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(54) **LOAD-BEARING PREFABRICATED DOUBLE-SKIN FAÇADE TIMBER WALL ELEMENT**

(57) The present invention belongs to the field of construction, more precisely to the field of prefabricated walls. The load-bearing prefabricated double-skin façade timber wall element comprises a timber frame and two transparent glass surfaces separated by an air cavity. The inner thermal-insulating glass unit (IGU) is bonded to the timber frame with the stiff polyurethane adhesive, while the outer laminated fully-tempered glass unit is connected to the timber frame with weather-resistant silicone adhesive. A cover strip is placed from the inner side over the timber frame in order to ensure correct and precise application of the polyurethane adhesive for gluing the inner insulating glass unit, while a soft plastic spacer is installed between the timber frame and the single-layer outer glazing in order to ensure precise installation of the weather-resistant silicone adhesive. The thermal-insulating three-layer glazing on the inside of the timber frame is attached frontally to the timber frame with the polyurethane adhesive.

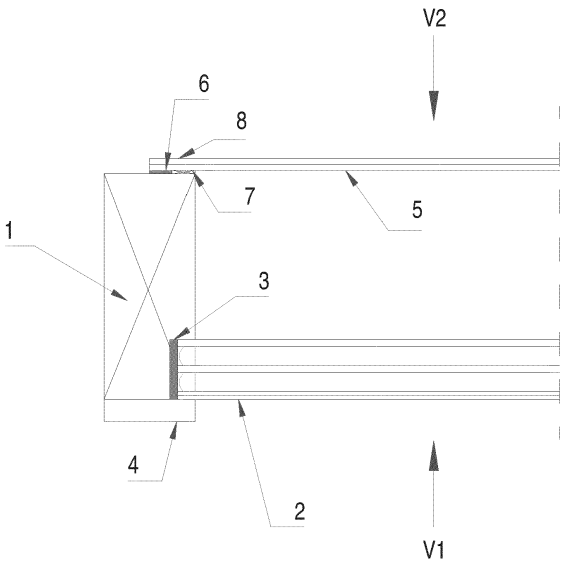

Figure 2

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Description

Field of the invention

[0001] The present invention belongs to the field of construction, more precisely to the field of prefabricated walls. The invention relates to a load-bearing prefabricated double-skin façade timber wall element.

Background of the invention and the technical problem

[0002] In modern multi-storey prefabricated timber construction, we are increasingly striving to use an increased share of glazing, which is located primarily on the south side of the building envelope. As a result, due to the mentioned asymmetry in the stiffness of wall elements, such storeys are distorted, which is particularly problematic in the increased number of storeys of timber buildings located in highly active seismic or partly windy areas. In order to minimize energy losses through building envelope the coefficient of thermal transmittance (U-value) should be as low as possible, this is why exclusively three-layer insulation glazing as fixed glazing fastened to a timber frame has been used for years. While the greatest possible sound insulation of such timber-glass wall elements is to be achieved at the same time, it is advisable to use an additional layer of single-layer glazing, which is attached to the timber frame at a certain distance from the insulating glazing. The so-called double-skin façade (DSF) element is obtained, which, in comparison to known solutions of the classic fixed three-layer insulating glazing, shows an increased degree of thermal and sound insulation. A DSF wall element is basically a special type of vertical building envelope consisting of two, in most cases transparent layers, insulating glazing and single glass pane, separated by an air cavity (duct).

