Wydział Inżynierii Lądowej

POLITECHNIKA WARSZAWSKA

BUILDING MATERIALS

LABORATORY PRACTICAL TASK

Glass construction products

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1. Aim of the task

The aim of the exercise is to get acquainted with the criteria and methods of assessing the quality of glass products by making appropriate markings and classifying a given product, as well as getting acquainted with the methods and criteria used in the process.

2. Theoretical background

2.1 Definitions

Glass - is a non-crystallized material, obtained by cooling melted at 1300 ÷ 1500 °C glass raw materials (mainly sand with limestone, dolomite, soda and others);

Building glass – glass used in construction industry;

Plain glass – any glass product (soda-lime-silicate glass: float, drawn, rolled, laminated, borosilicate glass and glass-crystalline materials) or any processed glass made of these products, without changing the profile or deflection;

Drawn plain glass –obtained by cutting a drawn glass strip. The surface of the glass can be sanded, polished or matte. The glass can be toughened, absorbing or transmitting a specific range of radiation;

Rolled plain glass – obtained by cutting a roll formed glass strip with a raw, untreated, patterned or polished surface. Rolled glass can be reinforced or toughened. The boards can be colorless or colored, that is, colored in the mass or applied to the surface with an enamel layer;

Float glass - obtained by cutting a glass strip that is formed on the surface of a molten metal (usually tin). Float plate glass can undergo the same treatment as drawn plate glass, e.g. toughened, bent etc .;

Glass shaped piece - a small-size element made of solid glass or with a void inside**;**

Insulating glass unit - a glazing unit made of two or more glass panes separated by a distance frame along the edge;

Optical defects - defects that distort the appearance of objects when viewed through glass;

Point defects - spherical or semi-spherical disruptions in transparency visible when looking through glass;

Linear / longitudinal defects - defects that may be on or in the glass in the form of deposits, stains or scratches that occupy a longer length or longitudinal area;

Stain - A defect larger than a punctate defect, often irregularly shaped, partially mottled in structure.

2.2 Introduction

2.2.1 Chemical composition

The chemical composition of ordinary glass (soda-lime-silicate) is shown in Table 1.

Tab. 1. Chemical compostion of soda-lime-silicate glass

Chemical compund	**% of mass**
SiO_2	69 ÷ 74
CaO	5 ÷ 12
Na_2O	12 ÷ 16
MgO	0 ÷ 6
Al_2O_3	0 ÷ 3

2.2.2 Selected physical properties

Selected properties of construction glass are presented in Table 2.

Property	**Value, range of values or description**
Density	2500 kg/m^3
Compressive strength	300 ÷ 1000 MPa
Flexural strength	30 ÷ 70 MPa
Hardness	5 ÷ 7 w skali Mohsa
Thermal conductivity coefficient, λ	0,95 ÷ 1,00 W/(m x K)
Coefficient of linear thermal expansion, α	8,9 ÷ 9 x 10^{-6} 1/K
Light transmittance	up to 90%
Durability	Resistant to all weather conditions Not resistant to the atack of hydrofluoric and phosphoric acids

2.2.3 Building glass production

The production of building glass includes the following technological procedures:

1. Raw materials;
2. Fusion of raw materials;
3. Clarification and homogenization of the alloy;
4. Cooling and shaping;
5. Packaging, storage and distribution of products.

Plain glass production methods:

• The Forcault method

Used for the production of drawn plain glass. Disadvantages: waviness and streaks, distorting the picture. Application areas: Industrial construction, greenhouses etc.

• Colburn's method

Used for the production of rolled plain glass. Disadvantages: depending on the "wear" of the rollers - more or less intense waviness

Application areas: wired glass, ornamental glass, patterned glass, profiled glass

• Pilkington method

Used for the production of flat float glass. Perfectly smooth surfaces, the least optical defects.

Application areas: residential, public and office buildings.

2.2.4 Glass construction products

Currently, the most widely produced building glass product is plain glass, which is referred to as basic glass and is used in the production of, for example, insulating glass. The assortment of glass construction products is shown in Figure 1.

