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# Measurement and evaluation methods for optical anisotropic effects in thermally toughened glass
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Messung und Bewertung von optischen Anisotropie-Effekten bei thermisch vorgespanntem Glas
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*A comma is used as the decimal marker.*

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# Foreword

This DIN SPEC has been developed according to the PAS procedure. The development of a DIN SPEC according to the PAS procedure is carried out in DIN SPEC consortiums and does not require the participation of all stakeholders.

This DIN SPEC is the result of the project “BeNAF — Bewertungskriterien zur Normung von Anisotropie-Effekten bei thermisch vorgespanntem Flachglas” (Evaluation criteria for the standardisation of anisotropy effects in thermally toughened flat glass) within the framework of the initiative “WIPANO — Wissens- und Technologietransfer durch Patente und Normen” (Transfer of knowledge and technology through patents and standards) funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) (funding code 03TNH011G).

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At present, there are no standards covering this topic in the body of German Standards.

DIN SPECs are not part of the body of German Standards.

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# Introduction

In the context of thermally toughened flat glass, the term “anisotropy effects” is a matter of concern for architects, glass processors, façade designers and building owners. Although anisotropy effects (iridescence) are not considered to be a justified defect within the meaning of product standards and visual assessment guidelines, architects, building owners, façade consultants and, increasingly, building users perceive this effect as a visual impairment [1].

In national and international product standards and regulations, such as DIN EN 1863 (all parts), DIN EN 12150 (all parts), DIN EN 14179 (all parts) and ASTM C 1279, for the assessment of the visual quality of glass, anisotropies are not referred to as defects or flaws, but as visible effects or characteristic features of toughened glass that are excluded from the assessment of visual quality.

Due to its transparent appearance, glass is often used as a material in building and civil engineering. Glass is fundamentally an isotropic material whose physical properties are the same in all directions. However, (thermally induced) internal and (load-induced) external stresses transform glass into a birefringent material with optically direction-dependent (anisotropic) properties [2], [3].

Currently, no objective criteria exist for describing the optical quality in relation to anisotropy effects. This document addresses this issue.

The definition of the quality classes is the result of the research project mentioned in the Foreword (funding code 03TNH011G), in the course of which a variety of glass panes with differently developed anisotropy effects were measured by means of anisotropy scanners and additionally evaluated under real conditions.

This document is restricted to monolithic structures. The evaluation methods can also be applied to non-monolithic glazing structures (multiple laminated glass, laminated safety glass as well as insulating glass units, etc.). However, when several toughened glasses are superimposed, an increase in the visibility of the anisotropy effects is to be expected. However, other effects, that have not yet been fully quantified, play a role in these cases.

# 1 Scope

This document provides requirements for the reproducible evaluation of optical anisotropy effects on thermally toughened glass. For this purpose, quality classes have been defined for the evaluation of optical anisotropy effects based on various test procedures and evaluation methods.

There are various measuring systems for the photoelastic examination of toughened glass available on the market. This document specifies requirements for the measuring systems and describes the setup, relevant measurands, calibration, and accuracy of measurements. In addition, methods are given allowing for reproducible evaluation of the optical anisotropy effects. Based on evaluation zones and the analysis methods, quality classes for monolithic glass structures are defined.

The requirements and classifications described here refer to optically, visually perceptible properties of anisotropy effects. The technical properties (e.g. the characteristic strength and the fracture pattern) specified in the product standards DIN EN 1863 (all parts), DIN EN 12150 (all parts), and DIN EN 14179 (all parts) are not covered by this document. Other optical quality requirements, e.g. stains, scratches, etc., remain unaffected by this document.

# 2 Normative references

There are no normative references in this document.

