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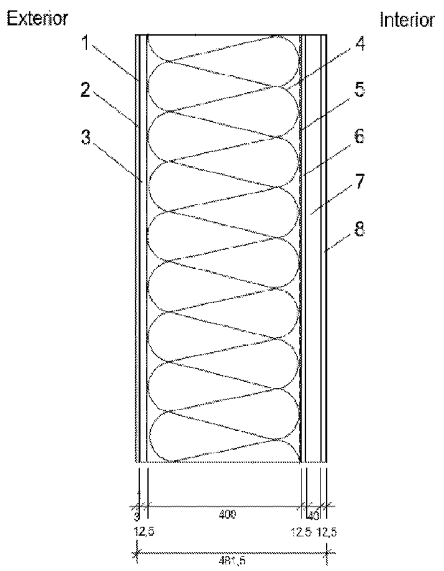

Fig. 5

(57) **Abstract:** The invention relates to the composition of the envelope of a wooden building, suitable for increasing bullet resistance for the protection of users of residential buildings. This composition from the exterior side includes: - first layer (1) of ceramic covering, - second layer (2) of bonding silicone sealant, - third layer (3) of OSB board, - fourth layer (4) of thermal insulation foamed geopolymer, - fifth layer (5) of diffusion-sealed vapour barrier, - sixth layer (6) of plaster fibre board, - seventh layer (7) of cast barrier high-density geopolymer, - eighth layer (8) of plaster fibre board.

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Wooden building envelope with high bullet resistance

Field of the Invention

The present invention relates to the composition of the individual layers of the envelope of a residential wooden building, which significantly increases bullet resistance against projectiles and fragments, while improving static, heat-accumulating and acoustic properties of the frame and increasing fire spread resistance.

Background of the Invention

The construction of residential wooden building envelopes is subject to bullet resistance assessment, while performing resistance tests against projectiles, fragments and stabbing weapons. Requirements for the use of natural renewable materials with optimal mechanical, thermal insulation, acoustic and ballistic parameters and with a high degree of fire resistance are generally preferred in the construction of building envelopes. However, in all construction systems of the envelopes of wood-based residential buildings developed so far, such materials and compositions are used, which cause the failure of meeting the requirements for bullet resistance and, at the same time, the mechanical, thermal insulation, acoustic and fire protection parameters are not optimal. The basic support frame of the light framework consists of slats made of structural timber (spruce, fir, larch, pine) assembled into a frame of the desired shape, connected by fasteners (steel nails, screws, clips, angles). The frame is sheathed with structural boards made of wood-based materials and binders (oriented strand boards (OSB), plaster boards, plaster fibre boards, cement-bonded particle boards, cement-bonded fibre boards). Thermal insulation materials based on natural fibres (wood fibre, materials based on agricultural crops), animal fibre-based materials (sheep fleece, llama and alpaca fleece), mineral fibre-based materials (fibre glass, stone mineral fibre) and synthetic polymer-based materials (expanded (EPS), extruded (XPS) polystyrene) are used as thermal insulation, as mentioned for example in Victor Almeida De Araujo, V.A., Cortez-Barbosa, J., Garcia, J.N., Gava, M., Laroca, Ch., César, S.F. (2016). Woodframe: Light framing houses for developing countries. Revista de la Construcción 15(2): 78-87. DOI: 10.4067/S0718-915X2016000200008. In terms of the composition of individual layers and in terms of material characteristics, these materials used do not have the density, strength and stiffness to meet the requirements for bullet resistance against the penetration of pistol and rifle bullets without additional modifications. For this reason, in the event of a projectile hit, the security of living inside a residential wooden building is very low. It is possible to prevent the penetration of the bullets fired from pistols and rifles by using such measures that increase the resistance of building envelope from structural point of view by applying resistant layers. The security situation in urban agglomerations continues to deteriorate, in particular in residential family houses, community centres, schools, kindergartens, church buildings, seniors' houses, sports and health facilities, public administration buildings owned by municipalities and the state. On the other hand, compositions of silicate material-based building envelopes (fired brick, aerated concrete, concrete) normally achieve the highest degree of bullet resistance, as stated for example by Kristoffersen, M., Toreskås, O.L., Dey, S., Børvik, T. (2021). Ballistic perforation resistance of thin concrete slabs impacted by ogive-nose steel projectiles. International Journal of Impact Engineering 156 (103957): 1-16. DOI: https://doi.org/10.1016/j.ijimpeng.2021.103957.

There are many ways to increase the bullet resistance of the construction of the envelope of residential buildings.

Document US 2017175388 A1 describes a method of increasing bullet resistance by using concrete blocks placed in the structure of interior and exterior walls of the building envelope in at least two layers, possibly covered with a layer of plaster board. The thickness of one layer of concrete blocks is 3 inches (76.2 mm). Concrete blocks are assembled in such a way that the joints placed in one layer are located differently from the joints in the next layer.

Document EP 0990746 A1 describes a building envelope construction that has a flexible, lightweight covering, which may be ceramic, applied to the exterior walls of the building, which increases bullet resistance. A hook-and-loop fastening system is used for the application of the covering. The disadvantage of this solution is the fact that the ceramic will tear the projectile into several smaller parts, but it will not prevent the penetration of these smaller parts inside the wooden building, i.e. the technical solution does not include a layer located under the ceramic covering, which would absorb all the energy of flying projectile in order to stop it. The ceramic floor covering does not contain a layer of thermal insulation material, which would fulfil the function of thermal insulation material and, at the same time, be able to absorb the energy of flying projectile due to its properties.

Document US 2010319522 A1 describes a concrete protection of a structural element against explosion or ballistic threats, comprising an envelope and concrete energy-absorbing layers placed around the structural element to be protected. The concrete energy-absorbing layers are made of very strong concrete, which can contain steel, ceramic, glass or Kevlar fibres in an amount of up to 120 kg/m^3. The thickness of concrete layer is at least 0.5 inch (12.7 mm).

Document US 2010326336 A1 describes a panel for ballistic protection, composed of several layers (PUR layer, concrete mix with ceramics). The surface of the panel contains a thermoplastic PUR layer that restricts ballistic penetration; another inner layer is steel mesh layer, and below that a concrete layer with a thickness between 2 and 5 inches (50.8 to 127.0 mm), fibreglass layer.

Document US 10240338 B2 describes a modular system of concrete panels covered with an elastic material that is resistant to projectiles and explosions.

Document US 2011239851 A1 describes an insulation panel with improved ballistic properties, which includes a first ballistic layer that increases the diameter of the impact and the energy with which the projectile enters the next layer is distributed over a larger area. This layer contains, for example, woven fibreglass. The second layer is designed for the projectile to break up in the layer or to rotate and change the direction. This layer has less tensile strength than the first layer. The third layer is supposed to stop the motion of the bullet by absorbing its residual energy. This layer contains, for example, aramid or polyethylene fibres in thermoplastic polymer resin.

Document US 2016376803 A1 describes ballistic and fire protection made of concrete panels that may contain rounded objects that prevent projectiles from penetrating through the panel. The panels are assembled together using vertical columns/structures. The purpose is to create ballistic and fire protection around the building and is therefore not directly part of the construction of building envelope. The outer surface of the structure is not provided with ceramic covering.

The solutions described above for the outer walls of residential buildings are not suitable for the rapid prefabrication of residential buildings based on light framework, the main support structural frame of which is made of structural timber. Therefore, the systems sought after are light, environmentally friendly systems, meeting mechanical, thermal insulation, acoustic, ballistic requirements with a high degree of fire resistance. These requirements could be met by an optimally developed type of geopolymer, which could be applied to the composition of the envelope of light framework.

The following types of geopolymers are known from the background of the invention:

Document CN110862271A describes the preparation of geopolymer foam material containing air ports. The preparation procedure consists in foaming a slurry of raw material containing geopolymer, alkaline activator, hydrogen peroxide and sodium dodecylbenzene sulfonate, which regulates the size of air ports. The subject of the document is not the application of geopolymer as a layer to increase bullet resistance of building framework. The foamed geopolymer does not contain a proportion of grog with a minimum size of 1.0 to 3.0 mm and, for this reason, does not have sufficient hardness and ballistic effectiveness. It contains open pores and is primarily intended for water treatment, air purification, heavy metal curing and as a catalyst carrier. The open pores of the geopolymer foam material significantly reduce the thermal insulation properties.

