Association of Public Insurance Companies (APIB)
Association des établissements cantonaux d'assurance incendie

SWISS HAIL IMPACT PROTECTION REGISTER (HSR)

APIB Test Specification No. 00a

GENERAL SECTION A

01.02.2014/ 00a-14en
Version 1.02

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1 General part A

1.1 General

The test specifications for the determination of hail impact resistance form the basis for the consistent, product-neutral testing and classification of building components in relation to their resistance to hail impact. They include the generally valid guidelines for the execution of a hail impact resistance test (Part A), binding instructions on the documentation of the test set-up and the results achieved (Part B), as well as supplementary specifications relevant to specific building components.
The standard SIA 261/1 (2003), Art. 6.2.4 refers to the Swiss Hail Impact Protection Register of the CFIA. Published in the Hail Impact Protection Register for the building components entered are the hail impact resistance classes achieved in the hail impact resistance test for all the component functions required in the component-specific test specifications. The Swiss Hail Impact Protection Register of the CFIA should make it easier for users to select a product that has been tested and classified. It has a similar structure to the Swiss Fire Protection Register of the CFIA.

1.2 Hail impact resistance

1.2.1 General

Projectiles made of transparent ice with a density of approx. 870 kg/m3 are used for the testing of hail impact resistance. They are manufactured in freezers using a variety of methods. The density of the ice projectile corresponds to the manufacturing method practised in a laboratory. Compared with natural hail, it represents the upper limits. The quality of the ice must be assured periodically by testing centres in inter-laboratory tests.

Calculation of kinetic energy:

$$E_H = \frac{m_H \cdot v_A^2}{2}$$

E_H: Energy of hailstone [J]
m_H: Mass of hailstone [kg]
v_A: Speed on impact [m/s]

Natural hailstones take on many different shapes. However, in principle a spherical hailstone is assumed for the test.
Calculation of the mass of the hailstone:

$$m_H = V_H \cdot \rho_{Eis} = \frac{4 \cdot \pi \cdot \left(\frac{d_H}{2}\right)^3}{3} \cdot \rho_{Eis}$$

m_H: Mass of hailstone [kg]
V_H: Volume of hailstone [m^3]
$\rho_{\text{of ice}}$: Ice density 870 [kg/m^3]
d_H: Diameter of hailstone [m]

The speed on impact according to SIA 261/1 (referred to as "velocity of fall" in SIA 261/1) is calculated from the diameter of the hailstone, density of the ice and density of the air, gravitational acceleration and air drag coefficient:

Calculation of the speed on impact:

$$v_A = \sqrt{\frac{4 \cdot \rho_{Eis} \cdot d_H \cdot g}{3 \cdot \rho_{Luft} \cdot c_w}}$$

v_A: Speed on impact [m/s]
$\rho_{\text{of ice}}$: Ice density 870 [kg/m^3]
$\rho_{\text{of air}}$: Air density 1.2 [kg/m^3]
d_H: Diameter of hailstone [m]
g: Gravitational acceleration 9.81 [m/s^2]
c_w: Air drag coefficient of a 0.50 [-] sphere with a slightly rough surface

The parameters were deliberately selected so that, in comparison with natural hail, the projectile travelled at a higher speed. By doing this, it could be ensured that the hailstones that occur in nature would, in all probability, have a lower kinetic energy than those used in the test.

1.2.2 Hail impact resistance class

The definition of a hail impact resistance class is based on the diameter of a hailstone:

- Hail impact resistance class 1 (HW 1) is defined by the kinetic energy on the impact of a hailstone with a 10 mm diameter
- Hail impact resistance class 2 (HW 2) is defined by the kinetic energy on the impact of a hailstone with a 20 mm diameter
- Hail impact resistance class 3 (HW 3) is defined by the kinetic energy on the impact of a hailstone with a 30 mm diameter
- Hail impact resistance class 4 (HW 4) is defined by the kinetic energy on the impact of a hailstone with a 40 mm diameter
- Hail impact resistance class 5 (HW 5) is defined by the kinetic energy on the impact of a hailstone with a 50 mm diameter

