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Glass in building — Explosion-resistant security glazing — Test and classification by shock-tube loading

Verre dans la construction — Vitrages de sécurité résistant à une explosion — Essai et classification par charge d'air envoyée d'un tube

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16934 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

Introduction

This International Standard provides a method for carrying out tests simulating high-explosive blasts in order to assess and classify the response of glazing to the overpressure and impulse characteristics of blast. This International Standard provides criteria for rating the level of damage to glazing from which can be assessed the hazard consequences to the area located behind the glazing. The increasing use of glazing designed to protect persons and property from accidental explosions, and from the effects of terrorist attacks with high explosives, has prompted the preparation of this International Standard.

A shock tube is a facility which simulates explosive blast waves to load test specimens with consistency, control and repeatability. Shock-tube tests provide an economic means to simulate relatively long-duration blast shock waves representing the effects of large explosive devices at some distance. The results can be assessed against broadly comparable arena tests.

Structural response to air-blast loading is dependent upon specimen size and edge constraint as well as material composition and thickness. The classifications and test results derived by using this International Standard can be used in conjunction with calculation procedures and further validation tests on framed glass during the process of designing complete glazing systems against explosive threats.

Glass in building — Explosion-resistant security glazing — Test and classification by shock-tube loading

1 Scope

This International Standard specifies a shock tube test method and classification requirements for explosion-pressure-resistant glazing, including glazing fabricated from glass, plastic, glass-clad plastics, laminated glass, glass/plastic glazing materials, and film-backed glass. This International Standard provides a structured procedure to determine the blast resistance and the hazard rating of glazing and glazing systems. This International Standard sets out procedures to classify such security glazing sheet materials by means of tests on specimens of a standard size in a standard frame for the purpose of comparing their relative explosion resistance and hazard rating.

The procedures and test method can also be used to test, but not classify, glazing systems where the sheet infill is incorporated into frames purposely designed as complete products of appropriate size for installation into buildings. This International Standard applies a method of test and classifications against blast waves generated in a shock tube facility to simulate high-explosive detonations of approximately 30 kg to 2 500 kg of trinitrotoluene (TNT) at distances from about 35 m to 50 m. The classifications approximately represent the reflected pressures and impulses that are experienced by these equivalent threat levels on the face of a large building facade positioned perpendicular to the path of the blast waves.

Classification is defined in terms of both blast shock-wave characteristics, expressed in terms of peak reflected pressure, impulse, positive phase duration and wave-form parameter (decay coefficient), and rating criteria, expressed in terms of degrees of glazing damage and fragment impact hazard. Classifications and ratings are assigned based upon the performance of the glazing and are specific to the blast characteristics under which the test has taken place. Glazing that has received an air-blast classification and rating is suitable for use in blast-resistant applications only for blasts of comparable characteristics and only if installed in a properly designed frame. Design based on knowledge of the air-blast resistance reduces the risk of personal injury.

2 Normative references

The following referenced documents are indispensable for the application 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 48:1994, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

3 Terms and definitions

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

3.1
air-blast pressure history
description of the pressure of a reflected or free-field air blast, as measured at a point on the surface and consisting of two separate phases:

— positive phase, which is characterized by a nearly instantaneous rise to a maximum pressure followed by an exponential decay to ambient pressure;

— negative phase, immediately following the positive phase, during which the pressure decreases below ambient for a period of time before returning to ambient

3.2
ambient temperature
air temperature around the test specimen measured within 30 min of the test

3.3
attack face
face of the test specimen intended to face the explosion source

3.4
blast shock wave
test pressure wave impinging on the attack face of the test specimen (defined in the terms below)

NOTE The pressure recorded and referred to shall be the peak positive pressure experienced by the test specimen positioned at the end of the shock tube. This is typically a reflected pressure.

3.5
breach
any perforation or opening through the test specimen or between the test specimen and the support frame, evident after the test, through which a 10 mm diameter rigid bar can be gently passed without force

NOTE An opening may be caused by the glazing sheet in-fill pulling away from the rebate sufficiently to result in a visible gap that exposes the edge of the sheet.