Document CN105967535A describes an inorganic geopolymer foam concrete for the production of a composite wall panel, prepared with an inorganic geopolymer foam concrete and a method of preparation. Inorganic geopolymer foam concrete contains components in parts by weight: 400 to 500 parts of inorganic geopolymer cement material and 0.5 to 10 parts of foaming agent, wherein the inorganic polymer cement material contains 2 to 20 parts by weight of active silica-alumina solution, 4 to 30 parts by weight of aqueous solution of alkaline salt, 1 to 20 parts of inorganic filler, and 0.05 to 3 parts of hardener. A lightweight and high-strength inorganic geopolymer foam concrete sandwich thermal insulation wall panel can be prepared from inorganic geopolymer foam concrete according to the invention. However, the geopolymer from foam concrete does not have such thermal insulation properties to completely replace standard thermal insulation material and is not produced by foaming into moulds in such a way to be produced in the required formats in the form of boards implemented in the wooden framework of wooden building.

Document CN103214263A describes a geopolymer material in the form of a thermal insulation board with an outer wall made of foam fly ash. Coal ash and mineral powder are foamed and held in a geopolymer thermal insulation board with an outer wall of foamed coal ash under the excitation of an alkaline activator using the cinerite activity of coal ash and mineral powder. The outer thermal insulation board made of geopolymer coal ash consists of the following materials in percentage by weight: 60%-95% of coal ash, 0.01%-30% of superfine slag powder, 0.01% to 30%

of fine aggregate, and 0.3% to 10% of foam stabilizer. Fine aggregate refers to materials including nanometer calcium carbonate, ground kaolin, powdered silica, silica fume, and the like. And mixed activator x is an alkaline mixed solution containing an amount of iron and active materials. The outer thermal insulation board made of geopolymer coal ash does not have such thermal insulation properties to be used in the composition of the outer walls of residential buildings without additional application of thermal insulation materials and cannot increase bullet resistance because it is fragile.

The task of the invention is to develop such a geopolymer that could be used as a layer serving to increase bullet resistance of the envelope of wooden buildings, and at the same time to create an optimal composition of envelope layers that would fully meet the requirements for bullet resistance as well as thermal insulation and other requirements applicable to the envelopes of wooden buildings.

Summary of the Invention

This task is accomplished by creating a structural system of the envelope of a wooden building according to the invention. For the purposes of the description of this invention, the term "envelope" of a wooden building means the outer wall including the support structure, i.e. the frame supporting the individual layers.

The summary of the invention is the envelope of a wooden building, which contains the following layers, arranged one after another in the direction from the exterior to the interior in this order:

The first layer of ceramic covering, which forms the surface of the envelope from the exterior side. As a result of the impact of the projectile, the ceramic covering will be damaged, resulting in the formation of sharp edges, which will damage the shell of projectile core, tearing and disintegrating it into several smaller parts, which pass further into the other layers of the envelope.

The ceramic covering is applied and fixed to the surface of the support structural OSB board through a second layer of a commercially available adhesive silicone sealant based on silane polymer.

The third layer consists of a structural OSB board, which is the underlying support layer for the ceramic covering, while stiffening the framework of the wooden building. The OSB boards are attached to the spruce slats, which form the main support framework of the envelope, using a nail joint or clips.

The fourth layer is thermal insulation made of foamed geopolymer, thanks to which it is not necessary to apply additional thermal insulation based on, for example, extruded polystyrene, mineral fibre or wood fibre under the ceramic wall covering, while meeting the requirements for thermal insulation properties for permanent residential buildings.

The geopolymer forming the fourth layer is applied in the form of trimmed boards between the structural elements of the main framework made of glued slatted timber. Thanks to its thickness, density, hardness and strength, geopolymer forms a layer that functions as thermal insulation, separates the individual parts of the damaged shell of the projectile from the flying core, thus reducing their speed and dynamic energy so that the deformed particles of the shell put higher resistance due to change in their shape, while reducing their dynamic energy, speed and penetration, up to the stage of stopping them. In the case of projectile core without shell, passing through the fourth layer of thermal insulation geopolymer changes the shape of the core, increases its diameter, and thus reduces dynamic energy. But not enough to allow the fourth layer to completely absorb dynamic energy of the projectile core and stop it completely.

The fifth layer is a standard diffusion-sealed vapour barrier, which increases the diffusion resistance of the structure so as to prevent the penetration of moist air with a relative humidity of 55.0 to 68.0% and a temperature of 16 to 35°C from the interior to the structure of the envelope, thus preventing it from condensing inside the frame of the envelope and preventing the degradation of wooden structural elements due to emerging rot or fungal attack. This vapour barrier layer has no effect on increasing bullet resistance of the structure.

The sixth layer is a plaster fibre board, which is applied in order to stiffen the structure of envelope and for the purpose of creating a pocket into which the trimmed boards of cast barrier high-density geopolymer forming the seventh layer are inserted.

The seventh layer is in the form of paving made of cast barrier high-density geopolymer. High-density geopolymer is preferably applied in the form of trimmed boards between the structural elements of the main framework made of glued slatted timber. Due to its density, hardness and strength, high-density geopolymer forms a layer that absorbs all energy of all flying particles and core of the projectile. The residual flying particles of the damaged shell of projectile, which have an irregular shape, whose flight path is curved after passing through the first layer of geopolymer, and whose dynamic energy has not been completely absorbed by the fourth layer, are completely stopped by the seventh layer of barrier high-density geopolymer, as well as the core. In the case of the core of flying projectile, dynamic energy is completely absorbed and the projectile is completely stopped.

From the interior side, the eighth layer is applied and attached by means of screws, which is a standard plaster fibre board. The board is applied to the structure of the envelope of the interior sides to create pockets into which the trimmed high-density geopolymer boards are inserted, forming the seventh layer, while forming the visible side of the interior.

In preferred embodiments of the invention, the envelope of a wooden building includes the following layers with the following specific parameters:

- first layer, consisting of ceramic covering with a thickness of 3.0 to 5.0 mm and a density of 2000 $kg/m^3 \pm 50\ kg/m^3$;
- second layer consists of a 0.5 to 2.0 mm thick bonding layer of flexible adhesive silicone sealant based on silane polymer, containing 80.0 to 95.0 wt%, preferably 90.0 to 95.0 wt% of silicon $[R_2SiO]_n$, 1.0 to 10.0 wt%, preferably 5.0 to 7.0 wt% of trimethoxyvinylsilane and 0.5 to 1.0 wt%, preferably 0.6 to 0.8 wt% of 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol, which has the function of fixing the ceramic covering to the layer of structural OSB board;
- third layer, which consists of structural OSB board, preferably with a thickness of 12.5 to 22.0 mm with a density of 550 $kg/m^3 \pm 20\ kg/m^3$, consisting of oriented flat chips of spruce and pine wood in the amount of 52 to 57 % wt%, melamine-formaldehyde resin binder in the amount from 18 to 20 wt%, polymeric diphenylmethanediisocyanate in the amount from 10 to 15 wt% and paraffin in the amount from 2.5 to 3 wt%, related to the total weight of OSB board;

