Saimaa University of Applied Sciences
Technology, Lappeenranta
Double Degree Programme in Civil and Construction Engineering

Popov Nikita

SUITABILITY OF NOKIAN BULLETPROOF PROFILE SYSTEM IN RUSSIA

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ABSTRACT
Popov Nikita
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Tutors: Martti Muinonen- Saimaa University of Applied Sciences, Harri Plukka, company Nokian Profiilit Oy.

The aim of this research is to assess suitability of Nokian bulletproof system in Russian market of bulletproof products, to consider possible affect of Russian standards, make calculations in accordance with Russian standards.

The general meaning of R65-BP system, requirements and main properties of bulletproof structures are given in the presentation part. Bulletproof properties are described in tables in accordance with Russian and European classification. Presentation part contains photos and a 3-dimensional model of R65-BP system.

The specific terms and definitions which could help to understand all following information are given in definitions part.

Market study shows main manufacturers of bulletproof structures in Russian market. Systems of other manufacturers are described and compared with Nokian bulletproof system. The competitiveness in bulletproof products is evaluated.

In technical part the comparison of Russian and Europe standards is done. Standards which could be applicable to aluminum bulletproof profiles are considered. The relations and differences between those standards are shown. The possible affect of Russian standards is evaluated by calculations of few curtain wall and roof structures.

Keywords: Aluminium Profiles, Bulletproof Windows, Facades, Curtain Walls, GOST, SNiP, Bullet Resistance.

CONTENT

1 PRESENTATION OF BULLETPROOF SYSTEM

1.1 Introduction

Bulletproof windows and doors installed at facilities which are under threat of armed attack. Windows and glazed facades are weakest places of the building. That is why the main attention must be paid to windows, doors and glazed facades reliability and resistance during safety design process of the whole building. Also these structures have a higher risk of being attacked because being transparent these structures give possibility to aim through them.

Figure 1.1 Police building of western administrative district of Moscow equipped with R65-BP system.

In addition to bulletproof properties, windows, doors and facades must have other important functional characteristics. First of all it is important that the bulletproof structure does not attract intruder’s attention and does not spoil the facade and interior design. Another important factor is that the bulletproof structure performs the functions of a usual translucent structure, such as thermal insulation and functions of opening.

1.2 History overview

Nokian Profiles appeared as an architectural systems’ division of Nordic Aluminium which is the leading manufacturer of aluminum products in Finland nowadays. Nordic Aluminum was an aluminum department of Nokia AB concern which was established in 1966. Since 1990 this department became a separate company and since 1996 its name is Nordic Aluminium. In year 2010 Nokian Profiles became a separate company.

Nokian Profiles produce a solid aluminum bulletproof profile system which consists of window, door and fixed facade systems. It could be used for facades, windows, doors and partition walls of public buildings, banks, tribunals and other buildings which are needed to be protected.

R65-BPis a bulletproof profile system for doors and windows developed from the usual old R65 system. R65 was one of the first systems developed at the time of Nokia AB concern. R65-BP system has appeared in Russian market in 1997.

Bulletproof facade system is developed from a widespread R54 facade system. It has the same physical properties like a usual system. Bullet resistance is achieved by adding armor steel plates.

1.3 Architectural properties of aluminum bulletproof profiles

Windows, doors and facades made of aluminum are modern and perspective products. Nowadays architects and builders increasingly use windows, facades and other constructions made of aluminum profiles because of its strength, reliability, durability, resistance to external influences and lightness.

High rigidity and high load capacity of bulletproof profiles makes it possible to produce large-size products with the size of leafs up to 2000(height)x1200 mm.

The service life of aluminum is over 80 years. All fittings, rubber parts could be upgraded or changed during the entire lifetime.

Because of good bullet resistance without weak zones bulletproof windows made of R65-BP profile could be installed in a row. To disguise the building's protection properties or save the architectural meaning of the building it is possible to install bulletproof windows in a second row. In this case exterior windows could be opened through bulletproof windows.

In esthetical mind, products made of R65-BP are almost the same as systems made of usual profiles and usual glazing. It can be anodized as most of aluminum profiles or painted in any color in accordance with RAL universal scale.

Bulletproof profiles R65-BP of 2-5 bulletproof classes do not have internal reinforce steel plates, this means greater strength of cross section and absence problems with the accumulation of moisture inside the profile.

R65 is the only one aluminum bulletproof system which has a balanced weight of the cross section. This allows to use them for the manufacture of structures with high stiffness and high load capacity.

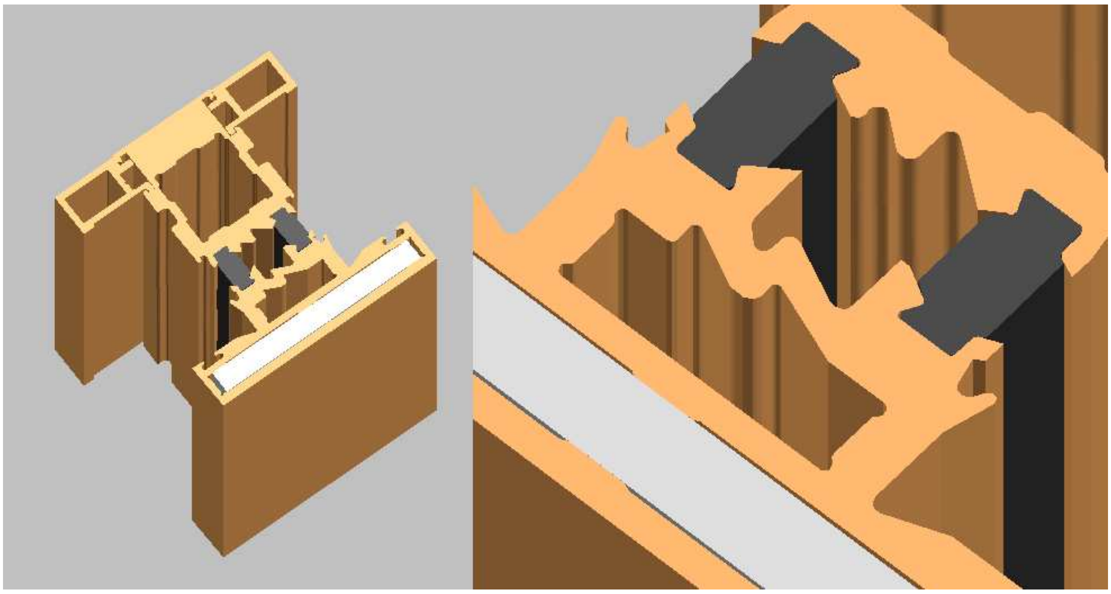


Figure 1.1 General view and cross section of R65-BP frame element

Nokian Profiles has all necessary range of bulletproof profiles for windows, doors and facades including all necessary accessories and unique angle elements.

1.4 Bullet resistance properties

The main feature of bulletproof profiles is a section which could withstand bullets not only because of material thickness and its strength but also because of the special shape of its cross section. The cross section consists of air gaps and partitions which have a zigzag form to make a bullet to change the angle of incidence a little. When a bullet takes a tilted direction its path through a structure becomes longer and the energy of a bullet decreases more effectively. It is much harder to produce such section shape which is made of armor steel because of another production technology. Aluminum has advantages in terms of production of such complex forms because of production technology of aluminum profiles called extrusion. Extrusion is a process of making objects of fixed cross-sectional profile. The material in cold or hot condition is pushed or drawn with special tools which are needed to cut or shape material with pressure.

Bulletproof system is developed from the R65 system and made of AW 6060 alloy. Bulletproof profiles are available in full aluminum versions or steel reinforced versions with armor steel parts. Special bulletproof aluminum system R65BP could provide bullet resistance of large products of all classes of protection at sites of different functionality.

To evaluate the bullet resistance special tests were made according to Russian and European norms. Possible classes are 3, 5, 5a according to GOST R 51112-97, GOST R 50941-96 and classes FB2,FB5 and FB6 according to EN 1522.

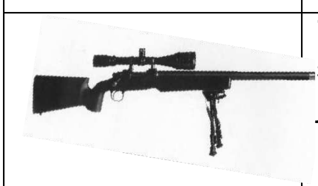
Table 1.1 Possible bulletproof classes according to GOSTs.

Class	Weapon	Test Bullet	Bullet weight	Bullet speed	Test range
3	 AK74	5,45 mm, steel, non heat-treated	3,4 g	890-910 m/s	5-10 m
	 AKM	7,62 mm, steel, non heat-treated	7,9 g	710-740 m/s	5-10 m
5	 Dragunov Sniper Rifle	7,62 mm, steel, non heat-treated (57-H-323C)	9,6 g	820-840 m/s	5-10 m
	 AKM	7,62 mm, steel, heat-treated	7,9 g	710-740 m/s	5-10 m

5a	 AKM	7,62 mm, special (57-Б3-231)	7,4 g	720-750 m/s	5-10 m
6a	 Dragunov Sniper Rifle	7,62 mm, special (7-Б3-3)	10,4 g	800-835 m/s	5-10 m

Bulletproof profiles R65-BP has received a Certificate of Compliance which confirms accordance to GOST R 51112-97, GOST R 51072-97 and GOST R 50941-96. It means that during ballistic test bullets did not break through any part of the structure.

Table1.2 Possible bulletproof classes according to UNI EN 1522.

Class	Weapon	Test Bullet	Bullet weight	Bullet speed	Test range
FB2	 Handgun	9 x 19 mm Luger, steel jacketed/round nose/soft core	8,0 g	390-410 m/s	4,5-5,5 m
FB5	 Rifle	5.56 x 45 mm, copper alloy jacketed/pointed bullet/soft core steel penetrator	4,0 g	940-960 m/s	9,5-10,5 m
FB6	 Rifle	5.56 x 45 mm, copper alloy jacketed/pointed bullet/soft core steel penetrator	4,0 g	940-960 m/s	9,5-10,5 m
	 Rifle	7,62 x 51 mm, steel jacketed/pointed bullet/soft core	9,5 g	820-840 m/s	9,5-20,5 m

Bulletproof profile R65-BP has received a Certificate of Compliance which confirms accordance to GOST R 51112-97, GOST R 51072-97 and GOST R 50941-96. It means that during ballistic test bullets did not break through any part of the structure.

Bulletproof profile R65-BP has received high marks and recommendations for technical strengthening of cashier booths and operational barriers in the biggest Russian bank Sberbank of Russia.

Special bulletproof glazing which is used with bulletproof profiles made with all of following technological processes: glass tempering, tempered glass connection between them using a special polymer composition and coating the material with special protective membrane. Protection degree depends on material thickness. For example material thickness about 20 mm provides protection against pistol bullets of small calibers and a thickness of 40 mm could protect against machine gun bullets. Glazing must have the same class of bullet resistance, as well as a profile with which it applies.

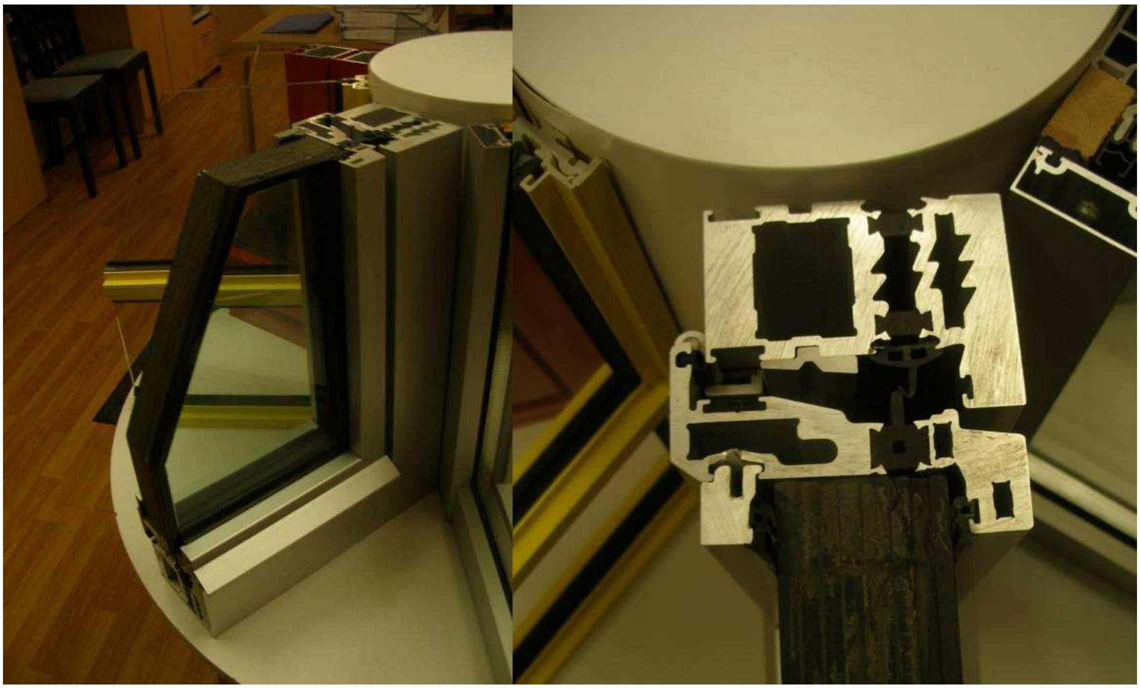


Figure 1.3 General view and cross section of R65-BP structure with glass.

2 DEFINITIONS

Alloy – a metallic solid solution composed of two or more elements. Alloying a metal is done by combining it with one or more other metals or non-metals that often enhances its properties.

Armor steel – is alloyed steel for the manufacture of armor protection of military facilities. Also applies to technical needs. Armor steel plates subjected to special thermal or chemical treatment to make them harder and tougher.

Bullet resistance – properties expressed in bullet resistance class which is revealed through shooting tests.

Bulletproof glazing – a translucent product composed of many layers which can withstand a hand grenade fragment, or to withstand bullets from a firearm. This type of glass is used for glazing windows, doors, facades, partitions and cabins. Specially crafted billets of glass are used in manufacturing process of this type of glass. Thickness of each glass billet is 5-10 mm, they are glued together in a certain sequence.

Curtain wall – an outer covering of a building in which the outer walls are non-structural, but merely keep out the weather. As the curtain wall is non-structural it can be made of a lightweight material reducing construction costs. When glass is used as the curtain wall, a great advantage is that natural light can penetrate deeper within the building. The curtain wall facade does not carry any dead load weight from the building other than its own dead load weight. The wall transfers horizontal wind loads that are incident upon it to the main building structure through connections at floors or columns of the building. A curtain wall is designed to resist air and water infiltration, sway induced by wind and seismic forces acting on the building, and its own dead load weight forces.