3.6
cartridge paper
thick white paper for pencil and ink drawings, typically about 130 g/m^2

3.7
fragment
any particle with a united dimension of 25 mm (1 in) or greater as defined in Clause 8

NOTE The united dimension of a glass particle is determined by adding its width, length and thickness. Glazing dust, slivers and all other smaller particles are not accounted as fragments.

3.8
fragment collecting mat or surface
clean, smooth surface at nominal floor level in the protected area suitable for observing and collecting ejected fragments

NOTE It shall extend over an area of width and of depth from the rear face to the witness panel as defined for a witness area in Clause 6 at a level at least 0,5 m but not exceeding 1,0 m below the bottom edge of the test specimen when that is representative of a typical window. The level of the mat may be adjusted to correspond with the intended level of floor in relation to the position of a non-standard test specimen in the building as defined in Clause 8.

3.9
glazing
glass or plastics glazing sheet material, including glass/plastic combinations

NOTE Glazing may also refer to a fenestration assembly in which glass or plastic sheet infill is set in and is complete with a framing system for installation into a building.

3.10
impulse
I_{pos}
area under the positive phase of the pressure-time trace

NOTE 1 This is usually obtained by automatic electronic numerical integration of the gauge readings. This is also sometimes called the specific positive phase impulse. If sharp irregularities in the recorded trace result in non-representative transient dips into negative pressure or the negative phase is absent, the positive phase impulse should be calculated over the period of the mean pressure-time trace duration.

NOTE 2 Different subscripts may be used for the blast parameters, as described in Annex A. For example, the positive phase impulse, I_{pos}, may be denoted I_c where it denotes the classification impulse or I_t where it denotes the impulse calculated from the measured test values.

3.11
peak pressure
P_{max}
initial peak positive reflected pressure above ambient atmospheric pressure experienced at the attack surface of the test specimen following an instantaneous rise at the time of arrival of the shock front

NOTE If the measured pressure-time trace has sharp spikes or irregularities, the trace should be smoothed to produce a pressure-time trace that closely matches the mean path of the recorded trace. The peak pressure, P_{max}, of relevance is the resulting smoothed value at the time of arrival.

3.12
positive phase duration
t_{pos}
duration of the positive phase of the mean pressure-time trace

NOTE The mean pressure-time trace should have positive phase duration, waveform and peak pressure such that the area under this curve equals the positive phase impulse obtained by direct integration of the original recorded trace. The duration can normally be derived by reference to the time of the peak of the impulse-time curve.

3.13
pressure-time wave trace
pressure values plotted against time

NOTE The instantaneous rise at the shock front to the peak positive pressure, P_{max}, is followed by a non-linear decay to ambient pressure over a time called the positive phase duration. The shape of the decay curve may be modelled by an exponential decay curve having a decay coefficient, A, also known as a waveform parameter. In a free-field blast, a period of negative pressure then follows for a period of time before returning to ambient. Within the confines of a shock tube, this period of negative pressure is sometimes absent or reduced in value.

3.14
protected area
area on the side of the test specimen away from the source of the shock wave

3.15
rear face
protected area side of the test specimen opposite to the attack face

3.16
reflected pressure
pressure experienced by a surface which obstructs the flow of a blast wave

NOTE The shock wave moving through the air impacts the test specimen and is “reflected”, producing a pressure on the surface having a value higher than would have occurred within an unobstructed flow or on the side of a target parallel to the direction of travel of the pressure wave.

3.17
test specimen
sample of glazing submitted for test

3.18
witness panel
panel of deformable material positioned behind the test specimen in order to register the incidence of material forcibly detached from the test specimen during test

NOTE The composition and location of the witness panel is described in Clause 6.

3.19
witness panel perforations
any holes in the surface of the witness panel caused by impact of any material as a result of the blast

NOTE The number, size and depth of penetration of such perforations can be used as a guide to the injury potential of material detached from the test specimen.