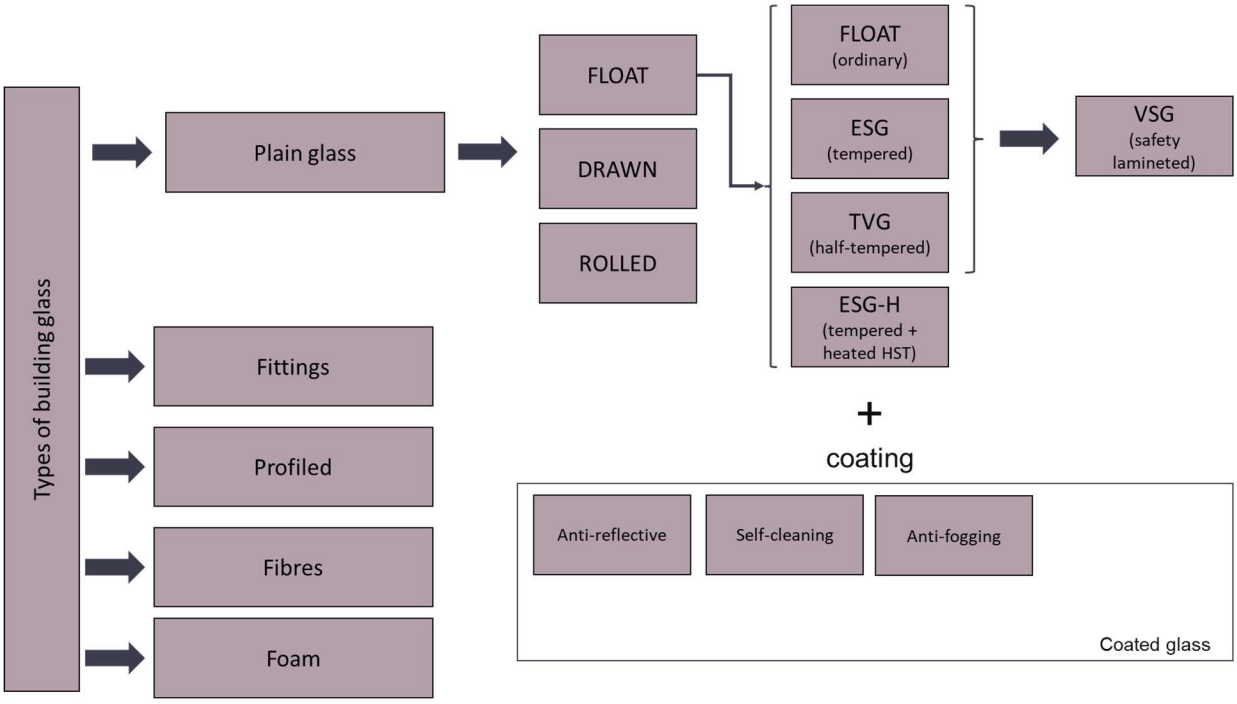


Fig. 1. Glass construction products

2.2.5 Selected properties of plain glass

The properties of the three types of plain glass are compared in Table 3.

Tab. 2. The comparision of the selected properties of three types of plain glass

Property	**Type of plain glass**		
	FLOAT	**TVG**	**ESG**
Flexural strength	45 MPa	70 MPa	120 MPa

Resistance to surface temperature difference	40K	100K	150K
Cutting	YES	**NO**	**NO**
Crack mesh	Radial surface cracks, large pieces of glass	Radial surface cracks, **small pieces of glass**	Mesh-shaped crackings, **small pieces of glass**

2.2.6 Construction and marking of insulating glass units (IGU)

The structure and marking method of glazing units used in the construction industry are shown in Figures 2 (single-chamber glazing) and 3 (double-chamber glazing).

