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Determination of span rating for natural fibre-reinforced plastic composite (NFC) deck boards

Détermination de la portée nominale des lames de platelage en composite plastique renforcé de fibres naturelles (NFC)

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Contents

Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

Introduction

Natural fibre-reinforced plastic composites (NFC) are made of one or several cellulosic materials combined with one or several thermoplastics. Currently, cellulosic materials mainly come from different natural plant sources and the most common thermoplastics, including virgin and recycled forms, are polyethylene, polypropylene and polyvinyl chloride. In the past, these composites used to be called wood plastic composites (WPC). In this document, NFC is used instead of WPC, in line with the terminology used in ISO 16616.

The production of NFC in the thermoplastics industry has gained much acceptance in recent years and is expected to keep growing rapidly. This type of composite material has become an important family of engineering materials due to the increasing need for sustainable and biodegradable renewable materials, which are known as "green composites." NFC has sustainable character due to the presence of wood as a natural component, which enables environmental protection and minimization of waste formation. Such materials offer significant advantages which justify their use.

NFC has recently found wide applications in construction and decoration areas including decking, fencing, flooring, landscaping, railings, window framing, and roof tiles. Meanwhile it is also applied for packaging, automotive industries, furniture and other items.

For deck boards used in outdoor environments, some performance measurements, such as temperature and moisture effects, ultraviolet resistance, freeze-thaw resistance, etc., are used in the determination of the span rating in order to assist in the proper installation and using. However, due to the lack of a unified testing method to evaluate a span rating indicating the board's ability to comply with functions identified for its specific end use, therefore, it would be required to establish an ISO standard for removing the barriers of deck boards in the application and sales, and encouraging technology development in the NFC production field.

Determination of span rating for natural fibre-reinforced plastic composite (NFC) deck boards

1 Scope

This document specifies the procedures to establish a span rating for natural fibre-reinforced plastic composite (NFC) deck boards and deck boards used as stair treads, provided that the stair treads are produced from the same materials and processing techniques as the deck boards. This document covers test methods of performance, acceptance criteria and determination of span rating. It is intended to establish the basis for code recognition of deck boards used in exterior applications where combustible construction is allowed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 4892-2:2013, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 16616:2015, *Test methods for natural fibre-reinforced plastic composite (NFC) deck boards*

EN 15534-1:2014, *Composites made from cellulose-based materials and thermoplastics (usually called wood-polymer composites (WPC) or natural fibre composites (NFC)) — Part 1: Test methods for characterization of compounds and products*

ASTM D7032-17, *Standard Specification for Establishing Performance Ratings for Wood-Plastic Composite and Plastic Lumber Deck Boards, Stair Treads, Guards, and Handrails*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
natural fibre-reinforced plastic composite
NFC
product made thereof being the result of the combination of one or several cellulosic materials with one or several thermoplastics

3.2
flexural strength
maximum load achieved by the test specimen during flexural test, and reported as modulus of rupture (MOR)

3.3
flexural stiffness
value calculated from a linear least squares fit of the stress-strain curve over the range of 10 % to 40 % of ultimate stress, and reported as either modulus of elastic (MOE) or MOE × moment of inertia (EI)

Note 1 to entry: If the cross-section of deck boards is complicated to calculate moment of inertia, it is better to use EI to indicate flexural stiffness.

3.4
span rating
maximum centre-to-centre support spacing for the specified end use

4 Test specimen

Test specimens with the original thickness and width of the product are used in the tests unless otherwise specified. In general, test specimens of the product are rectangular in cross-section for deck boards and stair treads.

5 Sampling

It is important to select test specimens that reflect the variability of the population. It is essential to consider batch-to-batch and shift-to-shift variability when sampling actual production. Test specimens shall be selected from several production runs of a given item.

6 Conditioning

Prior to testing, all specimens shall be conditioned to environmental conditions appropriate for the intended end-use of the product. Alternatively, the test specimens used for the determination of the product performance shall be conditioned for a minimum of 72 h and testing shall be carried out at the standard atmosphere 23/50 (23 °C ± 2 °C, 50 % ± 5 % RH) in accordance with ISO 291. When the product is to be subjected to a water soak environment, the test specimens shall be tested within 30 min upon removal from the treatment.

