Size effect of bonded area for bonded joints between ETICS with an acrylic thin-film plaster and sheet metal component

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Abstract. The issue of anchoring sheet metal components has been part of construction practice for a very long time. Sheet metal components can be found on most contemporary buildings and due to the increasing thickness of insulation the possibility of anchoring to the supporting substrate is a problem. This paper discusses the issue of the bonded joint size dependence on the load capacity for fastening sheet metal elements to ETICS facades. A thixotropic silane modified polymer adhesive was used for this research. It was concluded that the size has a significant effect on the load capacity of the joint and their dependence was described.

1 Introduction

Plumbing elements are an important part of every modern building. These elements are mainly used to cover and prevent water from entering the structure. A correct and well-executed technological procedure is therefore very important. In these times of energy crisis, more and more attention is being paid to the energy self-sufficiency of buildings and one of the ways to achieve this goal is to insulate them. In practice, this insulation is most often done with ETICS systems with 200 mm thick thermal insulation [1,2] And the anchoring of plumbing elements into these insulation systems is highly inappropriate due to the perforation of the system and possible water seepage. Previous research has already shown that glued joints are a very suitable alternative for fastening through the thermal insulation system to the substrate and shows its high load-bearing capacity which exceeds the load-bearing capacity of the plaster guaranteed by the manufacturer [3].

The paper continues the initial series of tests and focuses on the effect of the bonded joint size and the possible negative effect of the thermal insulation on the tensile capacity and discusses the possibility of further research.

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2 Materials and used method

2.1 Materials

In a study of bonded joints for fastening sheet metal elements to modern facades, hot-dip galvanized steel was the most suitable material of the three tested with the highest adhesion 0,694 MPa. [3] For this reason, hot-dipped galvanized steel brand S235JR (1.0038) according to the EN 10025-2 standard [4] with a tensile strength of min. 360.0 MPa and a yield strength of 235.0 MPa were selected and manufactured for this size dependence test.

The thixotropic silane modified polymer adhesive ARDEX CA 20 P for external applications produced by Ardex Baustoff GmbH was chosen for bonding to the substrate.

ETICS was used as the base substrate with the following layer sequence: CETRIS BASIC - 16mm, Adhesive and screed matter UNI AM - 3 mm, EPS Polystyrene - 40 mm, Adhesive and screed matter UNI AM - 3 mm with Fabric R117 mesh 4x4.5 mm, 145 g/m^2, Universal primer UNI PUTZGRUND, Polished acrylic plaster KUNSTHARZ-PUTZ - 1,5 mm.

2.2 Methods

2.2.1 Preparation of Test Specimens

For this test, samples were made from the following materials: base particleboard, cement screed, thermal insulation, cement screed with fiberglass fabric, polished acrylic plaster and a metal circular target. For the tensile test, the metal targets were made of hot-dip galvanized steel in the following sizes: 125 mm^2, 250 mm^2, 500mm^2, 1000 mm^2 and 2000mm^2. For the test was used a façade composition that corresponds with the actual composition commonly used on buildings with a contact insulation system. For the tests, thermal insulation which is soft and easily deformable was used on purpose. The intention was to measure the deformation of the adhesive as a dependence of its interaction with the thermal insulation, which has a significantly lower tensile strength than the adhesive under test. A 1250 mm x 200 mm test specimen was made, with 3 mm thick trowel cement and 40 mm thick thermal insulation. On top of the thermal insulator, a screed cement was applied in two layers, with fibreglass fabric fitted between the two layers. After the screed had cured, the plaster application process started. This process consists of two parts: the primer and the plaster itself, with a thickness of 1.5 mm. Then the metal circular target was bonded, with close attention to the exact size of the bonded area without internal bubbles and a constant adhesive thickness of 3 mm to avoid negative influence on the results [5]. The composition of the test specimen for the tensile test is shown in Figure 1.