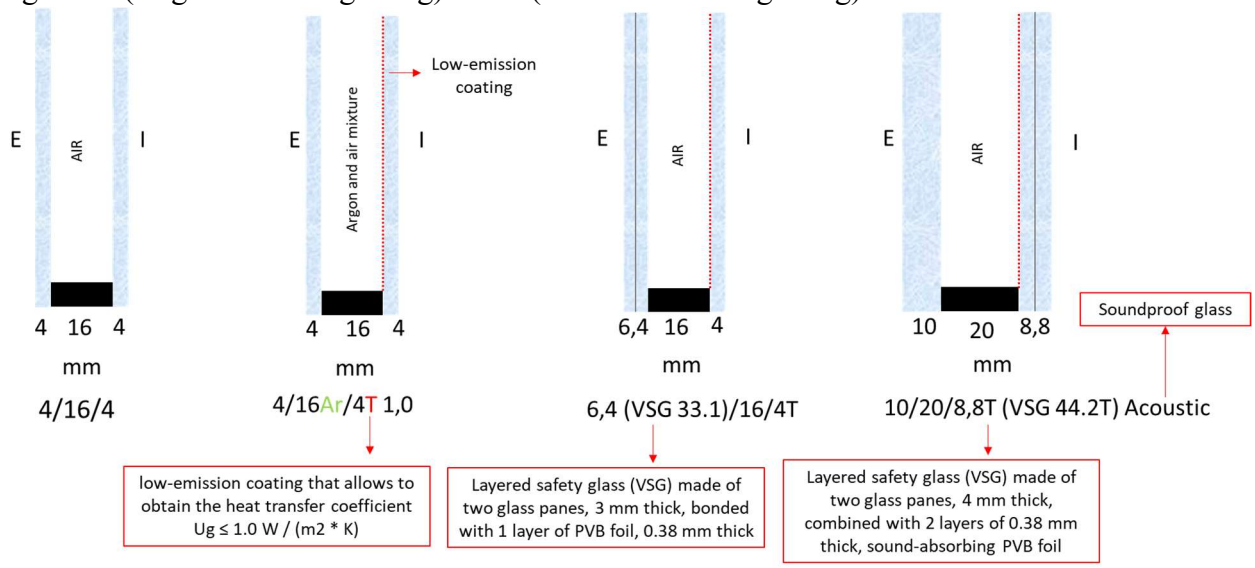


Fig. 2. Construction and marking single-chamber glazing units

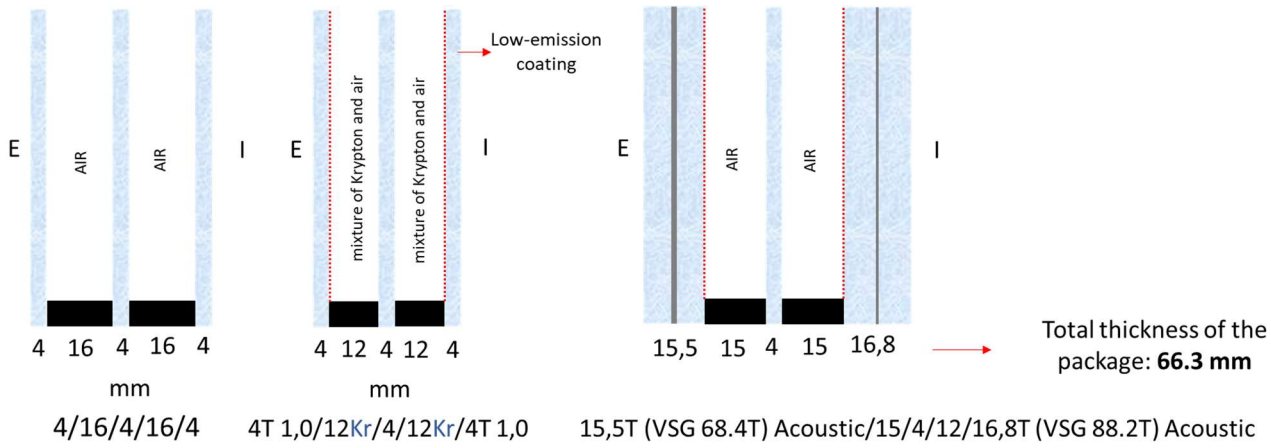


Fig. 3. Construction and method of marking double-chamber glazing

3. Laboratory task

3.1 Checking the shape and dimensions of the IGU

3.1.1 Materials and equipment

- IGU;
- Line gauge with an accuracy of 1.0 mm or better.

3.1.2 Measurement

Height (H) and width (B)

In the case of insulating glazing units with a rectangular shape, it should be clearly stated which dimension is width B and which is length H, as this is related to the position of the glazing.

Carry out the measurements separately for both external individual panes as shown in the diagram in Figure 4.

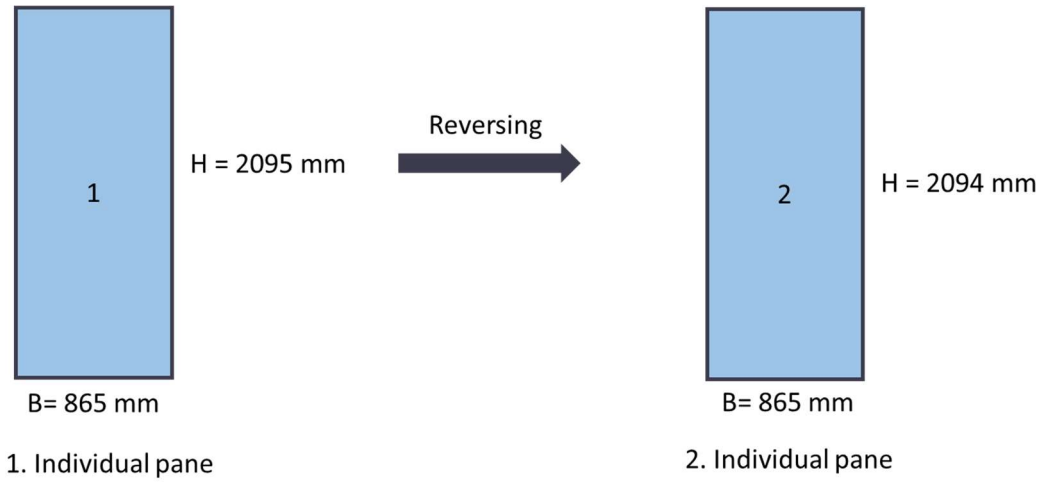


Fig. 4. Diagram for determining the height and width of both individual panes of which the IGU is made

Squareness

The squareness of a single pane is expressed as the difference in the length of its diagonals, according to the formula (1). Perform the measurements separately for both external single glazing according to the diagram shown in Figure 5.

