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RILEM TECHNICAL COMMITTEE

Recommendation of RILEM TC 190-SBJ: service-life prediction of sealed building and construction joints

Durability test method: determination of changes in adhesion, cohesion and appearance of elastic weatherproofing sealants after exposure of statically cured specimens to outdoor weathering and simultaneous mechanical cycling*

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1 Introduction

Weatherproofing joint seals in building façades or other construction applications are exposed to thermally or psychrometrically induced cyclic movements. This joint movement imposes cyclic mechanical strain on the seal, which, depending on the exposure conditions and the construction design, can vary substantially in rate and amplitude. During their entire service life, joint seals are exposed to cyclic mechanical strain and environmental degradation factors. Cyclic joint movement, sunlight, temperature variations (heat, cold) and moisture in the form of humidity, condensation or rain are considered to be the primary environmental and service degradation factors leading to sealed joint failure.

This technical recommendation provides a framework for assessing the effects of cyclic movement and weathering on statically cured test specimens in outdoor natural weathering-based procedures. While default values for the test parameters are provided in the test method, the experimenter may adapt test conditions to better reproduce service conditions.

2 Scope

This RILEM recommendation specifies outdoor weathering procedures for determining the effects of cyclic movement and natural weathering on laboratory-cured, elastic weatherproofing joint sealants (one- or multi-component).

3 Safety concerns

This standard does not purport to address safety concerns, if any, associated with its use. It is the responsibility of the user of this recommendation to

*The text presented hereafter is a draft for general consideration.

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establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

4 Related standards

Outdoor weathering methods described in this recommendation are technically related to those published in ASTM C1589, ASTM D1435, ASTM G7 and ISO 877-2, but differ in that the exposure of sealants is carried out in conjunction with simultaneous mechanical movement.

5 Normative references

The following standards contain provisions, which, through reference in this text, constitute provisions of this RILEM Technical Recommendation (RTR). At the time of publication, the editions indicated were valid.

5.1 ASTM standards

ASTM C1589 (2004) Practice for Outdoor Weathering of Construction Seals and Sealants.
ASTM D1435 (2005) Practice for Outdoor Weathering of Plastics.
ASTM G7 (2005) Practice for Atmospheric Environmental Exposure Testing of Non-Metallic Materials.
ASTM G113 (2005) Standard Terminology Relating to Natural and Artificial Weathering Tests of Non-Metallic Materials.

5.2 ISO standards

ISO/CD 877-2 (2006) Plastics—Methods of Exposure to Direct Weathering, to Weathering Using Glass-Filtered Daylight, and to Intensified Weathering Using Fresnel Mirrors.
ISO 6927 (1981) Building Construction—Jointing Products—Sealants Vocabulary.
ISO 11600 (2002) Building Construction—Jointing products—Classification and Requirements for Sealants.
ISO 13640 (1999) Building Construction—Jointing Products—Specifications for Test Substrates.

6 Definitions

For the purpose of this RILEM technical recommendation, the definitions provided in ISO 6927 apply.

7 Summary of test procedure (principle)

Test specimens are prepared in which the sealant to be tested adheres to two parallel support surfaces (substrates). The specimens are conditioned statically (no movement) in a laboratory controlled climate. The conditioned specimens are then exposed to the outdoor climate and simultaneously to repetitive cycles of enforced mechanical movement. Outdoor weathering is carried out for a minimum of 12 months; the default duration for outdoor exposure is 36 months.

The novel design of the support, which incorporates pivoted hinges, allows simultaneous extension and compression of the sealant in the test specimen. Simultaneous extension and compression of the test specimen is induced by extending or compressing one end of the test specimen with a suitable device, for instance a fully automated cyclic movement machine, a tensile test machine, or a hand-operated vice, and inserting the separator (see 12.4) upon completion of the operation in the extended end of the specimen.