3.20
witness panel indents
any detectable deformation of the surface of the witness panel caused by impact of any material as a result of the blast

4 Classification and hazard rating

A hazard rating is applied to glazing based on its performance under the classification blast conditions chosen for the test. The rating is specific only to those blast conditions. Hazard rating criteria are defined in Table 1.

Classifications are assigned according to the blast intensity measured in terms of pressure, impulse and duration. Each classification code is one of a series having defined blast values as listed in Table 2.

5 Test specimens

Test specimens may be submitted in two forms, as described in 5.1 and 5.2.

5.1 Glazing sheet

Glazing sheet submitted for test in a standard configuration and mounted in a standard frame in order to demonstrate or prove performance in relation to other sheet materials. For the purpose of obtaining a classification of the sheet material in accordance with this International Standard, a minimum of three test specimens, each (1 100 ± 5) mm × (900 ± 5) mm, shall be tested and shall be clearly identified by type and with an indication of the attack face. One additional specimen shall be provided for pre-test measurements. The test pieces shall conform to the specification of the manufacturer and shall be representative of normal production quality. They shall be arrissed for ease of handling.

For the purposes of obtaining a test assessment, a single glazing sheet test specimen may be supplied. The results cannot be used to classify the glazing.

5.2 Fenestration assemblies

This is glazing submitted complete with a framing system, fabricated and of a size typical for installation in a building and made up as a test specimen appropriate for mounting in the test apparatus.

The blast resistance of a fenestration assembly may be assessed by being tested and rated in accordance with the provisions of this International Standard. The test report and test report summary shall state that the results are applicable only to the product as tested. The number of assemblies tested shall be stated and shall be agreed prior to test. The results cannot be used to classify the fenestration assembly or the glazing infill independently as a sheet material.

5.3 Multiple specimens — Probability of achieving blast resistance

The air-blast resistance capacity of glazing does not imply that a particular specimen will resist the specific air blast for which it is rated with a probability of 1,0. However, the probability that a single glazing or glazing system will resist the specific air blast at the particular level for which it is rated increases proportionally with the number of test specimens that successfully resist that air blast at that level. The protection afforded against a blast by a single item of glazing depends not only upon the glazing but also upon the manner in which it is attached to the structure in which it is mounted.

5.4 Handling and storage

The test specimens shall be handled and stored in compliance with the manufacturer's instructions.

5.5 Marking

Each specimen shall be marked with the manufacturer's model and serial numbers and the date of manufacture. The attack side is intended to be oriented towards the explosive charge and shall be marked by the manufacturer to assure proper installation in the test frame. A number shall be assigned to each test specimen and marked accordingly.

5.6 Measurements

Thickness measurements of the glazing material shall be made at each corner, 25 mm from each edge and recorded. If the glazing sheet specimens are supplied already mounted in a frame and if four test specimens are supplied, one of the specimens shall be selected at random and inspected for details. Measurements shall include the edge dimensions of the frame and the glazing material; the cross-sectional dimensions of the frame and thickness measurements of the glazing material. The frame and glazing materials shall be verified to comply with the manufacturer's specifications. If necessary for verification, the fourth specimen shall be disassembled. Measurements and records shall be made of the bolts, screws or other devices used for fixing the test specimen to the test specimen support and those used to mount the support onto the shock tube.

5.7 Photography

Prior to the test, a photographic record that adequately portrays the test specimens, the test frame and the test configuration shall be made. This photographic record shall consist of still photographs and may include motion pictures or video.

6 Apparatus and equipment preparation

6.1 Shock tube — Pressure-generating device

The shock tube shall be a device capable of reproducing the required plane shock wave to simulate the effects from a high-explosive source and applying the blast load to a test specimen. The shock tube shall be capable of reproducing the shock wave consistently from test to test within a 0 % to + 15 % accuracy of a desired value for both the peak pressure and the impulse.