- fourth layer, which consists of thermal insulation from thermal insulation foamed geopolymer with closed pores with a thickness of 400.0 mm ± 10.0 mm, dimensions of 575.0 – 600.0 mm ± 5.0 mm x 610.0 – 1220.0 mm ± 5.0 mm with a density of 95 kg/m^3 ± 5 kg/m^3 and a coefficient of thermal conductivity λ = 0.060 – 0.120 W/(m.K), which consists of an alumino-silicate binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, fly ash of class C in the amount from 10 to 12 wt%, alkaline activator of water glass Na_2SiO_3 in the amount from 45 to 47%, disintegrated silicon grog based on silicon carbide SiO_2 with a size from 1.0 to 3.0 mm in the amount from 4.0 to 5.2 wt%, and aluminium powder with a size from 5 nm to 2.0 mm in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer; implemented between structural elements of the framework;
- fifth layer, which consists of diffusion-sealed vapour barrier with a thickness of 0.3 to 0.5 mm made of polyethylene PE with a density of 918.0 kg/m^3;
- sixth layer, which consists of plaster fibre board, preferably with a thickness of 12.5 mm to 22.0 mm with a density of 1150.0 kg/m^3 ± 50.0 kg/m^3, which is composed of plaster in the amount from 95 to 98 wt% and with paper fibres in the amount from 2.0 to 5.0 wt% and with an implemented surface hydrophobic layer of keratin in the amount from 0.1 to 0.2 wt%; related to the total weight of plaster fibre board;
- seventh layer, which consists of monolithic paving made of cast barrier high-density geopolymer with closed pores with a thickness of 40.0 mm ± 5.0 mm, dimensions of 575.0 mm ± 5.0 mm x 575.0 mm ± 5.0 mm with a density of 1000 kg/m^3 ± 5 kg/m^3, which consists of an alumino-silicate binder based on metakaolinwith a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, fly ash of class C in the amount from 10 to 12 wt%, alkaline activator of water glass Na_2SiO_3 in the amount from 1 to 10%, and disintegrated silicon grog based on silicon carbide SiO_2 with a size from 1.0 to 10.0 mm in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer;
- eight layer, which consists of plaster fibre board, preferably with a thickness of 12.5 to 22.0 mm with a density of 1150.0 ± 50.0 kg/m^3, which is composed of plaster in the amount from 95.0 to 98.0 wt% and with paper fibres in the amount from 2.0 to 5.0 wt% and with an implemented surface hydrophobic layer of keratin in the amount from 0.1 to 0.2 wt%; related to the total weight of plaster fibre board.

The present invention relates to the materials used and the composition of the envelope of wooden column structure of a wooden building, which has suitable thermal insulation properties, a high degree of the class of reaction to fire performance while meeting the requirement for increased bullet resistance for the protection of users of residential buildings. The invention of the composition of the envelope for increasing bullet resistance is particularly suitable as a construction of the outer walls of residential buildings based on wooden framework, which are subject to higher requirements for ballistic protection of building users against the external environment. At the same time, the composition of the structure of building envelope is designed on the basis of framework in order to realize it by prefabrication on the production line using automated technology, used for the production of standard panels of the outer walls of the column structure of wooden prefabricated residential buildings. The invention of the composition of envelope wall with increased bullet resistance is suitable for applications in the construction of envelopes of wooden residential buildings against the potential of hit by and passage of ammunition from small arms and rifles through the envelop into the interior. The solution uses knowledge from the field of new types of geopolymers and combines them with the traditional framework of the outer wall frame of a wooden residential building.

Explanation of drawings

The invention will be explained in detail by drawings which illustrate:

Fig. 1: microscopic structure of thermal insulation foamed geopolymer at a magnification of 1:1000,
Fig. 2: macroscopic structure of thermal insulation foamed geopolymer on a scale of 1:1,
Fig. 3: microscopic structure of cast barrier high-density geopolymer at a magnification of 1:1000,
Fig. 4: macroscopic structure of cast barrier high-density geopolymer on a scale of 1:1,
Fig. 5: diagram of the envelope of a wooden building in section,
Fig. 6: perspective view of the envelope of a wooden building from the interior side,
Fig. 7: perspective view of the envelope of a wooden building from the exterior side,
Fig. 8: perspective view of the framework of the column structure of the envelope of a wooden building from the exterior side with implemented thermal insulation made of thermal insulation foamed geopolymer.

Examples of the invention embodiments

Example 1: *Composition of the envelope of a wooden family house with high bullet resistance.*
The following composition of exterior sides was applied for the production of the envelope of a wooden family house with a column structure forming a frame of wooden slats:

- first layer 1 of ceramic covering with a thickness of 3.0 mm and with a density of 2000.0 kg/m^3 ± 50.0 kg/m^3; In other embodiments, the layer 1 of ceramic covering can have a thickness of up to 5.0 mm.
- second layer 2 of 0.5 mm thick bonding layer of a standard commercial flexible adhesive silicone sealant based on silane polymer, containing 90.0 wt% of silicon $[R_2SiO]n$, 5.0 wt%, 5.0 wt% of trimethoxyvinylsilane and 0.7 wt% of 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol, which has the function of fixing the ceramic covering to the structural support OSB board. In other embodiments, the second layer 2 can have a thickness of up to 2 mm, or has a thickness varying from 0.5 mm to 2 mm depending on the unevenness of the substrate.
- third layer 3 of commercially available structural OSB board with a thickness of 12.5 ± 0.2 mm with a density of 550 kg/m^3 ± 20 kg/m^3, consisting of oriented flat chips of spruce and pine wood in the amount from 55% wt%, melamine-formaldehyde resin binder in the amount of 20.0 wt%, polymeric diphenylmethanediisocyanate in the amount of 10.0 wt% and paraffin in the amount of 2.5 wt%, related to the total weight of OSB board. In other embodiments, the third layer 3 can have a thickness of up to 22 mm.
- fourth layer 4 of thermal insulation from thermal insulation foamed geopolymer with a thickness of 400.0 mm ± 10.0 mm, dimensions of 575.0 – 600.0 mm ± 5.0 mm x 610.0 – 1220.0 mm ± 5.0 mm with a density of 450.0 kg/m^3 ± 20.0 kg/m^3 and a coefficient of thermal conductivity λ = 0.062 W/(m.K), which consists of an alumino-silicate binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount of 40.0 wt%, fly ash of class C in the amount of 10.0 wt%, alkaline activator of water glass Na_2SiO_3 in the amount of 45.0%, disintegrated silicon grog based on silicon carbide SiO_2 in the amount of 5.0 wt% and aluminium powder in the amount of 0.5 wt% related to the total weight of geopolymer; implemented between structural elements of the framework made of glued slatted timber with the cross-sectional dimensions of slats of 40.0 x 400.0 mm and a length of 2800 mm, which form the main support structural element of the envelope connected to

each other by nails or screws. The fourth layer 4 consists of blanks, which are inserted side by side into a wooden framework, or can also form larger boards.

- fifth layer 5, which is diffusion-sealed commercially available vapour barrier with a thickness of 0.5 mm made of polyethylene PE with a density of 0.918 kg/m^3. In other embodiments, the fifth layer 5 can be weaker, the minimum thickness is 0.3 mm.
- sixth layer 6 of plaster fibre board with a thickness of 12.5 ± 0.2 mm with a density of 1150.0 kg/m^3 ± 50.0 kg/m3, which is composed of plaster in the amount of 95.0 wt% and with paper fibres in the amount of 4.8 wt% and with an implemented surface hydrophobic layer of keratin in the amount of 0.2 wt%; related to the total weight of plaster fibre board. In other embodiments, the sixth layer 6 can have a thickness of up to 22 mm.
- seventh layer 7 of monolithic paving made of cast barrier high-density geopolymer with a thickness of 40.0 mm ± 5.0 mm, dimensions of 575.0 mm ± 5.0 mm x 575.0 mm ± 5.0 mm with a density of 1000.0 kg/m^3 ± 5.0 kg/m^3 8, which consists of an alumino-silicate binder based on metakaolinwith a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount of 40 wt%, fly ash of class C in the amount of 10 wt%, alkaline activator of water glass Na_2SiO_3 in the amount of 45.0%, disintegrated silicon grog based on silicon carbide SiO_2 in the amount of 5.0 wt%, and aluminium powder in the amount of 0.5 wt% related to the total weight of geopolymer. The seventh layer 7 consists of paving bricks that are placed next to each other and on top of each other, or can also form larger boards.
- eight layer 8 of plaster fibre board 9 with a thickness of 12.5 ± 0.2 mm with a density of 1150.0 ± 50.0 kg/m^3, which is composed of plaster in the amount of 95.0 wt% and with paper fibres in the amount of 4.8 wt% and with an implemented surface hydrophobic layer of keratin in the amount of 0.2 wt%; related to the total weight of plaster fibre board, applied from the interior side. In other embodiments, the eight layer 8 can have a thickness of up to 22 mm.