At regular intervals (default value: every 3 months), the specimens are visually inspected in their extended/compressed state (extension/compression up to the full rated movement capability of the sealant tested) for changes in appearance, cohesion and adhesion. The depth of any cohesive or adhesive flaw is determined according to the rules provided in ISO 11600 and the general condition of the sealant is reported.

Default test parameters and, for some procedures, alternative options are defined in this technical recommendation (see Table 1). In cases of dispute, the default method is the reference method. The experimenter may deviate from the default values for the following test parameters (deviations from the default values must be highlighted in the test report):

(a) Support substrate—default: anodised aluminium as specified in ISO 13640;
(b) L-shaped support element dimensions—default: 120 mm × 20 mm × 15 mm × 2.0 mm (length × width × height × thickness);

Table 1 Overview of default and alternative choices of key test parameters

Procedure Conditioning	Default A	Alternative option or alternative test parameter B
Outdoor weathering (on exposure rack)	• Exposure (inclination) angle: 45° • Exposure orientation: facing equator • Minimum height above ground: 0.5 m • Specimen backing: unbacked exposure • Exposure duration: 3 years • Visual inspection: every 3 months	• Exposure (inclination) angle: latitude angle • Specimen backing: backed exposure • Exposure duration: minimum 1 year
Movement parameters for mechanical cycling	• One cycle/2 months (extension/compression switched every month)	

(c) Sealed joint dimensions—default: 100 mm × 20 mm × 15 mm (length × width × depth);
(d) Conditioning method (A or B)—default: A;
(e) Outdoor exposure—default: exposure rack with 45° inclination angle facing the equator;
(f) Mechanical cycling: amplitude and duration (number of cycles)—default values are specified in the test procedure.

8 Significance and use

Tests conducted in accordance with this RTR are used to evaluate the relative stability of sealants when exposed outdoors with mechanical movement. Laboratory procedures provided in this recommendation are not suitable for evaluating the behaviour of sealants under dynamic cure conditions (movement during cure).

The durability of sealants can vary strongly depending on the location of the exposure because of differences in ultraviolet (UV) radiation, time of wetness, temperature, pollutants, and other factors. It cannot be assumed, therefore, that results from one exposure in a single location will be useful for determining the durability in a different location. Exposures in several locations with different climates that represent a broad range of anticipated service conditions are recommended. Because of year-to-year climatological variations, results from a single, short-term outdoor exposure test cannot be used to predict the absolute rate at which a material degrades. Several years of repeat exposures are needed to get an average test result for a given location.

Since test results of outdoor exposure vary with geographic location, as well as seasonal and annual climate changes, the stability of materials is generally determined relative to controls with known performance exposed simultaneously, unless the stabilities of a series of materials exposed at the same time are being compared. Therefore, it is strongly recommended that control materials with known durability should be included with each exposure test. Control materials should be exposed along with the test specimens for the purpose of comparing the performance of test materials to the controls. It is preferable to use two control materials of similar composition and construction to the test specimens, one with relatively good durability and one with relatively poor durability. Unless otherwise specified, at least three replicate specimens of each test and control material are to be used.

Since solar radiation is one of the most important factors in the deterioration of sealants during weathering, exposure stages are best defined in terms of the amount of radiation received by the specimens. Timing based on radiant exposure can reduce seasonal and year-to-year variations in weathering caused by inconsistent conditions of total solar and solar UV irradiance. Solar ultraviolet measurements may be made using instruments, which record broadband or narrow-band ultraviolet radiation energy levels. Total solar UV radiant exposure is the recommended measurement for exposure stages because ultraviolet has a much greater effect than visible and near infrared radiation on most sealants and its variations are not readily detected in measurements of full spectrum solar radiation due to the small percentage of UV in the full spectrum. Studies have shown that better correlations are obtained among exposures made at different times when timing is based on incident solar UV radiation rather than on incident total solar radiation. An inherent limitation in solar-radiation timed exposures is that they do not reflect the duration of temperature and moisture exposures. Variations in moisture and temperature can cause large differences in the amount of degradation produced by the same radiant exposure. Characterizing and monitoring the relevant environmental factors during exposure is an important part of environmental exposure tests.