[0003] In general, several subsystems of DSF elements are known from publications, which differ from each other according to the type or arrangement of glazing, width of the air duct, use of blinds, method of ventilation and air exchange between the duct and the interior of the building (Saelens D., Roels S., Hens H. Strategies to improve the energy performance of multiple-skin facades. 2008*),* however, none of these has so far been considered as having a horizontal load-bearing capacity. Installation of ventilation, which would also be optimal for the building, is not suitable for load-bearing DSF systems. Ventilation requires openings executed in the load-bearing elements of the DSF system, which significantly affects the horizontal load-bearing capacity of such a DSF wall element. The influence of openings on the horizontal load-bearing capacity and rigidity are generally known from some reference studies of such influences on classical timber-frame wall elements without the use of glazing (Kozem Šilih E., Premrov M. Influence of openings on horizontal load-carrying capacity of timber-frame wall elements with fibre-plaster sheathing boards. Advances in engineering software. 2012*;* Kozem Šilih E., Premrov M., Kuhta M., Šilih S. A parametric numerical study on the horizontal load-bearing capacity of the FPB-sheated timber framed wall elements with openings. International journal of civil engineering. 2015), which show that the influence of openings on the timber-frame wall elements is much more considerable than in case of cross-laminated (CLT) load-bearing wall elements (Šupek S., Dujic B., Zarnic R. Influence of openings on shear capacity of KLH walls, Proceedings of the 30th Assembly of Building Constructors. 2008).

[0004] The technical problem, which is solved by the present invention, is design of a prefabricated load-bearing element that will exhibit significantly improved horizontal load-bearing capacity compared to the known solutions. The object of the invention is thus a load-bearing prefabricated double-skin façade timber wall element - DSF, which will be useful in multi-storey new constructions of prefabricated timber buildings, as well as in structural and energy renovations of prefabricated timber buildings.

State of the art

[0005] So far, some façade elements that are transparent and at the same time have some horizontal load-bearing capacity, have been developed.

[0006] Alibaba and Odeniz (2016, doi.org/10.3130/jaabe.15.635) disclose double-skin wall façade elements and their performance in different temperatures, however, these solutions did not use timber as the frame material and also not used as load-bearing elements at al.

[0007] For timber-glass wall elements described by Ber (Glazing influence on horizontal load-carrying capacity and stiffness of timber-framed walls: PhD thesis. 2015*),* Premrov et al. (doi: 10.2495/CMEM-V5-N6-928-939), Strukelj et al (doi: 10.1016/j.conbuildmat.2015.05.112), Ber et al (doi: 10.1007/s40940-018-0086-5), Frangez et al (Experimental and numerical investigations of timber-glass shear walls. V: WCTE 2016: Proceedings. World conference on timber engineering, 2016*),* which also showed a certain degree of horizontal load-bearing capacity and rigidity and, of course, the legally prescribed minimum value of thermal insulation, three-layer insulating glazing, the so called single-skin façade, was used, which was fixed to the timber frame with different types of adhesive and different types of bonding line.

[0008] Patent CH707540 discloses a transmitting glass wall element for light timber buildings. The element has an insulating glass unit (IGU), composed of three glass panes divided by spacers filled with gas, i.e., the single-skin façade, which is mounted into a timber frame, so that outer edge of an IGU and the inner edge of the timber frame form a gap, height of which is equal to the thickness of the glass pane. Further, during the technological process, the gap is filled with a viscous adhesive.

Timber frame together with a glass infill joint together with a circumferential adhesive layer form a load-bearing composite element. The thickness of an IGU is equal to the thickness of the adhesive layer, while width of adhesive layer is between 5-9 mm.

Description of the solution to the technical problem

[0009] Known and already widely used load-bearing fixed timber-glass wall elements, where only three-layer insulating glazing (single-skin façade) is used do not provide sufficient horizontal load-bearing capacity and stiffness, hence the invention is based on double-skin façade (DSF) elements. The essence of the invention is in that the both glass panes are rigidly connected to the timber frame and thus assure transformation the horizontal load through the bonding line to the glass pane. To assure structural behavior of the wall element is it of the utmost importance to use an UV-resisting silicone adhesive for the outer glazing and a stiffer polyurethane adhesive for the inner insulating glazing.

[0010] The use of a timber frame and the simultaneous introduction of the load-bearing function, have never been proposed or used before in the field of DSF systems. Furthermore, the invention allows for a simultaneous increase in the racking resistance of the DSF prefabricated element, as well as its sound and thermal resistance, which are classified as building-physical properties. None of the known solutions has so far met both constructional and building-physical properties at the same time.