From the hailstone diameters of 10 to 50 mm described above we can derive the following measurements: speed on impact (speed) and kinetic energies (class limit) per hailstone diameter:

Hail impact resistance	Diameter [mm]	Mass [g]	Speed [m/s]	Calculated impact energy [J]
HW 1	10 mm ± 2%	0.5 ±5%	13.8 ±5%	≥ 0.04
HW 2	20 mm ± 2%	3.6 ± 5%	19.5 ± 5%	≥ 0.7
HW 3	30 mm ± 2%	12.3 ± 5%	23.9 ± 5%	≥ 3.5
HW 4	40 mm ± 2%	29.2 ± 5%	27.5 ± 5%	≥ 11.1
HW 5	50 mm ± 2%	56.9 ± 5%	30.8 ± 5%	≥ 27.0

Table 1 Hail impact resistance classes based on the kinetic energy of the ice spheres

The building component is allocated to the hail impact resistance class in which it remains free from damage. In this respect, the class limit is decisive.
Example: A building component with a hail impact resistance class of HW 3 remains undamaged on the impact of a hailstone with a diameter of 30 mm

1.2.3 Classification

The results are logged in the test report and forwarded to the CFIA by the manufacturer for approval to go on the Hail Impact Protection Register. The building component functions and damage criteria for the individual component are defined in the test specifications relevant to that component. Classification varies according to the building component function.
Basically it is new materials that are put to the test. In the case of many materials, the resistance to hail impact changes over their service life (positively or negatively).

1.3 Definition of damage

1.3.1 General

Building components often have to fulfil several functions (e.g. waterproofing, appearance, mechanical protection). The definition of the occurrence of damage can also be just as varied. The individual functions of building components can be affected by quite different mechanical effects. When a building component is regarded as damaged has to be specified for each individual component function. This threshold is specified with the damage criterion.

1.3.2 Building component function

The building component fulfils one or more functions. For example, the building component must be waterproof ("watertightness" building component function) or it must comply with high expectations in terms of aesthetics ("appearance" building component function). The following building component functions are taken into consideration in test specifications:

Waterproofing:	the building component prevents the penetration of water
Light transmission:	the building component permits light transmission
Light screening:	the building component prevents light irradiation
Mechanical properties:	the building component performs a physical/mechanical function
Appearance:	the building component has an aesthetic function

In order to keep testing expenditure to a minimum, the test specifications are limited to these five most important building component functions. Other functions, such as self-cleaning and light reflection for example, are deliberately not taken into consideration in these test specifications. The hail impact resistance test must include all the component functions listed in the component-specific test specifications.

1.3.3 Damage criterion

The limit between an undamaged and damaged building component is defined using the damage criterion. The damage criterion defines the threshold at which, if it is reached or exceeded, the building component function can no longer be fulfilled and, as far as this function is concerned, the component will be regarded as being damaged. It must be recorded in the test report for each of the component functions defined in the test specification relevant to the particular component whether it is to be regarded as undamaged or damaged in respect of the damage criterion.

1.3.4 Measurement method

The measurement method describes how the building component function should be tested. If the building component fulfils a number of functions, then a correspondingly higher number of measurement methods are to be applied.

1.4 General test specifications

1.4.1 Ageing

The test specifications apply both for the testing of products in mint condition and for the retrospective testing of older materials that have already been incorporated into a building. In the case of products that are subject to rapid ageing (in particular plastics and components which include plastic), this is to be recorded in the Swiss Hail Impact Protection Register (HPR). The manufacturers have the option of specifying a guarantee period for the hail impact resistance tested.

1.4.2 Test principle

The test principle is based on the simulation of the natural effects of hail by means of individual impact on building components that are part of the building shell by firing ice manufactured in a laboratory at them.