$$Squareness = |d_1 - d_2| \text{ [mm]} \quad (1)$$

Gdzie:

d_1, d_2 – length of both diagonals of a individual pane, mm

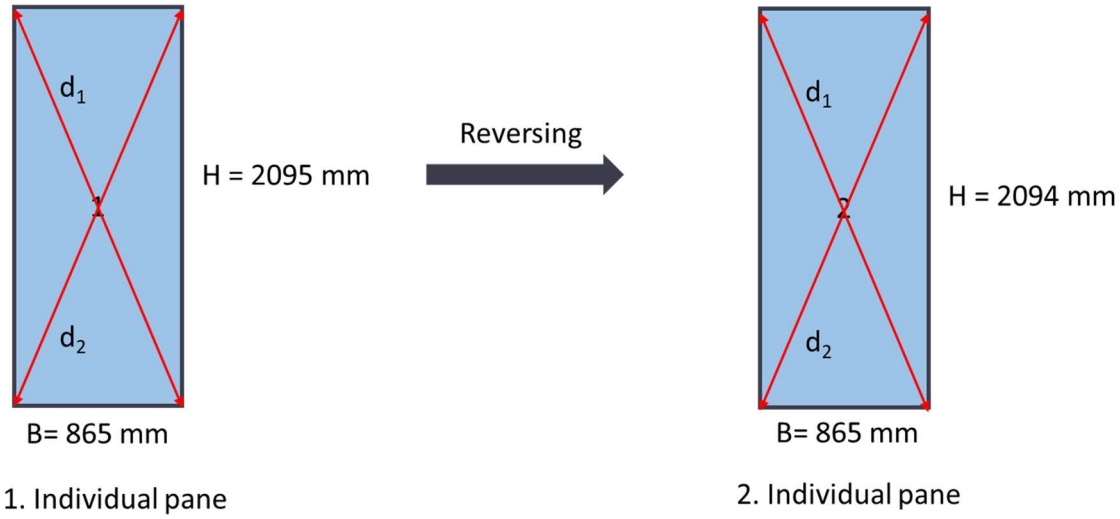


Fig. 5. Scheme for determining the length of the diagonals of both single panes of which the IGU is build

3.2 Panes shifting and the thickness of the IGU

3.2.1 Materials and equipment

- IGU;
- Square (90°);
- Caliper with an accuracy of 0.1 mm or better.

3.2.2 Measurement

Determine the shifting of panes (p) using a square and a caliper for each edge of the insulating glass unit with an accuracy of 0.1 mm according to the diagram shown in Figure 6. Measure the thickness of the insulating glass unit (g) using a caliper with an accuracy of 0,1 mm in each of the corners and in the center of the IGU according to the scheme shown in Figure 7.

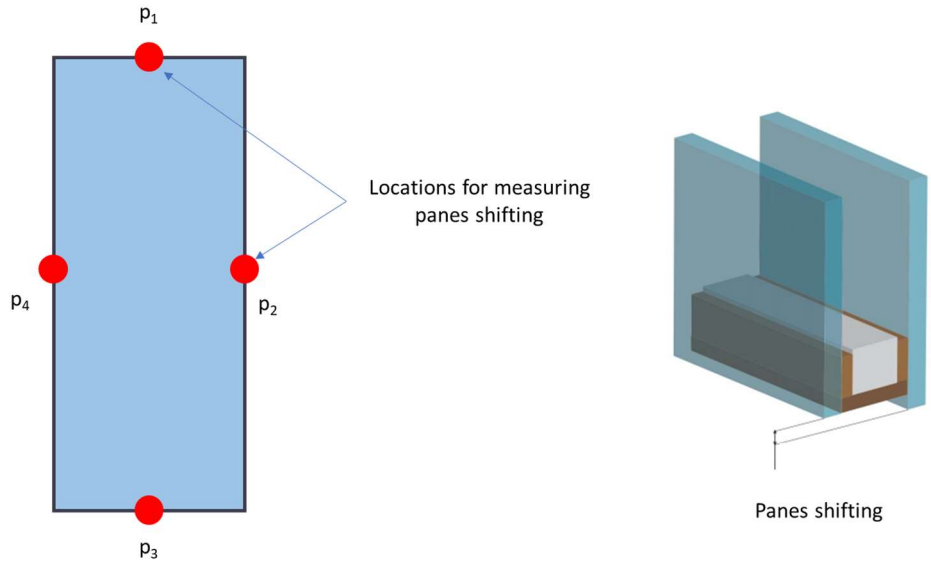


Fig. 6. Locations for measuring panes shifting and the visualization of the panes shifted