Example 2: *Production of thermal insulation foamed geopolymer*

The thermal insulation foamed geopolymer is created by the process of geopolymerization, when the component of the alumino-silicon binder based on metakaolin in the form of powder with a glass amorphous structure with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt% is mixed with fly ash of class C in the form of powder in the amount from 10 to 12 wt% and aluminium powder in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer. After the subsequent addition of an alkaline solution of the activator of water glass Na_2SiO_3 in the amount from 45.0 to 47.0 wt%, OH^- ions react with the aluminosilicate surface in the powder mix and break the covalent bonds of Si-O-Si, Si-O-Al and Al-O-Al that are present in metakaolin binder powder, Si and Al ions are gradually released into the solution. The increasing amount of silicon (Si) in the activation solution also increases the concentration of Si, Al and Ca released into the solution, while chemically bonding geopolymer precursors (oligomers), through water molecules that create macromolecular solid chains. This final phase of geopolymerization creates a zeolite structure, which is the last stage of long-term transformations of aluminosilicates containing a certain amount of sodium or potassium components. The resulting structure of the thermal insulation foamed geopolymer is formed by randomly arranged three-dimensional structure, which has high hardness and strength.

Example 3: *Production of cast barrier high-density geopolymer*

The cast barrier high-density geopolymer is created by the process of geopolymerization, when the component of the alumino-silicon binder based on metakaolin in the form of powder with a glass amorphous structure with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt% is mixed with fly ash of class C in the form of powder in the amount from 10 to 12 wt%, powder of disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt% and aluminium powder in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer. A higher proportion of grog affects the higher resistance and hardness of geopolymer. After the subsequent addition of an alkaline solution of the activator of water glass Na_2SiO_3 in the amount from 45.0 to 47.0 wt%, OH^- ions react with the aluminosilicate surface in the powder mix and break the covalent bonds of Si-O-Si, Si-O-Al and Al-O-Al that are present in metakaolin binder powder, Si and Al ions are gradually released into the solution. The increasing amount of silicon (Si) in the activation solution also increases the concentration of Si, Al and Ca released into the solution, while chemically bonding geopolymer precursors (oligomers), through water molecules that create macromolecular solid chains. This final phase of geopolymerization creates a zeolite structure, which is the last stage of long-term transformations of aluminosilicates containing a certain amount of sodium or potassium components. The resulting structure of the cast barrier high-density geopolymer is formed by randomly arranged three-dimensional structure, which has high hardness and strength.

Example 4: *Testing of mechanical-physical properties of thermal insulation foamed geopolymer and cast barrier high-density geopolymer and various materials with increased bullet resistance - comparison by demonstration test using the three-point bending method*

As part of the research and development of the frame of envelope of a light framework of a wooden building, the project EVA 4.0, “Advanced research supporting the forestry and wood-processing sector’s adaptation to global change and the 4th industrial revolution” (grant no. CZ.02.1.01/0.0/0.0/16_019/0000803), financed by OP RDE, included a test carried out on tested materials through a demonstration test using the method of determining the ultimate bending strength using the three-point bending loading method according to EN 310 (1993) “Wood based panels. Determination of modulus of elasticity in bending and of bending strength”. Test samples of the tested materials with dimensions of 40 x 40 x 160 mm (height x width x length) were first conditioned for 336 hours at a temperature of 20 ± 2°C and a relative air humidity of 65 ± 5% to a steady equilibrium moisture content. The bending strength was calculated from the determined resulting values of the maximum force and deflection obtained from the three-point bending demonstration tests performed on the TIRA Test 2850 universal testing machine (TIRA GmbH, Germany).

For comparison, the same tests were carried out with samples of selected materials that are commonly used in the compositions of envelopes of residential buildings and are subject to requirements for thermal insulation properties and increased bullet resistance:

a) thermal insulation foamed geopolymer with closed pores with density $\rho = 95\ kg/m^3 \pm 5\ kg/m^3$ (fourth layer 4)
b) cast barrier high-density geopolymer with closed pores with density $\rho = 1000\ kg/m^3 \pm 5\ kg/m^3$; (seventh layer 7)
c) concrete C25 with density $\rho = 2320\ kg/m^3 \pm 5\ kg/m^3$;
d) solid fired brick with density $\rho = 1820\ kg/m^3 \pm 5\ kg/m^3$;
e) expanded polystyrene with density $\rho = 60\ kg/m^3 \pm 0.5\ kg/m^3 \pm 5\ kg/m^3$.

The resulting values of ultimate bending strength σ [MPa] determined by demonstration test using the three-point bending method according to EN 310 are summarized in Table 1.

Table 1: The resulting values of ultimate bending strength σ determined according to EN 310

Type of material	**Ultimate bending strength σ [MPa]**
Thermal insulation foamed geopolymer (fourth layer 4)	0.70901
Cast barrier high-density geopolymer (seventh layer 7)	2.85024
Concrete C25	2.78376
Fired brick solid	2.01297
Expanded polystyrene	0.000000025

The results given in Table 1 show that the ultimate bending strength of the cast barrier high-density geopolymer forming the seventh layer 7 according to the present invention is higher as compared to other tested materials based on silicates used in the compositions of building envelope. The use of the seventh layer 7 of this material in the composition of the envelope improves its bullet resistance.

Example 5: *Bullet resistance testing of envelope structure with applied cast barrier high-density geopolymer and various structural systems - comparison by demonstration method of projectile penetration through envelope structure*

As part of the research and development of the frame of envelope of a light framework of a wooden building, the project EVA 4.0, “Advanced research supporting the forestry and wood-processing sector’s adaptation to global change and the 4th industrial revolution” (grant no. CZ.02.1.01/0.0/0.0/16_019/0000803), financed by OP RDE, determined bullet resistance of the developed composition and then compared it with commonly used compositions of the envelopes of wooden buildings (light framework, panel structure made of solid cross-glued wood, log structure made of solid wood) and compositions with the use silicate materials (concrete C25, solid fired bricks). Bullet resistance was determined using the procedure according to the methodology established by standard ČSN 39 5360 (2018) “Resistance tests of protective means. Technical requirements and testing”. Test samples of the tested envelope compositions had dimensions of 500 x 500 mm (height x width), the thickness of the given test sample was defined according to the thickness of the wall composition specified in Example 1. The sample was placed at the desired distance from the muzzle. For each class of ballistic protection (hereinafter referred to as “TBO”), ČSN 39 5360 defines the distance of the sample from the muzzle. The sample was placed at a distance of 5 m from the muzzle for TBO 2, 3, 4 and at a distance of 10 m for TBO 1, 5, 6, 7. The weapon was placed horizontally so that the axis of the muzzle formed a right angle with the impact surface of the sample. During each shot, the velocity of the projectile was measured at a distance of 2.5 m from the muzzle, with the chronograph measuring this velocity over a 1 m long section. The accuracy of velocity measurement had to be better than 1%. The centre of the chronograph was at a distance of 2.5 m from the muzzle of the weapon. A test board made of aluminium foil with a thickness of 0.5 mm was placed at a distance of 150 ±10 mm behind the tested sample. The testing of samples of the outer walls of wooden buildings took place under normal operating conditions, which are determined by temperature of 21 ± 3°C and relative air humidity in the range of 40% to 80%. The assessment of bullet resistance classes was carried out on the basis of defined conditions according to ČSN 39 5360, which are: prescribed weapon calibres, shape, weight, material of the projectile and its velocity. The classes of bullet resistance are scaled to TBO classes 1 to 7. In order to carry out tests of bullet resistance of envelope frames, powerful rifle ammunition of long weapons was used, with six-time repeated shot at different points of the outer wall sample.

