Accelerated climate aging tests of structural insulated panels with waste-based core materials

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Abstract. One of the challenges of climate change in the building sector is related to the durability of materials, i.e., the resistance to degradation due to weathering over time. The durability of building components can be assessed through long-term natural outdoor climate exposure or appropriate accelerated climate aging in the laboratory. SINTEF Research Centre owns a climate simulator apparatus to perform aging tests according to the Nordtest method NT Build 495:2000. The aim of this article is to show the results from an accelerated climatic aging test performed on three different configurations of a structural insulated panel (SIP), which is characterized by waste-based core materials. The samples were tested for one month, corresponding to about one year of natural outdoor climate exposure. The results from the test performed in the climate simulator include information on the sample changes occurring during the analyzed period, together with the scale of such changes and the time of occurrence. Therefore, the test results are qualitative and based on the fact that a change in the performance properties of the samples corresponds to a change in their appearance during the test. This includes, for instance, signs of degradation, such as cracks, loss of gloss, or delamination.

1. Introduction

The durability of building materials and components has recently gained increasing attention in connection to future climate change challenges. The resistance to degradation due to weathering over time can be assessed through long-term natural outdoor climate exposure or appropriate accelerated climate aging in the laboratory. Several apparatuses can be used in laboratories to subject test samples to various climate exposures with different aging methods and standards [1]. SINTEF Research Centre owns a climate simulator apparatus to perform aging tests according to the Nordtest method NT Build 495:2000 [2].

Structural insulated panels (SIP) are made up of two oriented strand boards (OSB) boards, i.e., wood-based, surrounding the core insulation (usually EPS). Concerning their durability, the biggest problem is exposure to humidity, although a waterproof treatment. Despite that, to study these degradation processes on SIP, the SIPA – Structural Insulated Panel Association carried out a durability assessment on SIP when exposed to distinct moisture conditions. The average results showed no significant loss of mechanical strength compared to the control sample [3].

Nanoparticles significantly affect the thermal behavior of facades through the reduction of the surface temperature. Also, they allow the improvement of the characteristics of materials such as cement, increase the durability of composite materials, allow weight reduction, and confer antimicrobial, anti-corrosive, and self-cleaning properties to facades [4,5,6]

The production of building materials, in particular mortars, and the consequent management of their construction and demolition waste (RCD), has become an important issue worldwide due to the significant volume of waste generated annually by this industry, with a significant contribution to carbon dioxide emissions into the atmosphere [7]. As such, there has been a growing concern to create new applications for this waste and waste from other industries in developing alkali-activated mixtures (i.e., without incorporating Portland cement). Its reuse alters the status of "waste", thus creating a "sub-product", generating a fundamental step towards waste management and control success and a direct contribution to the circular economy in the construction industry.

Considering a lack of durability assessment on this innovative systems, this article aims to show the results from an accelerated climatic aging test performed on different configurations of SIP characterized by waste-based core materials and dark finishing coatings incorporating nanoparticles with high NIR (Near-Infrared) reflectance. The results focus on the performance of the surface treatment of the samples. This test is performed in connection to the Circular 2B (Circular Construction in Energy-efficient Modular Buildings) project [8] funded by the EEA grants. Circular 2B project aims to optimize a commercial modular envelope solution, a SIP, produced by the consortium's industrial partner by replacing standard original materials with functionally equivalent materials. The project focuses on the development of new waste-based materials, such as the SIP core, by replacing the original insulation slab with an equivalent, incorporating residues, such as plastics, construction and demolition waste, and slag. Also, watertightness was treated by applying an acrylic painting doped with nanoparticles.

2. Methods

We performed artificial climatic aging tests in SINTEF's climate simulator, as described in section 2.1, according to the Nordtest method NT Build 495:2000 [2]. This test was developed by SINTEF about 50 years ago and the method description was developed and later approved as the Nordtest method after many years of experience, including comparisons with natural climatic aging of façade materials [9,10]. The objective of the accelerated climate aging tests was to define the durability of specific variants of the SIP qualitatively.

The samples were subjected to accelerated aeing for 1 month, which corresponds to about 1 year of natural outdoor climate exposure.

Note that the performed tests are not usually run to provide an estimatation of the service life expressed in terms of the number of years, as their main purpose is to compare the aging properties of different materials and components.

The results from the tests performed in the climate simulator include information on the changes occurring during the analyzed period, together with the scale of such changes, and the time of occurrence. The main findings are, therefore, qualitative and based on the fact that a change in the performance properties of the samples corresponds to a change in their appearance during the test. This includes, for instance, signs of degradation, such as cracks, loss of gloss, or delamination.