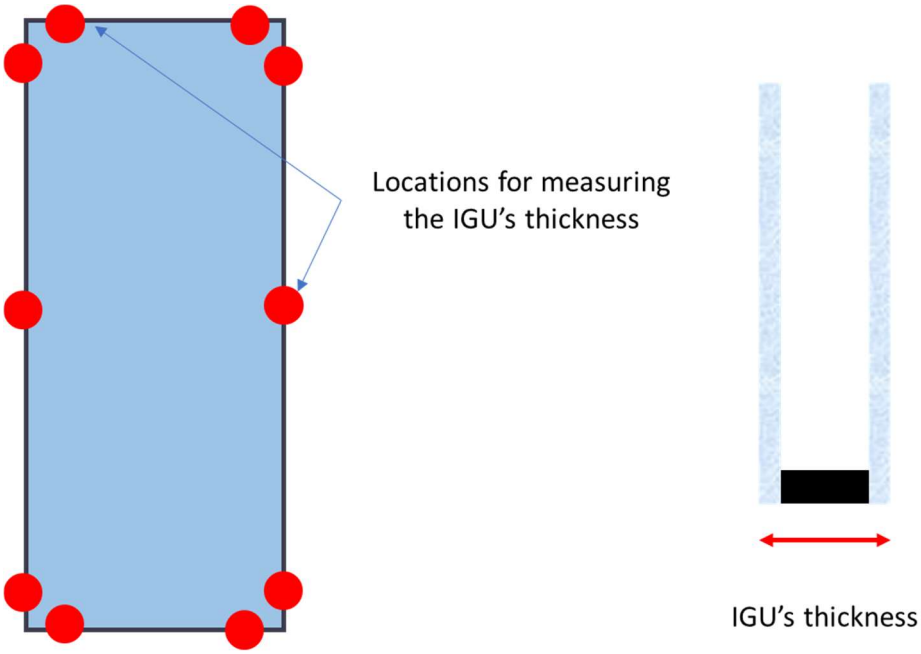


Fig. 7. Locations for measuring the IGU's thickness

3.3 Visual assessment of the quality of IGU

3.3.1 Materials and equipment

- IGU;
- White color marker.

3.3.2 Measurement

The assessment should be carried out from a distance of not less than 3m. in the case of coated products and not smaller than 2m. for other products, at an observation angle as perpendicular to the glass surface as possible (Fig. 8). The assessment is carried out under diffuse lighting conditions against a cloudy sky or a solid gray background.

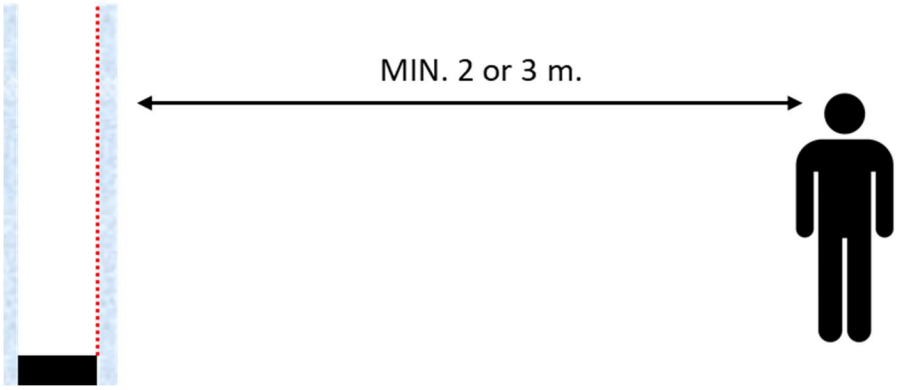


Fig. 8. The position of the observer in relation to the IGU during the visual assessment

For the purposes of the assessment, the surface of the insulating glass unit should be divided into three zones (Fig. 9):

- R - 15 mm wide from the edge, normally covered with a frame or corresponding to the edge seal;
- E - 50 mm wide, at the edge of the visible area;
- M - main zone.

The assessment should be made by looking at the glass from the inside of the room.