For comparison, the same tests were carried out with samples of outer wall, in which the fourth layer 4 of thermal insulation foamed geopolymer and the seventh layer 7 of cast barrier high-density geopolymer were replaced by other materials so that the given composition of the envelope always met the requirements to achieve the same overall heat transfer coefficient U = 0.12 – 0.15 W/m^2K determined by standard ČSN 730540-2 (2011) "Thermal protection of buildings - Part 2: Requirements" (Table 2):

a) Envelope 01: Envelope composition according to Example 1, with the replacement of the fourth layer 4 for thermal insulation foamed geopolymer with closed pores with density ρ = 95 kg/m^3 ± 5 kg/m^3 with λ = 0.062 W/m.K and the replacement of the seventh layer 7 for cast barrier high-density geopolymer with closed pores with density ρ = 1000.0 kg/m^3 ± 5.0 kg/m^3 with λ = 0.811 W/m.K, total composition thickness d = 482 mm;
b) Envelope 02: Envelope composition according to Example 1) with the replacement of the fourth layer 4 for thermal insulation of pressed stone wool ρ = 95.0 kg/m^3 ± 5.0 kg/m^3 with λ = 0.063 W/m.K and with the replacement of the seventh layer 7 for concrete type C25 ρ = 2320.0 kg/m^3 ± 5.0 kg/m^3 with λ = 1.312 W/m.K, total composition thickness d = 482 mm;
c) Envelope 03: Envelope composition according to Example 1) with the replacement of the fourth layer 4 for thermal insulation of pressed stone wool ρ = 140.0 kg/m^3 ± 5.0 kg/m^3 with

λ = 0.068 W/m.K and with the replacement of the seventh layer 7 for solid fired bricks ρ = 2320.0 kg/m^3 ± 5.0 kg/m^3 with λ = 0.883 W/m.K, total composition thickness d = 482 mm.

The resulting TBO valuesof envelope samples 01-03 determined by demonstration test using the method according to ČSN 39 5360 are summarized in Table 2.

Table 2: The resulting assessment of the achieved class of bullet resistance of envelope samples determined according to ČSN 39 5360

Type of envelope	**Calibre of the weapon**	**Type of projectile**	**Velocity of projectile [m.s^{-1}]**	**Weight of projectile [g]**	**TBO**
Envelope 01	7.62x51	CP/Fej.	820±10	9.8	TBO7
Envelope 02	7.62x51	CP/Pbj.	830±10	9.5	TBO6
Envelope 03	7.62x51	CP/Pbj.	830±10	9.5	TBO6

The results given in Table 2 show that Envelope 01 with the composition of layers according to the invention was resistant to the passage of the given type of projectile (core and shell) meeting bullet resistance TBO7. Bullet resistance TBO6 was only achieved for the envelope compositions Envelope 02 and Envelope 03. The use of thermal insulation foamed geopolymer and cast barrier high-density geopolymer significantly increased bullet resistance of the envelope (Table 2) while maintaining the same thickness of the frame and better thermal insulation properties.

Example 6: *Testing of thermal insulation properties of cast barrier high-density geopolymer material and various materials with increased bullet resistance - comparison by demonstration method of determining the coefficient of thermal conductivity λ by demonstration test*

As part of the research and development of the frame of envelope of a light framework of a wooden building, the project EVA 4.0, “Advanced research supporting the forestry and wood-processing sector’s adaptation to global change and the 4th industrial revolution” (grant no. CZ.02.1.01/0.0/0.0/16_019/0000803), financed by OP RDE, determined for tested materials through a demonstration test using the method of determining the heat transmission in calibrated cabinet with an integrated hot plate and temperature probes according to EN 12939 (2001) “Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Thick products of high and medium thermal resistance" the coefficient of thermal conductivity λ [W/m.K], which characterizes the amount of heat that passes through the structure of a given material for a given time period. The coefficient of thermal conductivity λ is used to calculate the overall heat transfer coefficient U [W/m^{2}K] according to Example 5. Samples of the tested materials with dimensions of 300 x 500 x 500 mm (height x width x length) were first conditioned for 336 hours at a temperature of 20 ± 2°C and a relative air humidity of 65 ± 5% to a steady equilibrium moisture content. Subsequently, material samples with applied temperature probes applied to the surface of the materials were inserted between the integrated hot and cold boards of the Taurus TLP 900 type calibrated cabinet (Netzsch Taurus Instrument GmbH, Germany), which is constructed according to the requirements of EN 12939. Here, the surface of one side of the tested material was heated to a constant temperature of 40 ± 2°C and the surface of other side was cooled to a temperature of -10 ± 2°C for 672 hours until the temperature stabilization phase on the tested material. Based on the calculation defined by EN 12667 (2001) "Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance", the coefficient of thermal conductivity λ [W/m.K] was determined, which characterizes the intensity of heat flow that passed through the structure of the given material for the given time period and which is a characteristic of the thermal insulation efficiency of material properties, is used to calculate the overall heat transfer coefficient U [W/m2K] according to Example 5.

For comparison, the same tests were carried out with samples of selected materials that are used in the compositions of envelopes of residential buildings and are subject to requirements for thermal insulation properties and increased bullet resistance:

a) thermal insulation foamed geopolymer with closed pores with density ρ = 95.0 kg/m^3 ± 5.0 kg/m^3
b) cast barrier high-density geopolymer with closed pores with density ρ = 1000.0 kg/m^3 ± 5.0 kg/m^3;
c) concrete C25 with density ρ = 2320.0 kg/m^3 ± 5.0 kg/m^3;
d) solid fired brick with density ρ = 1820.0 kg/m^3 ± 5.0 kg/m^3;
e) stone wool with density ρ = 140.0 kg/m^3 ± 5.0 kg/m^3.

The resulting values of the coefficient of thermal conductivity λ [W/m.K] determined by demonstration test according to ČSN EN 12939 (2011) "Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Thick products of high and medium thermal resistance" are summarized in Table 3.

Table 3: The resulting values of the coefficient of thermal conductivity λ determined according to ČSN EN 12939

Type of material	**Coefficient of thermal conductivity λ [W/m.K]**	**Class of reaction to fire performance**
Thermal insulation foamed geopolymer (fourth layer 4)	0.062	A1
Cast barrier high-density geopolymer (seventh layer 7)	0.811	A1
Concrete C25	1.312	A1
Fired brick solid	0.883	A1
Stone wool	0.068	A1

The results given in Table 3 show that of the tested materials used for envelopes of residential buildings, which have the class of reaction to fire performance A1, the best values of the coefficient of thermal conductivity λ determined according to ČSN EN 12939 were shown by the thermal insulation foamed geopolymer material, which has the impact on increasing bullet resistance (Example 2).

Example 7: *Testing of thermal insulation properties of the composition of envelope of a framework of a wooden building with an applied layer of thermal insulation foamed geopolymer and cast barrier high-density geopolymer and various compositions of materials with increased bullet resistance - comparison by method of determining the overall heat transfer coefficient U*

As part of the research and development of the frame of envelope of a light framework of a wooden building, the project EVA 4.0, "Advanced research supporting the forestry and wood-processing sector's adaptation to global change and the 4th industrial revolution" (grant no. CZ.02.1.01/0.0/0.0/16_019/0000803), financed by OP RDE, investigated and determined the thermal insulation properties of various variants of outer frames with increased bullet resistance using the method of determining the overall heat transfer coefficient U [W/m2K] according to ČSN 73 0540-4 (2005) "Thermal protection of buildings - Part 4: Calculation methods" and standard ČSN EN ISO 6946 (2020) "Building components and building elements".

For comparison, the same tests were carried out with samples of outer wall in Example 1, in which the fourth layer 4 of thermal insulation foamed geopolymer and the seventh layer 7 of cast barrier high-density geopolymer were replaced by other materials so that the given composition of the envelope always met the requirements to achieve the same overall heat transfer coefficient determined by standard ČSN 730540-2 (2011) "Thermal protection of buildings - Part 2: Requirements" for houses with a total passive energy balance of $U = 0.12 – 0.15\ W/m^2K$:

a) Envelope type 01: Envelope composition according to Example 1 with used thermal insulation foamed geopolymer with closed pores in the fourth layer 4 with density $\rho = 95.0\ kg/m^3 \pm 5.0\ kg/m^3$ s $\lambda = 0.062$ W/m.K and cast barrier high-density geopolymer with closed pores in the seventh layer 7 with density $\rho = 1000.0\ kg/m^3 \pm 5.0\ kg/m^3$ s $\lambda = 0.811$ W/m.K, total composition thickness d = 482 mm;

b) Envelope type 02: Envelope composition according to Example 1 with the replacement of the fourth layer 4 for thermal insulation of pressed stone wool $\rho = 95.0\ kg/m^3 \pm 5.0\ kg/m^3$ with $\lambda = 0.068$ W/m.K and with the replacement of the seventh layer 7 for concrete type C25 $\rho = 2320.0\ kg/m^3 \pm 5.0\ kg/m^3$ with $\lambda = 1.312$ W/m.K, total composition thickness d = 482 mm;

c) Envelope type 03: Envelope composition according to Example 1 with the replacement of the fourth layer 4 for thermal insulation of pressed stone wool $\rho = 150.0\ kg/m^3 \pm 5.0\ kg/m^3$ and with the replacement of the seventh layer 7 for solid fired bricks $\rho = 2320.0\ kg/m^3 \pm 5.0\ kg/m^3$ with $\lambda = 0.883$ W/m.K, total composition thickness d = 482 mm.