1.4.3 Test apparatus

The test takes place in the laboratory. The test apparatus accelerates the projectile to the required speed. You can select whatever trajectory you like (horizontal, vertical or inclined), however the angle of impact defined in the test specifications for the specific building component must be complied with. The target area is aimed at and the results of the impact are inspected. The test specimen is fixed on the support according to the test specifications relevant to the particular building component (Figs. 1 & 2).

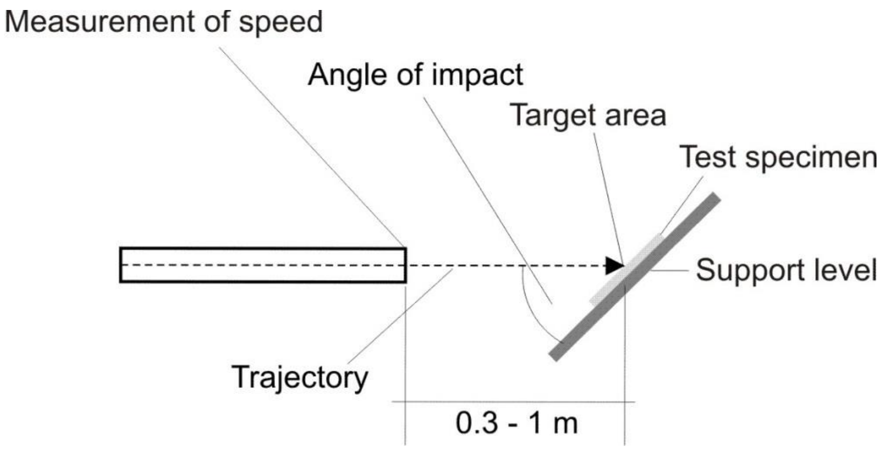


Figure 1 Test apparatus for the simulation of hail impact with horizontal trajectory and angle of impact of 45° ± 2° (dimensions in metres)

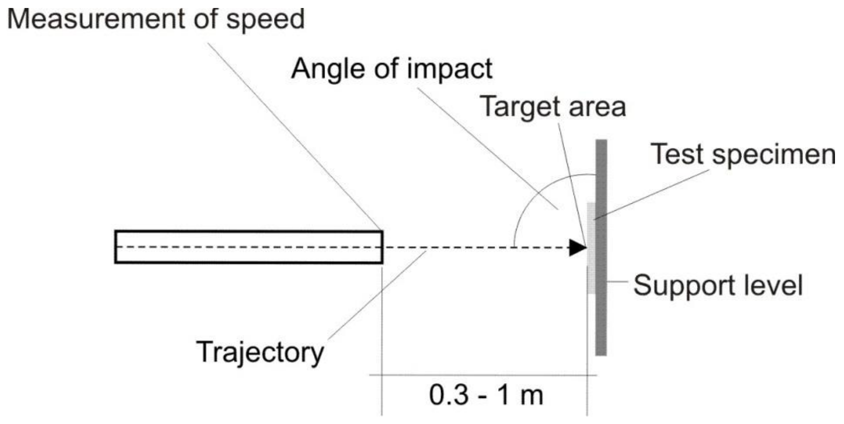


Figure2 Test apparatus for the simulation of hail impact with horizontal trajectory and angle of impact of 90° ± 2° (dimensions in metres)

1.4.4 Test specimen holder

The test specimen holder is used for fixing test specimens and is matched to the test apparatus (vertical or horizontal trajectory). In order to comply with the prespecified angle of impact, the test specimen holder must be adjustable and it must be possible to measure the angle. The test specimen holder must not be shifted or deformed by the impact of the shot. The ratio of the test specimen holder weight to the projectile must be very high (>1000), in particular in the case of rigid test specimens with a high modulus of elasticity.

In the case of the vertical trajectory set-up, the test specimen can also be supported directly on the ground (roof application). In this case, you must make sure that the point at which the stress is introduced to the test specimen must match the conditions in practice. Vibration transmission between the ground, target equipment and sample holder must be prevented using suitable means. Dynamic wave reflections in irregularly mounted support plates of the contact area of the target frame (corresponds to vibrations that emanate from the floor structure on which the target equipment is standing) must be prevented using appropriate means and uncoupled from the substructure.