[0011] A load-bearing prefabricated timber wall element with double-skin façade according to the invention comprises a timber frame encasing an inner insulating glass unit (IGU) and an adhesive layer suitable for the structural connection of timber and glass on one side, as well as the single-layer outer glazing glued with a weather-resistant silicone adhesive suitable for connecting timber and glass on the outer side. A soft plastic spacer is installed between the timber frame and the outer laminated fully tempered glass in order to ensure precise installation of the silicone adhesive. A cover strip is placed from the inner side over the timber frame in order to ensure correct and precise application of the polyurethane adhesive for gluing the inner three-layer insulating glazing. As thermal insulating glazing on the inside of the timber frame, a three-layer glazing is used, which is attached frontally to the timber frame with polyurethane adhesive.

[0012] The present invention can be used in any timber building, while it especially allows for mass construction of prefabricated multi-storey timber buildings with an increased share of fixed glazing even in seismically or wind-active areas, which was practically impossible until now. Namely, the above-described construction significantly reduces the torsion of a multi-storey building by individual storeys. Consequently, the resistance of such a building to horizontal loads such as wind and seismic load is considerably increased, which cannot be achieved by a conventional glazed façade.

[0013] The element according to the invention is not ventilated, i.e., without any openings, but may be combined with other elements when used in construction of buildings.

[0014] Compared to single-skin façade elements as described in patent CH707540B1, the advantage of the invention is in the increased horizontal load-bearing capacity and horizontal stiffness as well as in the increased sound and partly thermal resistance. In comparison to the already developed double-skin façade elements (*Alibaba and Odeniz (2016, doi.orgl10.3130/jaabe.15.635),* an important advantage lies particularly in the fact that the double-skin timber-glazed façade elements according to the invention have horizontal load-bearing capacity and an environmentally friendly timber frame, while known elements do not.

[0015] The invention is applicable for load-bearing transparent timber-frame wall elements in prefabricated timber construction, both in the case of new buildings and in the case of energy and structural renovations of dilapidated old buildings. The invention could be used in several fields:

- In the field of new multi-storey prefabricated timber buildings where it can significantly contribute to increasing the horizontal load-bearing capacity and stiffness of the entire building; this is especially important in lower storeys, where the horizontal load impact on the wall elements is greatest.
- In the field of seismic renovation of multi-storey prefabricated timber construction, where an existing classic timber-frame wall element of the building envelope is easily replaced with a load-bearing DSF prefabricated wall element proposed in the invention.
- It can also be used as a component wall element of structural modular upgrades of existing buildings, which allows obtaining important new floor areas on the existing building.
- It is also possible to use it in concrete, brick and steel construction, wherein the building-physic properties are mainly exploited and the mechanical properties of the timber-glass panel are exploited to a lesser extent.

[0016] A load-bearing prefabricated double-skin façade timber wall element according to the invention will be further described based on exemplary embodiments and figures, which show:

Figure 1 Load-bearing prefabricated timber wall element with double-skin facade from the inside (left) and the outside (right)

Figure 2 Schematic representation of the attachment of an inner three-layer insulating glazing and a single-layer outer glazing to a timber frame

Figure 3 Experimental force-displacement diagrams for the wall element as shown in Figure 1

[0017] As shown in Figure 1 the load-bearing prefabricated timber DSF element comprises a timber frame 1, an inner IGU (insulating glass unit) 2, an adhesive suitable for the structural connection of timber and glass 3, a cover strip 4, a glued outer laminated fully tempered glass 5, a weather-resistant silicone adhesive suitable for connecting timber and glass 6, a soft plastic spacer 7 and an enamelled glass edge 8. Thermal insulating three-layer glass unit 2 on the inside of the timber frame 1, is attached frontally to the timber frame 1 with polyurethane adhesive 3, and on the outside, laminated fully tempered glass 5 is provided, which is glued with the weather-resistant structural silicone adhesive 6 to the timber frame 1.

