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ANALYSIS OF STRENGTH AND DEFORMATIVITY OF GLASS PLATE JOINTS UNDER STATIC LOADING

Слабким місцем будь-якої конструкції завжди є вузол з'єднання елементів. У роботі наведено результати дослідження зчеплення скляних пластин, які з'єднані між собою по всій поверхні за допомогою клейових матеріалів та виготовлених по технології триплексування, за дії статичного навантаження. Встановлено несучу здатність та деформативність таких з'єднань. Для проведення досліджень було спроектовано, виготовлено та випробувано 6 серій дослідних зразків. Отже, об'єктом дослідження є 6 серій дослідних зразків для випробування зчеплення скляних пластин між собою. Дослідний зразок складався з 3 скляних пластин, товщиною 10 мм, з'єднаних між собою за допомогою технології триплексування та різних клейових матеріалів. Перед склеюванням скляні пластини дослідних зразків серії I–V очищали від бруду та знежирювали. Клей наносили на всю поверхню однієї пластини. Далі скляні пластини міцно з'єднувались між собою за допомогою лежат та витримувались протягом 5–10 хв. Тривалість тужавіння залежала від клейових матеріалів. Тужавіння клею зразків четвертої та п'ятої серії здійснювалось під променями ультрафіолетової лампи. Пластини дослідних зразків шостої серії з'єднували між собою за технологією триплексування, де між пластинами вкладалась полімерна плівка EVASAFE (Bridgestone, Японія), а дослідні зразки нагрівались до температури 130 °C і витримувались 30 хв.

Розроблено методика експериментальних досліджень. Установка для випробування складалася із стенду для статичних випробувань конструкції на міцність. Зовнішнє навантаження N прикладалось за допомогою гідравлічного домкрата та відбувалось покроково. Величина ступеня навантаження становила 1,0 кН та контролювалась за допомогою динамометра аж до повного руйнування дослідного зразка. На кожному ступені навантаження відбувалась витримка 10 хв, після чого виконували зчитування показів приладів.

На основі отриманих результатів зроблено аналіз роботи зчеплення скляних пластин та побудовано усереднений графік залежності деформацій зсуву та дотичних напружень $\tau=N/A$ для серій дослідних зразків. Завдяки цьому забезпечується можливість отримання міцності та деформативності для серій дослідних зразків.

Ключові слова: шари скла, триплекс, дослідний зразок, скляні пластини, вузол з'єднання елементів.

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1. Introduction

The weak point in any structure is always a junction of elements. Glass steel structures were no exception. When designing glass supporting structures, it is necessary to understand that glass is a material whose relative plastic deformations are practically equal to zero. In other words, glass is a brittle material [1].

The joining of glass surfaces is a procedure of high technical significance. Today, the most common method of joining glass is adhesive bonding and glass joining using the triplex technology. The triplex compound is that a polymer film is inserted between the glass. The advantage of adhesive bonding is the ability to join surfaces of complex shape. In most cases, such compounds are tight and impervious to vapors and liquids.

Connection is one of the most critical parts of structures [2, 3]. In 2017, the study of glass multilayer columns for central compression was started at the Lviv Polytechnic National University (Ukraine) [4, 5]. At the same time, it became necessary to determine the ductility of adhesion of

the layers of triplex glass, which is becoming more widely used as a carrier material. Patents were obtained for a prototype for testing the adhesion of plates to each other [6]. An example of the use of glass as a structural supporting element is the Talus du Temple glass pavilion near the French town of Noyers (architect Dirk Jan Postel, 2001). The pavilion 5.04×5.1 m in size is covered by a wooden roof, the walls of the pavilion 2.3 m high consists of two 10 mm layers of float glass. The walls are connected to the base and the roof using steel corners with neoprene gaskets. The construction during its existence suffered two strongest storms, which proved its strength.

The above examples show the possibility of using glass as a supporting structural element [7–10]. However, to date, there are no norms, rules or methods for calculating such structures. Given all of the above, this study is relevant today and has a great prospect of practical application in the future in Ukraine and in the world. Thus, the *object of research* is six series of prototypes for testing the adhesion of glass plates to each other [6]. And the *aim of research* is to determine the strength and deformability of such compounds.

2. Methods of research

6 series of prototypes were made of non-tempered M4 sheet glass (Table 1). The prototypes consisted of 3 glass plates interconnected using triplex technology and ad-

hesive materials. The general view of the prototypes is shown in Fig. 1.

Before gluing, the glass plates of the prototypes of the I–V series were cleaned of dirt and fat-free. Glue was applied on the entire surface of one plate.