As a rule, the test specimens are fastened rigidly to the support frame by means of clamps and other equipment so they cannot move and without any cushioning.

1.4.5 Angle of impact

The angle of impact is defined as the angle between the trajectory and support plane of the test specimen (Figure 2). The angle of impact for components that are to be used as part of roofs is 90° ± 2°, whereas for components on a facade the angle of impact is 45°± 2°.

1.4.6 Target area

The target areas are defined in the test specifications relevant to the building component and represent the conjectured weak points on the building component which are known as "critical target areas". These are targeted during trial tests, in order to determine the appropriate weakest point of the building component. These are the points at which the actual test is then carried out. If further weak points are to be expected in the component that are not defined in the test specifications relevant to that particular building component, they must also be targeted and the results specified in words and pictures in the test report.

1.4.7 Projectile

Spheres and special shapes made of laboratory ice are used as projectiles. They are made in appropriate moulds (for example made of silicone rubber, manufactured using a melting process) with desalinated water and stored at -20°C.

For valid testing, the following conditions must be fulfilled:

- Storage temperature: Freezer at -20°C ± 3°C
- Storage period: Period from manufacture to impacting at least 48 hours, maximum storage period in freezer 8 weeks
- Shape: Sphere (standard) or special shapes
- Diameter: 10 to 50 mm, according to Table 1, ± 5 %
- Mass: 0.5 to 56.9 grammes, according to Table 1, ± 5% established using scales (scale graduation 0.01 grammes)
- Appearance: On visual inspection devoid of any cracks and with few pores, mould seam scraped off
- Conditions: Projectile must remain intact until impact
- Handling: Using insulated gloves only

Basically projectiles are to be used at an ice temperature of -20°C ± 3°C. Exceptions are described in the test specifications for the particular building components.

If additional impacts with a projectile that is not spherical are required in the particular building component test specifications, the nipple-shaped projectile shown in the detailed drawing in Appendix A can be used. The mass of the appropriate nipple-shaped projectile corresponds to that of a spherical projectile with the same diameter. The projectiles are fired "nose-first" (hemispherical protuberance) at the test specimen.

In addition to using the same diameter, the component is also be targeted with the next-smallest nipple-shaped projectile.

If you use a projectile which differs from this one, the test centre must prove that the projectile selected causes the same damage pattern.

1.4.8 Test conditions

The test is carried out at an ambient temperature of 20°C ± 2°C and relative air humidity of 50% ± 20%.

1.4.9 Dimensions of test specimen

The dimensions of the test specimen are given in the test specifications pertaining to the particular building component. It is possible to deviate from these dimensions, provided there is justification.

1.4.10 Number of test specimens

The number of test specimens is defined in the test specifications for the particular building component.

1.4.11 Pre-storage of test specimen

The pre-storage of the test specimen is defined in the test specifications relevant to the building component and describes the long-term storage of the test specimen before the test.

1.4.12 Pre-treatment of test specimen

The pre-treatment of the test specimen is defined in the test specifications relevant to the building component and controls the handling of the test specimen immediately before the test.

1.4.13 Speed of projectile

The speed of the projectile is measured with the aid of an electronic measuring device with an accuracy of ± 1% at a distance of 0.3 – 1 m from the surface of the test object (object – middle of speed measuring section). The value must be measured electronically to at least 2 decimal places.

1.4.14 Execution of test

In order to test the sample for a specific hail impact resistance, the test specimen is targeted with the kinetic energy of the appropriate hail impact resistance class (Fig. 3). The test is carried out separately for each building component function. To ensure that the energy value of the class limit is definitely achieved, we recommend firing using a slightly higher energy level.