Note that, before and after the aging tests in the climate simulator, the samples will be subjected to other specific tests to examine relevant characteristics of the materials, such as water permeability, adhesion, hard body impact, color and solar reflectance. This will make it possible to examine how the accelerated aging of the materials affects these different characteristics. However, the results of these additional tests are out of the scope of this article.

2.1. *The climate simulator*

SINTEF’s climate simulator is a non-commercial accelerated climate aging apparatus in which test samples are subjected by rotation to four different climate zones, as shown in Figure 1.

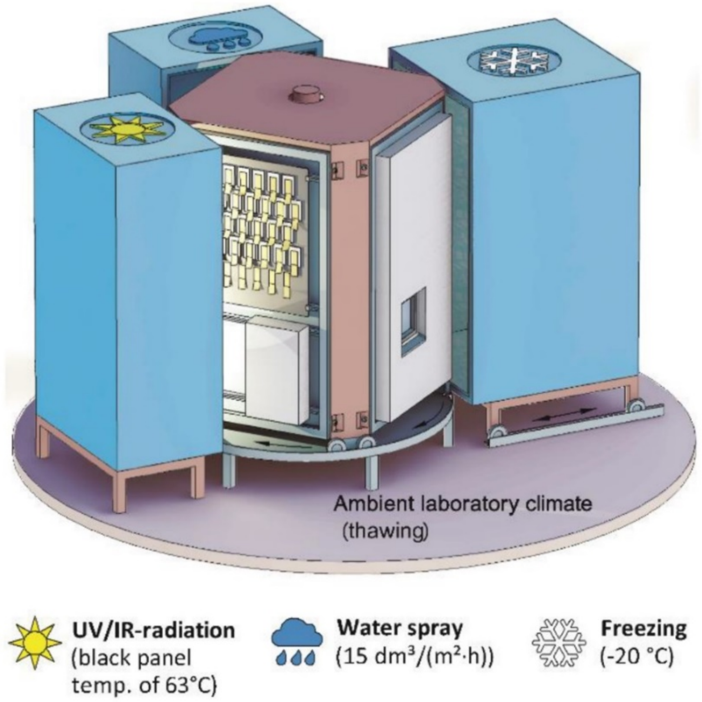

Figure 1 Illustration of SINTEF's climate simulator with the four climate zones used for testing according to NT Build 495. The mid-section is rotating clockwise. Source: [3]

The first zone is an ultraviolet (UV) and infrared (IR) irradiation chamber, where UV radiation is applied using fluorescent UV tubes with a relative spectral distribution in the UV band close to that of global solar irradiance. The black panel's temperature reaches a designated value (normally 63 °C) within 45 minutes of exposure to UV light and heat radiation. The black panel temperature may be chosen as 35±5 °C, 50±5 °C, or 75 ±5 °C, based on ISO 4892 [11]. The temperature is controlled using infrared halogen lamps and the UV intensity can vary at different levels depending on the choice of the UV tubes. For instance, for one specific set of UV tubes, the UVA and UVB intensities are averaged to 15 W/m^2 and 1.5 W/m^2, respectively.

The second zone is a water spray zone, where the specimens are wetted with a spray of demineralized water. The suggested strain is 15 $dm^3/m^2/h$, but several spraying conditions may be used. Furthermore, to allow water to drip off the examined samples, the spraying is terminated 10 min before the rotation into the third zone.

The third zone is a freezing zone, where an air temperature of -20±5 °C is suggested, but it is also possible to use other air temperatures if registered and reported.

The fourth and last zone is the ambient laboratory thawing zone, where the specimens are thawed at the laboratory climate of 23±5 °C and 50%±10% relative humidity.

The exposure time is 1 hour in each climate zone in the given sequence.

2.2. The tested samples

Three different SIP configurations were tested, as illustrated in Table 1.

Table 1 Main materials of the three tested variants.

	Configuration 1	Configuration 2	Configuration 3
Int.	Oriented strand board (OSB)	Oriented strand board (OSB)	Oriented strand board (OSB)
	Waste-based core	Waste-based core	Waste-based core
	Oriented strand board (OSB)	Oriented strand board (OSB)	Oriented strand board (OSB)
	Commercial basecoat	Commercial basecoat	Commercial basecoat
Ext.	Acrylic paint	Acrylic paint dopped with nanoparticles	-

The samples were prepared by sealing all the lateral faces with epoxy glue, which means the front and back surface will be exposed to the climate simulator. The specimens were positioned in one of the four test faces in the mid-section of the climate simulator. The test was stopped after 30 days.

3. Results and discussion

The test revealed different performances of the surface treatment of the samples. Visual control during and after the test sequence revealed the results showed in Table 2.

Table 2 Results from testing in the climate simulator.