Table 1

Prototype characteristics

No. of pos.	Series	Prototype brand	Bonding area, cm ²	Material for connecting plates	Plate thickness, mm	Glass characteristics	
						Glass mark	Compressive strength, MPa
1	I	SZ-1.1	50.7	Den Braven Montagefix-AQ (black color)	10	M4	700
2		SZ-1.2					
3	II	SZ-2.1		Den Braven Zwaluw Aqua-Silicone (transparent color)			
4		SZ 3-2.2					
5	III	SZ-3.1		Topex 42E113 hot glue			
6		SZ-3.2					
7	IV	SZ-4.1	Loxeal Adhesives UV 30-23 Engineering UV glue				
8		SZ-4.2					
9	V	SZ-5.1		4			
10		SZ-5.2					
11	VI	SZ 3-6.1		84	Polymer film EVASAFE (Bridgestone, Japan)		
12		SZ-6.2					
13		SZ-6.1					
14		SZ-6.2					

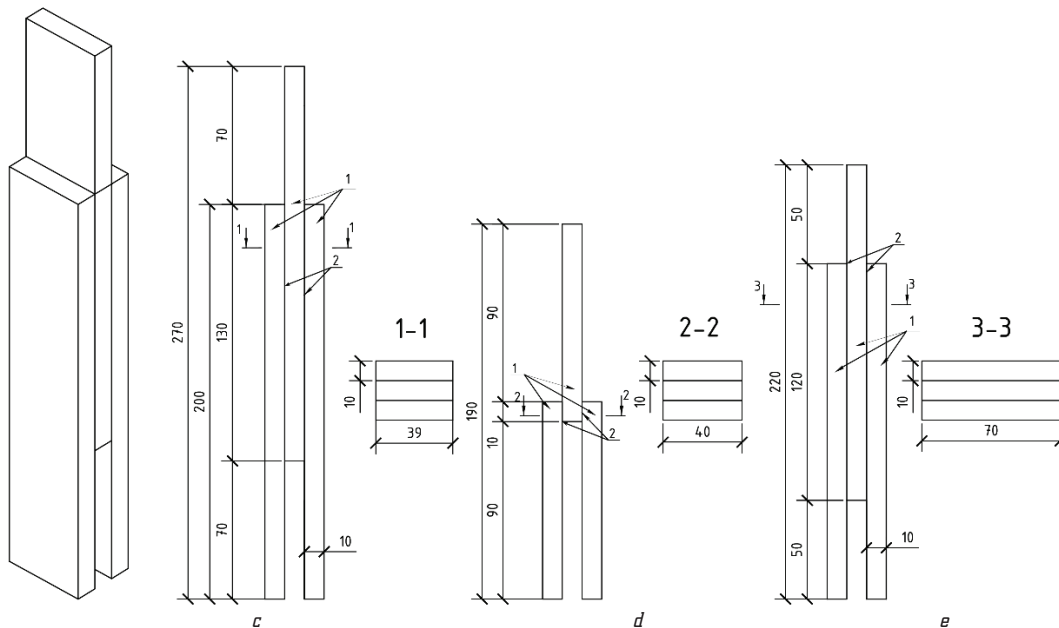
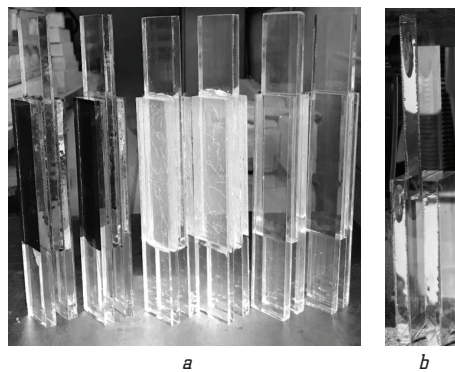


Fig. 1. General view of the prototypes: *a* – general view of the prototypes of the I–IV series; *b* – general view of prototypes of the V series; *c* – structural diagram of prototypes of the I–IV series; *d* – structural diagram of prototypes of the V series; *e* – structural design of prototypes of the VI series; 1 – glass plate; 2 – seam clutch of glass plates

Then the glass plates were firmly connected to each other with a vise and held for 5–10 minutes. The curing time depended on the adhesive materials. Gluing of prototypes of the fourth and fifth series was carried out under the rays of an ultraviolet lamp. The plates of the experimental prototypes of the sixth series were interconnected using the triplex technique, where EVASAFE polymer film (Bridgestone, Japan) was placed between the plates, and the experimental prototypes were heated to a temperature of 130 °C and held for 30 minutes.