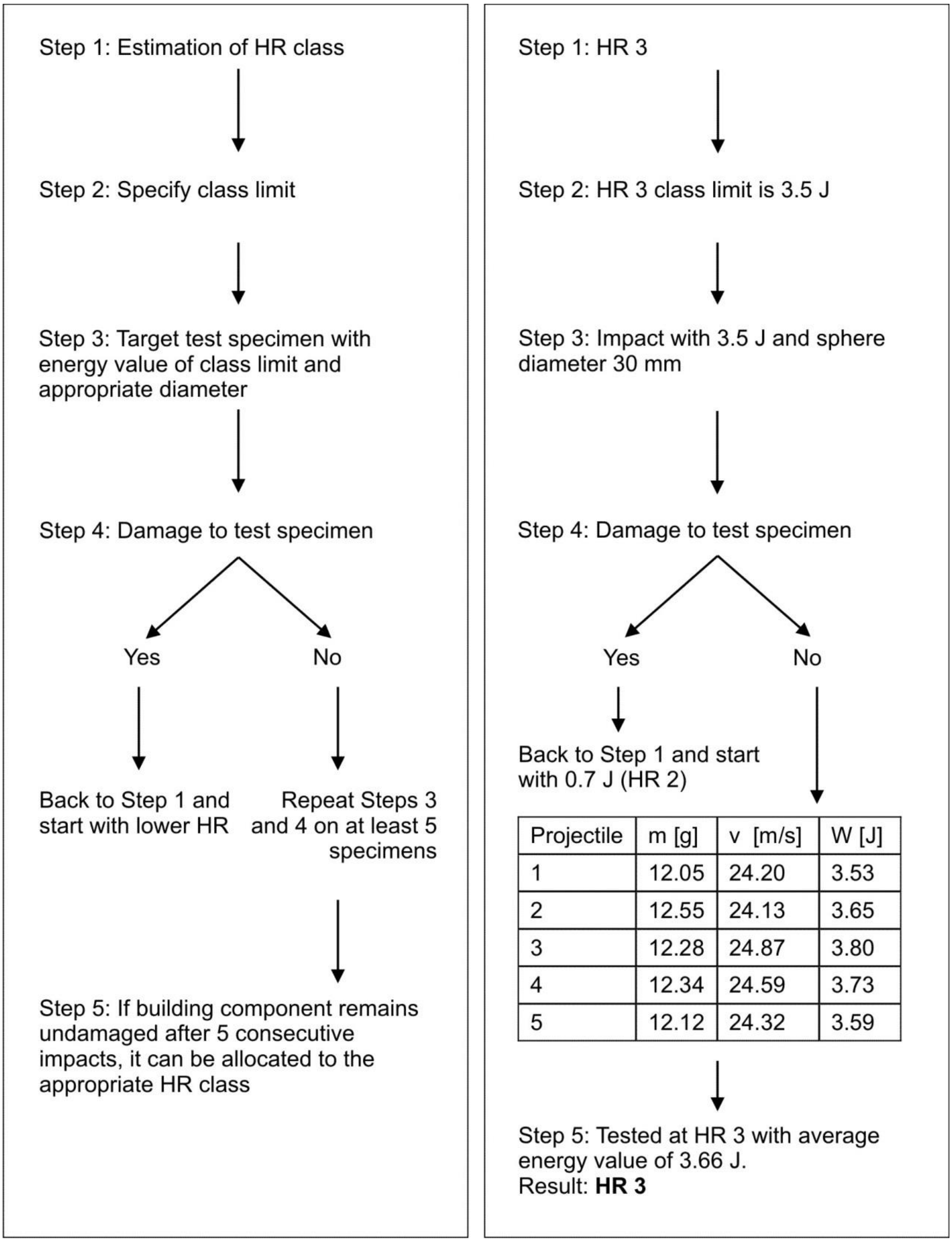
The appropriate projectile diameter must be used for each hail impact resistance measurement: the test for a hail impact resistance class of 2 (HW 2) necessitates a diameter of at least 20 mm, for HW 3 a diameter of 30 mm, for HW 4 a diameter of 40 mm and for HW 5 a 50 mm diameter.