Full Metal Jacket (FMJ) – is a bullet consisting of a soft core encased in a shell of harder metal, such as gilding metal, cupronickel or less commonly a steel alloy.

Impost – vertical or horizontal fixed part of window used in windows with many leafs to increase stiffness and to separate glazing.

Installation depth – a deep dimension which is taken by setting window in window opening. Installation depth measured between the closest point on a window frame and the farthest point of frame.

Insulated Glass Unit (IGU) – a translucent structure made of two or more glasses fastened together in order: glass – gas – glass – etc. Its purpose as replacement of glass is to improve such characteristic as thermal resistance of window.

Insulated profiles – are profiles with insulating thermal insert. They are used in constructions for heating residential and commercial facilities.

Muzzle energy – the kinetic energy of a bullet as it is expelled from the muzzle of a firearm. It is often used as a rough indication of the destructive potential of a given firearm or load. The heavier the bullet and the faster it moves, the higher its muzzle energy and the more damage it will do.

Natural frequency – the frequency with which a system oscillates in the absence of external forces; or, for a system with more than one degree of freedom, the frequency of one of the normal modes of vibration.

Not insulated «cold» profiles – are profiles without insulating thermal insert. They are mostly used in constructions for unheated facilities.

Specific energy – is the energy per unit mass or per unit of cross-section area of bullet.

Stiffness – the resistance of an elastic body to deformation by an applied force along a given degree of freedom when a set of loading points and boundary conditions are prescribed on the elastic body. It is an extensive material property.

Thermal insulation – is an element of construction that reduces heat transfer. Thermal insulation element usually called thermal insert or thermal brake. Usually it is made of nylon, polystyrene or ethylene propylene diene monomer rubber. Aluminum has high thermal conductivity that is why manufacturers produce two types of profiles that have different areas application. They are insulated «warm» profiles and not insulated «cold» profiles.

Window fittings – are metal movable and stationary elements of window which are needed to provide the connection between frame and sash, as well as to provide a tight contact between sash and frame. Fittings are tools which hang doors and leafs. Fittings are locks for locking the window or door, window or door handles.

3 COMPETITIVE SITUATION IN BULLETPROOF PRODUCTS IN RUSSIA

3.1 Introduction

The aim of research is to describe the market situation in bulletproof window, door and facade systems, estimate the competitiveness of Nokian Bulletproof profile system in Russian market and analysis of factors affecting the competitiveness of Nokian Bulletproof profile system. To evaluate the competitiveness of this product a wide range of issues must be solved. The main target is to obtain objective information about companies that sell bulletproof windows and doors in Russian market and their products.

Product competitiveness – is relative characteristic of product which reflects contrast to the competitor products. Competitiveness is determined with the degree of conformity to the same social needs and costs to satisfy these needs.

Cost means the price of consumption including buyers costs associated with purchasing a product and all expenses incurred in its consumption or use.

Competitiveness of the product is characterized by three groups of indicators:

- Utility (the quality and effect of using)
- Determining costs for consumers while satisfying their needs with the product (the cost of acquisition, use, maintenance, repair, recycling)
- Competitiveness of proposals (way to promote products to the market, conditions of delivery and payment, distribution channels)

3.2 Monitoring of competitive companies

Nowadays there is a huge industry which produces special bulletproof structures. The most common and popular structures are cash register units, cab guards, bullet-proof windows, burglary window special constructions, currency exchange offices and doors. Production of such structures usually is a chain of manufacturing steps and transport links. Usually there are several companies involved in this process. Basically they are raw material supplier, profile designer, profile elements manufacturer, profiles producer, glazing producer, manufacturer of ready-made constructions and installation companies. There are also other companies which in different degrees are taking a part in this process, for example logistics and promotion companies.

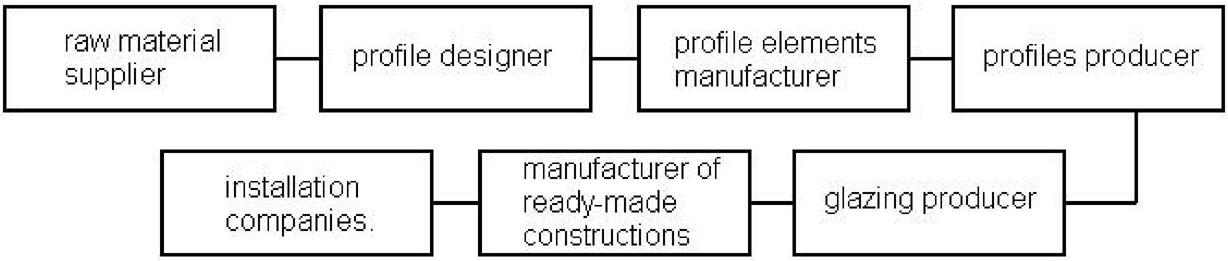


Figure 3.1 Production chain

In case of Nokian Profiles two of these stages are carried out. Nokian Profiles develops and produces their own structures. Details for these profiles are made to order and strictly according to specifications and requirements of Nokian Profiles. Generally it is illustrated in figure.

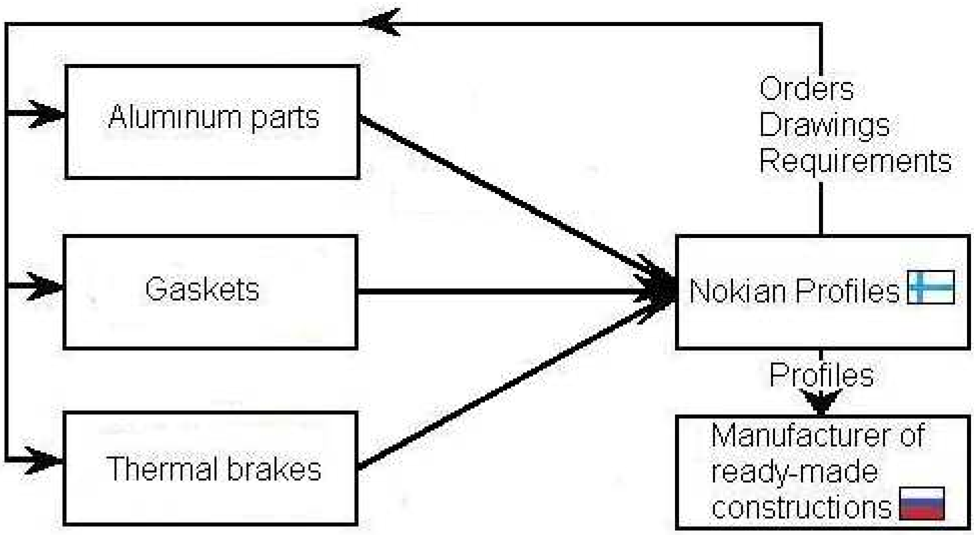


Figure 3.2 Nokian Profiles production scheme.

While amount of valuable and protected objects in Russia is rising demand of bulletproof constructions is growing. At the same time the number of brands and companies that offer such kind of products is also increasing. Here are some other biggest companies which bulletproof profile systems presented in Russian building market: Schuco International (Germany), Ginko (Italy), Geka exclusive (Germany), Reynaers (Belgium), Sapa (Sweden), Stalprofil (Sweden), Plafen

(Russia), Anton Wetzel (Germany), Unilux AG (Germany), Purso (Finland), Forster (Germany) and smaller companies. Of course among them there is a very tough competition. One of the main differences between the competitors is the quality, range of equipment and technology.

To assess market conditions and differences between competitors a review of companies should be made. Review begins with the most widespread brand Schuco International.

3.3 Analysis of competitors

Study of market conditions is a basis for evaluating the competitiveness of a product. Therefore, the problem is to determine the group of factors that influence the demand in a Russian bulletproof market.

The competitiveness of companies that sell bulletproof profiles in Russian market mostly depends on following factors: bulletproof properties, installation depth, thermal insulation, work experience and reputation in a Russian market, time of delivery and price.

To assess market conditions and differences between competitors a review of companies should be made. Review begins with most widespread brand Schuco International.

Schuco is the European leader in the production of aluminum profiles. Schuco International KG was founded in 1951 in Bielefield city in Germany. Schuco has grown from a very small company to a universal corporation with annual sales of funds of more than 2 billion EUR. Turnover for the year 2010 in the world is 2.35 billion EUR.The company operates in 75 countries around the world. The company has 5,000 employees all over the world. The company has offices in Moscow and representative offices in 9 other cities in Russia.

Schuco company proposed the principle of unity of supply aluminum profiles of different nomenclature, components, materials and equipment for manufacturing and assembling structures. Schuco produces fittings in accordance with their internal standards. Such fittings differ from the standard of Euro fittings and these systems cannot be used in combination with the profiles of other manufacturers. For example the whole Variotec series could be used only with Schuco profiles. Schuco claims that their hardware which is different from the standard Euro fittings are much more reliable. But among Russian companies, there are reports of specific hardware faults of Schuco fittings. Other flaws made by technology of Schuco International, is the high cost of equipment and components, which leads to high cost of the finished product. In addition, delivery of profiles and components, which are not produced in Russia, but in Germany is made within 2 - 3 weeks, which leads to an increase in terms of manufacturing orders and the negative impact on the clientele.

Schuco company produces and supplies to the Russian market bulletproof structures for windows, doors and facades. For manufacture of bulletproof windows and doors company produces S 70 DH aluminum profiles and FW50+, FW60+ for facades.

S 70 DH is the main bulletproof Schuco system. S 70 DH profiles are thermally insulated. Possible burglar resistance classes are WK1, WK2 and WK3. Possible bullet resistance classes are FB4 and FB6 for windows and FB6 for doorsin accordance with EN 1522-1. Installation depth for windows with FB4 class is 82-92mm. Installation depth for windows and doors with FB6 class is 110-130mm. Possible types of opening are turning, turning and tilting.

FW50+ and FW60+ is a usual facade profile system which is used in normal constructions. But the manufacturer also claims that these systems may be used to provide FB4 class bullet resistance of the facade.

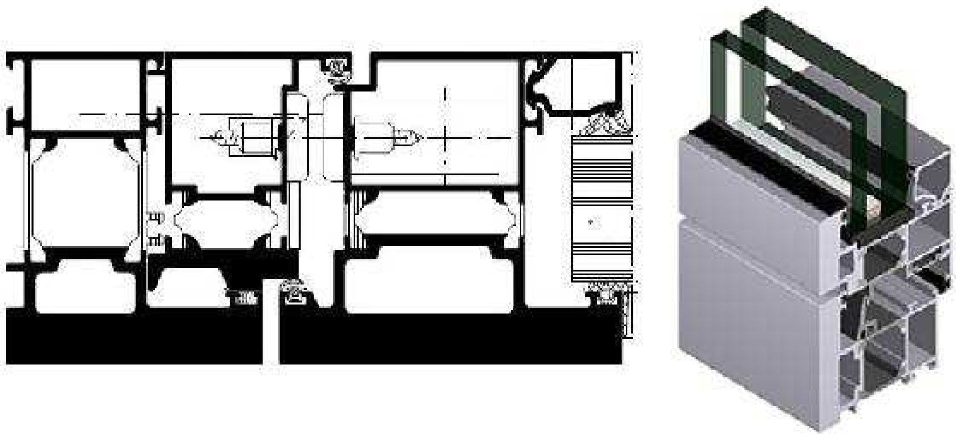


Figure 3.3 Schuco R70 DH system

Table 3.1 Schuco bulletproof system range.

Purpose	Name	Material	Bulletproof classes	Thermal insulation	Install depth (mm)	Visible width (mm)
Windows	Royal S 70 DH	Aluminum	FB4, FB6	Insulated (U_f>2.8W/m^{2}K)	82-92, 110-130	>117
Doors	Royal S 70 DH	Aluminum	FB6	Insulated (U_f>2.8W/m^{2}K)	110-130	>144
Facades	FW50+ (FW60+)	Aluminum	FB4	Insulated (U_f>1.82W/m^{2}K)	-	>50

Reynaers company was founded in year 1965 in Duffel city in Belgium. Reynaers company has offices in more than 30 countries in Europe. Reynaers covers most of Europe, Asia, Middle East and Africa. Annual turnover of the company currently is more than 300 million Euro. Reynaers company has a representative offices in Russia. These offices are situated in Moskow and Ekaterinburg. Reynaers also have representatives in 7 other regions of Russia. Reynaers concern sells its products in Russia for the past eight years. Company also manufactures equipment for setup, software for structural analysis. Reynaersaluminiumrus offers a full range of Reynaers products including CS 77-BP system.

CS 77-BP is a bulletproof aluminum profile system for windows and doors. This system is based on CS 77 system. Needed bullet resistance is provided by adding steel plates in one or more layers. Possible bulletproof classes are FB4 and FB6 in accordance with EN 1522-1. Possible burglar resistance class is WK2. Installation depth for windows and doors with FB4 and FB6 classes is 106mm. Types of opening are turning, turning and tilting windows.

CS 77 is thermally insulated. Its U-value depends on the combination of frame and sash. Lowest possible U-value of this system is 1,93 W/m^{2}K. Sound protection is R_w<42dB.