The unit for testing consisted of a stand for static structural strength tests. An external load N was applied using a hydraulic jack and occurred step by step. The magnitude of the load was 1.0 kN and was monitored using a DOSM-3-50 dynamometer (Ukraine) for the I–V series prototypes and a ring dynamometer for the VI series prototypes until the experimental prototype was completely destroyed. At each load stage, an exposure of 10 min took place, after which readings of the readings of the instruments were performed.

Prototype 1 was positioned vertically. In order to avoid local chipping and breaking of glass in places where the prototype rests on the metal, a felt pad was laid. To measure absolute deformations, dial gauges 5 were used with a division value of 0.001 mm for prototypes of the IV–VI series and 0.01 mm for the I–III series. Measurements of absolute deformations were carried out until the complete destruction of the prototypes of the I–V series. For VI series of prototypes, instruments were removed at a load of 80 % of the expected destructive load.

3. Research results and discussion

Prototypes of the I–III series were destroyed along the seam of adhesion of the layers of glass, the destruction occurred gradually upon reaching the destructive load value, SZ-1.1 N_{max} – 8.82 kN, SZ-1.2 N_{max} – 8.77 kN, SZ-2.1 N_{max} – 13.13 kN, SZ-2.2 N_{max} – 13.93 kN, SZ-3.1 N_{max} – 1.34 kN and for SZ-3.2 N_{max} – 1.32 kN. Prototypes of the IV series collapsed instantly after reaching a destructive load value, which was 32.3 kN for the brand of the SZ-4.1 prototype and 33.1 kN for the SZ-3.2 N_{max} . Shear deformation was not more than 0.5 mm. The IV prototypes collapsed along the glass plates without breaking the adhesion joints of the glass layers.

Prototypes of the V series were destroyed instantly after reaching the destructive value of the load, which was 9.57 kN for the brand of the prototype SZ-5.1 N_{max} and 8.45 kN for the SZ-5.2. Shear deformation was not more than 0.5 mm. Prototypes of the V series collapsed along the seam of adhesion of the layers of glass.

Prototypes of the VI series collapsed instantly after reaching a destructive load value, which was for: SZ-6.1 N_{max} – 89.09 kN, SZ-6.2 N_{max} – 88.56 kN, SZ-6.3 N_{max} – 88.64 kN та для SZ-6.4 N_{max} – 89.02 kN. Shear strain was not more than 1 mm. Prototypes VI collapsed on glass plates without destroying the seams of adhesion of the layers of glass. Therefore, the adhesion strength of the glass layers during shear strain could not be determined.

To do this, reduce the area of connection of the glass plates and repeat the experiment.

Based on the results of the study, an average graph of the dependence of shear deformations and shear stresses $\tau = N/A$ for a series of prototypes was constructed (Fig. 2).

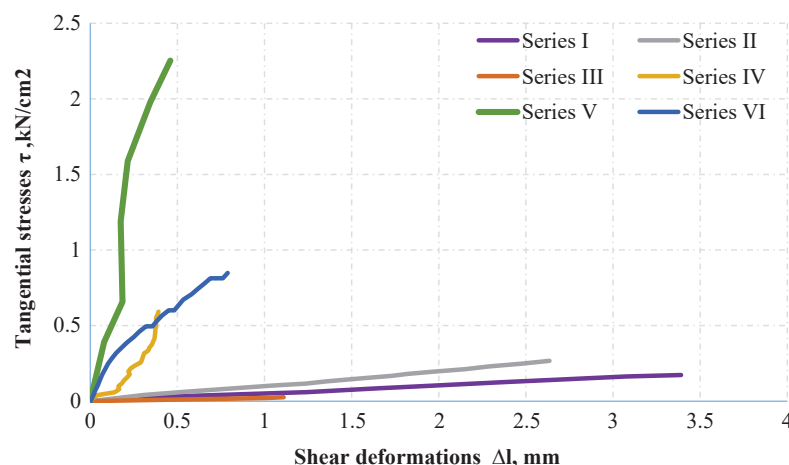


Fig. 2. Dependence of shear deformations and shear stresses τ

As can be seen from the graph in Fig. 2, the highest shear stresses in prototype V with Loxeal Engineering Adhesives UV 30-23 UV glue. The greatest shear deformation was in series I with Den Braven Montagefix-AQ glue (black).

4. Conclusions

An experimental research technique has been developed, which made it possible to compare the adhesion of glass plates to each other using the technology of triplex and adhesive materials under the action of a static load. In the prototypes of the I–III series of destruction, destruction occurred gradually, while the destruction of the IV–VI series occurred instantly. It is more expedient to use triplex technology when using joints in load-bearing structures made of glass, since the prototypes V were destroyed along the glass plates without breaking the adhesion joints of the glass layers

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