The design of the exposure rack, the location of the specimen on the exposure rack, the spacing between the specimens and the colour of the specimens can affect specimen temperature and time of wetness. In order to minimize variability caused by the location of the specimens, it is recommended that test specimens be placed on a single test panel or on test panels adjacent to each other during exposure.

The results obtained with this recommended procedure will vary depending on the choice of the experimental test parameters (exposure conditions, movement amplitudes, et cetera). When conducting outdoor weathering exposures, it is important to consider how well the test conditions reproduce property changes and failure modes associated with end-use environments for the sealants to be tested. The applicability of test data therefore will be at the discretion of the users of this method and depends on their interpretation of the movement and exposure conditions of a given job site situation.

As a method of test, the procedure, in principle, can be practised with any substrate, but the standard (default) test substrate is anodised aluminium. It should be noted that a job site will have many substrates and all or most of them will be different from the standard test substrate. Thus, results obtained with this method using the standard test substrate will not be predictive of actual field adhesion.

9 Outdoor exposure conditions

9.1 Test sites

Exposures can be conducted in any type of climate. However, in order to get more rapid indication of outdoor durability, exposures are often conducted in locations that receive high levels of solar radiation, temperature and moisture. Typically, these conditions are found in hot desert and subtropical or tropical climates. Equally important, however, is to ensure that the selected exposure climates reflect known attributes of the use climate. For example, if the use environment for the sealant being evaluated will include freeze/thaw cycling, specimen exposure in a Northern climate may be advisable. In addition, exposures are often conducted in areas where specimens are subjected to salt particulates (seashore) or industrial pollutants.

9.2 Location of test fixtures

Test fixtures or racks shall be located in cleared areas. The area beneath and in the vicinity of the test fixtures should be characterized by low reflectance and by ground cover typical of the climatological area where the exposures are being conducted. In desert areas, the ground is often gravel to control dust. In most temperate climates, the ground cover should be low-cut grass. If the test fixtures are placed on a rooftop, the specimens may be subjected to different environmental conditions than at ground level. These differences may affect the test results.

The lowest row of test specimens on a test fixture or rack shall be positioned at a minimum height of 0.5 m above ground such as to avoid contact with vegetation and to prevent damage during area maintenance. Test fixtures shall be placed in a location so that there is no shadow on any specimen when the sun's angle of elevation is greater than 20°.

9.3 Exposure orientation

Exposure racks shall be oriented such that specimens face the equator. Specimens can be exposed at a number of different orientations (exposure angles) in order to simulate end-use conditions of the sealant to be evaluated. Two standard exposure angles considered in this recommendation are as follows:

45° Exposure angle (default): Exposure rack is positioned so that the exposed surfaces of specimens are at an angle of 45° from the horizontal.

Latitude angle (option): Exposure rack is positioned so that the exposed surfaces of specimens are at an angle from the horizontal that is equal to the geographical latitude of the exposure site.

The specimen shall be mounted on the exposure fixture with the sealant joint oriented parallel to the horizon.

9.4 Specimen backing

Two types of specimen backing may be used. Comparisons between materials should only be made with exposures conducted with the same specimen backing.

Unbacked exposure (default): Specimens are exposed so that the specimen is subjected to the direct effects of weather on both (front and back) surfaces.
Backed exposure (option): Specimens are attached to a solid surface so that only the front surface is directly exposed to weather.[1]

Note: The support recommended for this test procedure covers the back of the sealant joint, which is not directly exposed to the weather. However, surface temperatures on the back of the specimen may still vary between backed and unbacked exposure.

10 Construction of test fixture (exposure rack)

10.1 Materials of construction

All materials used for test fixtures shall be non-corrodible without surface treatment.[2] For backed exposures, use the same (non-corrodible) construction material as for the exposure rack. Fastening devices for fixing the test specimens on the rack shall be made from non-corrodible material that does not degrade or contaminate the specimens.