	Configuration 1	Configuration 2	Configuration 3
Start. 11.11.22		09.12.22 Visible cracks in the front face observed in all the samples	02.12.22 Visible cracks in the front face observed in all the samples
End 11.12.22	No cracks or delamination observed	Delamination observed in areas close to the cracks	Delamination observed in areas close to the cracks

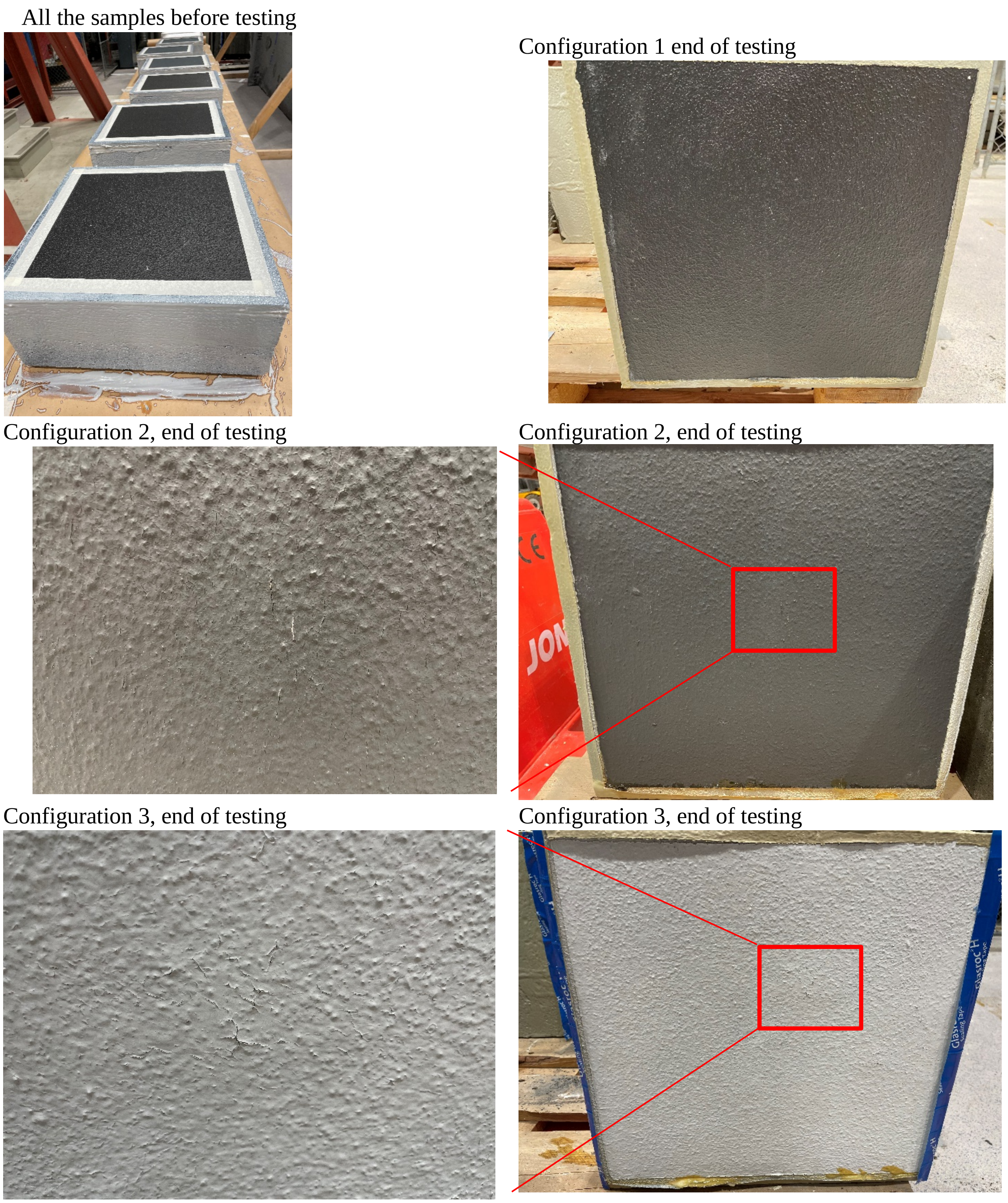

Figure 2 Pictures of the different samples before (upper left corner) and after the testing in the climate simulator.

4. Conclusions

The article presented the results from an accelerated climatic aging test performed on three different configurations of an innovative structural insulated panel (SIP), which is characterized by waste-based core materials.

Visual control of the samples during and after the test sequence indicated a higher performance of configuration 1 compared to configurations 2 and 3. Further developments will include that the samples will be subjected to other specific tests to examine relevant characteristics of the materials, such as water permeability, adhesion, hard body impact, color and solar reflectance. The results will be compared to comparable tests performed before the aging test.

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