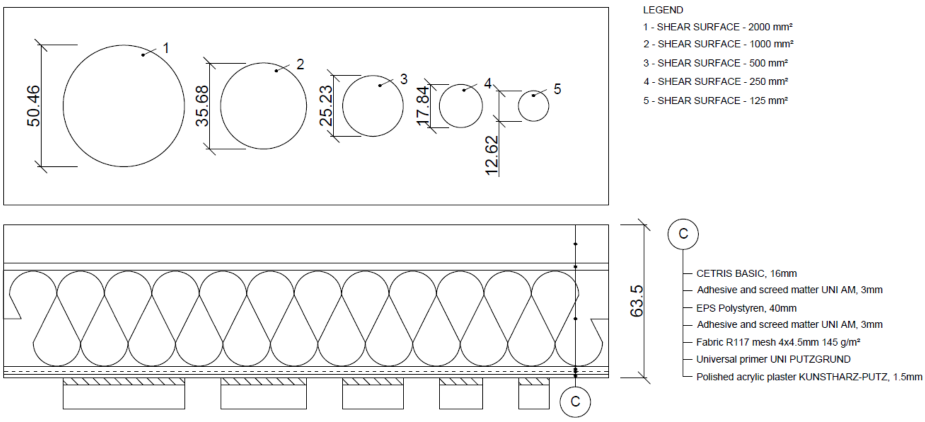

Fig.1. Test specimen for a tensile test.

2.2.2 Adhesion Tests

For this test, only tensile adhesion in the transversal direction was chosen, where the point of the test is to record the force course in relation to the elongation of the adhesive that is required to tear the adhered metal from the substrate. The tests were carried out on a LaborTech E.2 measuring device fitted with L06 vice jaws under normal laboratory conditions at a temperature of (+20±3) °C and relative humidity of (55±10) % with load bearing carried out at 2 mm per minut until failure, defined by a drop in force to 50% of the maximum achieved tensile force. The most important values for the evaluation were the maximum achieved force F (in N). The tensile test was based on the procedure defined by the Czech technical standard ČSN 732577 [6]. The tensile strength σ_{adh} (in MPa) was subsequently calculated according to the following relation :

$$\sigma_{adh} = \frac{F}{A} = \frac{F}{125;\,250;\,500;1000;\,2000} \tag{1}$$

3 Results

The results were used to generate two charts showing the dependence of the applied force F on the area A shown on Figure 2 and a tensile strength σ_{adh} on the area A is in Figure 3.

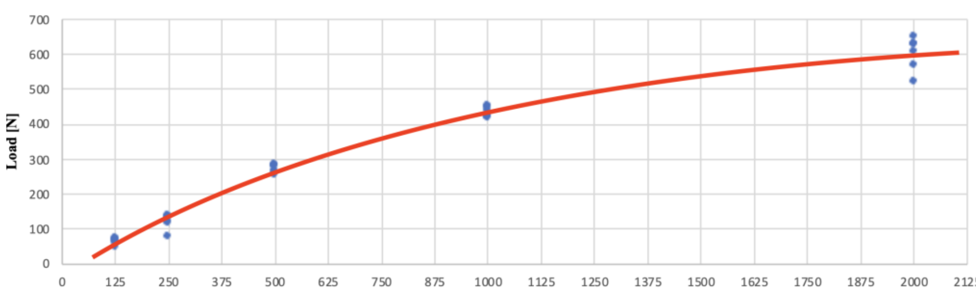

Fig. 2. Dependence of the applied force F on the area A.

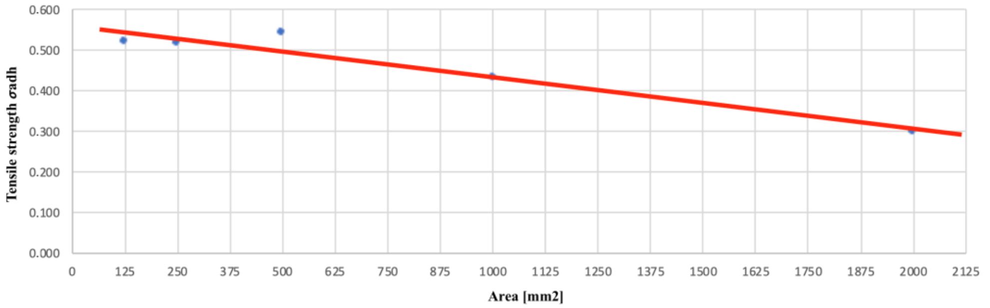

Fig. 3. Dependence of the applied tensile strength σ_{adh} on the area A.

The data from the deformation diagrams were tabulated in a clear way, with the decisive point for the evaluation being the maximum tensile force. