**УНИВЕРСИТЕТ ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ**
**Международна юбилейна научно-приложна конференция УАСГ2012**

**15-17 НОЕМВРИ 2012**
**15-17 NOVEMBER 2012**

**International Jubilee Conference UACEG2012: Science & Practice**
**UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY**

# BONDED GLASS- ALUMINUM COMPOSITE MEMBERS. A NEW SOLUTION TO LARGE SPAN BUILDING ENCLOSURES.

**D. Dakov[1], S. Trifonov[2]**

***Keywords*****:** *structural glass, aluminum structures, composite structures*

***Research area*****:** *metal structures*

**ABSTRACT**

A new type of glass- metal composite structural members, built of aluminum tubes and glass panes bonded together is discussed in this paper. A brief description of the previous research in the larger field of bonded glass composite members is given, along with the general characteristics of different adhesives. A comparison between the newly presented glass- aluminum bonded members and the glass-steel members, studied before by other authors, is done as a part of the paper. Some results of a FEM simulation of the behavior of a 3,0m long bonded glass-aluminum composite member subjected to four point bending (simply supported beam, loaded by two concentrated forces) are given as a part of the ongoing PHD research of the second author.

## 1. Introduction.

Modern architecture demands for large span glazed facades and roofs as part of the imposing design of prestigious projects around the world.

This demand for large span building enclosures, which are elegant in the same time, gave rise to the development of new types of structural members such as laminated glass beams, cable structures and glass- stainless steel composite members.

The glass- aluminum composite members, introduced in this paper, come as a new alternative to middle and large span glazing enclosures. The concept aims to combine the refined design of the composite glass- metal members and the reliability of the standard aluminum glazing systems.

[1] D. Dakov, Prof. Dr., 1000 Sofia, Bulgaria, Hr. Smirnenski str. 1, UACEG, „Metal, Timber and Plastic Structures“ department, dakov_fce@uacg.bg

[2] S. Trifonov, M.Sc.Eng., 1000 Sofia, Bulgaria, Hr. Smirnenski str. 1, UACEG, „Metal, Timber and Plastic Structures“ department, eng.st.trifonov@gmail.com

## 2. Previous research in the larger field of glass- metal structural members.

The use of adhesives in structural glass applications has only recently become a serious research objective. Two studies representative of the research tendencies are discussed here.

Weller, Meier and Weimar investigated the bending behavior of several types of glass- steel composite sections in [3].

The 1100mm long specimens, shown on the following figure, were subjected to four point bending tests.

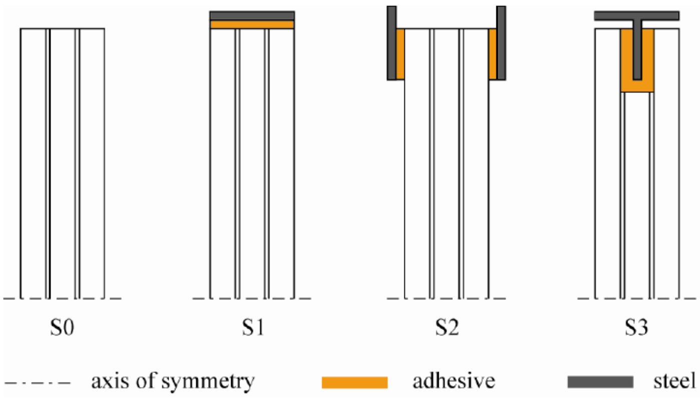


**Figure 1.** Half cross sections of tested beams, as in [3]. Laminated glass beam without reinforcement tested for comparison.

Depending on the type of reinforcement used (types S2 and S3 providing better adhesion), the stiffness and the ultimate load of the specimens vary. Over and above the common outcome of the tests is that all types of reinforced beams demonstrate better behavior compared to glass beams without steel reinforcement.

Louter and Veer studied the behavior of “reinforced glass beams” through scaled specimens in [2]. Glass beams reinforced by steel strips were studied when subjected to four point bending.

The specimens of both beam layouts studied carried, to a different extend, increasing bending load after the initial cracks, which is again a very positive outcome, taking into account the general safety concerns regarding the brittle behavior of glass.

## 3. Glass- aluminum composite members.

The concept of composite glass- aluminum members, using standard aluminum profiles and glass webs, can be best described using the figure below.