10.2 Test fixture design

Test racks shall be constructed to hold specimens or specimen holders of convenient width and length. Racks shall be constructed so that any contamination from specimens higher on the exposure rack cannot run down onto specimens in lower positions. For unbacked exposures, the test racks shall be constructed so that most of the specimens are freely exposed to the weather on both (front and back) sides.

[1] Surface temperatures of specimens in backed exposures are likely to be higher than for specimens in unbacked exposures.

[2] Aluminium alloys 6061T6 and 6063T6 have been found suitable for use in most locations.

11 Instrumentation for recording climatological data and specimen exposure conditions

11.1 Climatological data

Instruments for recording climatological data during the exposure period should be operated in the immediate vicinity of the exposure racks. Instruments for recording the following climatological data are recommended:

- Ambient temperature (daily maximum and minimum temperature)
- Relative humidity (daily maximum and minimum humidity)
- Total solar radiation
- Total solar ultraviolet radiation
- Daily rainfall

11.2 Temperature measurement with insulated and uninsulated sensors[3]

Insulated (default) or uninsulated (option) temperature sensor, complying with the requirements outlined in ISO 4892, Part 1, Sect. 5.1.5, shall be mounted on the specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens. Readings shall only be taken after sufficient time has elapsed for the temperature to become constant. Under given operation conditions the (uninsulated) black panel thermometers tend to indicate lower temperatures than the (insulated) black standard thermometers. The temperature difference between the two ranges between 3°C and 12°C, being

[3] There are inconsistencies between the ISO 4892-1 and ASTM G151 standards in the terminology used for the temperature sensors. In ISO 4892-1, the two types of black temperature sensors are differentiated by referring to the insulated as the “black standard thermometer” and to the uninsulated as the “black panel thermometer”. ASTM G151 standard differentiates between the two types by naming them “insulated black panel thermometer” and “uninsulated black panel thermometer”. This RTR follows the designation used by ISO 4892-1.

smaller at lower irradiance levels. The default thermometer is the (insulated) black standard thermometer.

It is further advisable to determine time of wetness on the front surface of specimens.

12 Materials and equipment for preparation of test specimens

12.1 Support

Anodized aluminium support (as shown in Fig. 1) for the preparation of test specimens, consisting of two pivoting, L-shaped support elements of dimensions 120 mm × 20 mm × 15 mm × 2.0 mm (length × width × height × thickness) riveted onto an anodised aluminium back-plate. Riveting of the support elements on the base-plate shall be such that they can be turned freely with minimal friction on the pivot (fulcrum). For the specification of the anodised aluminium, refer to ISO 13640. If other support materials are to be used, they must be characterised and must be described in the test report. If other support dimensions are used, they must be described in the test report and care must be taken to ensure the same level of irradiance and water exposure at the specimen surface.