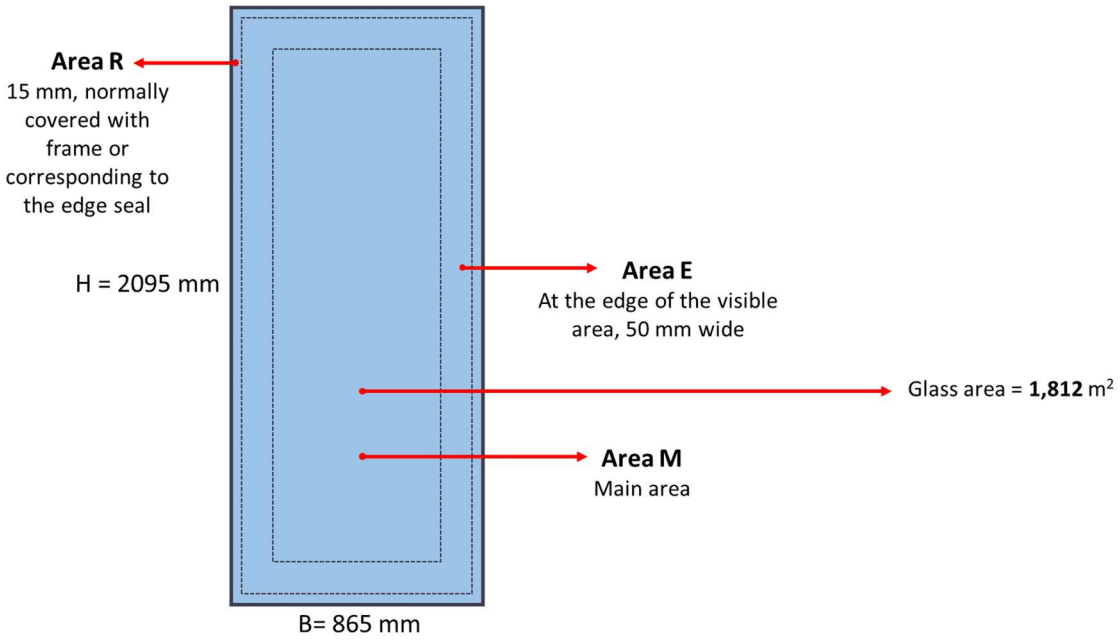


Fig. 9. Division of the assessed IGU into zones

Mark the observed point or line / longitudinal defects with a marker on the glass surface and then determine the dimensions of the defect. Defects less than 0.5 mm are not taken into account in the visual inspection.

Types of point defects:

- Blisters (gas inclusions);

• Dots (leftovers from the manufacturing process);

• Foreign body inclusions;

Types of linear / elongated defects:

• Stains;

• Hairline scratches;

• Remaining scratches;

• Nicks and chips at the edges.

Procedure for assessing the dimensions of a chipped glass corner is shown in Figure 10.

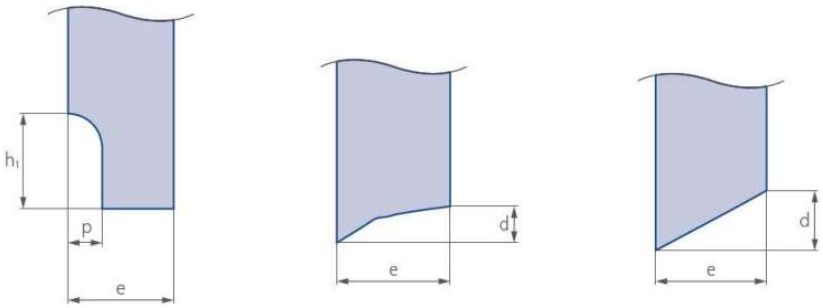


Fig. 10. Dimensioning a chipped glass corner.

3.4 Checking the shape, dimensions and weight of the glass block

3.4.1 Materials and equipment

- Glass block;
- Line gauge with an accuracy of 1.0 mm or better;
- Angle gauge with an accuracy of 1° or better;
- Caliper with a depth gauge (measuring accuracy = 0.1 mm or higher);
- Electronic scales with an accuracy of 10g. or higher.

3.4.2 Measurement

Measure the length (l), width (b) of the faces and height (h) of the sample at the four corners as shown in Figure 11.

Squareness should be determined at the corners of both faces using an angular gauge with an accuracy of 1 °, as shown in Figure 12.

The concavity and convexity of the external surfaces should be determined along the diagonals of both surfaces using a line gauge and a caliper with a depth gauge with an accuracy of 0.1 mm, according to the Figure 13.

The weight of the glass block is determined using a balance with an accuracy of 10g.

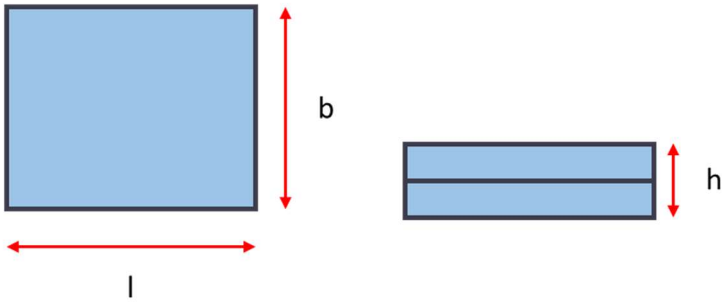
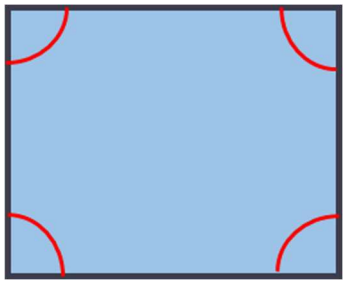
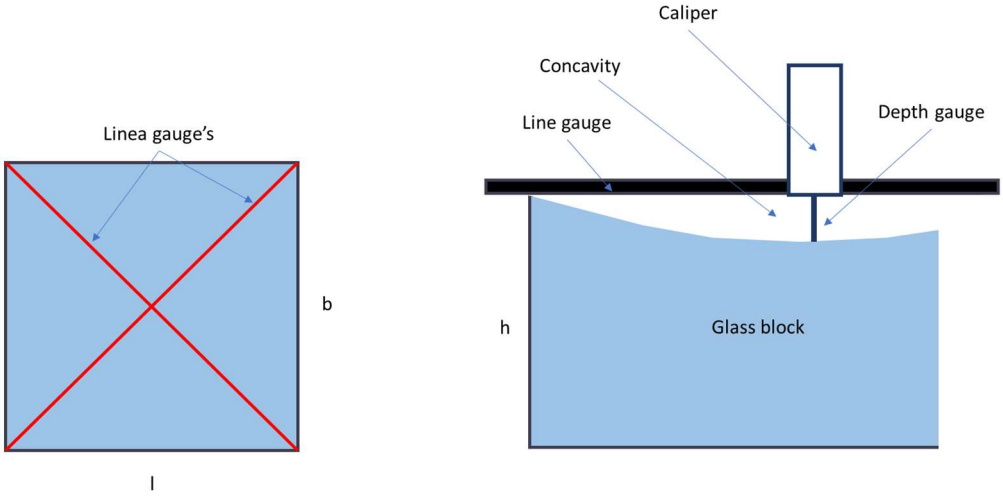


Fig. 11. Diagram of a glass block with dimensions marked.