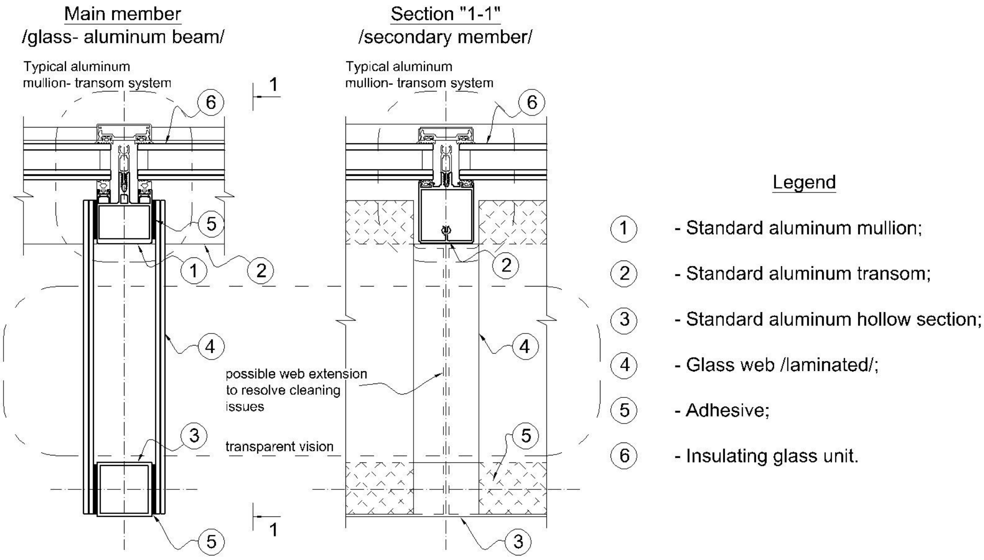


**Figure 4.** Glass- aluminum composite members.

It is seen from the figure above that glass could help in minimizing the nontransparent elements by means of strengthening and stiffening of the aluminum parts.

By forming the future development of such composite members it is important to take into account the mechanical properties of the structural materials involved.

**Table 1.** Main mechanical properties of glass, compared with aluminum's and steel's.

| **Characteristic** | **Designation** | **Unit of measurement** | **Value for glass** | **Ratios** | |
|---|---|---|---|---|---|
| | | | | $\frac{aluminum}{glass}$ | $\frac{steel}{glass}$ |
| Self weight | $g$ | $kN/m^3$ | $25,00$ | $1,1$ | $3,1$ |
| Elasticity modulus | $E$ | $MPa$ | $70000$ | $1,0$ | $3,0$ |
| Poisson's ratio | $\upsilon$ | - | $0,22-0,24$ | $1,3$ | $1,3$ |
| Coefficient of thermal expansion | $\alpha_T$ | $m/m.K$ | $9.10^{-6}$ | $2,5$ | $1,4$ |
| Strength | $f_y$, $f_{0,2}$ or $f_u$ | $MPa$ | 120 [1] | 1,3 [2] | 2,0 [3] |

[1]- Bending strength of fully tempered glass;
[2]- Yield strength of steel grade S235 (most popular steel for structural applications);
[3]- 0,2% strength of aluminum alloy AW 6060 T66 (one popular aluminum alloy for glazing applications).

Based on the table above, and knowing the stress- strain curves of glass, aluminum and steel, it could be assumed that aluminum seems to behave more similarly to glass in terms of stiffness and strength than steel. That presents the aluminum as a promising alternative to steel in composite applications.

A benefit of the structural shape is the increased torsional stiffness of the member, provided by the usage of two glass webs instead of one.

Regardless of the architectural and structural benefits discussed above, the system proposed might also have some disadvantages.

The very different thermal expansion coefficients of glass and aluminum might be a potential issue. This however applies mostly to external structures, since modern aluminum systems have very good thermal properties guarantying that the temperature variations of the aluminum mullion's body will only be within the range of the temperature variations within the interior.

Another potential issue might be the cleaning of the inner space between the glass webs if not sufficiently designed.

## 4. Adhesive materials for glass- aluminum structural members.

The adhesive joints in structural glass applications give well- known benefits in terms of stress distribution and architectural appearance. However an analysis of the ageing process of the adhesive under the influence of different factors such as temperature, UV light and moisture is recommended for each particular case in order to assess the durability of the system.

The adhesives used for structural glass applications can be divided into two groups: flexible (though elastic) and hard (brittle) adhesives [4]. Silicones and polyurethanes are some of the flexible adhesive systems and acrylic adhesives and epoxy resins are considered as hard adhesives.

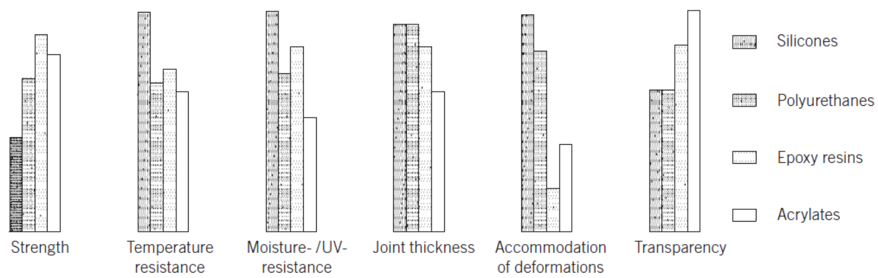


**Figure 6.** Properties of different types of adhesives, as in [4].

The hard adhesives have very high strengths but low elongation at tear. They are not able to accommodate large deformations and are susceptible to brittle behavior.