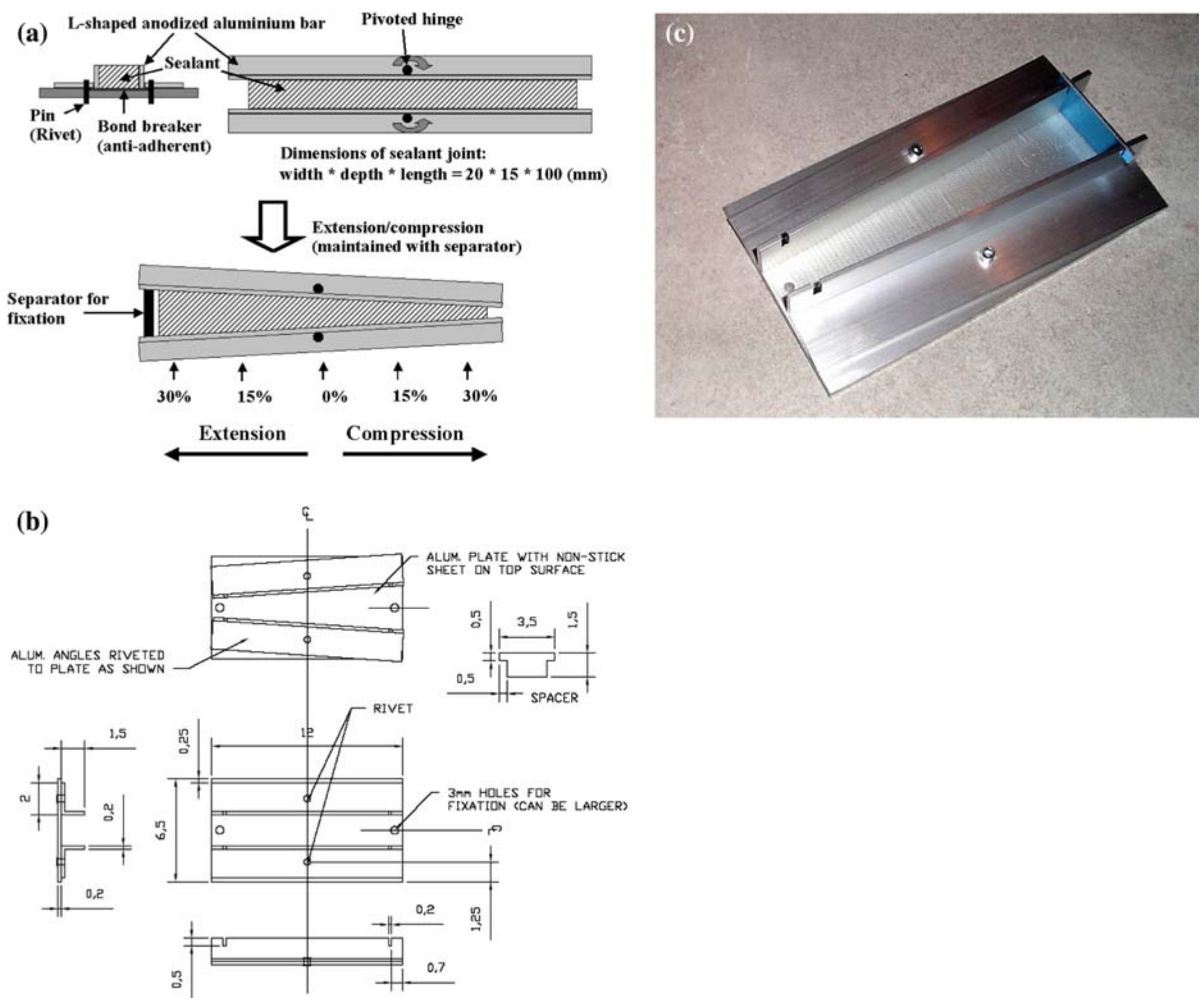

Fig. 1 (**a**) Schematic drawing of test specimen: sealant in anodised aluminium support used for cyclic mechanical movement of sealant, (**b**) engineering drawing of support (all measurements in centimetres), and (**c**) photo of support used for cyclic mechanical movement of sealant

12.2 Spacers

Spacers for the preparation of the specimens, of dimensions 20 mm × 15 mm × 10 mm, shall be used with anti-adherent surface (see Fig. 1a–c). If the spacers are made of material to which the sealant adheres, their surface must be made anti-adherent, e.g. by a thin wax coating.

12.3 Anti-adherent substrate (bond breaker)

Anti-adherent substrate for the preparation of test specimens, e.g. polyethylene (PE) or polytetrafluoroethylene (PTFE) film, preferably coated on one face with a pressure-sensitive adhesive (PSA) for easier installation, shall be used, preferably according to the advice of the sealant manufacturer. The anti-adherent substrate shall not restrict the movement of the L-shaped pivoted support elements.

