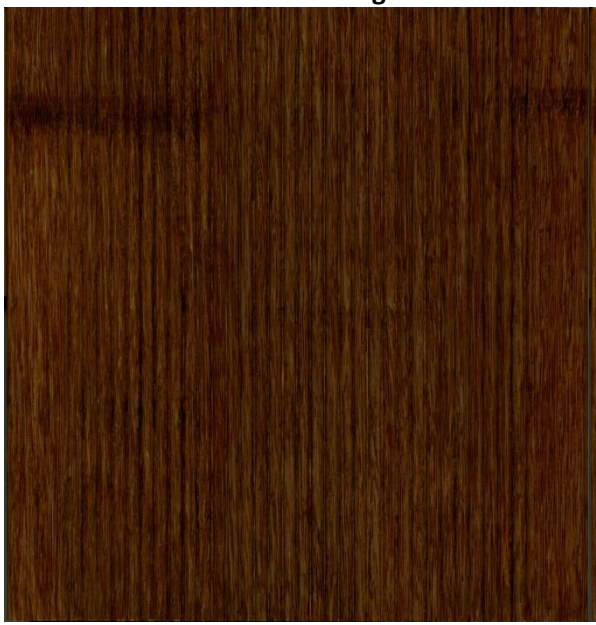
Specimens E2 (top) and E3 (bottom)