Rys. 12. Location points for measuring glass block's squareness



Rys. 13. Scheme for determining the concavity / convexity of the front surfaces of a glass block

1.2 Visual assessment of the quality of a glass block

1.2.1 Materials and equipment

- Glass block;
- Marker koloru białego.

1.2.2 Measurement

Glass blocks are tested by lighting in conditions similar to diffused daylight. The sample illuminated from below is observed from a distance of about 3 m at right angles to the face surface of the glass block. Mark the observed defects with a marker and then define their dimensions.

4. Summary of test results

Tab. 3. Summary of test results for an insulating glass unit (IGU)

Product type:	Insulating single-chamber glass unit (IGU)		
Reference standard:	**EN 12379-1:2018-08 / EN 572-8+A1:2016-03**		
Mark:			
Nominal dimensions: (mm):	H =	B =	g =
1. Shape and dimensions			
1. Individual pane			
H =	B =	d_1 =	d_2 =
		Squareness =	
2. Individual pane			
H =	B =	d_1 =	d_2 =
		Squareness =	
Glass area =			
2. Panes Shifting			
p_1 =	p_2 =	p_3 =	p_4 =
MAX(p_1 …. p_4) =			
3. IGU's thickness			
g_1 =	g_2 =	g_3 =	g_4 =
g_5 =	g_6 =	g_7 =	g_8 =
g_9 =	g_{10} =		
MIN(g_1 …. g_{10}) =		MAX(g_1 …. g_{10}) =	
4.Visual inspection			

Defect type (dimensions in mm)	Quantity (pieces) / Single length of line defect / Total length of line defect (mm)	Area

point deffects Ø ≤ 1		
points deffects 1 < Ø ≤ 3		
points deffects 3 > Ø		
dots Ø ≤ 1		
dots 1 < Ø ≤ 3		
stains Ø ≤ 17		
dots Ø > 3 and stains Ø > 17		
Hairline scratches ≤ 0,15		
Other linear defects		
Chipped edge	h_1 = p = e =	
Chipped edge	h_1 = p = e =	

Tab. 4. Summary of the results of the glass block test

Product type:	Glass block		
Reference standard:	**EN 1051-2:2009**		
Nominal dimensiones: (mm):	l =	b =	h =
Dimensional tolerance class:			
1. Shape and dimensiones			
1. Visible surface		**2. Visible surface**	
l =	b =	l =	b =
Thickness			
h_1 =	h_2 =	h_3 =	h_4 =
Squareness			
α_1 =	α_2 =	α_3 =	α_4 =
α_5 =	α_6 =	α_7 =	α_8 =
Convexity / Concavity			
1. Visible surface			
1 diagonal	CONVEXITY / CONCAVITY / LACK		**Size =**
2 diagonal	CONVEXITY / CONCAVITY / LACK		**Size =**
2. Visible surface			
1 diagonal	CONVEXITY / CONCAVITY / LACK		**Size =**
2 diagonal	CONVEXITY / CONCAVITY / LACK		**Size =**
2.Visual inspection			
Defect type	Quantity (pieces) / Single length of line defect / Total length of line defect (mm)		

5. Requirements / dimensional tolerances

Tab. 5. Dimensional tolerances t for nominal lengths and widths for Float glass according to EN 572-8 tab. 4 - exact dimensions (dimensions in mm)

The nominal thickness of a pane	tolerance t		
	Nominal size of the glass		
	(H,B) ≤ 1500	1500 < (H,B) ≤ 3000	(H,B) > 3000
2,2.8,3,4,5,6	± 1,0	± 1,5	± 2,0
8,10,12	± 1,5	± 2,0	± 2,5

Tab. 6. Maximum allowed differences between diagonals for float glass (dimensions in mm) according to EN 572-8.

The nominal thickness of a pane	Maximum allowed differences between diagonals		
	Nominal size of the glass		
	(H,B) ≤ 1500	1500 < (H,B) ≤ 3000	(H,B) > 3000
2,3,4,5,6	3	4	5
8,10,12	4	5	6

Tab. 7. Maximum allowed panes shifting (dimensions in mm.) according to EN 1279-1.