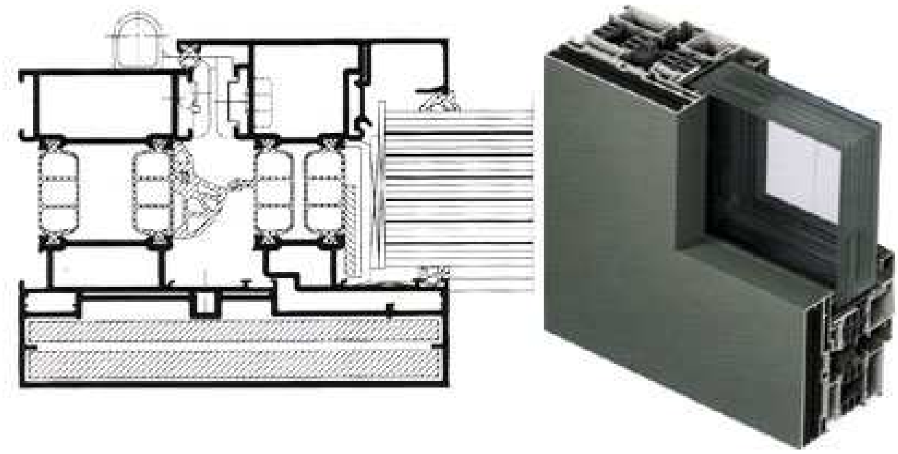


Figure 3.4 Section and general view of CS 77-BP system

Table 3.2 Reynaers bulletproof system range

Purpose	Name	Material	Bulletproof classes	Thermal insulation	Install depth (mm)	Visible width (mm)
Windows	CS 77-BP	Aluminum	FB4, FB6	Insulated (U_f>1.93W/m^{2}K)	106	>128
Doors	CS 77-BP	Aluminum	FB4, FB6	Insulated (U_f>1.93W/m^{2}K)	106	>159
Facades	-	-	-	-	-	-

SAPA AB was founded in year 1963 in Vetland, Sweden. Nowadays it has over 13.000 employees all over the world. SAPA profiles produce aluminum systems for doors, windows, facades and skylights. SAPA is one of the four largest suppliers of building systems based on aluminum profiles in Europe. But in Russian market SAPA profiles is not very popular. In Russian window industry this brand is much rarer than other European biggest aluminum profile producers like Schuco and Raynaers. SAPA closed its representative office in Russia in late march 2011 because of economical reasons.

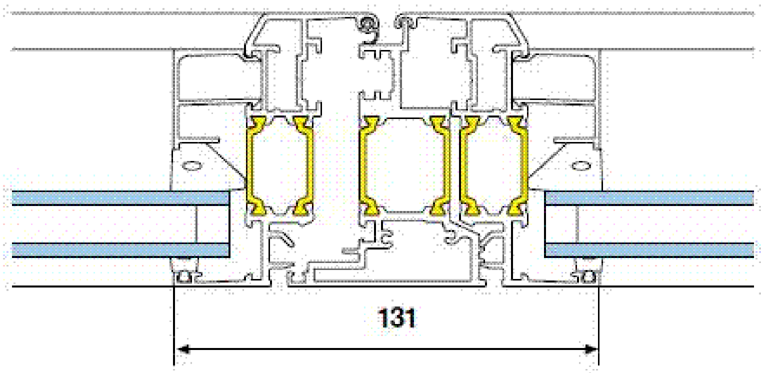
SAPA aluminum window profile 1074, SAPA aluminum door profiles 2060 and 2074 are usual systems which could be reinforced with armor steel plates. The main feature of these profile systems is that it is not needed to make some changes in the shape of the cross section to reinforce the profile with armor steel plates, The form of the basic profile section has special grooves to put there steel plates if it is needed.

Window profile 1074 is thermally insulated. Reinforced SAPA window profile 1074 could provide bullet resistance of FB2, FB3 and FB4 classes according to DIN EN 1522. Installation depth is 74 mm. The value of installation depth does not depend on classes of bullet resistance. Only fixed or inward opening windows are possible.

Door profile 2060 is a cold profile which could provide FB2, FB3, FB4 and FB6 bulletproof classes according to DIN EN 1522. Installation depth is 60 mm.

Door profile 2074 is thermally insulated profile which could provide FB2, FB3 and FB4 classes according to DIN EN 1522. Installation depth is 74 mm.

Window and door insulated profile system without reinforce steel plate could provide U_f>2,5W/m^{2}K.



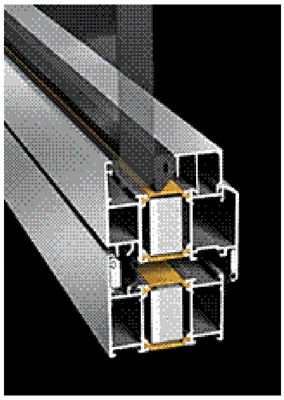


Figure 3.6 Section and general view of SAPA 1075 system which could be reinforced with steel plates.

Table 3.4 SAPA bulletproof system range

Purpose	Name	Material	Bulletproof classes	Thermal insulation	Install depth (mm)	Visible width (mm)
Windows	1074	Aluminum+ Steel	FB2-FB4	Insulated (U_f>2,5W/m^{2}K)	74	100
Doors	2060	Aluminum+ Steel	FB2-FB6	not Insulated	60	153
Doors	2074	Aluminum+ Steel	FB2-FB4	Insulated (U_f>2,5W/m^{2}K)	74	139
Facades	-	-	-	-	-	

Stalprofil AB is a Swedish company established in year 1987. Stalprofil produces profile systems made of stainless steel. Stalprofil has a few profile systems which could be reinforced with armor steel parts. They are SP 56500 with thermal brake, SP 35000 without thermal brake (so called cold profile) and SP 76500 (fire insulated profile).

Reinforced SP 56500 profiles could provide C1, C2, C3, C4, C5 bulletproof classes according to DIN 52290 which is equal to FB2, FB3, FB4, FB6, FB7 according to current Euro standard EN 1522. Installation depth for windows and doors with FB4 and FB6 classes is 65mm. Burglar resistance class is WK2.

This profile could be used for doors and windows

SP 56500 profiles are thermally insulated. The lowest possible U-value isU_f=2,9W/m^{2}K. Sound protection is R_w<39dB.

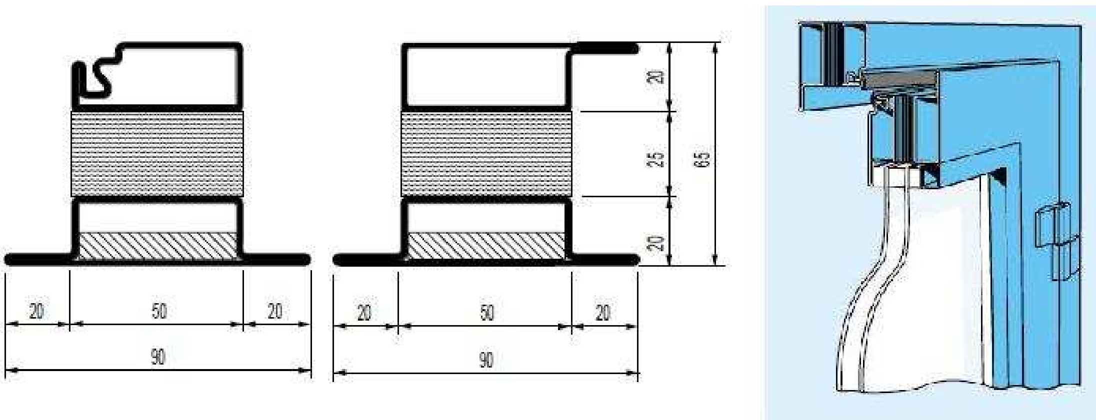


Figure 3.5 Section and general view of Stalprofil 56500 system

Table 3.3 Stalprofil bulletproof system range

Purpose	Name	Material	Bulletproof	Thermal	Install-	Visible

			classes	insulation	depth (mm)	width (mm)
Windows	SP 56500	Steel	FB2-FB7	Insulated (U_f>3.7W/m^{2}K)	65	130
Doors	SP 56500	Steel	FB2-FB7	Insulated (U_f>3.7W/m^{2}K)	65	130
Facades	-	-	-	-	-	-

Ginko is an Italian company which provides aluminum bulletproof windows and doors. Ginko windows are not very common in Russia, there is only one company in Russia which sells their structures. Ginko manufactures the whole windows, not only the profiles. But the technical decisions of their bulletproof system should be considered.

Ginko has a bulletproof Atena 110 window system which is reinforced with steel plates. It could provide FB6 class of bullet resistance. The technical decisions of GinkoAtena 110 system you can see in the figure 3.6

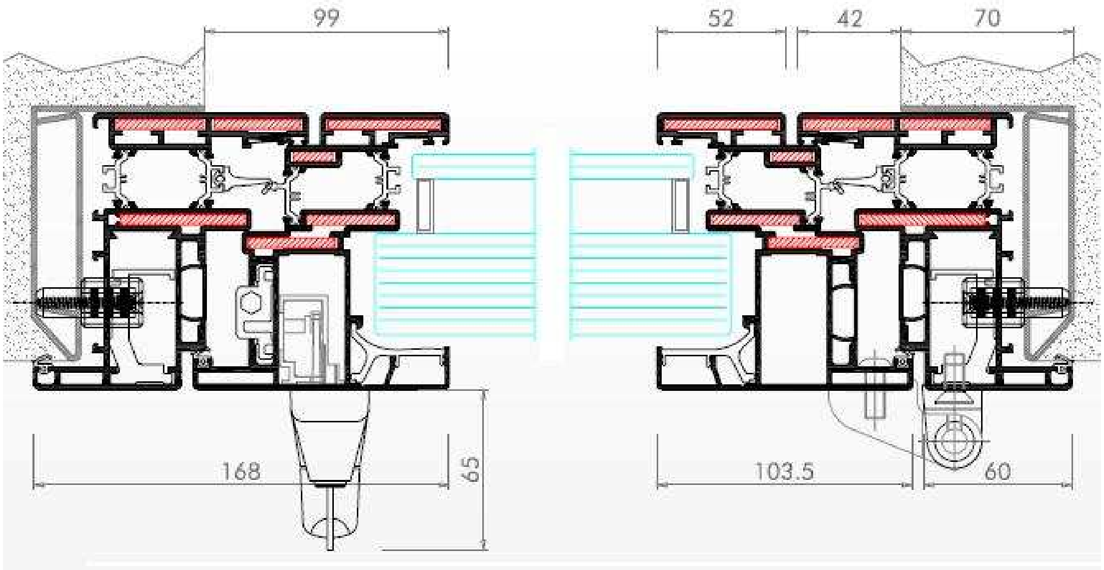


Figure 3.6 The section of Atena 110 openable window

Another less known manufacturer in Russia of bulletproof steel profiles is Forster. Forster is one of the leading manufacturer of steel profiles in Europe. Forster has representative offices in Russia, most of European countries, North America and Australia. Profiles are manufactured in a headquarters in Switzerland. Forster was founded in year 1874 in Arbon, Switzerland. But the production of its main thermally-insulated profile system Unico started only in year 2007.

Forster systems are little known in Russian market nowadays. The company started its operations in Russia in 2006. Forster Unico system for doors and windows and Forster thermfix system for facades could provide FB4 class of bullet resistance. Installation depth of Unico system is 90 mm. The lowest possible U-value isU_f=1,9W/m^2K. Sound protection is R_w<42dB.

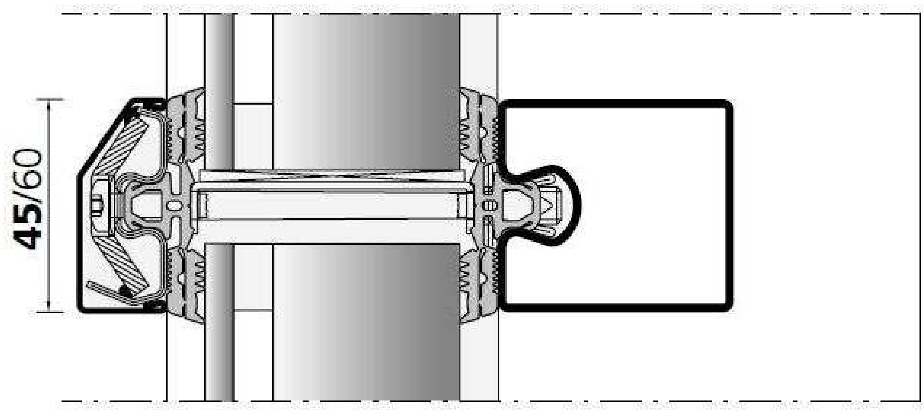


Figure 3.7 Forster thermfix bulletproof facade system

Bulletproof window constructions made of wood are also represented in Russian market. Bulletproof wooden structures are classified as luxury and oriented on other customers, in contrast to all previous systems reviewed.

Most common wooden bulletproof windows on Russian market are made by Gekaexclusiv and Unilux companies.

Gekaexclusiv bulletproof system is made of wood and reinforced with steel plates. It could provide the bullet resistance of FB6.

Unilux could provide till a limited level bulletproof glazing, but their wood and wood-aluminium systems are not bulletproof.

3.4 Assessment of competitiveness

Assessment of product’s competitiveness is made by comparison of production parameters with the parameters of a basis for comparison. Competitiveness of the product is a relative term. It could be measured only by comparison with another product.

The competitiveness of products is approximately evaluated to show plusses and minuses of each system and to find best competitors.

Analysis of the competitiveness of products depends on the chosen method of evaluation. To assess the competitiveness of Nokian bulletproof system the mixed method of analysis is used. Mixed method allows to express the ability of the product to compete in certain market conditions with the help of a comprehensive quantitive indicator which name is the factor of competitiveness. The factor of competitiveness can be calculated with the formula (3.1)

$$C_j = \sum_{ij=1}^{n} L_i \times \left(\frac{P_{ij}}{P_{in}}\right)^{\beta_i} \qquad (3.1)$$

C_j– is competitiveness factor;

i=1,…,n – is a number of product parameters;

j=1,…,n – is a number of production type;

L_i – is a factor of importance in comparison with other product characteristics;

P_{ij} – is a competitive value of the i-th parameter for the j-th production type;

P_{in} – is a best value of the i-th parameter, which could fulfill needs of this parameter.

β_i=+1 if increasing of parameter P_{ij} leads to increasing of competitiveness of the product. For example: thermal resistance or bulletproof properties.

β_i=-1 if increasing of parameter P_{ij} leads to decreasing of competitiveness of the product. For example: price, U-value or Installation depth.

Using the formula (3.1), the competitiveness of product can be described in relation to other products. A table of comparing parameters is used in comparison of the production. The result of comparison with mixed method is a conclusion of the competitiveness of the production. The conclusion is complemented with assessment of advantages and disadvantages of the production in comparison with analogues and possible actions that should be done to improve the situation in Russian market.

The object of investigation is Nokian Profiles bulletproof profile system R65-BP.

Nokian Profiles Bulletproof system has R65 Bulletproof system for windows, doors and facades. Bulletproof system R65 was presented in Russian bulletproof market since year 1997 and it has a good reputation among Russian manufacturers of bulletproof constructions.