The resulting values of heat transfer coefficient U [W/m2K] determined according to ČSN 73 0540-4 are summarized in Table 4.

Table 4: The resulting values of heat transfer coefficient U determined according to ČSN 73 0540-4

Type of envelope	**Heat transfer coefficient U [W/m²K]**	**Overall thermal resistance R_T [m².K/W]**
Envelope 01	0.148	5.11
Envelope 02	0.159	6.22
Envelope 03	0.162	6.24

The results given in Table 4 show that the tested envelope frame Envelope 01 with the composition with the applied thermal insulation foamed geopolymer and cast barrier high-density geopolymer was resistant to the passage of the given type of projectile (core and shell) meeting bullet resistance TBO7. Bullet resistance TBO6 was only achieved for the envelope compositions Envelope 02 and Envelope 03. The use of thermal insulation foamed geopolymer and cast barrier high-density geopolymer significantly increased bullet resistance (Table 2) while maintaining the same thickness of the frame and better thermal insulation properties (Example 5).

Industrial applicability

The invention can be used mainly in the wood industry, building industry and architecture. The solution is particularly suitable for the production program of envelope of framework types of wooden buildings for residential family houses, community centres, schools, kindergartens, church buildings, senior houses, sports and health facilities, public administration buildings owned by municipalities and the state, and other types of buildings with the prefabrication system. This is mainly the construction of the envelope fulfilling the covering, supporting and dividing function, which, due to its material composition and from the point of view of the parameters of the materials used, must simultaneously meet mechanical requirements: thermal insulation, acoustic resistance, bullet resistance, and a high degree of fire resistance. The envelope can be realized on the production line in the factory and then, after taking it over at the construction site, only assembly is carried out at the place of use.

CLAIMS

1. Envelope of a wooden building with high bullet resistance, including individual layers arranged one after another in the direction from the exterior to the interior, while the first layer (1) is made of ceramic material **characterized in that** the first layer (1) is a ceramic covering with a thickness from 3.0 to 5.0 mm, with a density of 2000 $kg/m^3 \pm 50 kg/m^3$, the second layer (2) is a bonding silicone sealant with a thickness from 0.5 to 2.0 mm, the third layer (3) is an OSB board with a thickness from 12.5 to 22.0 mm, the fourth layer (4) is a thermal insulation foamed geopolymer with closed pores from an alumino-silicon binder based on metakaolin with a disintegrated silicon grog based on silicon carbide SiO_2, fly ash, alkaline activator of water glass Na_2SiO_3, and aluminium powder with a thickness of 400.0 ± 10.0 mm, the fifth layer (5) is a diffusion-sealed vapour barrier with a thickness from 0.3 to 0.5 mm, the sixth layer (6) is a plaster fibre board with a thickness from 12.5 to 22.0 mm, the seventh layer (7) is a cast barrier high-density geopolymer with closed pores from alumino-silicon binder based on metakaolin with a disintegrated silicon grog based on silicon carbide SiO_2, alkaline activator of water glass Na_2SiO_3 with a thickness of 40.0 ± 5.0 mm, and the eighth layer (8) is a plaster fibre board with a thickness from 12.5 to 22.0 mm.

2. Envelope according to claim 1 **characterized in that** the first layer (1) has a thickness in the range from 3.0 to 5.0 mm, the second layer (2) has a thickness in the range from 0.5 to 2.0 mm, the third layer (3) has a thickness in the range from 12.5 to 22.0 mm, the fourth layer (4) has a thickness of 400.0 ± 10.0 mm, the fifth layer (5) has a thickness in the range from 0.3 to 0.5 mm, the sixth layer (6) has a thickness from 12.5 to 22.0 mm, the seventh layer (7) has a thickness from 40.0 ± 5.0 mm, and the eighth layer (8) has a thickness in the range from 12.5 to 22.0 mm.

3. Envelope according to claim 1 or 2 **characterized in that** the first layer (1) has a thickness of 3.0 mm, the second layer (2) has a thickness of 1.0 mm, the third layer (3) has a thickness of 12.5 mm, the fourth layer (4) has a thickness of 400.0 mm, the fifth layer (5) has a thickness of 0.3 mm, the sixth layer (6) has a thickness of 12.5 mm, the seventh layer (7) has a thickness of 40.0 mm, and the eighth layer (8) has a thickness of 12.5 mm.

4. Envelope according to any of claims 1 to 3 **characterized in that** the fourth layer (4) has a density of 95 kg/m^3 ± 5 kg/m^3 and a coefficient of thermal conductivity λ = 0.060 – 0.120 W (m.K).

5. Envelope according to any of claims 1 to 4 **characterized in that** the fourth layer (4) is formed by an assembly of blanks.

6. Envelope according to claim 5 **characterized in that** the blanks forming the fourth layer (4) have the dimensions of 575.0 to 600.0 mm ± 5.0 mm x 610 to 1220.0 mm ± 5.0 mm.

7. Envelope according to any one of claims 1 to 3 **characterized in that** it further includes a framework made of glued slatted timber with the cross-sectional dimensions of slats of 40.0 x 400.0 mm and a length of 2800 mm, while the fourth layer (4) is arranged in this framework.

8. Envelope according to any of claims 1 to 7 **characterized in that** the seventh layer (7) is formed by an assembly of paving bricks.

9. Envelope according to claim 8 **characterized in that** the paving bricks forming the seventh layer (7) have the dimensions of 575.0 mm ± 5.0 mm x 575.0 ± 5.0 mm.

10. Envelope according to any of claims 1 to 9 **characterized in that** the seventh layer (7) has a density of 1000 kg/m^3 ± 5 kg/m^3.

11. Envelope according to any of claims 1 to 10 **characterized in that** the thermal insulation foamed geopolymer forming the fourth layer (4) consists of an alumino-silicate binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, of fly ash of class C in the amount from 10 to 12 wt%, of alkaline activator of water glass Na_2SiO_3 in the amount from 45 to 47%, of disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt%, and of aluminium powder in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer.

12. Envelope according to any of claims 1 to 11 **characterized in that** the cast barrier high-density geopolymer forming the seventh layer (7) consists of an alumino-silicate binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, of fly ash of class C in the amount from 10 to 12 wt%, of alkaline activator of water glass Na_2SiO_3 in the amount from 1 to 10 %, of disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer.

13. Envelope according to any of claims 7 to 12 **characterized in that** the seventh layer (7) is placed in the pocket formed by the framework, the sixth layer (6), and the eighth layer (8).

14. Method of preparing the thermal insulation foamed geopolymer forming the fourth layer (4) of the envelope according to any of claims 1 to 13 **characterized in that** the component of the alumino-silicon binder based on metakaolin in the form of a powder with a glass amorphous structure with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt% is mixed with fly ash of class C in the form of a powder in the amount from 10 to 12 wt% and with aluminium powder in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer, and then adding alkaline solution of activator of water glass Na_2SiO_3 in the amount from 45.0 to 47.0 wt% and disintegrated silicon grog based on silicon carbide SiO_2 with a size from 1.0 to 10.0 mm in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer.

15. Method of preparing the cast barrier high-density geopolymer forming the seventh layer (7) of the envelope according to any of claims 1 to 13 **characterized in that** the component of the alumino-silicon binder based on metakaolin in the form of a powder with a glass amorphous structure with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40.0 to 42 wt% is mixed with fly ash of class C in the form of a powder in the amount from 10.0 to 12.0 wt% and with a powder of disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt% and with aluminium powder in the amount from 0.3 to 0.6 wt% related to the total weight of geopolymer, and then adding alkaline solution of activator of water glass Na_2SiO_3 in the amount from 45.0 to 47.0 wt% and disintegrated silicon grog based on silicon

carbide SiO_2 with a size from 1.0 to 10.0 mm in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer.