[0018] Figure 2 shows the connection of the inner glazing with a polyurethane adhesive thickness of 7 mm and connection of the outer glazing with the silicone adhesive thickness of 3 mm, which were also tested experimentally. However, these are essentially variable values, that were further analysed parametrically-numerically with specially developed computational mathematical models of DSF wall elements.

[0019] The selected thicknesses of all glazing can also be variable, but only DSF wall elements with the thicknesses shown in Figure 2 were experimentally tested, and the other values were parametrically calculated using the previously mentioned mathematical models.

[0020] Figure 3 shows a comparison of the results between the experimental tests performed on three full-scale test samples of wall elements (P1, P2 and P3) with the polyurethane adhesive for the inner glazing as shown in Figure 1 and described above. All tested DSW-P test subjects show similar response. Adhesively bonded joint with a thickness of 7.0 mm allows for significant in-plane deformation of the wall element. Compared to previous investigations performed at FGPA UM (IQ-Home TRL5 internal report), we find that the thickness of the adhesive has a key effect on the stiffness and partly the load-bearing capacity of the wall element. A noticeable consequence of the thicker adhesive layer is also a greater slip between the glass and the timber frame in the connecting plane.

Claims

1. A load-bearing prefabricated double-skin façade timber wall element, comprising a timber frame (1) having:

   - a three-layer insulating glazing designed as laminated float glass panes (2) on an inner side of the timber frame (1), said panes (2) being glued to the timber frame (1) with a polyurethane adhesive (3), and
   - a single-layer outer glazing designed as laminated fully tempered glass (5) on an outer side of the timber frame (1), said laminated fully tempered glass (5) being glued to the timber frame (1) with a weather-resistant structural silicone adhesive (6).

2. The load-bearing prefabricated double-skin façade timber wall element according to claim 1, wherein a cover strip (4) is provided on the inner side of the timber frame (1) to ensure correct and precise application of the polyurethane adhesive (3) for gluing the inner three-layer insulating glazing (2).

3. The load-bearing prefabricated double-skin façade timber wall element according to claim 1 or claim 2, wherein a soft plastic spacer (7) is provided between the timber frame (1) and the single-layer outer glazing (5) to ensure precise installation of the weather-resistant silicone adhesive (6) for gluing the laminated fully tempered glass unit (5).

4. The load-bearing prefabricated double-skin façade timber wall element according to any of the preceding claims, wherein the laminated fully tempered glass (5) is provided with an enamelled glass edge.

5. The load-bearing prefabricated double-skin façade timber wall element according to any of the preceding claims, wherein the thickness of the polyurethane adhesive is 7 mm and the thickness of the silicone adhesive is 3 mm.