Table 3.5 Nokian Profiles bulletproof system range

Purpose	Name	Material	Bulletproof classes	Thermal insulation	Install depth (mm)	Visible width (mm)
Windows	R65-BP	Aluminum, Alu+Steel	FB2, FB4, FB6, FB7	Insulated (U_f>2.6W/m^{2}K)	116	>113
Doors	R65-BP	Aluminum, Alu+Steel	FB2, FB4, FB6	Insulated (U_f>2.6W/m^{2}K)	116	>136
Facades	R54	Aluminum+ Steel	FB2, FB4, FB6	Insulated (U_f>2.6W/m^{2}K)	-	>50

There is no sense to analyze the competitiveness of each company. The main task of this section is to assess competitiveness of Nokian Profiles Bulletproof systems in comparison with most famous companies that offer similar products in Russian market. They are Schuco, Reynaers,SAPA and Stalprofil.

To evaluate the competitiveness the table of factors is done below. Each factor for each company is expressed in points from 0 to 5. Evaluation of each factor is based on analysis of competitors which was made in article 3.3. In evaluation of competitiveness are considered such factors as variety of bulletproof classes, design and technical solutions, range of bulletproof systems, thermal insulation, costs and popularity.

Variety of bulletproof classes of Nokian profiles, Stalprofil evaluated as best.Reynaers and Schuco profiles get 4 because they could provide only FB4 and FB6 classes. Sapa profiles get 2 because only cold door system could provide FB6 class.

Nokian has the best technical solutions because of zigzag shape cross section elements. Reynaers get 4 because of special profile which could be reinforced with different amount of steel plates. Shico get 3 because its bulletproof properties are reached only because of aluminum mass. Sapa and Stalprofil get 1 because their profiles are not designed only for bulletproof structures, they could be only reinforced with steel plates. Because of it Sapa and Stalprofil profiles have a lot of weak places.

Companies with window, door and facade systems get 4. Companies with only door and window systems get 2.

Thermal insulation evaluated according to information described in article 3.3

Popularity is evaluated approximately according to amount of customers and sellers.

Architectural properties are evaluated according to visible widths and installation depths which are given in article 3.3. The values are given for inward openable windows, doors and normal facade systems.

Table 3.5 Comparison factors

	Variety of BP classes	Technical solutions	Range of bulletproof systems	Thermal insulation	Popularity and prevalence	Archi-tectural proper ties
Nokian Profiles	5	5	4	2	2	4
Schuco	4	3	4	2	5	4
Reynaers	4	4	2	5	4	4
SAPA	2	1	2	2	0	5
Stalprofil	5	1	2	0	2	4

The most important factors are variety of bulletproof classes, technical solutions and range of bulletproof systems. They are specific for bulletproof structures Most important factors are accounted with L_i=1.2 importance factor.

The other factors are specific for all translucent structures and accounted with L_i=1.0 importance factor.

Table 3.6 Comparison of competitiveness factors

	NokianProfiles	Reynaers	Schuco	Stalprofil	SAPA
C	5.36	5	4.84	3.12	2.6

4 Possible affect of Russian norms concerned to R65-BP system.

4.1 Relations between Russian standards and European standards.

It is important to assess the degree of difference between European standards and similar Russian standards to show possible affect of these standards to design of profiles. The current regulatory construction database of Russian Federation provides full security and reliability of constructions which were built and designed in accordance with it. During last two decades there was no development and upgrade of Russian regulatory construction database. That is why this database is obsolete in terms of materials and technology. But in terms of planning it has not affected the quality of design. Design quality has been confirmed by construction practice for a 20 years period.

Bulletproof R65-BP system was made in accordance with European standards, most important of which are EN 1990 Basics of structural design and EN 1991 Actions on structures. The most used parts of EN 1991 are EN 1991-1-1 Densities, self-weight, imposed loads for buildings, EN 1991-1-3 Snow loads and EN 1991-1-4 Wind actions. Classes for bullet resistance determined in accordance with old standard DIN EN 52290, which was replaced in year 1998 by UNI EN 1522:2000 Bullet Resistance. Comparison of these standards will be also given in this article.

The table 4.1 of correspondence standards, which are most often used in design of profiles, is showed below.

Table 4.1 Relations between EN and Russian standards.

Eurocode number	Eurocode name	GOST, SNiP number	GOST, SNiP name
EN 1990	Basics of structural design	GOST 27751-87 SNiP 2.01.07-85*: Article 1	Reliability of building structures and bases. Basics of calculations Loads and effects 1 General provisions. Classification of loads, Load combinations
EN 1991-1-1	Densities, self-weight, imposed	SNiP 2.01.07-85*:	Loads and effects: 1 General provisions.

	loads for buildings	Article 1 Article 2 Article 3	Classification of loads, Load combinations 2 Construction and ground weight 3 Loads of equipment, people, animals, stored materials
EN 1991-1-3	Snow loads	SNiP 2.01.07-85*: Article 5	Loads and effects: 5 Snow loads
EN 1991-1-4	Wind actions	SNiP 2.01.07-85*: Article 6	Loads and effects: 6 Wind loads
EN 1999	Design of Aluminum Structures	SNiP 2.03.06-85	Aluminum Structures
UNI EN 1522	Bullet Resistance	GOST R 50941-96 GOST R 51112-97 GOST R 51072-97	Protective cab Requirements for bullet resistance and test methods Protective doors

Substantial package of SNiPs and GOSTs for design various types of constructions is a direct analog of Eurocodes. It should be noticed that methods of calculation of building structures with limit states method have been taken in Russian construction norms before they were included in Eurocodes.

The first of July of 2010 a new law, Technical Regulations on the Safety of Buildings and Structures, began to operate. Technical Regulations on the Safety of Buildings and Structures requires the fulfillment of standards included in a special list of regulations approved by Government of Russian Federation All of above mentioned SNiPs and GOSTs were included in this list. Technical Regulations also determines the timing of updating of these regulations. According to Technical Regulations, all of mentioned standards must be updated before the first of July of 2012.

4.2 Analysis of differences between standards concerned to windows and facades

4.2.1 Differences in basis of structural design

4.2.1.1 General provisions

EN 1990 determines the basis of design. It contains principles for carrying capacity, usability and durability of load-bearing structures. These principles are based on principles of limit states with using partial coefficients of reliability.

GOST 27751-87 is an analogue of EN 1990. GOST 27751 sets common rules for the calculation of any building structures based on principle of limit states. It consists of following articles: Basis of calculation, normative and design values of strength and other characteristics of materials and soils, normative and design values of loads, accounting of work environment, accounting of liability of buildings and structures.

4.2.1.2 Requirements

In contrast to EN 1990, GOST 257751 do not indicate design working life of buildings and construction elements. GOST 257751 sets levels of responsibility of buildings. To take the responsibility of buildings into account, all buildings are divided into 3 groups: I-increased level of responsibility, II-normal level of responsibility and III-reduced level of responsibility.

Increased level of responsibility is set for buildings' failures of which can lead to serious economical, social and environmental damages. Such buildings are: tanks for petroleum with capacity of 10000 m3 or more, pipelines, industrial buildings with span of 100 m or more and unique buildings and structures.

Normal level of responsibility is set for typical widely used structures. They are: residential, public, industrial, agricultural buildings and structures.

Reduced level of responsibility is set for auxiliary structures and temporary buildings.

The factor of reliability and responsibility γ_d needs to be included in calculation of load-bearing structures. Internal forces and displacements which are caused by loads and impacts must be multiplied by the factor of reliability. γ_d depends on the level of responsibility of the structure. Increased level of responsibility corresponds with γ_d=0,95…1,2. Normal level of responsibility corresponds with γ_d=0,95.Reduced level of responsibility corresponds with γ_d=0,8…0,95.

Degree of durability is not normalized. There is a classification of design working life in SNiP II-A.3-62 The Classification of Buildings and Structures. Key Provisions of the Design document. This standard has been canceled.

4.2.1.3 Principles of limit states design

The same as in EN 1990, in accordance with GOST 257751 constructions are calculated by the method of limit states. Limit states are divided into two groups. They are ultimate limit states and serviceability limit states. Definition and composition of these groups are absolutely the same.

GOST 257751 sets following design situations: persistent design situations, transient design situations and accidental design situations. GOST 257751 does not contain seismic design situations, unlike EN 1990.

4.2.1.4 Actions and environmental influence

GOST 257751 has the same classification of actions like in EN 1990.

The same as in EN 1990, the main characteristics of actions are their characteristic values.

In accordance with GOST 257751, characteristic value of own weight of construction is defined by design values of structural and geometric parameters and information about densities provided by manufacturer.

Characteristic value of wind loads, snow loads and other atmospheric loads must be defined as highest annual values in accordance with article 5 and article 6 of SNiP 2.01.07-85.

Characteristic value of technological static loads is caused by hardware, equipment, materials and people defined as maximum expected values for intended conditions of manufacturing in accordance with article 3 SNiP 2.01.07-85. This article contains characteristic values of technological and static loads which depend on type of the building or placement. It also contains partial factors γ_f for different types of equipment.

Characteristic value of technological dynamic loads is caused by moving mechanisms, machines and vehicles defined with values of parameters determining dynamic loads or values of the mass and geometric dimensions of the moving mechanism or machine part. Dynamic loads are caused by cranes defined in accordance with article 4 of SNiP 2.01.07-85.

Characteristic value of seismic and explosive impacts must be defined by special SNiPs. They are SNiP 11-7-81 Construction in Seismic Zones and SNiPII-11-77 Protective Structures of Civil Defense.

Worst possible deviations of the loads because of variability of loadings or deviation from normal operating conditions accounted are taken into account by load partial factor γ_f. The value of γ_f may be different for different limit states and various design situations.

SNiP 2.01.07-85 sets that fatigue actions and environmental influences are taken into account by working conditions factor γ_d. For example, γ_d for aluminum constructions can be found in accordance with table 15 of SNiP 2.03.06-85 Aluminum constructions.

4.2.1.5 Calculations of actions

General provisions of calculations in Russian standards are the same as in EN 1990. The main features of SNiP 2.01.07-85 are combinations of actions and safety factors.

Design value of the load F must be defined as the multiplication of its characteristic value by partial factor for a load γ_f. Load partial factors are taken from SNiP 2.01.07-85.

Design value of material characteristics X must be defined as a characteristic value divided by material reliability factor γ_m>1. It depends on material class and is given by manufacturer.

Design resistance R of the material is defined as characteristic resistance R_n divided on material reliability factor $\gamma_{m.}$

All actions are divided in permanent actions, variable long-time actions, short time actions and accidental actions.

Permanent and accidental actions have the same definition as in EN 1990.

Variable long-time actions are weight of temporal partition walls, weight of fixed equipment including liquids and materials they are filled with, liquids' and gases' pressure, stored materials, loads of people and animals taken with a low characteristic values, loads of cranes of 4K-8K mode of operation, temperature and climate actions taken with a low characteristic, snow design loads taken with low values by multiplied with 0,5 factor characteristic values, dust and water on surfaces.

Variable short-time actions are actions of transported or tested machinery, weight of people and materials caused by repairing, full characteristic loads of people and animals except big halls with large crowd of people, full characteristic loads of cranes, full characteristic snow load, wind loads, ice loads and full characteristic temperature and climate loads.

According to SNiP 2.01.07-85 there are two combinations of actions: basic combinations and special combinations. The basic combination consists of permanent actions, variable long-time actions and short-time actions. The special combination consists of permanent actions, variable long-time actions and short-time actions and one of accidental actions.

In case of calculations including permanent and at least two variable loads, design values of variable loads must be multiplied by combination factor for variable long-time actions ψ_1 and for variable short-time actions ψ_2. In basic combinations ψ_1=0,95, ψ_2=0,9. In special combinations ψ_1=0,95, ψ_2=0,8 and accidental actions are taken into account without combination factor.

In case of calculations including permanent and one variable load, combination factors are not used. One variable load is a load of one source or few sources if their actions are combined together in characteristic or design values

4.2.2 Ultimate limit states

Aluminum structures must be designed so that the basic design requirements for ultimate limit states are satisfied. Basic design requirements contained in EN 1999-1-1 Design of Aluminum Structures: General Rules and its Russian analog SNiP 2.03.06-85 Aluminum Structures.

These two standards have many differences in issues of ultimate limit state design. The fundamental difference is that EN 1999-1-1 divides all structures in four groups, depending on the type of the cross-section.

Class 1 cross-sections are those that can form a plastic hinge with the rotation capacity required for plastic analysis without reduction of the resistance.

Class 2 cross-sections are those that can develop their plastic moment resistance, but have limited rotation capacity because of local buckling.

Class 3 cross-sections are those in which the calculated stress in the extreme compression fibre of the aluminum member can reach its proof strength, but local buckling is liable to prevent development of the full plastic moment resistance.

Class 4 cross-sections are those in which local buckling will occur before the attainment of proof stress in one or more part of the cross section.

Aluminum window and facade profiles may relate to 1, 2 and 3 class of cross-sections. More details about class definition are written in article 6.1.4 of EN 1999-1-1.

SNiP 2.03.06-85 sets design values of material resistance for different aluminum classes. Russian standards set their own classes of aluminum which are similar with European classes. Bulletproof profiles are made of aluminum class AW 6060 which is similar with Russian AD31 class. AD31 has design compressive, tensing and tensile strength R=55MPa.