16. A layer for thermal insulation and to increase bullet resistance of the envelope of a wooden building **characterized in that** it consists of a thermal insulation foamed geopolymer containing an alumino-silicon binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, fly ash of class C in the amount from 10 to 12 wt%, alkaline activator of water glass Na_2SiO_3 in the amount from 45 to 47%, disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt% and aluminium powder in the amount from 0.3 to 0.6 wt% and disintegrated silicon grog based on silicon carbide SiO_2 with a size from 1.0 to 10.0 mm in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer.

17. A layer for increasing bullet resistance of the envelope of a wooden building **characterized in that** it consists of a cast barrier high-density geopolymer containing an alumino-silicon binder based on metakaolin with a composition of SiO_2 (50.0%), Al_2O_3 (46.0%), Fe_2O_3 (0.5), CaO (0.5%), MgO (0.1%), Na_2O_3 (0.1%), K_2O (0.6%) wt% in the amount from 40 to 42 wt%, fly ash of class C in the amount from 10 to 12 wt%, alkaline activator of water glass Na_2SiO_3 in the amount from 1 to 10% and disintegrated silicon grog based on silicon carbide SiO_2 in the amount from 4.0 to 5.2 wt% and disintegrated silicon grog based on silicon carbide SiO_2 with a size from 1.0 to 10.0 mm in the amount from 4.0 to 5.2 wt% related to the total weight of geopolymer.