7 Evaluation methods of performance

7.1 General

Deck boards and stair treads are structural elements and shall be tested in flexure to establish a span rating. For products often used in diverse outdoor environments, the temperature and moisture effects (see 7.2) shall be used in the determination of the span rating. In addition, several other performance measures shall be evaluated and used to adjust the span rating in order to assist in the proper installation and using, including tests on ultraviolet resistance (see 7.3), freeze-thaw resistance (see 7.4), biodeterioration effects (see 7.5), creep-recovery (see 7.6), and creep-rupture (see 7.7), mechanical fastener holding capacity (see 7.8), and slip resistance (see 7.9).

7.2 Temperature and moisture effects

7.2.1 Temperature effect

Testing shall be conducted to verify that allowable span and load ratings are applicable at a range of temperatures expected in service. For the purposes of this document, the lower and upper temperatures shall be −30 °C ± 2 °C and 55 °C ± 2 °C, respectively. Flexure tests shall be conducted to failure at the desired span. A minimum of 10 specimens shall be tested at each temperature. The flexural strength and flexural stiffness shall be determined in accordance with ISO 16616:2015, 6.2.

The average change in properties between the flexural strength and stiffness of the standard control flexural specimens and the specimens tested at low and high temperatures shall be calculated as a percentage and reported. The average change shall be calculated by determining the difference between the standard control and temperature conditioned values and dividing that difference by the control value.

7.2.2 Moisture effect

Testing shall be conducted to verify that allowable span and load ratings are applicable at moisture conditions expected in service. Flexural tests shall be conducted to failure at the desired span. A minimum of 10 specimens shall be tested at moisture conditions potentially experienced in service (for example, high humidity, submerged), or under standard condition which is submersion in water for 14 d. The average maximum flexural strength and stiffness shall be determined in accordance with ISO 16616:2015, 6.2.

The average change in properties between the standard control specimens and those tested at the in-service moisture condition of interest shall be calculated as a percentage and reported. The average change shall be calculated by determining the difference between the control and moisture conditioned values and dividing that difference by the standard control value.

7.2.3 Acceptance criteria

The most restrictive effect (either temperature or moisture) shall be used to adjust the performance rating of deck boards and stair treads. The span rating shall be reduced by the most restrictive effect determined from 7.2.1 or 7.2.2.

7.3 Weatherproofing

7.3.1 Test method

To determine the mechanical property degradation after xenon lamp exposure, a minimum of five full-size or full-thickness specimens shall be tested for up to 2 000 h (340 nm, 0,51 w/m^2) in the direction of the exposed side as specified in Method A of ISO 4892-2:2013, Table 3.

A minimum of five exposed and five unexposed test specimens shall be tested in accordance with ISO 16616:2015, 6.2. The surface intended for exposure in service shall be exposed to the xenon lamp source. The flexure test shall be conducted with the exposed surface in tension.

When testing equipment does not allow either full-size or full-thickness test specimens, coupon specimens removed from the surface of the full-size cross-section shall be used. However, when using data generated from coupon specimens, the user shall justify the estimation of the impact on the full-size product.

7.3.2 Acceptance criteria

The average percent change in properties between the exposed and unexposed specimens shall be calculated and reported. The average change shall be calculated by determining the difference between the unexposed and exposed values and dividing that difference by the unexposed value. For acceptance, the average flexural strength of exposed test specimens shall be within 10 % of the average flexural strength of unexposed specimens. If the decrease exceeds 10 %, the span shall be reduced by the amount in excess of 10 %.

7.4 Freeze-thaw resistance

7.4.1 Test method

A minimum of five specimens shall be tested in accordance with ISO 16616:2015, 6.10.2. Whenever possible, the test specimens shall be prepared using the full cross-section of the as-manufactured product.

A minimum of five exposed and five unexposed specimens shall be tested in accordance with ISO 16616:2015, 6.2. If more than one deck board profile is being evaluated and all profiles are manufactured with the same product formulation, then freeze-thaw testing of only one profile is required.