Flexible adhesives, although having relatively lower strength, have normally very high elongation at break. Therefore, taking into account the different thermal expansions of glass and aluminum, the flexible systems seem to be the best solution to glass- aluminum composite members.

Apparently the polyurethanes have the best combination among the adhesives of high strength and sufficient ability to accommodate deformations. In addition they are one of the adhesive types recommended by EN 1999-1-1 [1].

Based on the above the polyurethanes are chosen as an adhesive type at this stage of research.

## 5. Numerical analysis of a 3,0m long composite members, subjected to four point bending.

The 3,0m long simply supported member modeled is shown on the figure below. The load configuration chosen allows examining the behavior of the member by the influence of pure bending (the area between the two concentrated forces).

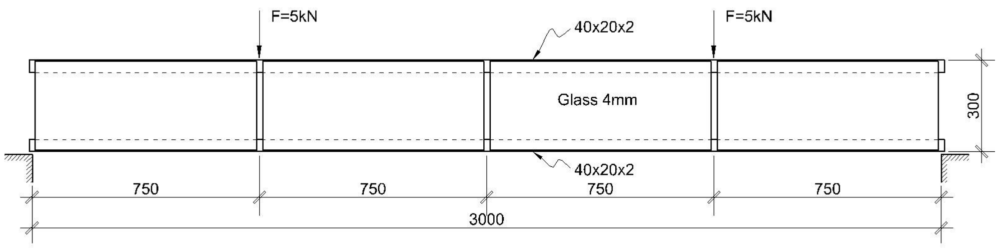


**Figure 7.** Schematic representation of the member analyzed.

The full information about the mechanical properties of the adhesive was not available at the time of writing, so only linear analysis was possible.

The linear analysis is not able to provide adequate information about the behavior of the members under extreme loads, but yet it gives a good idea of the stress distribution between the different components of the composite members.

Some results from the analysis are shown on the following figures.

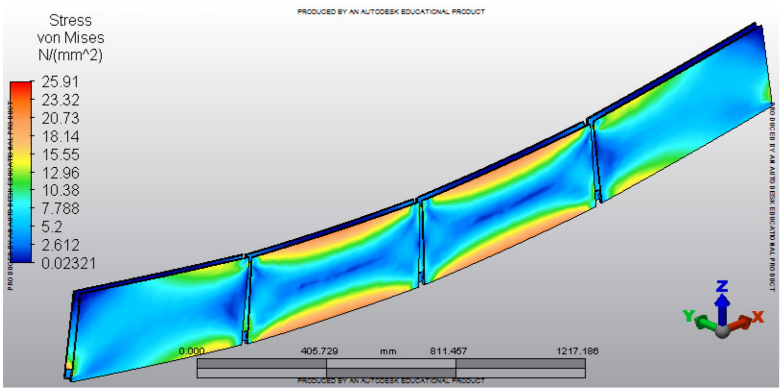


**Figure 8.** Stress von Mises diagram of the glass webs.

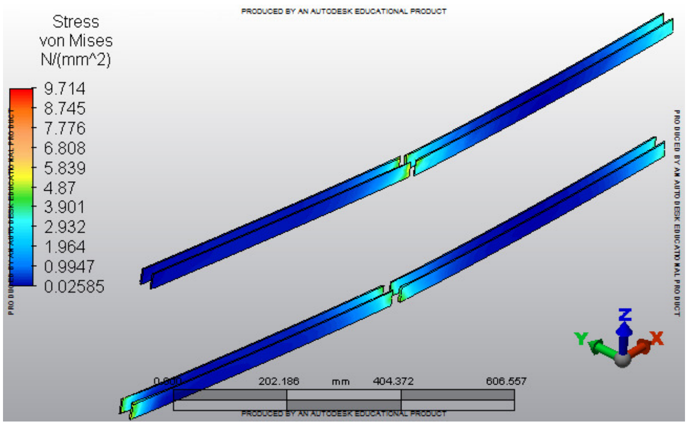


**Figure 9.** Stress von Mises diagram of the adhesive.

It is seen that under relatively high external loads the stresses in the glass webs and the adhesive are still within the allowable limits.

Yet it is obvious that the adhesive area is susceptible to stress concentrations and some special considerations regarding this issue need to be taken into account.

## 6. Discussion and future directions of the ongoing research.

Previous research in the field of composite glass members demonstrates promising results regarding the future applications of those kinds of structures.

The numerical analysis in this paper, although linear, shows that the glass- aluminum composite members could also be able to bear very large external loads.

The research of the authors will continue in diverse directions enriching the information about the composite behavior of the three materials involved.

A series of tests of small scale specimens under simple loads is also planned in order to gain sufficient information about the mechanical characteristics of the adhesive.

Comprehensive nonlinear analysis to predict the behavior of the members under extreme loads is necessary and an experimental validation and update of the models to be used are considered as a very important part of the continuing research.

### LITERATURE


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