# 3 Terms and definitions

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

DIN and DKE maintain terminological databases for use in standardization at the following addresses:

— DIN-TERMinology Portal: available at https://www.din.de/en/services/din-term

— DKE-IEV: available at https://www.dke.de/DKE-IEV

**3.1**
**analyser**
polarization filter positioned between the specimen and the observer, which is in most cases rotatable and which, after the light waves have exited the birefringent material, filters those light waves depending on its direction of polarization

**3.2**
**anisotropy effect**
**iridescence**
effect by which a retardation in polarized light caused by a stress-field-induced birefringence in the glass can become visible, with the stress fields being caused by the creation of zones of different stresses in the glass cross-section during thermal toughening

**3.3**
**anisotropy scanner**
measurement systems for the quantification of retardations related to anisotropy effects

**3.4**
**azimuth angle**
isoclinic angle
angle between the orientation of the principal stresses and a specified coordinate system

**3.5**
**Babinet-Soleil compensator**
optical compensator consisting of movable quartz wedges, which can be used for the local determination of retardations in polariscopes or polarimeters

**3.6**
**refractive index**
ratio of the speed of light (or, more precisely, phase velocity) in vacuum to that in a given medium

[SOURCE: DIN 58629-1:2006-01, 2.32, withdrawn]

**3.7**
**Brewster's angle**
angle at which the intensity of the reflecting parallel light beam is close to zero

Note 1 to entry: For glass, Brewster's angle is approximately 56°.

Note 2 to entry: Due to the reduced reflection, anisotropy effects are most visible at an angle close to Brewster's angle. If unpolarized light strikes the interface of two media at Brewster's angle, then the reflected light is polarized perpendicular to the plane of incidence.

**3.8**
**birefringence**
optical property of an optically anisotropic material having orientation-dependent refractive indices, which leads to different propagation velocities of light in different propagation directions

[SOURCE: DIN EN 61757-1-1:2017-11, 3.2.2, modified — the notes to entry have been deleted]

**3.9**
**retardation**
optical path difference that light waves have after exiting birefringent materials (due to stresses) with the path difference depending on the main stress difference, which can be measured quantitatively by means of anisotropy scanners and is visible qualitatively as interference colours

**3.10**
**isochromats**
points or areas connected to form lines with the same main stress difference, the same retardation, and the same interference colour

**3.11**
**isoclines**
points connected to form lines at which the main stress directions correspond to the directions of the (linear) polarization filters

Note 1 to entry: Isoclines do not appear when circular polarizing filters are used.

**3.12**
**Sénarmont compensation**
method for measuring the retardation using linearly polarized light and a quarter-wave plate by rotating the analyser by up to 180°

**3.13**
**Tardy compensation**
method for measuring the retardation using circularly polarized light and a quarter-wave plate by rotating the analyser by up to 180° irrespective of the sample orientation

**3.14**
**polarizing filter**
optical component which absorbs the components of the light waves that are not parallel to the optical axis of the filter

Note 1 to entry: Linear polarizing filters produce polarized light waves which propagate only linearly in one plane of oscillation. Circular polarization filters consisting of a linear polarization filter and a quarter-wave plate produce polarized light waves whose field vectors oscillate circularly about an axis.

**3.15**
**polarized light**
light whose oscillations are partially or completely suppressed in certain directions at a given time

Note 1 to entry: The oscillation vector can follow a linear, circular or elliptical shape.

[SOURCE: DIN 58629-1:2006-01, 2.87.1]

**3.16**
**photoelasticity**
branch of optics which enables the states of stress of birefringent materials to be determined by analysis of isoclines and isochromats

**3.17**
**thermally toughened glass**
glass within which a permanent surface compressive stress, additionally to the basic mechanical strength, has been induced by a controlled heating and cooling process in order to give it greatly increased resistance to mechanical and thermal stress and prescribed fragmentation characteristics

[SOURCE: DIN EN 12150-1:2020-07, 3.1, modified – the note to entry has been deleted]

**3.17.1**
**flat thermally toughened soda lime silicate safety glass**
thermally toughened soda lime silicate safety glass which has not been deliberately given a specific profile during manufacture

[SOURCE: DIN EN 12150-1:2020-07, 3.2]

**3.17.2**
**curved thermally toughened soda lime silicate safety glass**
thermally toughened soda lime silicate safety glass which has been deliberately given a specific profile during manufacture

[SOURCE: DIN EN 12150-1:2020-07, 3.3, modified — the note to entry has been deleted]

**3.17.3**
**flat heat strengthened soda lime silicate glass**
heat strengthened soda lime silicate glass which has not been deliberately given a specific profile during manufacture

[SOURCE: DIN EN 1863-1:2012-02, 3.5]

**3.17.4**
**curved heat strengthened soda lime silicate glass**
heat strengthened soda lime silicate glass which has been deliberately given a specific profile during manufacture

[SOURCE: DIN EN 1863-1:2012-02, 3.1]

# 4 Testing of thermally toughened glass

The visual quality with regard to optical anisotropy effects should be tested non-destructively on monolithic toughened flat glass and thermally bent glass. Testing of the entire glazing assembly (e.g. insulating glass unit) is not included in this document. Guidance on the evaluation of non-monolithic structures can be found in Annex D.

The test shall be carried out after the toughening process has been completed. The toughening process is considered to be completed as soon as the glass leaves the cooling area of the toughening furnace. The measurement is possible directly beyond the cooling area (online) or separate from it (offline).

# 5 Measurement

## 5.1 General

The measurements are performed using anisotropy scanners. An anisotropy scanner fundamentally consists of a light source, optical polarization elements, and digital sensors (camera, linear sensor, etc.). The optical anisotropy effects can be quantified using either a polarimeter or a polariscope.

Based on photoelastic methods and high-speed image processing, the anisotropy scanners measure the optical retardation, in nanometres (nm), and optionally the azimuth angle, in degrees (°). The results are presented as false colour images with a scale of the range of the measured values. Using these images, the glass panes can be evaluated based on the methods and criteria specified in 5.8.

In addition to flat glass panes, curved glass panes can also be analysed. In the case of curved panes, the maximum acceptable deviation from the perpendicular incidence of light shall be considered in the same way.

## 5.2 Requirements

The anisotropy scanner shall be designed to detect reproducible values of optical retardation independent of the orientation of the glass. The optical components of the scanners shall be adequate for the wavelength range of the light source. The methods should be based on a light incidence that deviates from the perpendicular only to a limited extent. To cover a larger measuring field, several sensors or cameras are to be used if necessary. The required number depends on the desired image resolution in pixels per millimetre (px/mm) and the deviation from the perpendicular incidence of light acceptable for the respective measuring method. The calculation of the measurands specified in 5.5 shall be based on an image resolution of at least 0,5 px/mm.

The measuring range of the systems should cover 0 nm to 300 nm in the relevant evaluation zone. This ensures that retardations can be detected in monolithic thermally toughened architectural glass with thicknesses ranging from 4 mm to 15 mm. If the measuring range of a scanner system is limited, then the detectable glass thickness shall be reduced, or redundant measures shall be taken to ensure that the samples' retardations do not exceed the measuring range.

## 5.3 Setup

### 5.3.1 Method A — Calibrated polarimeters

A polarimeter measures the optical retardation and the orientation of the stress (azimuth) by means of a polarization-sensitive matrix or a line scan detector (“polarization camera”) using quasi-monochromatic circularly polarized light. Instead of a mechanical or electro-optical rotating analyser, as known from Sénarmont’s or Tardy’s polarimeter setups, it is sufficient to analyse a number of discrete polarization planes, typically 0°, 45°, 90° and 135°.

Proprietary polarization cameras can contain multiple sensors (one for each polarization direction) or a subdivided sensor (one quadrant for each polarization direction) in combination with suitable beam splitting optics. Alternatively, each pixel of the camera can be equipped with individual micro-polarizers (similar to the colour filters of a single-sensor RGB camera).

Since the measuring range is physically limited to a certain fraction of the illumination wavelength, the measuring range can be extended, e.g., by analysing several wavelengths and subsequently correlating these mathematically.

### 5.3.2 Method B — Calibrated polariscopes

With suitable calibration of circular polariscopes, optical retardation can be quantified from isochromatic images. Due to the arrangement of the optical polarization elements, maximum optical retardations in circular polariscopes are determined, which are independent of the orientation of the measuring object.

Various approaches exist by which to calculate retardations from the intensity values (or colour values) measured by the digital sensor. One approach is to calibrate the measurement system using a Babinet-Soleil compensator. The calibration table obtained establishes the relationship between intensity value (or RGB colour) and retardation. All information is thus available to calculate, using an analysis algorithm, a new image with retardation (in mm) per pixel.

## 5.4 Test conditions

The operator shall use the anisotropy scanner in accordance with the manufacturer’s recommended procedures.

## 5.5 Relevant measurands

### 5.5.1 Retardation

Optical retardation in nm.

### 5.5.2 Azimuth angle (optional)

Azimuth angle in ° (requires a reference edge to be defined).

## 5.6 Calibration

The extent of calibration depends on the method used. As a rule, the provisions of the scanner manufacturer shall be adhered to. Suitable calibration methods ensure that constant measured values are obtained under the given ambient conditions (temperature, humidity, vibration, and dust) throughout the lifetime of the apparatus.

The operator shall ensure that calibration and verification are carried out in accordance with the practices recommended by the equipment manufacturer.

### 5.7 Measurement uncertainty

The technical capabilities of the polarimeter or polariscope may vary depending on the type of instrument and the glass application. The minimum requirements for the measuring range and the maximum permissible error are given in Table 1. Recommended procedures for the verification of accuracy can be found in Annex A.

**Table 1 — Measuring range, maximum permissible error and reproducibility of the measuring systems**

| Glass thickness | Minimum measuring range for the retardation | | Maximum permissible error | | Reproducibility |
|---|---|---|---|---|---|
| | from | to | Retardation | Azimuth angle | Deviation |
| < 10 mm | 0 nm | 120 nm | ±10 nm | optional | ±5 % |
| 10 mm to 19 mm | 0 nm | 300 nm | ±10 nm | optional | ±5 % |

For applications simulating anisotropy effects in building facades, a greater maximum permissible error of ±5 nm and ±4° is recommended.

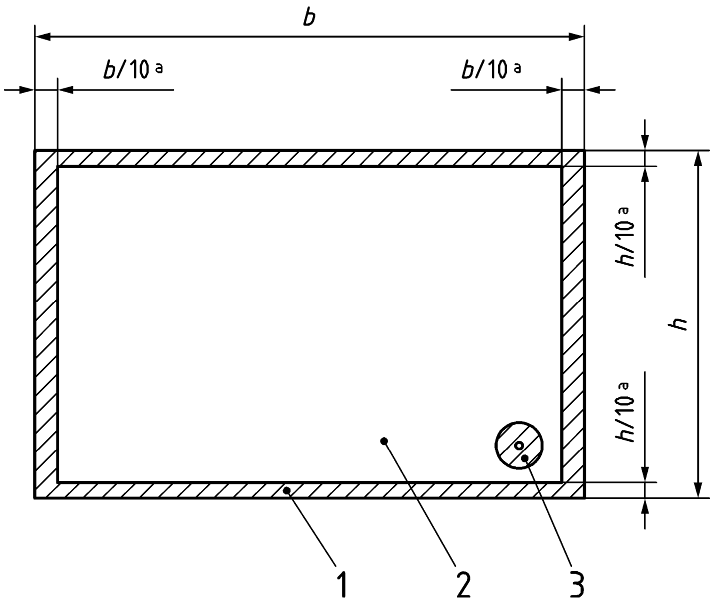
### 5.8 Analysis/evaluation criteria

#### 5.8.1 Evaluation zones

For analysis of the retardation images, evaluation zones are established as shown in Figure 1. These are necessary because certain areas (edges, corners, and areas surrounding bore holes) show very substantial retardations, which are unavoidable due to the physical boundary conditions of heat toughened glass.

ZONE E and ZONE H: These areas are excluded from the evaluation.

ZONE M: The analysis is performed exclusively for this zone.




**Key**

1 Zone E: Excluded area at the edge with 10 % of the respective clear width and height dimensions all around

2 Zone M: Zone to be analysed

3 Zone H: Excluded area at bore holes with a zone radius = 6 × glass thickness + bore hole radius

*b* width dimension

*h* height dimension

▨ excluded area

[a] Min. 50 mm and max. 200 mm for glass thicknesses $t \leq 8$ mm and at max. 350 mm for $t \geq 10$ mm.

**Figure 1 — Evaluation zone**

### 5.8.2 Evaluation methods

#### 5.8.2.1 General

The evaluation is based on the relevant measured values from zone M. For the classification of the sample into the quality classes from Clause 6, use of at least one of the two evaluation methods, A or B, is necessary.

#### 5.8.2.2 Evaluation following method A — 95 % quantile value

The calculation is made on the basis of all retardation values and based on the empirical cumulative distribution function determined from them. The 95 % quantile value means that 95 % of the measured retardations are smaller than the determined value. The 95 % quantile value is given in nanometres.