7.4.2 Acceptance criteria

The average percent change in properties between the exposed and unexposed specimens shall be calculated and reported. The average change shall be calculated by determining the difference between the unexposed and exposed values and dividing that difference by the unexposed value. For acceptance, the average flexural strength of exposed test specimens shall be within 10 % of the average flexural strength of unexposed specimens. If the decrease exceeds 10 %, the span shall be reduced by the amount in excess of 10 %.

7.5 Biodeterioration

7.5.1 General

Termite and decay testing shall be required for deck boards and stair treads products containing wood, cellulosic, or other biodegradable materials.

7.5.2 Fungal decay resistance

7.5.2.1 Test method

Resistance to fungal decay shall be determined in accordance with either of the following test methods:

a) ASTM D7032-17, 4.8.1;

b) EN 15534-1:2014, 8.5.2 and EN 15534-1:2014, 8.5.3.

7.5.2.2 Acceptance criteria

Examination of test blocks shall reveal decay resistance equivalent to that of preservative-treated or the heartwood of naturally durable wood used in identical applications, as measured by visual inspection, and average weight loss.

However, mean specimen weight losses greater than 5 %, or significantly greater than controls, should be cause for concern.

7.5.3 Termites

7.5.3.1 Test method

Resistance to termite attack shall be determined in accordance with either of the following test methods:

a) ASTM D7032-17, 4.8.2;

b) EN 15534-1:2014, 8.2.

7.5.3.2 Acceptance criteria

Visual inspection of the test specimens shall demonstrate resistance to termite attack equivalent to that of preservative-treated or the heartwood of naturally durable wood used in identical applications.

7.6 Creep-recovery

7.6.1 Test method

A minimum of three specimens representative of the population being sampled shall be loaded in flexure in accordance with ISO 16616:2015, 6.2 to twice the design load for which code recognition is desired. Meanwhile, the load shall be increased by the factors β derived in 7.2, 7.3, and 7.4. Prior to loading, the test specimens shall be allowed to equilibrate to the test temperature conditions (for example, 20 °C ± 2 °C) and be maintained throughout the experiment. The load is applied for 24 h and the specimens are then allowed to recover with no superimposed load for 24 h. Deflection at mid-span shall be measured a minimum of four times:

a) prior to the application of load;

b) at 24 h with load on;

c) immediately after the load is removed;

d) after the 24 h recovery period.

Total deflection is the deflection that occurs between time zero and the end of the first 24 h loading period. The recovered deflection is the deflection at the end of the 24 h recovery period minus the total deflection. The percent recovery for each test specimen shall be defined as the recovered deflection divided by the total deflection multiplied by 100.

7.6.2 Acceptance criterion

The average percent recovery, rounded to the nearest percent, shall be 75 % or greater. For products where the total deflection is less than 3,2 mm, the unrecovered deflection shall be less than 1,6 mm.

7.7 Creep-rupture

7.7.1 Test method

A minimum of 10 specimens shall be loaded in flexure in accordance with ISO 16616:2015, 6.2 to a stress level appropriate for the intended end use. The load that is applied in this test shall be increased by each of the adjustment factors derived in 7.2, 7.3, and 7.4. Prior to loading, the test specimens shall be allowed to equilibrate to the test temperature conditions (for example, 20 °C ± 2 °C) and be maintained throughout the experiment. The load shall be maintained for a minimum of 90 days with deflection measurements taken at regular intervals to adequately describe the creep curve. It is recommended that for the first 24 h, measurements at eight-hour intervals are suggested, followed by daily measurements for the next seven days. Weekly measurements should be adequate for the remainder of the 90-day period unless there is evidence of tertiary creep (increasing creep rate).

7.7.2 Acceptance criterion

For each test specimen, there shall be neither structural failure nor evidence of tertiary creep.

7.8 Mechanical fastener holding

This test shall be conducted in accordance with ISO 16616:2015, 6.7. Any and all types of mechanical fasteners to be used with the product shall be evaluated. This includes, but is not limited to nails, screws, staples, bolts, and hidden fastener systems.