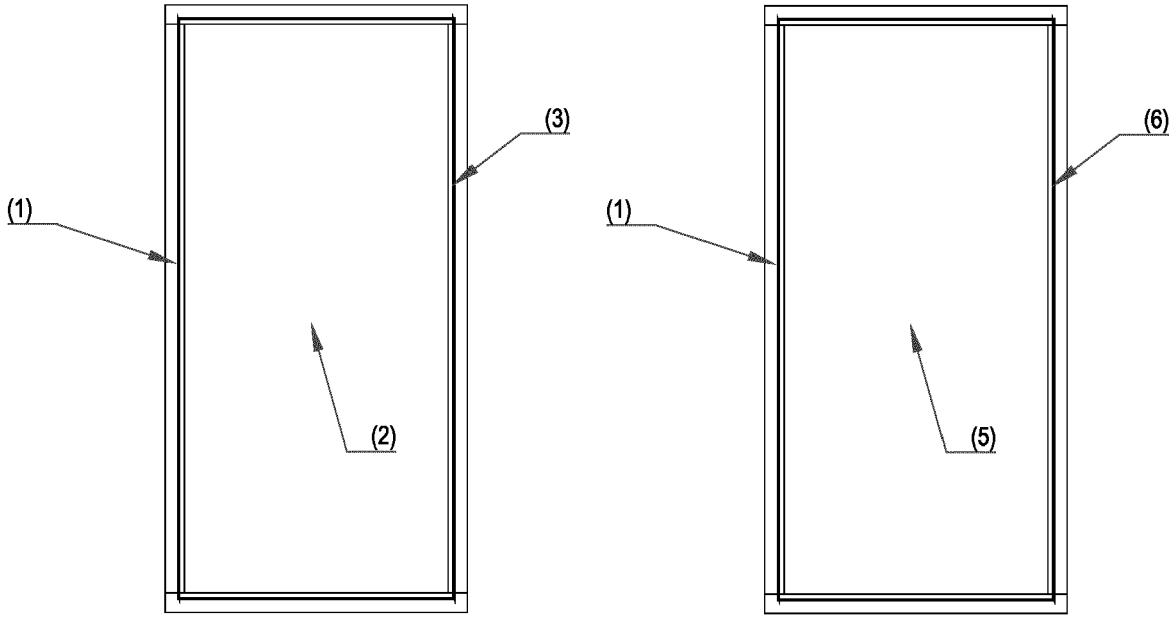

Figure 1

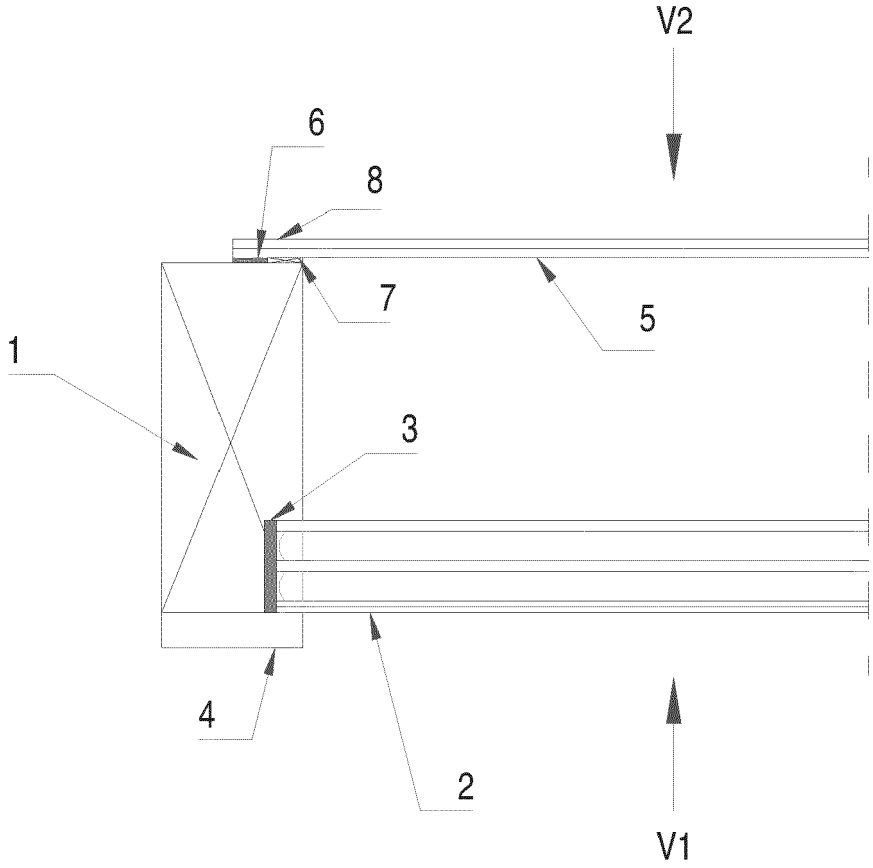

Figure 2

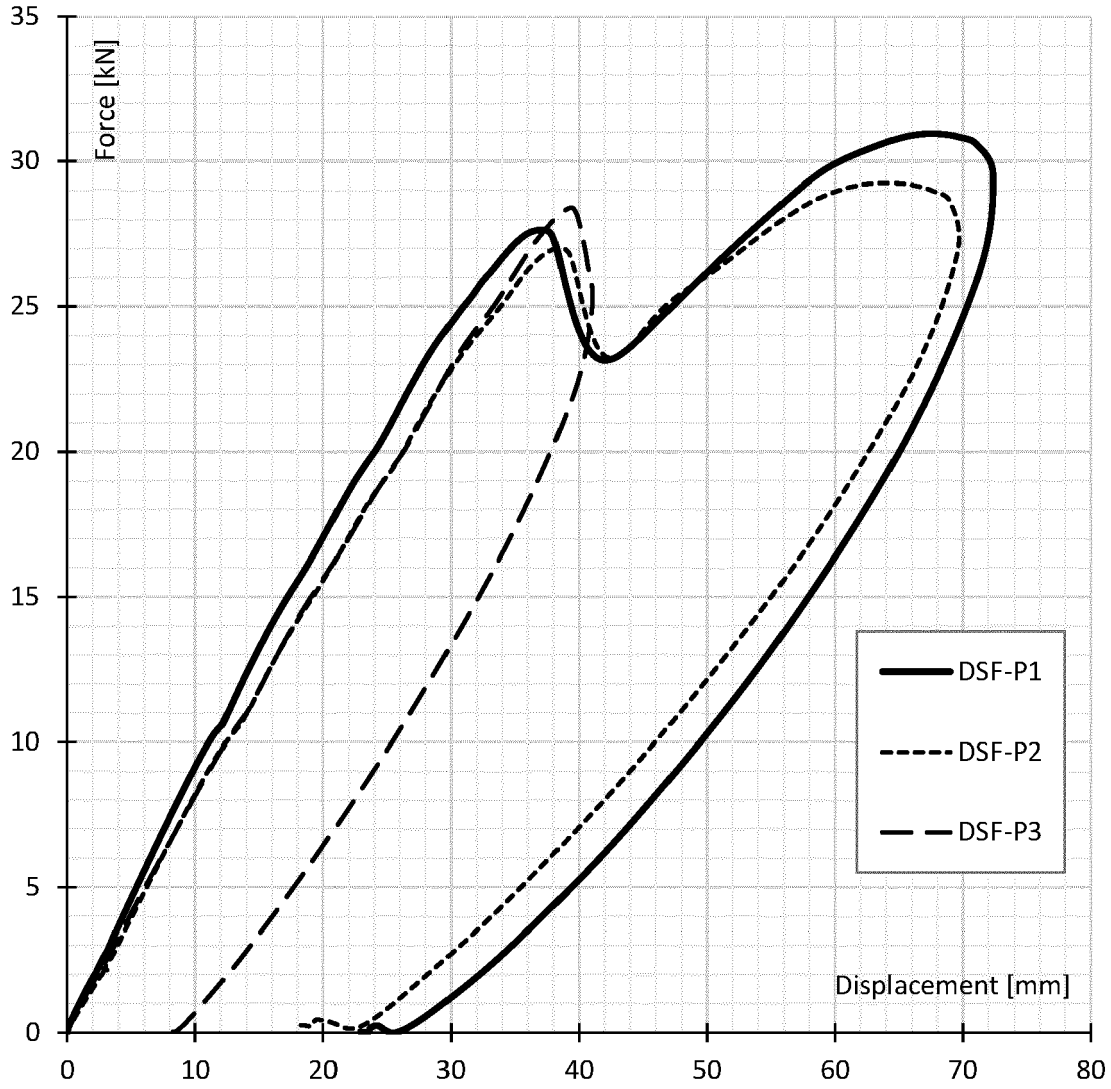
Force [kN]
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Displacement [mm]
DSF-P1
DSF-P2
DSF-P3

Figure 3

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 2038

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TECHNICAL FIELDS SEARCHED (IPC)
E04B
E06B

1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	1 March 2022	Melhem, Charbel

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