If the test specimen is damaged with a specific projectile size and corresponding speed, a new test specimen is targeted with the projectile size and speed of the next class limit down. If the test specimen remains undamaged, the test is extended to at least 4 more test specimens (total of at least 5 tests). If the test specimens remain undamaged after having been targeted, the building component can be allocated to the appropriate hail impact resistance class. Please note the following in this respect:

- The projectile must be fired within 60 seconds after its withdrawal from the storage container
- Multiple targeting of the same test specimen is possible, if there is no damage to the specified target area for that particular building component

If a building component is damaged when hit with a 20 mm projectile, it is possible, at the discretion of the testing institute, to abandon a further test with a projectile diameter of 10 mm and allocate the building component to hail impact resistance class 1 (HW 1). The prerequisite is that the building component can clearly be expected to be in sound condition because of the strikingly low kinetic energy (class limit). Abandoning the test with a projectile diameter of 10 mm is to be explicitly recorded in the test report and justified.

In the case of building materials that are not homogeneous in their structure, targeting with a projectile that has a smaller diameter (usually 20 or 30 mm) can cause damage where a projectile with a larger diameter would not cause any damage. The testing institute will decide on the execution of additional tests at critical points. The weakest point must be tested by firing at it five times. The results must be logged in the test report.



Projectile	m [g]	v [m/s]	W [J]
1	12.05	24.20	3.53
2	12.55	24.13	3.65
3	12.28	24.87	3.80
4	12.34	24.59	3.73
5	12.12	24.32	3.59

Figure3 Schematic sequence (left) and example (right) for carrying out the trial

1.5 Test without impact of projectile

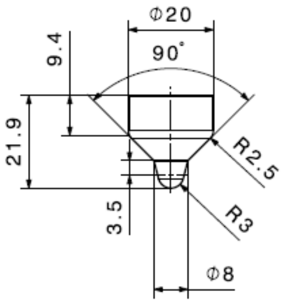
If demonstrably no changes are to be expected in the material composition, in the design and intended purpose, renewed testing of the hail impact resistance can be dispensed with. After examination of the documentation submitted, the CFIA will decide on the option of abandoning a further test.

1.6 Building components with certificate according to EN standards

If building components or component categories have already been tested for hail impact resistance according to EN standards, there is no need for further testing. If tests with projectiles made of other materials or of different shapes take place, allocation to hail impact resistance classes HW 1 to HW 5 will be undertaken using the conversion table given in the test specifications. The list of standards in the attached test specifications, according to which building components are to be tested, is binding.

Appendix A

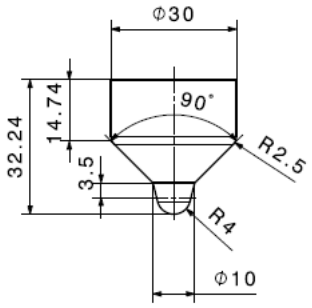
Nipple-shaped projectile 20 mm



Volumen: 4120mm^3
Gewicht: 3,6g

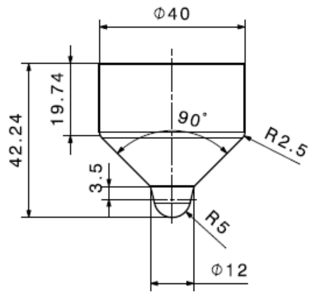
Volumen = Volume; Gewicht = Weight

Nipple-shaped projectile 30 mm



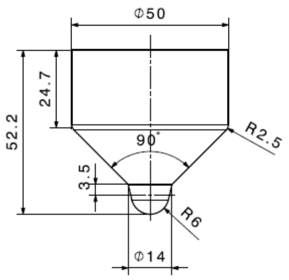
Volumen: 14171mm^3
Gewicht: 12,3g

Nipple-shaped projectile 40 mm



Volumen: 33541mm^3
Gewicht: 29,2g

Nipple-shaped projectile 50 mm



Volumen: 65404mm^3
Gewicht: 56,9g