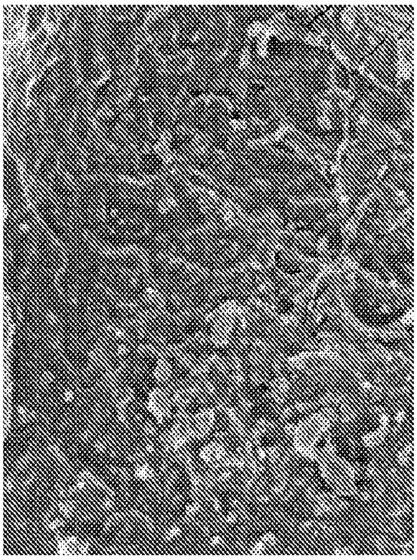

Fig. 1

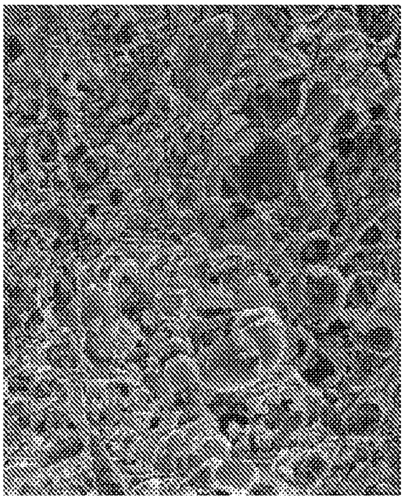

Fig. 2

Fig. 3

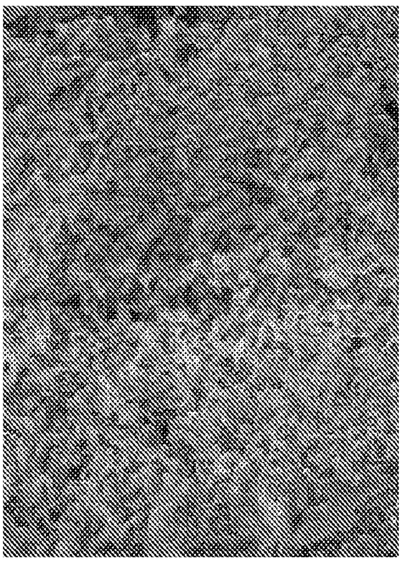

Fig. 4

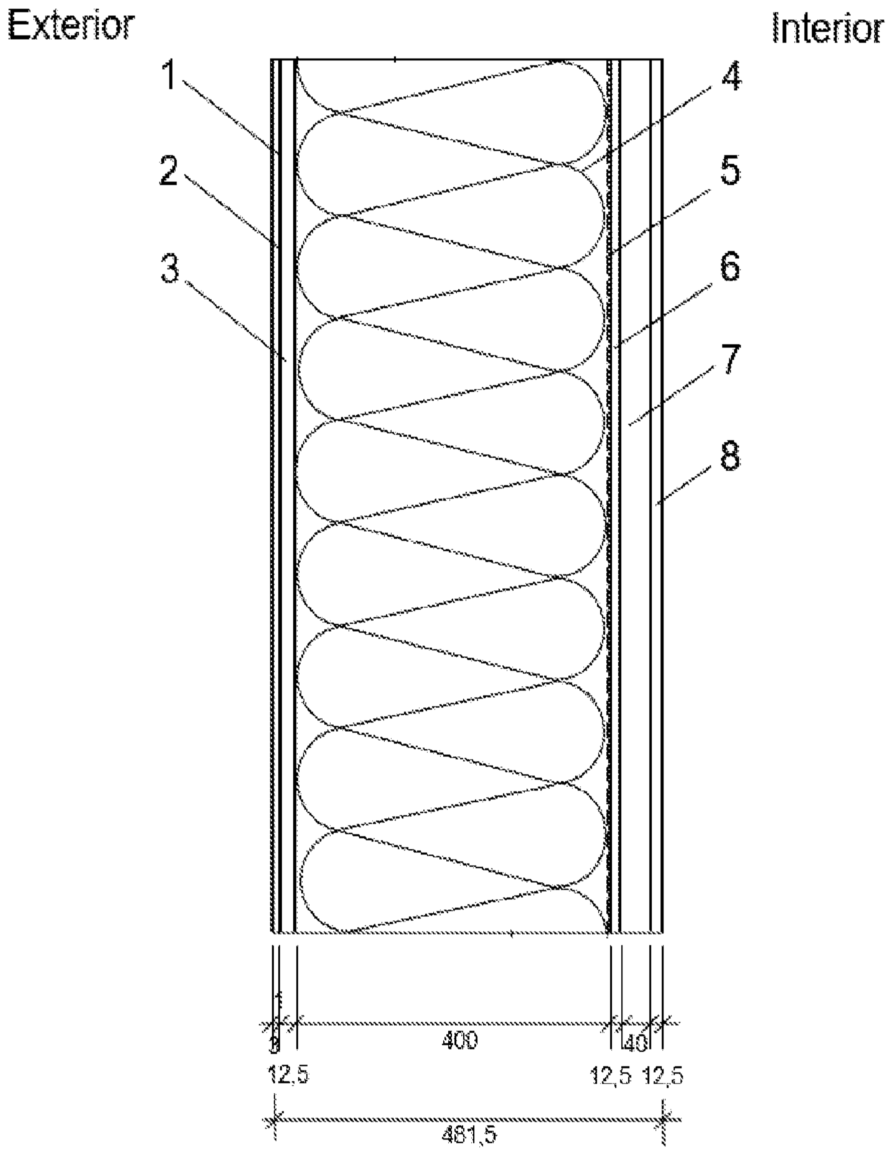

Fig. 5

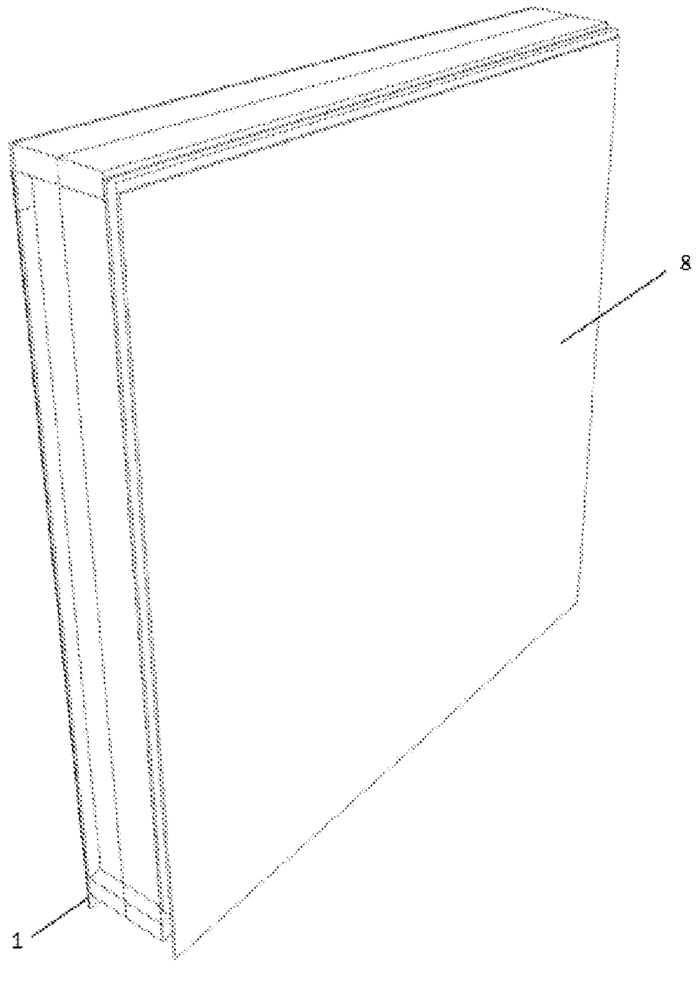

Fig. 6

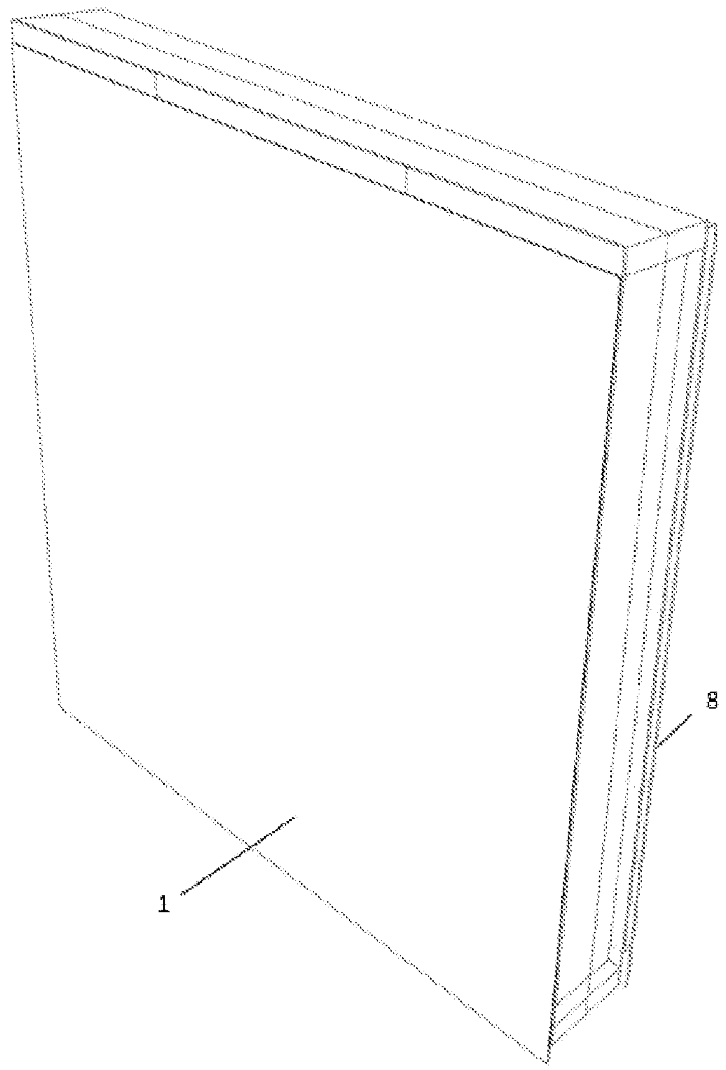

Fig. 7

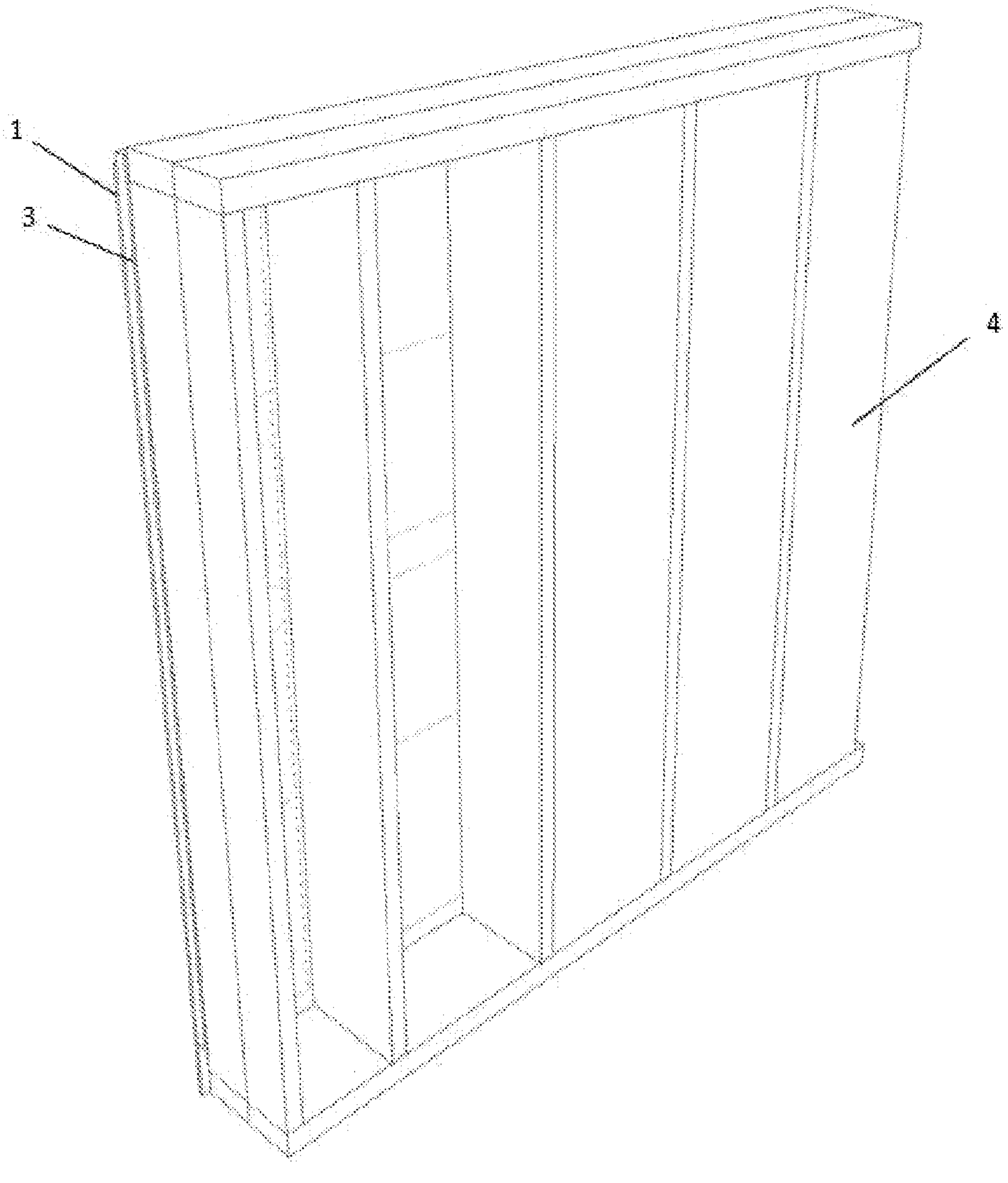

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2022/050076

A. CLASSIFICATION OF SUBJECT MATTER
INV. B32B3/04 B32B5/18 B32B9/00 B32B9/04 B32B13/00
B32B13/02 B32B13/10 B32B21/02 B32B27/32
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B32B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/326336 A1 (STRUTHERS CLAYTON W [US] ET AL) 30 December 2010 (2010-12-30) cited in the application claims 1-19; figure 2 -----	1-17
A	CZ 307 907 B6 (UNIV V LIBERCI TECCH [CZ]) 7 August 2019 (2019-08-07) claims 1-8; figure 1 -----	1-17

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 March 2023	06/04/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Chatron-Michaud, P

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CZ2022/050076

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2010326336	A1	30-12-2010	NONE	
CZ 307907	B6	07-08-2019	NONE	