Table 4.2 Calculation of aluminum structures on axial force and bending for the first group of limit states according to EN 1999-1-1 and SNiP 2.03.06-85

EN 1999-1-1	SNiP 2.03.06-85
1 Compressed elements Design value of axial load N_{Ed} shall satisfy: $N_{Ed} \leq N_{Rd}$ (4.1) The design resistance for axial compression N_{Rd} should be taken as the lesser of $N_{u,Rd}$and $N_{c,Rd}$. $N_{u,Rd}=A_{net}f_u/\gamma_{M2}$ (4.2) $N_{c,Rd}=A_{eff}f_0/\gamma_{M1}$ (4.3) In which A_{net} is the net section area, A_{eff} is the effective section area based on reduced thickness allowing for local buckling, γ_{M1}=1,1 γ_{M2}=1,25 are partial safety factors, f_0 is the characteristic value of proof strength,f_u is the characteristic value of the ultimate tensile strength. A_{eff}=A for 1,2 and 3 section classes.	1 Compressed elements Design value of axial load N shall satisfy: $N \leq A_n R \gamma_c$ (4.4) In which A_n is the cross-section area, R is design value of bending, compressive and tensile strength, γ_c is working conditions factor, γ_c=1 for aluminum profiles
2 Bended elements Design of bended elements should be done in accordance with formula: $M_{Ed} \leq M_{Rd}$() The design resistance for axial compression M_{Rd} should be taken as the lesser of $M_{u,Rd}$and $M_{c,Rd}$. $M_{u,Rd}=W_{net}f_u/\gamma_{M2}$ (4.5) $M_{c,Rd}=aW_{el}f_0/\gamma_{M1}$ (4.6) In which W_{el} is elastic modulus of the cross-section, $W_{net}$is elastic modulus of the net section area allowing for holes, a is the shape factor depending on cross-section class according to table 6.4	2 Bended elements Design of bended elements should be done in accordance with formulas: $(M_{max}/W_{n,min}) \leq R \cdot \gamma_c$ (4.7) $\tau = (Q_{max} \cdot S/I \cdot t) \leq R_s \gamma_c$ (4.8) In which $W_{n,min}$ is minimum elastic modulus of the main axis, I is the moment of inertia of the bending axis, S is the static moment of the main axis is a section width of material in a perpendicular direction to the main axis,R_s=0,6R is lateral resistance,
3 Bending and axial force Hollow profiles should satisfy following criteria: $\left(\frac{N_{Ed}}{N_{Rd}}\right)^{\psi} + \left[\left(\frac{M_{yEd}}{M_{yRd}}\right)^{1,7} + \left(\frac{M_{zEd}}{M_{zRd}}\right)^{1,7}\right]^{0,6} \leq$ $\leq 1,00$ (4.9) $N_{Rd}=A_{eff}f_0/\gamma_{M1}$ (4.10) $M_{y,Rd}=a_y W_{y,el} f_0/\gamma_{M1}$ (4.11) $M_{z,Rd}=a_z W_{z,el} f_0/\gamma_{M1}$ (4.12) In which a_y and a_z are shape factors	3 Bending and axial force Profiles with constant cross-section must satisfy following criteria: $\frac{N}{A_n} \pm \frac{M_x}{I_{xn}} y \pm \frac{M_y}{I_{yn}} x \leq R_y \gamma_c$ (4.13) Profiles which bent in one axis can be calculated with formula: $\frac{N}{A_n} \pm \frac{M}{W_{n,min}} \leq R_y \gamma_c$ (4.14) In which x and y is coordinates of the point of the section with respect to its principal axes, A_n is the cross-section

for bending about y and z axis. Shape factors depend on cross-section class according to table 6.4 of EN 1999-1-1.	area. $W_{n,min}$ is minimum elastic modulus of the bending axis.

4.2.3 Usability limit states

The second group of limit states is defined by achievement of ultimate strains of constructions. Ultimate strains of constructions make it difficult for the normal exploitation of constructions.

The main provisions on the calculation of deflections and displacements are same in Russian and European standards. In the calculation of building structures on the deflection and displacements a following rule $f \le f_u$ must be satisfied. It means that deflection of the structure f must not exceed limit deflection f_u defined by standard.

In both standards maximum deflection can be calculated with the formula:

$$\left[\frac{f}{L}\right] = \frac{5}{384}\frac{ql^3}{EI} \qquad (4.15)$$

Limit deflections for curtain walling are defined by EN 13830Curtain Walling. Maximum deflection of one impost per 1 glazing list is L/300 mm and maximum deflection is 15 mm. Limit deflection of one impost of structural glazing is L/200 mm and maximum deflection is 15 mm.

The ultimate strains like limit deflections and limit displacements of load-bearing and envelope structures are defined in article 10 of SNiP 2.01.07-85. But it does not set limit deflections for window or glazed facade structures.

Limit deflections for windows are defined by GOST 23166-99 Windows General Specifications. Limit deflection for window elements is L/300 mm and maximum deflection is 6 mm.

Limit deflections for aluminum imposts are 1/300 mm, in case of IG unit glazing, and 1/200 mm, in case of single glazing in accordance with SNiP 2.03.06-85 Aluminum constructions.

Table 4.3 Comparison of limit deflections

	Windows		Curtain walls	
Standard no.	EN 14351	GOST 23166-99	EN 13830	SNiP 2.03.06-85
Requirements	Not specified	L/300, max 6mm	L/300 (per 1 glass), max 15 mm. L/200 (structural glazing), max 15 mm	L/300 (IGU glazing). L/200 (single glazing)

4.2.4 Snow loads

4.2.4.1 Total design value of snow load

In Europe, snow loads are defined according to EN 1991-1-3 Snow Loads. In Russia, snow loads are defined according to article 5 of SNiP 2.01.07-85. Both standards set two different load arrangements which must be considered. They are undrifted load arrangement and drifted load arrangement.

In contrast to EN 1991-1-3, SNiP 2.01.07-85 does not take into account temperature factor C_t.

In accordance with SNiP 2.01.07-85 total design value of snow load on horizontal projection of the cover must be calculated by the following formula (4.16)

$$S = S_g \cdot \mu \qquad (4.16)$$

$S_g$is a design value of ground snow load. Design value of ground snow load depends on snow region. Snow regions are determined by map 1 of SNiP 2.01.07-85. Saint-Petersburg and Moscow correspond with III snow region, which has S_g=1,8 MPa according to table 4 of SNiP 2.01.07-85.

Shape coefficient μ is a factor of conversion from the ground snow load to the snow load of cover.

4.2.4.2 Environmental factor

Factor μ must be reduced by environmental factor C_e which depends on type of terrain and location of the building in relation to other objects.

Table 5.4 Comparison of environmental factor

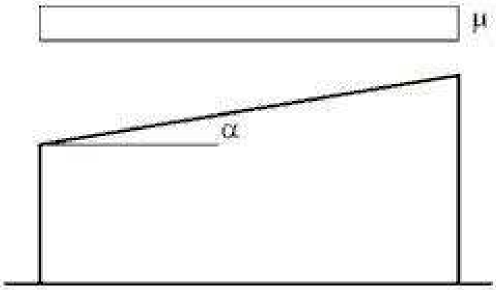
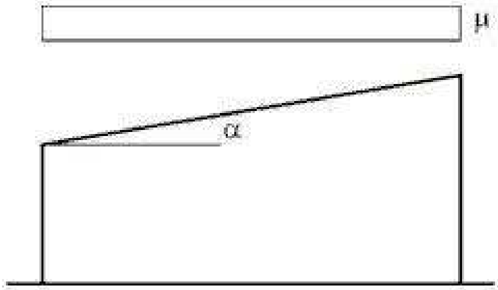
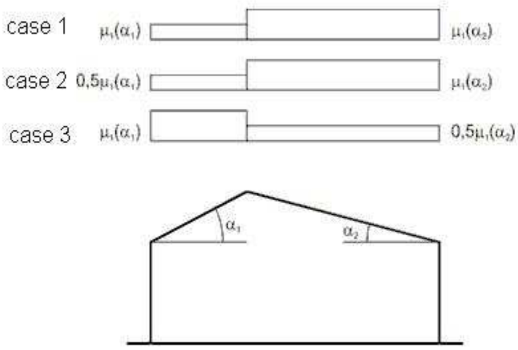
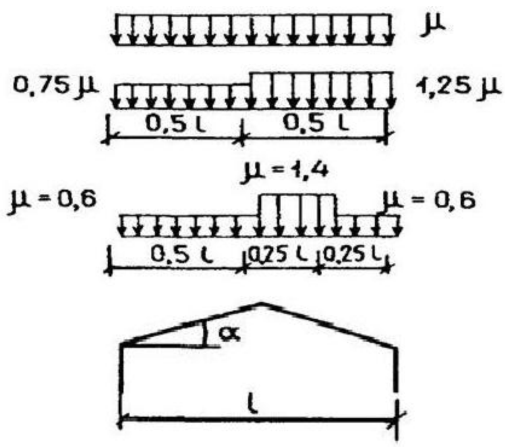
EN 1991-1-3	SNiP 2.01.07-85
Environmental factor C_e is defined depending on topography. a) For windswept topography C_e =0.8. Windswept topography are flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees. b) For normal topography C_e =1.0. Normal topography areas are areas with no significant removal of snow by wind because of terrain, other constructions or trees. c) For sheltered topography C_e =1.2. Sheltered topography areas are areas in which the designed construction is considerably lower than surrounding terrain o surrounded by high trees or higher constructions.	Environmental factor C_e is defined depending on topography, slope and height. a) Environmental factor $C_e$must be applied to calculation of structures with a slope <12%, which situated in areas with average wind speeds for three coldest months V≥2 m/s. Average wind speeds for three coldest months could be defined in accordance with table1 of SNiP 23-01-99 Building climatology. For example, for Moscow V=3,8 m/s, for St. Petersburg V=2,8 m/s. $C_e$must be calculated with formula: $C_e = \left(1{,}2 - 0{,}1 \cdot \mathrm{V} \cdot \sqrt{\mathrm{k}}\right)(0{,}8 + 0{,}002\mathrm{b})$ (4.17) k is a factor which takes into account changes of wind load depending on height. Values of k factor defined by b is a width of a cover. It must be <100m. b) Environmental factor C_e=0,85must be applied to calculation of structures with a slope 12…20%, which are situated in areas with average wind speeds for three coldest months V≥4 m/s.

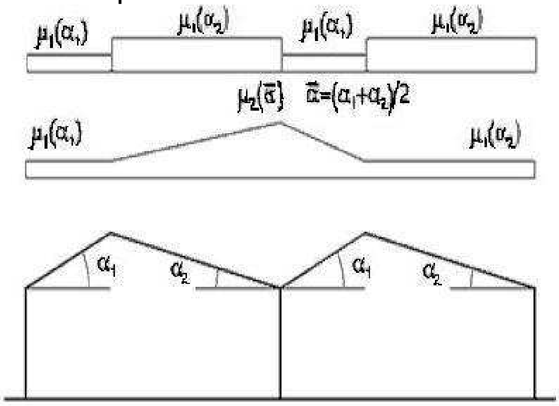
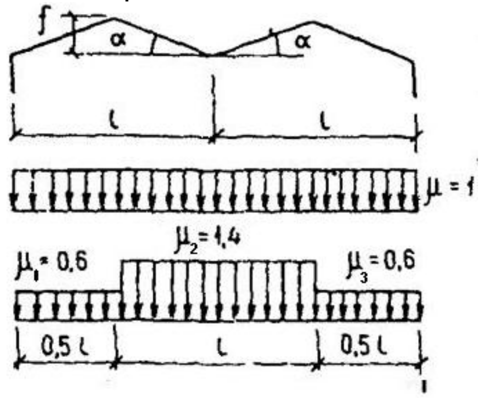
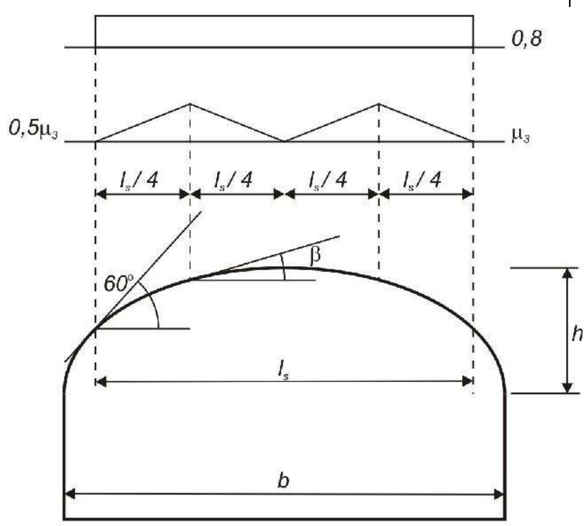
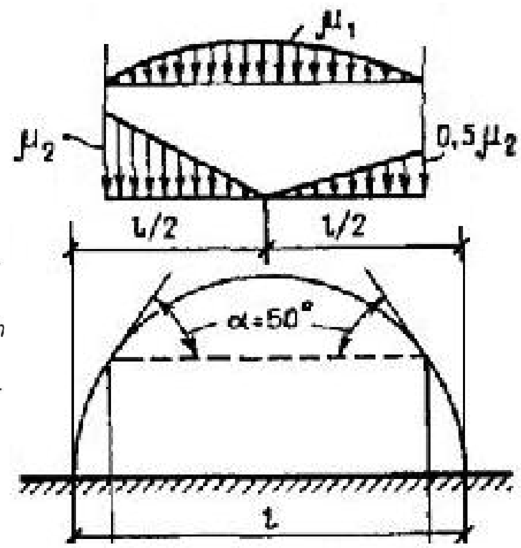
In accordance with SNiP 2.01.07-85, environmental factors do not apply in calculations for regions with average temperature of January more than -5 degrees, for buildings which are situated near higher buildings closer than ten differences of their heights and for areas b, b_1 and b_2 mentioned in schemes of snow load in article 5.2.3.2.

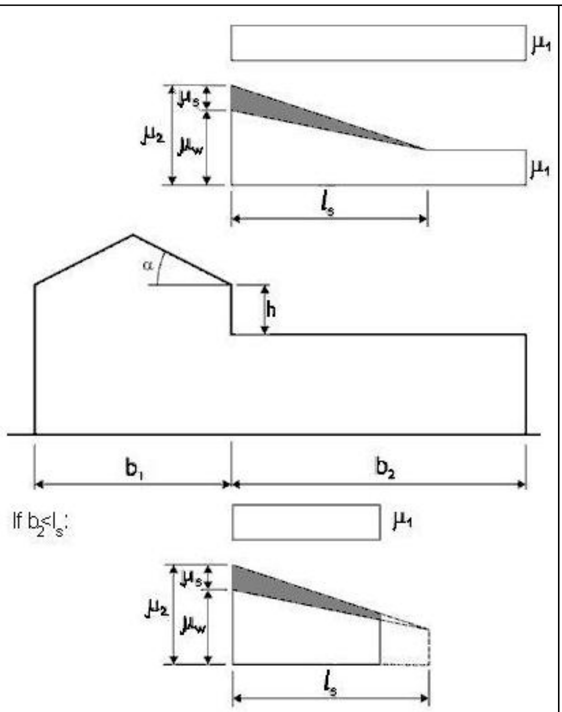
4.2.4.3 Shape coefficients

This part shows differences between shape coefficients and loading schemes of EN 1991-1-3 and SNiP 2.01.07-85.