before weathering

Spring



Summer

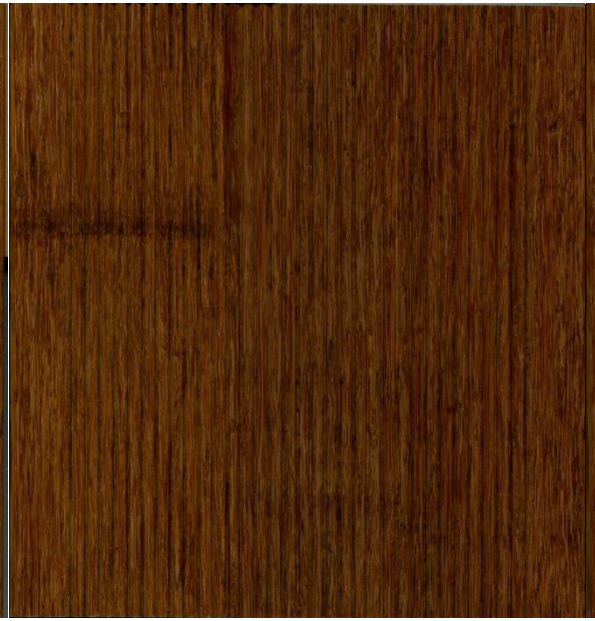


Fall

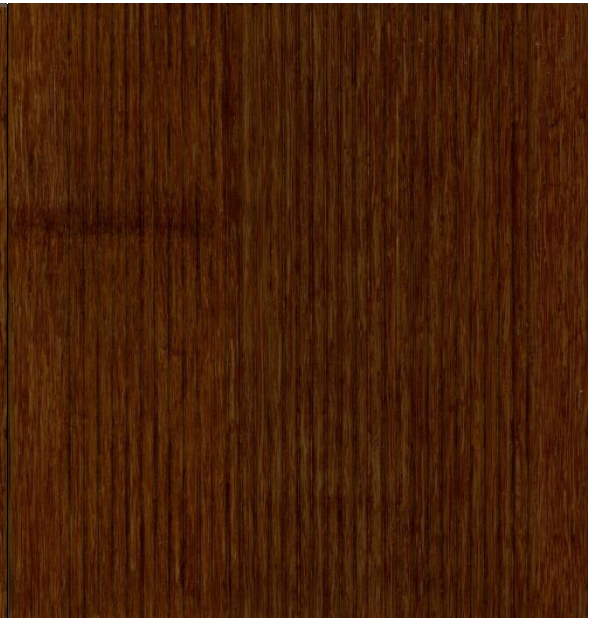
Winter

<u>Specimen XXL-1</u>

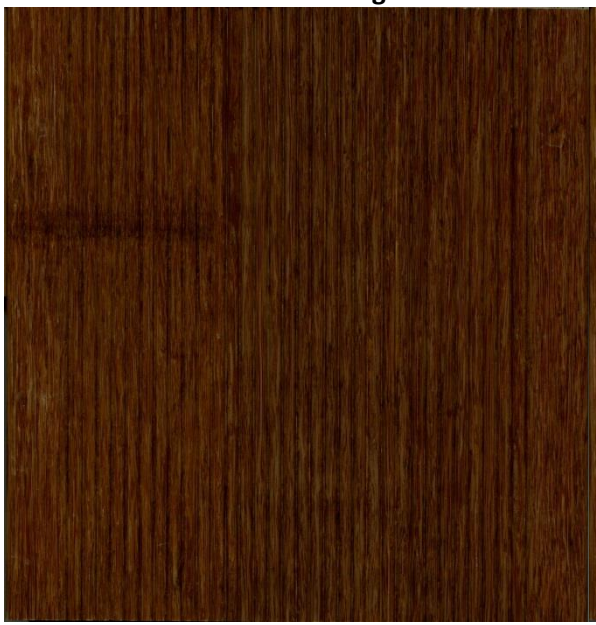
before weathering



Spring



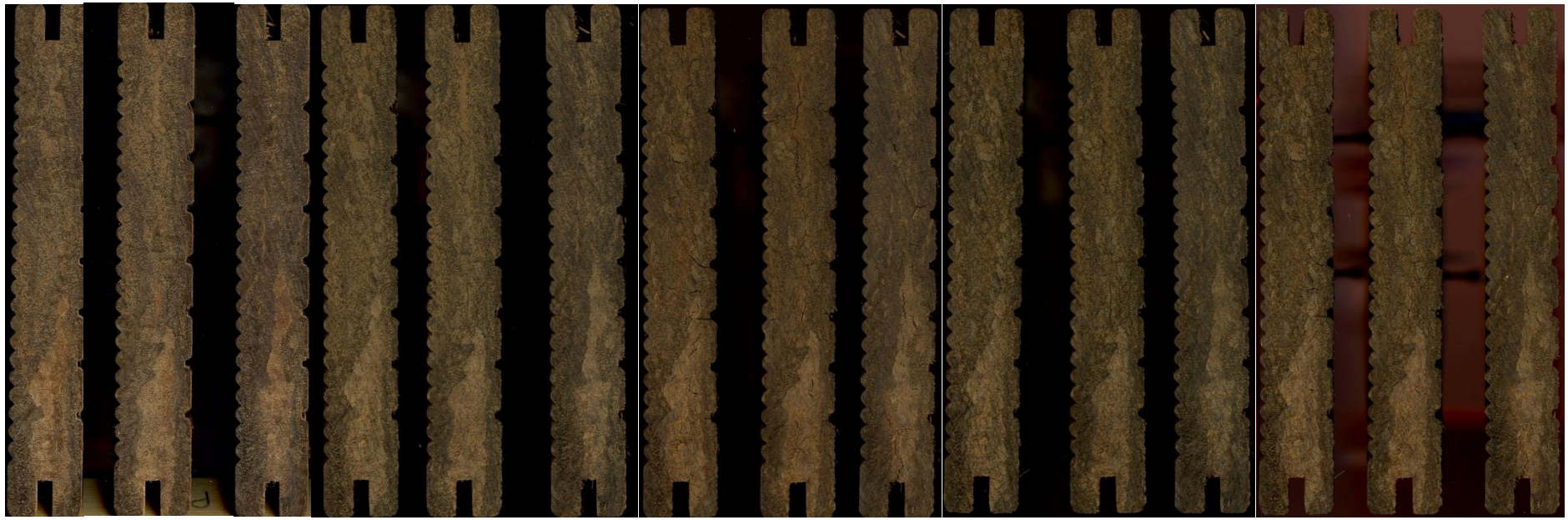
Summer



Fall

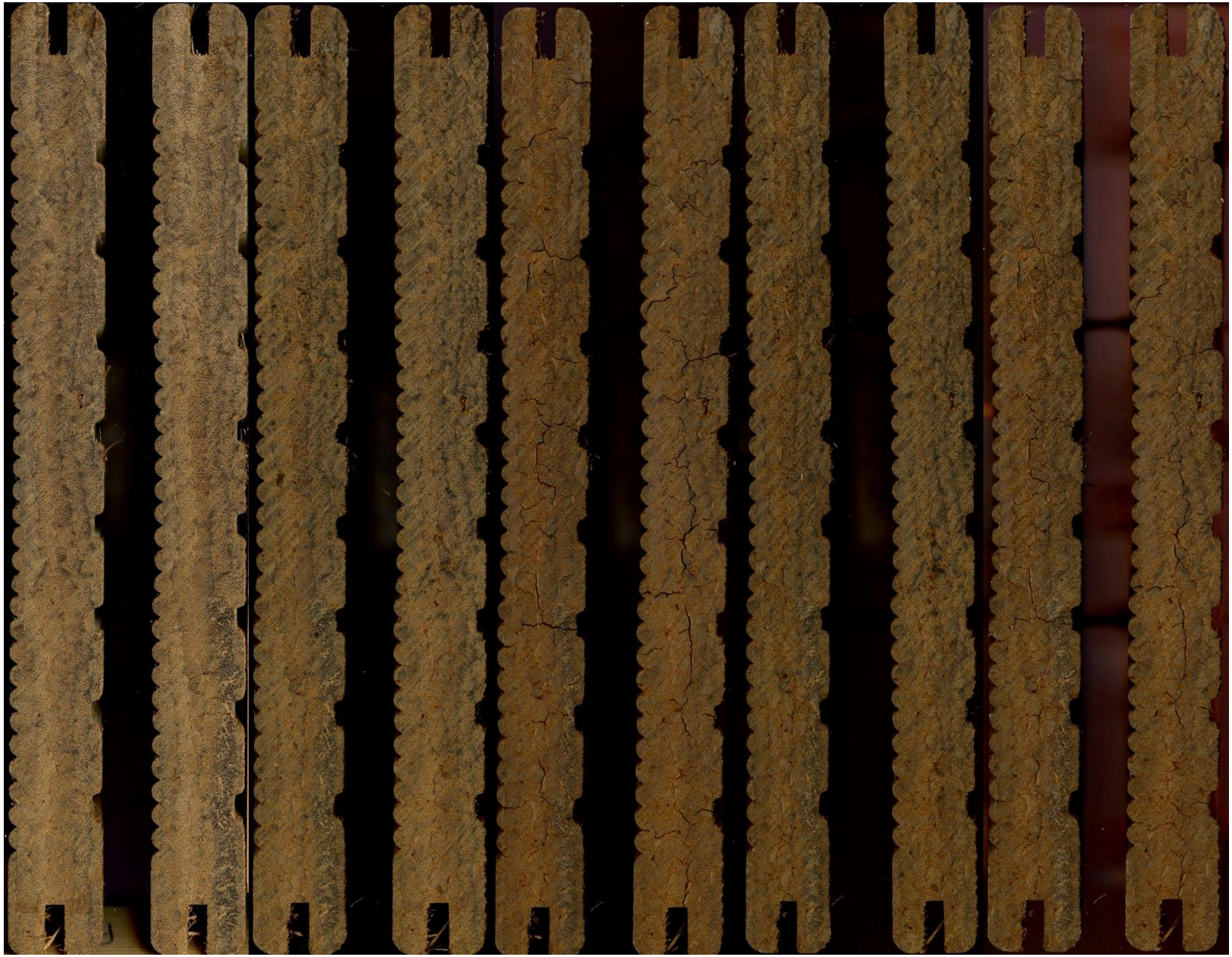
Winter

<u>Specimen XXL-2</u>

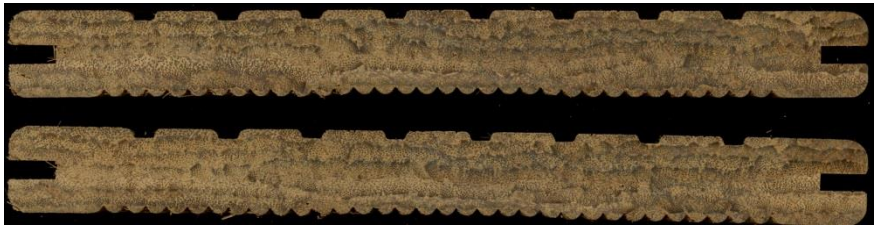


Specimens P1, P2, P3 **before weathering** **Spring** **Summer** **Fall** **Winter**

Specimens E1, E2, E3 **before weathering** **Spring** **Summer** **Fall** **Winter**



Specimens XXL-1, XXL-2 **before weathering** **Spring** **Summer** **Fall** **Winter**



Specimens of collectives PRIMUS (top), ELEGANCE (center) and XXL (below) whose ends (cross sectional surface) were trimmed by 2 cm