#### 5.8.2.3 Evaluation following method B — Isotropy value with a 75 nm threshold

The value is determined on the basis of retardation values with and without consideration of the orientation. The isotropy value is a threshold value that shall be based on a threshold. Retardations of up to 75 nm can be selected as threshold values, since experience has shown that, starting from that value, optical anisotropy effects can be perceived in natural light. The isotropy value is the areal proportion of retardations that are above the selected threshold. The isotropy value is given as a percentage.

NOTE Taking the orientation of the stress (azimuth) into account can result in higher isotropy values.

### 5.8.3 Additional evaluation methods

Other methods, such as various features of texture analysis, can also be determined, see [3] and [4]. They are not currently used for quality classification purposes.

### 5.9 Limitations

Measurements by scanner cannot be used for all types of glass available on the market. The following types of glass are excluded:

— glass with light-diffusing surfaces (e.g. satin-finish glass, patterned glass);

— non-transparent glass (e.g. enamelled or printed glass).

The measurement results are influenced by a number of other factors. These FACTORS should either be avoided or be documented to explain how they influence the results.

— The sample's TRANSMITTANCE at the wavelength(s) used to measure the optical retardation should be consistent with the information given by the equipment manufacturer.

— Deviations from FLATNESS of the glass after the heat treatment process (e.g. roller waves) can affect the measurement.

— The TEMPERATURE DIFFERENCE between the sample and the ambient temperature at the time of measurement can generate undesired external stresses in the sample and affect the measurement results.

— In general, care should be taken to ensure that no MECHANICAL STRESSES are introduced into the sample during the measurement.

## 6 Quality classes

### 6.1 General

For the purpose of quality classification, the evaluation zones and evaluation methods specified in 5.8 are applied to the results of the samples measured in the anisotropy scanner (retardation images with and without consideration of the orientation). Depending on which evaluation method is used, A or B, the sample is assigned to one of the quality classes given in Table 2 or Table 3.

### 6.2 Quality classes

The limit values given in Table 2 and Table 3 are based on reference experiments carried out on uncoated flat glass.

**Table 2 — Quality classes based on method A ($x_{0,95}$)**

| Glass thickness | Quality class | | |
|---|---|---|---|
| | A | B | C[a] |
| ≤ 6 mm | ≤ 70 nm | > 70 nm and ≤ 95 nm | > 95 nm |
| 8 mm | ≤ 80 nm | > 80 nm and ≤ 120 nm | > 120 nm |
| 10 mm | ≤ 95 nm | > 95 nm and ≤ 140 nm | > 140 nm |
| 12 mm | ≤ 115 nm | > 115 nm and ≤ 165 nm | > 165 nm |
| 15 mm | b | b | b |

[a] For limit values higher than the specified values and for glass without measurement.

[b] No reference values available; limit values shall be agreed with the glass manufacturer.

**Table 3 — Quality classes based on method B ($Iso_{75}$)**

| Glass thickness | Quality class | | |
|---|---|---|---|
| | A | B | C[a] |
| ≤ 6 mm | ≥ 95 % | < 95 % and ≥ 85 % | < 85 % |
| 8 mm | ≥ 90 % | < 90 % and ≥ 68 % | < 68 % |
| 10 mm | ≥ 85 % | < 85 % and ≥ 52 % | < 52 % |
| 12 mm | ≥ 70 % | < 70 % and ≥ 30 % | < 30 % |
| 15 mm | [b] | [b] | [b] |

[a] For limit values lower than the specified values and for glass without measurement.

[b] No reference values available; limit values shall be agreed with the glass manufacturer.

## 7 Test report

The test report shall include the following information:

a) reference to this document, including date of issue;

b) sample identification (e.g. batch, serial or order number);

c) date and time of the measurement;

d) measured dimensions and thickness of the glass;

e) quality class;

f) result of the evaluation using evaluation method A, in nm, or evaluation method B, in %;

g) image resolution of the anisotropy scanner, in px/mm;

h) measuring range of the anisotropy scanner, in nm.

In addition to those details, the test report can include the following information:

i) type and designation of the glass;

j) retardation image with scale, in nm, and indication of the analysed area, width × height, in mm;

k) additional evaluation results, such as mean value, maximum, 95 % quantile value, isotropy value, etc.;

l) scanner manufacturer, model and software version.

# Annex A
(informative)

# Guidance on verification of the measurement accuracy of the scanners

## A.1 General

At regular intervals specified by the measuring system manufacturer, compliance with the requirement for the maximum permissible error of a scanner in use, given in Table 1, shall be verified. For this verification, the following procedures are recommended. The test shall be carried out several times, at different angles of rotation (0°, 45°, 90°, 135°) and distributed over the full scan width. Due to the photoelastic sensitivity of the test equipment, consistent test conditions shall be ensured throughout the test. The verification carried out shall be confirmed by a test protocol.

## A.2 Method 1 — Retardation plates

Retardation plates[1] made of plastic, with at least three predetermined retardation levels (e.g., 50 nm, 75 nm, 100 nm, 150 nm), can be used for verification.

## A.3 Method 2 — Calibration plate

A calibration plate made of thermally toughened glass which reproduces the measuring range of the scanner and has been released by the measuring system manufacturer with verified values, is used for verification.

## A.4 Method 3 — Babinet-Soleil compensator

The verification is carried out using a Babinet-Soleil compensator, which has been inserted into the beam path of the scanner, by checking predetermined retardation values.

1 Information on the acquisition of retardation plates can be obtained from DIN Deutsches Institut für Normung e. V., Burggrafenstraße 6, 10785 Berlin.

# Annex B
(informative)

# Assessment of the probability and frequency of visibility of optical anisotropy effects at the installation site

## B.1 General

The parameters mentioned in the following clauses have an influence on the perception of the optical anisotropy effects. The more aspects or effects are present at the same time, the more likely it is that optical anisotropy effects will be visible in a façade. In Table B.1, all parameters are compared based on their risk classification.

## B.2 Glass

### B.2.1 Glass type

Anisotropies only occur in thermally toughened glass (toughened safety glass, heat-strengthened glass). With float glass (not toughened and with no external applied load) there is usually no risk of this effect occurring. The quality of the toughening process plays an important role. However, the possibility of reducing the visibility of anisotropies is limited by other technical properties of the glass products which are required to be complied with, e.g., the fracture pattern as described in [5] to [13] and the mechanical strength as described in [5] to [13].

### B.2.2 Coatings

The use of coatings that can be toughened requires a toughening process that is difficult to control and usually leads to higher retardations in the glass.

NOTE Coatings generally change the optical appearance of the glass. The reflection characteristics are significantly influenced by the coating.

### B.2.3 Glass thickness and glass structure

When toughened glass is processed into other glass products, such as laminated safety glass, insulating glass units, coated glass, etc., the visual perceptibility of anisotropies is increased by, among others, the following parameters:

— increasing thickness of the glass panes;

— increasing numbers of toughened panes included in a glass product;

— recesses and bores for special geometries, especially acute angles.

## B.3 Viewing conditions on site

### B.3.1 Viewing angle and direction

Optical anisotropy effects become significantly more visible when viewed at a shallower angle close to Brewster's angle than when viewed at right angles. Depending on the viewing direction and the position of the sun, anisotropy effects can be perceived to a lesser or greater extent.

The use of sunglasses with polarized lenses enhances the visibility of anisotropies and reduces reflections, so that the effect is perceived more intensely irrespective of the viewing angle. However, the visual appearance of the glazing perceivable in this way cannot usually be compared with the actual anisotropies, since the effects are distorted depending on the polarization filter direction.

### B.3.2 Location and surroundings of the building

The location of the building and its context in terms of its natural or urban surroundings have an influence on the visibility of anisotropies. Depending on the proportion of polarized light present in the natural daylight (degree of polarization), the optical effects are more or less pronounced. The degree of polarization from Rayleigh scattering in the atmosphere varies with the angle of light incidence as well as with the position of the sun relative to the glazing. It will be higher on days with clear blue skies than on cloudy days. In addition to that, the proportions of polarized light from scattering in the atmosphere are highest when the sun is low.

The environment also has significant influence. Reflection of daylight can increase the proportion of polarized light. If the building is in the immediate vicinity of the sea, a lake, a river, snow-covered surfaces or another highly reflective surface, then the polarization of natural light can be increased and existing anisotropies can be perceived more clearly. For high-rise buildings with a large proportion of façades reflecting the blue of the sky, anisotropies are also more likely to be visible.

### B.3.3 Building usage or background of the glazing

With a dark background, such as during construction or in the case of dark flooring, the optical anisotropy effects are more visible than when the building is used for offices with a light background.

**Table B.1 — Overview of the parameters that increase the probability of visibility of the optical anisotropy effects**

| | Parameters | | | Probability | | |
|---|---|---|---|---|---|---|
| | | | | **Low risk** | **Moderate risk** | **High risk** |
| Glass | Glass type | | float glass | x | | |
| | | | heat strengthened glass/toughened safety glass | | | x |
| | Coatings for toughened glass | | none | | x | |
| | | | not suitable for heat strengthening | | | x |
| | | | suitable for heat strengthening | | | x |
| | Glass structure | mono | general | | x | |
| | | | thin | x | | |
| | | | thick | | x | |
| | | laminated safety glass | with float glass | x | | |
| | | | thin toughened glass | | x | |
| | | | thick toughened glass | | | x |
| | | insulating glass unit | with float glass | x | | |
| | | | thin toughened glass | | x | |
| | | | thick toughened glass | | | x |

| | Parameters | | Probability | | |
|---|---|---|---|---|---|
| | | | Low risk | Moderate risk | High risk |
| Viewing | Viewing angle | perpendicular viewing | x | | |
| | | viewing at an angle | | | x |
| | | viewing with polarizing sunglass lenses | | | x[a] |
| | Degree of polarization on site/at the location of the building | mostly cloudy | x | | |
| | | mostly clear, blue skies | | | x |
| | Surroundings of the building | rural | | x | |
| | | urban | | x | |
| | | open waters | | | x |
| | | alpine | | | x |
| | | high-rise building | | | x |
| | Building use/ background | light background (e.g. office use) | x | | |
| | | dark background (e.g. as built) | | | x |

[a] Where analysers (polarizing filters) are used, anisotropy effects are always visible when polarized light is present. The visible anisotropy effects are artificially amplified and distorted. Without analysers, the perception of these effects can deviate greatly.

# Annex C
(informative)

# Visual assessment at the installation site

## C.1 General

For objective evaluations, monolithic glass panes shall first have been assessed in accordance with 5.8 and then assigned to a quality class.

The visual perception of anisotropy effects in natural environments significantly depends on the conditions stated in Annex B. The factors that are important for a visual assessment irrespective of the glass in question are the predominant degree of polarization of the incident light, the viewing angle, and the viewing direction as a function of the façade orientation and the position of the sun.

Therefore, it is recommended to carry out the visual assessment at the installation site on a test rig applying different test scenarios (best-case and worst-case). The use of analysers such as polarizing filters or sunglasses (with polarizing filters) is not recommended, as anisotropy effects will be distorted and real conditions not properly represented should such analysers be used incorrectly.

## C.2 Test conditions

The test conditions for the evaluation shall be documented. These include:

— date, time and place of the assessment;

— degree of polarization;

NOTE The degree of polarization can be determined by measurement or estimation based on the cloudiness degree of the incident light.

— orientation of the glass pane in terms of geographic direction;

— installation height of the glass pane;

— position of the sun in relation to the glass pane to be inspected;

— viewing angle (at right angles or close to Brewster's angle);

— background of the glass pane.

The features detected using the anisotropy scanner shall not be specially marked.

## C.3 Best-case scenario

A best-case scenario in which anisotropy effects are perceived only slightly would be, for example, an inspection in daylight under a completely cloudy sky, at right angles, and with a bright background to the glazing.

## C.4 Worst-case scenario

A worst-case scenario in which anisotropy effects are perceived more intensely would be, for example, an inspection in daylight with a completely clear blue sky, with the glass pane oriented at 90° to the sun, at a viewing angle close to Brewster's angle, and with a dark background to the glazing.

# Annex D
(informative)

# Guidance on the evaluation of non-monolithic structures

## D.1 Guidance

Non-monolithic glass structures can consist of various glass types. Therefore, it is currently not possible to define quality classes for them.

For isolated cases where non-monolithic glazing is to be evaluated, the following procedure can be recommended:

— evaluation and classification of monolithic single panes in accordance with this document;

— in exceptional cases: anisotropy scan of the entire glass pane using an offline anisotropy scanner;

— visual assessment in accordance with Annex C at the installation site.

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