12.4 Separators

Separators, of appropriate dimensions shall be used to hold the test specimens in extension up to the rated movement capability of the sealant.

12.5 Container

Container filled with demineralised or distilled water shall be used for conditioning according to Method B.

12.6 Ventilated convection-type oven

Ventilated convection-type oven, capable of being maintained at (70 ± 2)°C, shall be used for conditioning according to Method B.

12.7 Device for inducing movement in specimen

Device capable of inducing movement in the test specimen by extending or compressing one end of the test specimen. Various devices are deemed suitable for this task and this RTR intentionally does not restrict the nature of this device. Suitable devices may be a fully automated cyclic movement machine, a tensile test machine, or a hand-operated vice.

13 Preparation of test specimens

Bring the sealant to (23 ± 2)°C before preparation of the specimens (this is generally achieved by conditioning the packaged sealant for 24 h at this temperature). Prepare three specimens. For each specimen, assemble one support (12.1), see Fig. 1, by inserting two spacers (12.2) at the ends of the joint. Apply and fix the anti-adherent substrate (12.3) to the bottom of the joint (preferably with the help of the pressure-sensitive adhesive).

Follow the instructions of the sealant manufacturer concerning the sealant application, for instance, whether a primer is to be used on the contact surface of the L-shaped support elements.

Fill the hollow volume (dimensions: width × depth × length = 20 mm × 15 mm × 100 mm) formed by the support and spacers with the sealant, while taking the following precautions:

(a) Avoid the formation of air bubbles;
(b) Press the sealant to the inner surfaces of the pivoted support elements;
(c) Trim the sealant surface so that it is flush with the faces of the support elements and spacers.

Identify each specimen with a unique mark that will not be destroyed or become illegible during exposure.

14 Conditioning

14.1 General

Condition the specimens at rest (static conditioning) in accordance with Methods A (default) or B (option), as agreed between the parties concerned.

14.2 Method A (default)

Condition the specimens, with the spacers in place, for 28 days at (23 ± 2)°C and (50 ± 5)% relative humidity. After the conditioning, remove the spacers at both sides of the sealant joint.

14.3 Method B (option)

Condition the specimens first according to Method A. Then subject them three times to the following conditioning cycle:

(a) Three days in ventilated convection-type oven (12.6) at (70 ± 2)°C;
(b) One day in distilled water at (23 ± 2)°C;
(c) Two days in ventilated convection-type oven (12.6) at (70 ± 2)°C;
(d) One day in distilled water at (23 ± 2)°C.

This cycle may be carried out alternatively in the sequence (c)–(d)–(a)–(b). After the conditioning, remove the spacers at both sides of the sealant joint.

Note: Conditioning B is a normal conditioning method using the influence of water and heat to accelerate the cure of the sealant. It is not intended to give information on the durability of the sealant.

15 Test procedures

15.1 General

After conditioning and removal of the spacers, expose the specimens to the outdoor weathering and simultaneous mechanical movement cycles, as agreed by the parties concerned.

15.2 Exposure

Expose the specimens to outdoor weathering at the selected exposure site for a specified duration, as agreed by the parties concerned. The default exposure period is 3 years. The minimum (optional) exposure period is 1 year.

15.3 Cyclic movement of test specimens

Simultaneously to the outdoor weathering, expose the specimens to mechanical cycling at the rated movement capability of the sealant tested (e.g. ±25%, ±50%). Simultaneous extension and compression of the test specimen is achieved by extending or compressing one end of the test specimen with a suitable device, for instance a fully-automated cyclic movement machine, a tensile test machine, or a hand-operated vice, and inserting the separator (see 12.4) upon completion of the operation in the extended end of the specimen. The default is a monthly switching of the extension/compression position. Mechanical cycling is achieved by extending one end of the test specimen, then holding this extension for a period of 1 month. After this period, the test specimen is allowed to relax for 5 min. before the other end of the test specimen is extended. This extension is again held for a period of 1 month. The previously described extension/compression cycle is repeated at a minimum six times (six movement cycles correspond to a total exposure duration of 1 year). The default exposure period is 3 years.