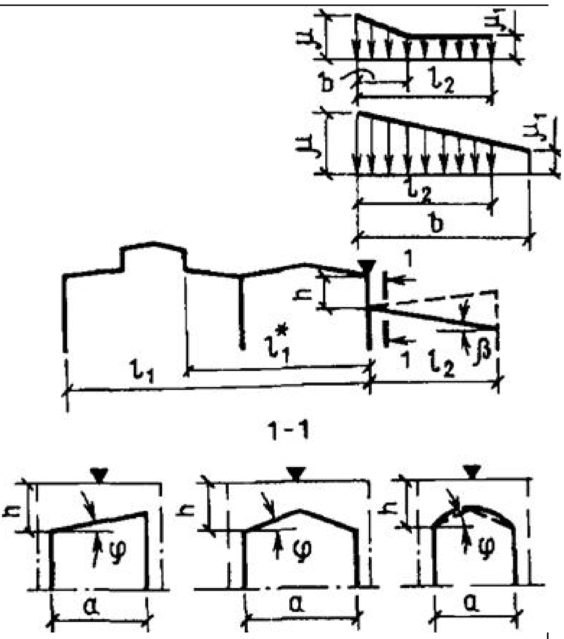
Table 5.5 Shape coefficients according to different standards

Shape coefficients and loading schemes according to EN 1991-1-3	Shape coefficients and loading schemes according to SNiP 2.01.07-85
1 Monopitch roofs  μ = 0.8 if 0° ≤α≤ 30° μ = 0,8(60 – α)/30 if 30° ≤α≤60° μ = 0 if α≥ 60°	1 Monopitch roofs  μ = 1 if 0° ≤α≤25° μ = 0,8(60 – α)/25 if 25° ≤α≤60° μ = 0 if α≥ 60°
2 Pitched roofs  $\mu(\alpha_1) = \mu(\alpha_2) = 0.8$ if 0° ≤α≤ 30° $\mu(\alpha_1) = \mu(\alpha_2) =$ 0,8(60 – α)/30 if 30° ≤α≤60° $\mu(\alpha_1) = 0$ if α ≥ 60°	2 Pitched roofs  μ = 1 if 0° ≤α≤25° μ = 0,8(60 – α)/25 if 25° ≤α≤60° μ = 0 if α ≥ 60° Case 2 μ_1=0,75 μ, μ_2=1,25 must be considered if 20° ≤α≤30°. Case 3 μ_1=0,6, μ_2=1,4, μ_3=0,6 must

	be considered if $10° \leq \alpha \leq 30°$ and there are places for walking or aeration devices.
3 Multi-span roofs  $\mu(\alpha_1) = \mu(\alpha_2) = 0.8$ if $0° \leq \alpha \leq 30°$ $\mu(\alpha_1) = \mu(\alpha_2) =$ $0,8(60 - \alpha)/30$ if $30° \leq \alpha \leq 60°$ $\mu(\alpha_1) = 0$ if $\alpha \geq 60°$ Case 2 $\mu(\overline{\alpha})=(\alpha_1+\alpha_2)/2$	3 Multi-span roofs  $\mu = 1$ if $0° \leq \alpha \leq 25°$ $\mu = 0,8(60 - \alpha)/25$ if $25° \leq \alpha \leq 60°$ $\mu = 0$ if $\alpha \geq 60°$ Case 2 $\mu_1=0,6$, $\mu_2=1,4$, $\mu_3=0,6$ must be considered if $\alpha \geq 15°$
4 Cylindrical roofs  Case1 $\mu_3 = 0,8$ Case 2 $\mu_3 = 0,2+10h/b$ if $\alpha \leq 60°$ $\mu_3 = 0$ if $0° \leq \alpha \leq 60°$	4 Cylindrical roofs  Case 1 $\mu_1=\cos 1,8\alpha$ Case 2 $\mu_2=2,4\sin 1,4\alpha$
5 Roofs which are close to a taller construction	5 Roofs which are close to a taller construction



Case1 $\mu_1 = 0{,}8$
Case 2 $\mu_2 = \mu_s + \mu_w$
$\mu_s=0$ if $\alpha \le 15°$, $\mu_s=0{,}5(\mu)$ if $\alpha \le 60°$
μ defined as additional load, which is 50% of full snow load for pitched roofs if $15° \le \alpha$



Case 1 $\mu=1+\frac{1}{h}(m_1 l_1' + m_2 l_2')$
In which h is height difference, l_1' and l_2' are lengths of upper and lower surfaces, m_1 and m_2 shares of blown to height difference snow from upper and lower surfaces.
$m_1= m_2=0{,}4$ if $\varphi \le 20°$
$m_1= m_2=0{,}3$ if $\varphi \ge 20°$
For lower roofs with length a<21m $m_2=0{,}5k_1k_2k_3$ and $m_2 \ge 0{,}1$. In which
$k_1=\sqrt{\frac{a}{21}}$, $k_2=1-\frac{\beta}{35}$, $k_2=1-\frac{\varphi}{30}$ and $k_2 \ge 0{,}3$
Length of high snow cover zone b=2h and b≤16m

4.2.5 Wind loads

Wind load should always be taken into account in calculations of window and facade constructions. In Europe, wind loads are defined according to EN 1991-1-4 Wind Loads. In Russia, wind loads are defined according to article 6 of SNiP 2.01.07-85.

The basic principles of calculation of wind load are similar in both standards. Baseline data to determine wind load is the value of wind pressure, which depends on region. Wind load belongs to variable loads. On rough surfaces should be considered a component of wind pressure directed parallel to the surface. In wind load calculation should be considered the pulsating component of wind load and wind pressure due to the shape of building.

Despite the similarity in basic principles those standards have differences. Dynamic and correlation coefficients are defined in different ways.

Table 4.6 European and Russian ways to calculate wind load

EN 1991-1-4	SNiP 2.01.07-85
The wind pressure acting on the external surfaces should be determined by the formula (). $w_e = q_p(z_e)c_{pe}$ (4.18) In which $q_p(z_e)$ is the peak velocity pressure, z_e is the reference height for the external pressure, c_{pe} is the pressure coefficient for the external pressure depending on building shape, terrain and wind direction. Peak velocity pressure $q_p(z_e)$ could be found with the formula () $q_p(z_e) = [1 + 7I_v(z_e)]\frac{1}{2}\rho v_m^2(z)$ (4.19) In which $I_v(z_e)$ is the turbulence intensity, ρ is the air density, $v_m(z)$ is the mean wind velocity at a height z above the terrain depends on the terrain roughness and orography and basic wind velocity v_b. Turbulence intensity $I_v(z_e)$ must be calculated with formula (4.20) $I_v(z) = \frac{\delta_v}{v_m(z)}$ (4.20) In which δ_v is the standard deviation of the turbulence, which can be found using formula (4.18) $\delta_v = k_r v_b k_l$ (4.21) The terrain factor k_r can be found according to article 4.3.2 of EN 1991-1-4. For the sea cost k_r=0,18 according to Finnish national annex. Turbulence factor k_l=1,0 for Finland. The mean wind velocity defined by the formula() $v_m(z)=c_r(z)\cdot c_0(z)\cdot v_b$ (4.22)	Pulsation component The calculating value of average component of wind pressure acting on the external surfaces should be determined by the formula (4.24). $w_m = W_0 k c_e$ (4.24) In which W_0 is the calculating value of wind pressure, k is the coefficient taking into account change of wind pressure depending on height, c_e is the aerodynamic coefficient. The calculating value of wind pressureW_0 is taken from table 5 of SNiP 2.01.07-85. It depends on wind area. Calculating value of wind pressure W_0 should be taken in accordance with map 3 and table 5 of SNiP 2.01.07-85. If area is mountainous or poorly studied W_0 must be calculated with formula (4.25) $W_0=0,61v_0^2$ (4.25) In which v_0 is the wind velocity at a height 10 m above the ground level for A type of terrain. The coefficient k defined in table 6 of SNiP2.01.07-85. It depends on The coefficient k is taken from table 6 of SNiP2.01.07-85. It depends on type of terrain and height. There are 3 types of terrain. Type A is open coasts of seas, lakes or reservoirs, deserts, steppe, tundra. Type B is terrain uniformly covered with objects or trees higher than 10 m. Type C is urban terrain with buildings higher than 25 m.

In which $c_r(z)$ is the roughness factor determined in accordance with article 4.3.2 of Finnish national annex EN1991-1-4, $c_0(z)$ is the orography factor taken in accordance with article 4.3.3 of Finnish national annex EN 1991-1-4. Basic wind velocity v_b should be calculated with formula (4.23) $V_b=c_{dir} \cdot c_{season} \cdot v_{b,0}$ (4.23) In which $c_{dir}$is the directional factor, c_{season} is the season factor, $v_{b,0}$ is the fundamental value of the basic wind velocity which is 21 m/s according to Finnish national annex. Recommended value of c_{dir}, c_{season} is 1,0. Change of pressure depending on height of building must be considered in accordance with article 7.2.2 of EN 1991-1-4.	The aerodynamic coefficient c_e depends on shape of building and wind direction.

Building shape and wind direction are considered by the pressure coefficient c_{pe} or force coefficient for structure or structural element c_f in EN 1991-1-4. In Russian standards it considered by aerodynamic coefficient c_e from SNiP2.01.07-85.

In EN 1991-1-4 pressure coefficient c_{pe} considers structures in more details. It divides building surface in more parts in comparison with SNiP2.01.07-85.

The differences between defining external pressure coefficient c_{pe} and aerodynamic coefficient c_e are shown below in application to rectangular plane buildings with pitched roofs which has loaded area more than 10 m^2.

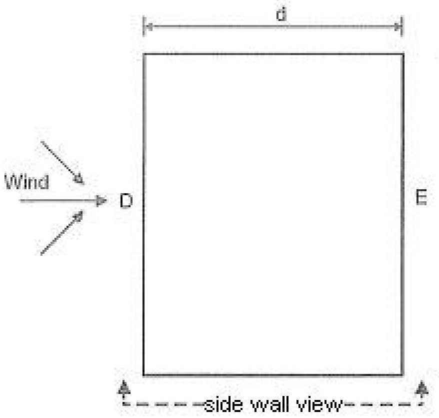
Table 4.7 Aerodynamic coefficients

EN 1991-1-4	SNiP 2.01.07-85
The external pressure coefficient c_{pe} depends on the size of the loaded area A. For loaded areas less than 1 m^2 the value of $c_{pe,1}$ pressure coefficient is given. For loaded areas more than 10 m^2 the value of $c_{pe,10}$ pressure coefficient is given. For areas between those	The external aerodynamic coefficient c_e for side on which the wind pushes is always c_e=+0.8.

values external pressure coefficient must be found with the formula (4.26).

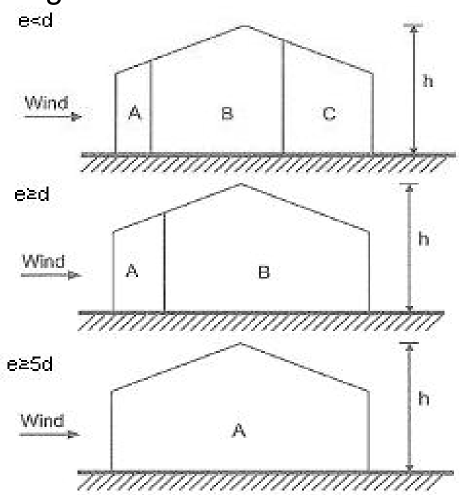
$c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10})\log_{10}A$ (4.26)

Plan of building with marks are shown in figure



Figure

In EN 1991-1-4 three cases of side wall separation are considered. The first case is if e<d. The second case is if e≥d. The third case is if e≥5d In which e=b or 2h whichever is smaller. All cases are illustrated in figure.

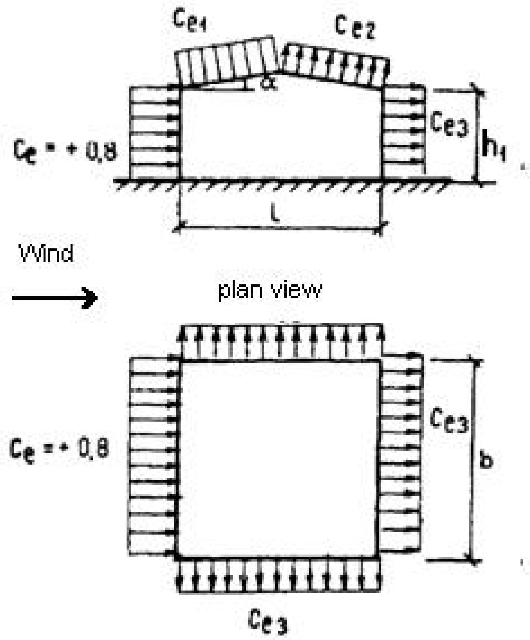


Figure

For example pressure coefficient for A-zone are $c_{pe}=-1.2$.

The values of pressure coefficients in this cases are described more detailed in table 7.1 of EN 1991-1-4.

Pressure coefficients for pitched roof structure are defined in a same way in accordance with an



The external aerodynamic coefficient c_{e3} for side on which suction is acting depends on ratio b/L and ratio h_1/L. Dependence is shown in table.

Table

b/L value:	C_{e3} value depending on h_1/L value equal to:		
	≤0.5	1	≥2
≤1	-0.4	-0.5	-0.6
≥2	-0.5	-0.6	-0.6

If wind load is acting on the end surface of the building, the aerodynamic coefficient must be c_e=-0.7 for all roof surface.

If it is not, aerodynamic coefficients c_{e1} and c_{e2} could be defined with a table.

	α value:	C_{e3} value depending on h_1/L value equal to:			
		0	0.5	1	≥2
c_{e1}	0	0	-0.6	-0.7	-0.8
	20	+0.2	-0.4	-0.7	-0.8
	40	+0.4	+0.3	-0.2	-0.4
	60	+0.8	+0.8	+0.8	+0.8
c_{e2}	≤60	-0.4	-0.4	-0.5	-0.8

article 7.2.5 of EN 1991-1-4.	

The wind forces for the whole structure or a structural component are calculated also in different ways.

Table 4.8 Wind forces

EN 1991-1-4	SNiP 2.01.07-85
There are two ways to calculate wind forces. The wind force F_w may be calculated using force coefficients in accordance with the formula (4.27) $F_w=c_sc_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref}$ (4.27) In which c_sc_d is the structural factor, c_f is the force coefficient for structure or structural element. Force $F_{w,e}$ acting on external surface may be calculated with the formula (4.28) $F_w = c_sc_d \cdot \sum w_e \cdot A_{ref}$ (4.28)	The wind force must be calculated with a formula (4.29) $W=\gamma_f \cdot A \cdot W_0 \cdot c \cdot k$ (4.29) In which the wind load safety factor γ_f=1,4. A is the area of structural component, W_0 is the calculating value of wind pressure, c is the aerodynamic coefficient, k is the coefficient taking into account change of wind pressure depending on height.

Structural factor c_sc_d is defined in section 6 of EN 1991-1-4. Factor c_sc_d=1 if the height of building is less than 15 meters, if a natural frequency of facade and roof elements is greater than 5 Hz.

Natural frequency of facade system consists of profiles' natural frequency and glazing's natural frequency. The fundamental natural frequency of profile element could be found with formula (4.30)

$$f_0 = K \cdot \sqrt{EI/mL^4} \qquad (4.30)$$

In which K=1,571 is the factor depending on support conditions, L is the length of the element, m is the weight of 1 meter of element.

The fundamental natural frequency of four-edge supported glass pane could be calculated with the formula (4.31).

$$f_0 = K \cdot \sqrt{Et^2/12(1-v^2)a^4} \quad (4.31)$$

In which v is Poisson's ratio for glass. Usually v=0.2,…,0.3.

To evaluate frequency of facade profile calculation of frequency for profile R54-140 is done below.

Length of profile is 4 meters, weight of 1 meter of profile is 2,46 kg, moment of inertia I_x is 326,94 cm^4, elastic modulus E_n is $70\cdot10^9$ Pa.

$$f_0 = K \cdot \sqrt{EI/mL^4} = 1{,}571 \cdot \sqrt{70 \cdot 10^9 \cdot 326{,}94 \cdot 10^{-8}/2{,}46 \cdot 4^4} = 30\ \mathrm{Hz}$$

Fundamental frequency of the element is higher than 5 Hz. Because of that, structural factor c_sc_d=1. In case ofof f_0<5 Hz, structural factor c_sc_d should be found in accordance with formula (4.32)

$$c_s c_d = \frac{1 + 2k_p I_v(Z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7I_v(Z_s)} \quad (4.32)$$

In which I_v is the turbulence intensity, z_s is the reference height for determining the structural factor, B^2 is the background factor, R^2 is the resonance response factor, k_p is the peak factor.

Reference height for vertical structures such as buildings $z_s=0.6h\geq z_{min}$, where z_{min} depends on terrain category and defined by table 4.1 of EN 1991-1-4.

The procedure to define B^2, R^2 and k_p factors is not mentioned in Finnish national annex. Therefore, those factors must be defined in accordance with annex B or alternative method in annex C.

Use of factor c_sc_d in accordance with annex C does not increase the original value of wind force more than 5%.

4.2.6 Comparison of bulletproof standards

The current standard, which establishes the classes of bullet resistance in Europe, is Euro standard EN 1522. It applied since the end of 1998. The euro standard EN 1522 applies all over Europe and replaces all bulletproof standards which have applied before. The euro standard EN 1522 applies to all bulletproof windows

There are several current standards, which set the same classes of bullet resistance in Russia. They are GOST R 50941-96, GOST R 51112-97, GOST R 51072-97.

Bulletproof classes depend on testing the weapon and the bullet which have the structure stood during the test. The main characteristic of a bullet is Muzzle energy. The muzzle energy of a bullet W can be calculated with the formula (4.33)

$$W = \frac{1}{2} mv^2 \quad (4.33)$$

Table 4.9 The comparison of muzzle energies of test bullets

UNI EN 1522				GOST R 51112-97			
Bulletproof class	Bullet weight (g)	Bullet speed (m/s)	Muzzle energy (J)	Bulletproof class	Bullet weight g	Bullet speed m/s	Muzzle energy g(m/s)
FB1	2.5-2.7	350-360	153-175	1	5.9	305-325	274-312
FB2	7.9-8.1	390-410	601-681		6.8	275-295	257-296
FB3	10.1-10.3	420-440	891-997	2	2.5	310-335	120-140
					5.5	415-445	473-545
FB4	10.1-10.3	420-440	891-997	2a	1.0 -5.7 per 1 fraction	390-410	76-479
	15.5-15.7	430-450	1433-1590	3	3.4	890-910	1347-1408
FB5	3.9-4.1	940-960	1723-1889		7.9	710-740	1991-2163
FB6	3.9-4.1	940-960	1723-1889	4	3.6	890-910	1425-1491
	9.4-9.6	820-840	3160-3387	5	9.6	820-840	3228-3387
FB7	9.7-9.9	810-830	3182-3410		7.9	710-740	1991-2163
				5a	7.4	720-750	1918-2081
				6	9.6	820-840	3228-3387
				6a	10.4	800-835	3328-3626

To compare European and Russian Bulletproof Classes it is not enough to compare muzzle energies. Muzzle energy is enough to evaluate the killer force of a bullet, but in case of such strong material as aluminum penetration characteristics of bullets must be evaluated.

Bulletproof class depends also on the type of the bullet core and the bullet envelope. Bullet core can be made of lead, soft steel, normal steel, heat-treated steel, armor-piercing steel or whole bullet could be made of lead. Bullet envelope can be made of lead, steel or copper.

A bullet core made of lead has the lower penetration efficiency. A bullet core made of soft steel has better penetration. A normal steel core is more effective than a soft steel core and a core made of heat-treated steel has the best penetration efficiency. Generally all bullets can be divided into expanding bullets and bullets with full metal jacket.

Table 4.10 Characteristics of test bullets according to Russian standards

Class	1		2		2a	3	
Image of cartridge							
Image of bullet							
Diameter (mm)	9,27	7,82	5,62	7,85	9,7	5,62	7,92
Core of bullet	steel	lead	steel	steel	lead	steel	steel
Full metal jacket	+	+	+	+	-	+	+

4	5		5a	6	6a
					
					
5,62	7,92	7,92	7,92	7,92	7,92
steel heat-treated	steel	steel heat-treated	armor-piercing steel	steel heat-treated	armor-piercing steel
+	+	+	+	+	+

Table 4.11 Characteristics of test bullets according to European standard

Class	FB1	FB2	FB3	FB4		FB5
Image of cartridge						
Image of bullet						
Diameter	5,72	9,03	9,12	9,12	10,97	5,70
Core of bullet	lead	lead	lead	lead	lead	soft steel
Full metal jacket	-	+	+	+	-	+

FB6		FB7
		
		
5,70	7,85	7,85
soft steel	lead	steel heat-treated
+	+	+

The penetration characteristic of a bullet depends on structure, composition and specific energy of a bullet. The most valuable factor, which defines the penetration characteristic of a bullet, is the specific energy of a bullet which depends on the energy of a bullet and its diameter.

To consider structural and composition properties, bullets could be divided generally in groups according to the table.

Penetration tests of 7.62x39 mm cartridge applied to the flesh showed that bullet without FMJ made a penetration channel equal to 35mm, bullet with lead core and FMJ made a 59 mm channel, bullet with steel core and FMJ made a 73 mm channel. Bullet 7H6 with heat-treated core is more than 30% effective than 7H6 with normal steel core in application to steel. These relations must be same in application to aluminum.

Table 4.12 Penetration efficiency of bullets with different composition in relation to steel core bullets with FMJ

Composition	Lead	Lead core with FMJ	Steel core with FMJ	Heat-treated steel core with FMJ	Armor-piercing steel
Efficiency	40%	80%	100%	130%	130-200%
Classes, which belongs to the group	FB1, FB4(second bullet), 2a	FB1, FB2, FB3, FB4, FB6(second bullet), 1(second bullet)	FB5, FB6(first), 1(first bullet), 2, 3, 5(first bullet)	FB7, 4, 5(second bullet), 6	5a, 6a

Specific energy of a bullet is a kinetic energy which corresponds to a unit of cross sectional area of the bullet. Specific energy of each bullet can be found with the formula (4.34).

$$W_{specific} = \frac{mv^2}{2\pi R^2} = \frac{W}{\pi\left(\frac{1}{2}D\right)^2} \quad (4.34)$$

In which D is the diameter of bullet, W is the kinetic energy of bullet which is taken to be equal to the value of maximum muzzle energy in this calculation. It is possible, because kinetic energy of bullet does not change significantly over a distance of 5-10 meters.

Table 4.13 Comparison of bulletproof classes, depending on specific energies of test-bullets

GOST	1	2	2a	3	4	5	5a	6	6a
$W_{max.sp}$ (J/cm^2)	463	565	649	5679	6014	6879	4226	6879	7364
	617	1127		4393		4393			

EN	FB1	FB2	FB3	FB4	FB5	FB6	FB7
$W_{max.sp}$ (J/cm^2)	681	1064	1527	1527	7406	7406	7049
				1683		7002	

In the table you can see that 2a, FB5 and FB6 bulletproof classes have not got right position according to their maximum specific energy. It means that structural and composition properties of the bullet must also be considered.

Class 2a has no analogs in EN 1522 because its test cartridge is a buckshot which consists of fractions. Influence of the buckshot on the structure is totally different. Closely spaced holes may be considered as a single area of damage.

Class FB5 and FB6 bullets have highest specific energies, but their position in EN 1522 means that they have lowest penetration properties in contrast with FB7 class. This is because FB7 bullet have got steel heat-treated core in contrast to FB5 and FB6 bullets, which have cores made of soft steel. To consider structural and composition properties, bullets can be divided generally in groups according to the table.

Penetration characteristics of Russian and European standards can be approximately compared according to table 4.12 and table 4.13.

Table 4.14 Relations between EN 1522 and GOST R 51112-97

<table>
<tr><td>EN</td><td>FB1</td><td colspan="2">FB2</td><td colspan="3">FB3</td><td>FB4</td><td colspan="2">FB5</td><td>FB6</td><td colspan="5">FB7</td><td></td></tr>
<tr><td>GOST</td><td colspan="2">1</td><td colspan="2">2</td><td>2a</td><td colspan="3">3</td><td colspan="3">4</td><td>5</td><td>5a</td><td>6</td><td colspan="2">6a</td></tr>
</table>

This comparison of bulletproof classes has an approximate accuracy. It approximately takes into account the composition factor and does not take the shape factor into account. Precise comparison of bulletproof classes could be done only by comparison of shooting tests' results.

4.2.7 Comparison of aluminum alloy classes

All aluminum alloys can be generally divided into foundry alloys and wrought alloys. Wrought alloys are used for aluminum profiles manufacturing. Further, only wrought alloys are considered.

Nowadays most of Russian aluminum extrusion factories use European system of aluminum alloys classification, but there are still some producers which use the Russian classification.

Aluminum alloys, which are used for manufacturing window and facade profiles, have alloying magnesium and silicon elements. These alloys do not contain admixtures of heavy metals and do not emit harmful substances. In window manufacturing AW 6060, aluminum alloys are used. Almost all European manufacturers of aluminum profiles use № 6060 and № 6063 alloys in accordance with universal standard ISO 209-1 (DIN EN 1706). In Russia since the Soviet times acts its own classification of aluminum alloys which can be found in GOST 4784-97.GOST 4784-97 replaced the old standard GOST4784-74. It contains old Soviet classification and also shows relations between Russian classes and universal classes according to ISO 209-1.

Most common aluminum alloys which are used in window and door profiles production are 6060, 6061, 6063, 6082 and 7005. All of these alloys have alloying magnesium and silicon elements. Physical properties of aluminum alloys depend on the percentages of the element. Comparison of most common wrought aluminum alloy classes with Russian alloys is done below in a table.

Table 4.15 Relations between universal and Russian aluminum alloy classes according to GOST 4784-97.

ISO 209-1	Yield strength (MPa)	GOST 4784-97	Yield strength (MPa)	Percentages of main alloying elements (%)		
				Silicon (Si)	Magnesium (Mg)	Manganese (Mn)
6060	190	AD31	195	0.3-0.6	0.35-0.6	0.1
6061	240-276	AD33	225-280	0.4-0.8	0.8-1.2	0.15
6063	172-225	AD31	195	0.2-0.6	0.45-0.9	0.1
6082	290	AD35	280	0.7-1.3	0.6-1.2	0.4-1.0
7005	290	1915	245	0.35	1.0-1.8	0.2-0.7

Alloys which are alloyed with magnesium and silicon elements have approximately the same density, elastic modulus and shear modulus as aluminum. But the yield strength of aluminum alloy is greater in few times than aluminum yield strength.

4.3 Possible effect evaluation

4.3.1 Introduction

Calculation of load-bearing facade elements must be done in accordance with two groups of limit states. They are ultimate limit states which are defined by strength and usability limit states which are defined by deflections. Usually the strength properties of load-bearing elements are used less than for a half. Therefore, in calculations of the facade elements the main role has the calculation of second group of limit states.

4.3.2 Description of the first considered example

Article 5.2 describes European and Russian ways of calculation and evaluation concerned to aluminum structures and differences between them. Examples of calculation should be considered to show how these differences can affect on aluminum structures in more details.

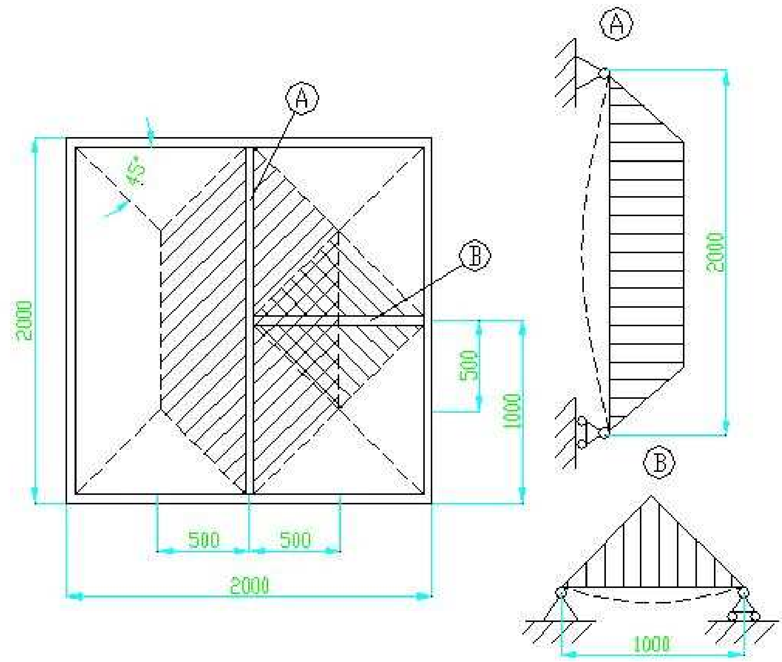


Figure 4.1 General view and design schemes of curtain wall structure

The first example is a curtain wall structure, which is subject to wind pressure. The frame is made of R54 profile system. The general view, dimensions, areas of wind load and design scheme are shown in the figure 4.1

The construction is projected for the city of Minsk, Republic of Belarus. This is because constructions for Belarus can be calculated in accordance with European and old Soviet standards. Both standards contain values of loading for this country. The structure is for a 20 meters height building. All sides of the building are equal to 30 meters. The terrain type is flat, uniformly covered with buildings higher than 15 meters. The task is to find out a wind pressure according to different standards, calculate needed moments of inertia and evaluate the difference.

4.3.3 Calculation of the first example according to EN

The basic value of wind velocity for Minsk according to TKP EN 1991-1-4 is v_b=24[m/s]

The basic velocity pressure $q_b = v_b^2/1600 = 24^2/1600 = 0.36\left[\frac{kN}{m^2}\right] = 360\left[\frac{N}{m^2}\right]$

The exposure factor is $c_e(Z) = 1.65$ for urban landscape and flat terrain.

The peak velocity pressure $q_p(z_e) = c_e(Z) \cdot q_b = 1.65 \times 360 = 594 \left[\frac{N}{m^2}\right]$

The pressure coefficient is $c_{pe} = +0.8$ forbuilding with area more than 10m^2.

The design wind pressure $w_e = q_p(z_e)c_{pe} = 594 \times 0.8 = 475.2 \left[\frac{N}{m^2}\right]$

The maximum deflection in a point for case A can be calculated with the formula (4.35)

$$[f] = \frac{1}{1920}\frac{2 \times a \times q \times L^4}{EI}\left[25 - 40\left(\frac{a}{L}\right)^2 + 16\left(\frac{a}{L}\right)^4\right] \quad (4.35)$$

The maximum allowed deflection can be found with the formula (4.36)

$$[f] = \frac{1}{300}L \quad (4.36)$$

Using the formula (3) and the formula (4), the formula (5) for calculating the maximum moment of inertia for A impost can be found.

$$I_{min} = \frac{1}{1920}\frac{300 \times 2 \times a \times q \times L^3}{E}\left[25 - 40\left(\frac{a}{L}\right)^2 + 16\left(\frac{a}{L}\right)^4\right] \quad (4.37)$$

The needed moment of inertia for A impost is

$$\mathrm{I_{min}} = \frac{1}{1920}\frac{300 \times 100 \times 475.2 \times 10^{-6} \times 200^3}{0.7 \times 10^5}\left[25 - 40\left(\frac{100}{200}\right)^2 + 16\left(\frac{100}{200}\right)^4\right] =$$

$$= 13.57[\mathrm{cm}^4]$$

The profile R54-40 with $\mathrm{I_x} = 19.28[\mathrm{cm}^4]$ must be chosen according to needed moment of inertia $\mathrm{I_{min}} = 13.57[\mathrm{cm}^4]$

The maximum deflection in a point for case B could be calculated with the formula (4.38)

$$[\mathrm{f}] = \frac{1}{120}\frac{2 \times \mathrm{a} \times \mathrm{q} \times \mathrm{L}^4}{\mathrm{E} \times \mathrm{I}} \qquad (4.38)$$

Using the formula 3 and the formula 4, the formula 5 for calculating the maximum moment of inertia for B impost can be found.

$$\mathrm{I_{min}} = \frac{1}{120}\frac{300 \times 2 \times \mathrm{a} \times \mathrm{q} \times \mathrm{L}^3}{\mathrm{E}} \qquad (4.39)$$

The needed moment of inertia for B impost is

$$\mathrm{I_{min}} = \frac{1}{120}\frac{300 \times 475.2 \times 10^{-6} \times 100 \times 100^3}{0.7 \times 10^5} = 1.697[\mathrm{cm}^4]$$

4.3.4 Calculation of the first example according to SNiP

The calculating value of wind load is W_0=600$\left[\frac{\mathrm{N}}{\mathrm{m}^2}\right]$. The aerodynamic coefficient c=0.8 for surface under pressure. The factor k=0.85 for building height h=20 m and urban landscape.

The design wind pressure $\mathrm{W} = \gamma_\mathrm{f}\mathrm{W_0ck} = 1.4 \times 600 \times 0.8 \times 0.85 = 571.2\left[\frac{\mathrm{N}}{\mathrm{m}^2}\right]$

The maximum allowed deflection is [f]=L/300

The needed moment of inertia for A-impost is

$$I_{min} = \frac{1}{1920}\frac{300 \times 100 \times 571.2 \times 10^{-6} \times 200^3}{0.7 \times 10^5}\left[25 - 40\left(\frac{100}{200}\right)^2 + 16\left(\frac{100}{200}\right)^4\right]$$

$$= 16.32[\text{cm}^4]$$

The profile R54-40 with $I_x = 19.28[\text{cm}^4]$ must be chosen according to needed moment of inertia $I_{min} = 16.32[\text{cm}^4]$

The needed moment of inertia for B-impost is

$$I_{min} = \frac{1}{120}\frac{300 \times 571.2 \times 10^{-6} \times 100 \times 100^3}{0.7 \times 10^5} = 2.04[\text{cm}^4]$$

4.3.5 Description of the second considered example

The second example is a curtain wall structure placed at 45 degrees which is exposed to snow loads, wind loads and self weight.

The frame is made of R54 profile system. The general view, dimensions, areas of wind load and design scheme are shown in the figure 4.2

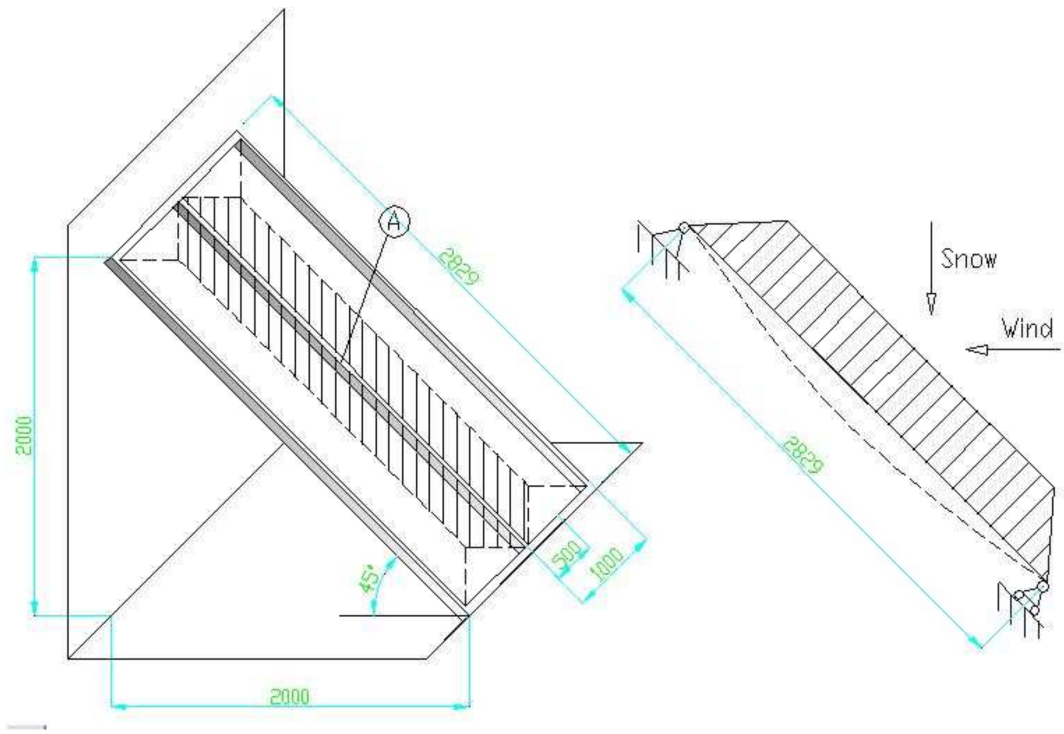


Figure 4.2 General view and design schemes of curtain wall structure

The circumstances of building dimensions and location are the same as in the first example.

4.3.6 Calculation of the second example according to EN

The design wind pressure for the second example is $w_e = \sin 45^0 \times 475.2 = 336.02 \left[\frac{N}{m^2}\right]$.

Shape coefficient μ = 0,8(60 – α)/30 = 0,8(60 – 45)/30=0.4

Environmental factor C_e=1.0 for normal topography

The design snow load is $S = S_g \times \mu \times C_e = 1600 \times 0.4 \times 1.0 = 640 \left[\frac{N}{m^2}\right]$

The design snow load for 45^0 is S = $\cos 45^0 \times 640 = 452.5 \left[\frac{N}{m^2}\right]$

Self-weight of glass is $F = 30 \left[\frac{Kgp}{m^2}\right] = 3000 \left[\frac{N}{m^2}\right]$for 4-10-4-10-4 and 4-6-4-6-4 IGU.

Self-weight which is acting on x-axis of the profile cross section is F = $\cos 45^0 \times 300 = 212.13 \left[\frac{N}{m^2}\right]$

Combination of actions must be done in accordance with the formula (4.40)

$$E_d = E\{G_{k,j};\ P;\psi_1 Q_{k,1};\ \psi_{2,i} Q_{k,i}\};\ \ j \geq 1;\ i > 1 \qquad (4.40)$$

Recommended valuesψ_1=0.7 and ψ_2=0.6 for congregation and shopping areas.

Combination of actions

$E_d = 212.13 + 0.7 \times 452.5 + 0.6 \times 336.02 = 730.492 \left[\frac{N}{m^2}\right]$

The needed moment of inertia for A-impost is

$$I_{min} = \frac{1}{1920} \frac{300 \times 100 \times 730.492 \times 10^{-6} \times 282.9^3}{0.7 \times 10^5} \left[25 - 40\left(\frac{100}{282.9}\right)^2 + 16\left(\frac{100}{282.9}\right)^4\right] = 72.91[cm^4]$$

The profile R54-100 with $I_x = 147.5[cm^4]$ must be chosen according to needed moment of inertia $I_{min} = 72.91[cm^4]$

4.3.7 Calculation of the second example according to SNiP

The design wind pressure for the second example is $w_e = \sin 45^0 \times 571.2 = 403.9 \left[\frac{N}{m^2}\right]$.

Shape coefficient μ=0,8(60 – α)/25 = 0,8(60 – 45)/25=0.48

Environmental factor C_e is not applied for structures with a 45^0 degrees slope.

The design snow load is $S = S_g \times \mu = 1200 \times 0.48 = 576 \left[\frac{N}{m^2}\right]$

The design snow load for 45^0 is S = $\cos 45^0 \times 576 = 407.3 \left[\frac{N}{m^2}\right]$

Self-weight which is acting on x-axis of the profile cross section is F = $212.13 \left[\frac{N}{m^2}\right]$

Combination of actions $E_d = 212.13 + 0.9 \times 407.3 + 0.9 \times 403.9 = 942.21 \left[\frac{N}{m^2}\right]$

The needed moment of inertia for A-impost is

$$I_{min} = \frac{1}{1920} \frac{300 \times 100 \times 942.21 \times 10^{-6} \times 282.9^3}{0.7 \times 10^5} \left[25 - 40 \left(\frac{100}{282.9}\right)^2 + 16 \left(\frac{100}{282.9}\right)^4\right] = 94.04[cm^4]$$

The profile R54-100 with $I_x = 147.5[cm^4]$ must be chosen according to needed moment of inertia $I_{min} = 94.04[cm^4]$

5 SUMMARY

The aim of this research is to make a presentation of Nokian bulletproof system, to find out main competitors, to assess competitiveness of Nokian bulletproof system in Russian market, to find out relations between European and Russian standards, to show differences between standards and evaluate possible affect.

The presentation of R65-BP system is done. The main requirements, architectural and bullet resistant properties of R65-BP system have been described.

Competitiveness situation in bulletproof production in Russia is done. The main competitors, their bulletproof systems and main manufacturers of ready-made production have been described. The main competitive factors are variety of bulletproof classes, technical solutions, range of production, thermal insulation and architectural properties. The comparison occurs only in these factors. Prices are not considered. The companies whose bulletproof structures were described are Schuco, Reynaers, Stalprofil, SAPA, Forster and Ginko.

The comparison showed that the main competitors in Russia of Nokian bulletproof system are aluminum profile manufacturers Schuco and Reynaers bulletproof systems.

The assessment of competitiveness showed that the most competitive system is R65-BP.

Nokian Profiles R65-BP system has better technical solutions, a variety of bulletproof classes and a range of production than its main competitors. To improve situation in Russian market the main attention should be paid to popularity and prevalence in Russian market. Thermal insulation of R65-BP system could be improved.

Relations between Russian and European standards, which are relative with bulletproof aluminum profiles, were found.

The analysis carried out for: basics of structural design, calculations according to two groups of limit states, snow loads and wind loads.

The analysis of Russian and European basis of design is done briefly because of the huge amount of general information which concerned all range of structures.

Principles of design in accordance with the first group of limit states were compared. The main principles are the same. The main difference is between European partial factors for aluminum structures, which is more than 1, and Russian safety factors for aluminum structures, which is 1 for aluminum profiles.

The comparison of the second group of limit states did not show the difference in application to window and curtain wall structures.

The comparison of snow load calculation principles showed that they are the same, but there are differences in environmental factors and shape coefficients. Environmental coefficients were defined in absolutely different ways. Shape factors in European standards decrease the snow loads a bit more in some cases.

The comparison of wind load calculation principles showed big differences between Russian and European standards in the way of calculating the design wind pressure. Different formulas and coefficients are used.

The calculations of two standard structures which are made of R54 profile were done to evaluate possible affect of Russian standards. The first one is a vertical curtain wall. The second one is a roof structure. The calculation in accordance with Russian standard gives a result load more than the calculation in accordance with European standard in both cases. But the difference is not very big. In both cases the same profiles should be used because of limited range of profiles. Approximately only in 20% cases the biggest cross section of profile should be used in accordance to Russian standards.

It is very important to notice that any construction project must comply with Russian standards. That is why the described way of calculation in accordance with Russian standards is also important.

The comparison of Russian and European Bulletproof classes is done. It is based on comparison of specific energies of bullets, their structure and composition. Firstly it was decided to compare only the muzzle energies of bullets but this comparison shows, that it is not enough because penetration properties of bullet must be also considered. The main factor is the specific energy, which defines energy of the unit of cross section of a bullet. Another important factor is the structure and composition of a bullet. For example, the bullet with heat-treated steel core is about 30% more effective than a bullet with normal steel core. The result of this comparison is a table of relations between bulletproof classes.

The relations between the mostly used alloys in manufacture of aluminum profiles are also shown.

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