The nominal thickness of a pane	Maximum allowed panes shifting	
	Number of chambers	
	1	2
ALL	1	2

Tab. 8. Thickness tolerances of insulating glass units according to EN 1279-1 tab. 3

L.P.	1st pane	2nd pane	IGU Thickness tolerances
1	Annealed glass	Annealed glass	± 1.0 mm
2	Annealed glass	Toughened glass	± 1.5 mm
3	Annealed glass	Laminated glass	
	thickness ≤ 6 mm and a total thickness ≤ 12 mm		± 1.0 mm
	other cases		± 1.5 mm
4	Annealed glass	Patterned glass	± 1.5 mm
5	Toughened glass	Toughened glass	± 1.5 mm
6	Toughened glass	Composite glass / polymers	± 1.5 mm
7	Toughened glass	Patterned glass	± 1.5 mm
8	Composite glass / polymers	Composite glass / polymers	± 1.5 mm
9	Composite glass / polymers	Patterned glass	± 1.5 mm

Tab. 9. Acceptable number of point defects of IGU according to EN 1279-1.

AREA	Dimensions (without halo) mm	Area of glass S (m^2)			
		S ≤ 1	1 < S ≤ 2	2 < S ≤ 3	S > 3
R	all dimensions	no limit			
E	Ø ≤ 1	< 3 for each area Ø ≤ 20 cm			
	1 < Ø ≤ 3	4	1 per 1 m of perimeter		
	3 < Ø	unacceptable			
M	Ø ≤ 1	< 3 for each area Ø ≤ 20 cm			
	1 < Ø ≤ 3	2	3	5	5 + 2/m^2
	3 < Ø	unacceptable			

Tab. 10. Acceptable number of residues in the form of dots and stains (spots) according to EN 1279-1.

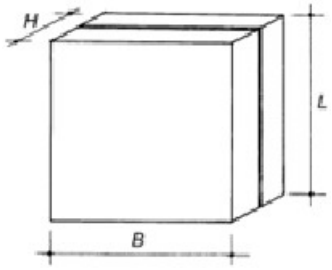
AREA	Dimensions (without halo) mm	Area of glass S (m^2)	
		S ≤ 1	S > 1
R	all dimensions	no limit	
E	Dots Ø ≤ 1	no limit	
	Dots 1 < Ø ≤ 3	4	1 per 1 m of perimeter
	Stains Ø ≤ 17	1	
	Dots Ø > 3 i Stains Ø > 17	1	
M	Ø ≤ 1	3 on each area Ø ≤ 20 cm	
	1 < Ø ≤ 3	2 on each area Ø ≤ 20 cm	
	3 < Ø	unacceptable	

Tab. 11. Acceptable number of linear and longitudinal defects according to EN 1279-1.

AREA	Defect type	Individual length (mm)	Sum of individual lengths (mm)
all area	Hairline scratch ≤ 0,15 mm	No limit	
R	Other linear defects	No limit	
E		≤ 30	≤ 90
M		≤ 15	≤ 45

Tab. 12. Shape, dimensions and nominal masses of glass blocks according to EN 1051-2.

Form/Shape	Dimensions, mm			Nominal mass, kg
	Length, L	Width, B	Height, H	
B	90	90	80	1,6
	115	115	80	1,2
	146	146	80	1,4
			98	1,6
			98	2,8
	190	190	50	2,1
			80	2,5
			80	3,6
			100	2,6

			100	5,1
	197	197	79	2,2
			98	2,7
			98	3,5
			98	4,6
	240	240	80	3,9
	298	298	98	7,0
	300	300	80	3,9
			98	7,0
E	190	90	80	1,4
			90	1,6
		95	80	1,3
			100	1,3
	197	95	80	1,4
			98	1,6
		146	80	1,9
			98	2,0
	240	115	80	2,1
1) Differences in the mass of the blocks with the same dimensions result from the variable thickness of the glass; 2) Dimensions should be checked with an accuracy of 0.1 mm; 3) The weight is determined with an accuracy of 10g. 4) Average mass should be within +/- 10% of the nominal mass				

Tab. 13. Tolerances in relation to dimensions, weight of glass blocks and visual assessment according to EN 1051-2.

Property	Tolerance / Limit value
Dimensions (b,l,h)	Class I: ± 1.0 mm Class II: ± 1.5 mm Class III: ± 2.0 mm
Squareness	90° ± 2°
Convexity / Concavity	Convexity in the visible surface ≤ 2.0 mm Concavity in the visible surface ≤ 1.0 mm
Visual inspection	No visible defects from a distance of 3 m.

6. The report

The report should include the following points:

1) Subject of study (basic information about the tested materials)
2) Findings (the results of determinations are presented in tables and complied as indicated)
3) Conclusions (bulleted statements formulated on the basis of the obtained results)
4) References

7. Literature

1. Chojczak W., Materiały budowlane. Ćwiczenia laboratoryjne. Część 2. Drewno, szkło, lepiszcza bitumiczne, tworzywa sztuczne, OWPW, 2018
2. Praca zbiorowa, Budownictwo ogólne. Tom I. Materiały i wyroby budowlane. Arkady, 2010