7.9 Slip resistance

Slip resistance (coefficient of friction) shall be determined in accordance with ISO 16616:2015, 6.8. Wet and dry slip resistance both parallel and perpendicular to the *L*-direction shall be evaluated. A minimum of five tests shall be conducted in each orientation.

NOTE *L*-direction is parallel to the longitudinal direction (length).

8 Determination of span rating

8.1 Deck board span rating

8.1.1 Flexural tests to failure at the span desired shall be conducted in accordance with ISO 16616:2015, 6.2. Sample size shall be a minimum of 28 specimens representative of normal production and be of the actual cross-section size and profile for which code recognition is desired.

8.1.2 The span rating shall be determined according to Formula (1):

$$C = (F \times \beta) / (2{,}5 \times b \times L) \tag{1}$$

where

C is the span rating, in kN/m^2;

F is the ultimate flexural strength, in kN;

β is the adjustment factor;

2,5 is the safety factor;

b is the deck board width, in m;

L is the specified span, in m.

8.1.3 The allowable maximum deck board span resulting from 8.1.2 shall be reduced by the adjustment factor, β. An example of this process is shown in Annex A.

The adjustment factor, β, shall be calculated according to Formula (2):

$$\beta = \beta_a \times \beta_b \times \beta_c \tag{2}$$

where

β_a is the temperature and humidity resistance adjustment factor derived in 7.2;

β_b is the UV-resistance adjustment factor derived in 7.3;

β_c is the freeze-thaw resistance adjustment factor derived in 7.4.

8.2 Two-span adjustment

When flexural testing is conducted to failure using a simple-span condition and the failure mode is flexural collapse or 3 % strain, two-span adjustments for flexural strength and stiffness shall be permitted. If the user intends to take the strength increases for hollow or thin-walled products, a confirming test using the two-span protocol is required to verify that the failure mode is not buckling or crushing at the support. For flexural strength, the increase is 23 %, and for flexural stiffness, the increase is 39 %. The strength increase (MOR) is applicable to stair treads only. The deck boards shall be tested according to the two-span method defined in Annex B.

The increases for flexural strength and stiffness in 8.2 are based on engineering mechanics for a continuous beam over two spans, where the support conditions are assumed to be pinned connections. Therefore, for these increases to apply, the actual installation of the stair tread should be such that the deck board remains in contact with its supports throughout its intended lifetime.

9 Report

9.1 Test report

Report the sampling plan and testing in accordance with the applicable standard used. Report the sample size and data used to make the calculations. For development of adjustment factors or other performance measures, provide plots of the data and any curves fitted to the data.

9.2 Product description

Report information concerning material specifications, thickness, size, and non-proprietary manufacturing process parameters.

9.3 Installation instructions

Provide installation details and fastening methods. Where applicable, provide a description of the methods of field cutting, application and finishing.

Annex A
(informative)

Adjustment factor — Examples

A.1 Example 1

The ratio of the average exposed MOR to the average unexposed MOR provides the loss factor (for example, 2 041/2 617 = 0,78).

a) Temperature effect = 0,78. This is a 22 % loss in property.

b) Moisture effect = 0,85. This is a 15 % loss in property.

c) UV effect = 0,92. This is an 8 % loss in property.

d) Freeze-thaw effect = 0,96. This is a 4 % loss in property.

Deck board end-use adjustment factor = 0,78.

0,78 is the more restrictive of a) and b). Neither c) nor d) exceed the 10 % limit and need not be applied.

A.2 Example 2

a) Temperature effect = 0,78. This is a 22 % loss in property.

b) Moisture effect = 0,85. This is a 15 % loss in property.

c) UV effect = 0,86. This is a 14 % loss in property, which is 4 % greater than the 10 % limit; therefore, use 0,96.

d) Freeze-thaw effect = 0,88. This is a 12 % property loss, which is 2 % greater than the 10 % limit; therefore, use 0,98.

Deck board end-use adjustment factor = 0,78 × 0,96 × 0,98 = 0,73.

0,78 is the more restrictive of a) and b). Both c) and d) exceed the 10 % limit and the amount in excess of the 10 % limit has to be applied.