15.4 Examination for defects

At regular intervals (default: every 3 months), visually examine the extended/compressed specimens for evidence of loss of adhesion or cohesion or any surface changes (cracking, crazing, chalking, et cetera). Whenever adhesion and/or cohesion loss is observed, measure the depth of the cracks using a measuring device capable of reading to 1 mm. Determine the quantity and width of the cracks for a specific extension/compression value achieved along the length of the specimen[4] according to Tables 2 and 3, respectively.

Determine the largest observed value for crack density, crack width and crack depth as well as the nature of the failure (adhesive or cohesive) for a specific extension/compression value achieved along the length of the specimen.

Because of the excessive stress experienced by the sealant near the corners of the specimen, during both preparation and testing, loss of adhesion and cohesion is more likely to occur in this region. Determine and report whether the adhesive or cohesive cracks fall within this peripheral region or whether they have propagated further into the bulk of the sealant, in accordance with the requirements defined in ISO 11600.

[4] For instance, changes in specimen surface appearance may be reported for 0%, 10%, 20%, and 30% tensile compression/extension movements. Note that the center section of the specimen, while not being exposed to tensile compression/extension movements, is exposed to a certain, but undefined, amount of shear movement resulting from the displacement of sealant material in the compressed section of the specimen. Therefore, acceleration factors for mechanical movement can not be derived from this test method due to the specimen design.

Table 2 Rating for quantity of cracks

Rating	Quantity of cracks (Q)
0	None, i.e. no detective cracks
1	Very few, i.e. some just significant cracks
2	Few, i.e. small but significant amount of racks
3	Moderate, i.e. medium amount of cracks
4	Considerable, i.e. serious amount of cracks
5	Dense, i.e. dense pattern of crack

Table 3 Rating for width of cracks

Rating	Width of cracks
0	Not visible at 10× magnification
1	Only visible under magnification up to 10×
2	Just visible with normal (corrected) vision
3	Clearly visible with normal (corrected) vision
4	Large cracks generally up to 1 mm wide
5	Very large cracks generally more than 1 mm wide

15.5 Exposure duration

The minimum exposure period (option) is 1 year; the default exposure period is 3 years. However, choose the minimum duration of the exposure period such as to induce a substantial (visible) degradation for the least stable material being evaluated.

16 Test report

The test report shall include the following information:

(a) The name and address of the test exposure site;
(b) Date of initiation and completion of exposure;
(c) The name, colour and type of sealant;
(d) The batch of sealant from which the specimens were produced;
(e) The test substrate;
(f) The primer used, if applicable;
(g) The method of conditioning used (see Sect. 14);
(h) The experimental parameters used (exposure conditions), i.e.

- Geographical location of exposure site,
- Exposure type (e.g. ground level or roof top),
- Ground coverage,
- Exposure angle,
- Climatological information regarding exposure site,
- Specimen exposure conditions (temperature, time of wetness).

(i) Any deviation from the default values specified in this method, e.g.

- Details of the mechanical cycling procedure, if applicable, specifically the amplitude of cycling;
- Nature of the thermometer used (if other than black standard thermometer has been used);
- Duration of exposure interval.

Note: If the experimenter deviates from the default values specified, both the default values as well as the actual conditions used must be reported.

(j) The type of damage (adhesive or cohesive failure as well as changes in surface appearance, such as discoloration), the quantity, width and the maximum depth of cracks (in mm), as well as the location of the cracks (bulk or peripheral region), observed after each exposure interval for a specific extension/compression value achieved along the length of the specimen; photographic documentation (minimum 75 mm × 100 mm print size) of the surface condition of the specimen with a minimum resolution of 800 dpi (31.5 dots per mm) *Note*: This requires a digital camera with a minimum resolution of 8 Megapixel.
(k) Any other observations the tester considers important in describing the condition of the specimen.

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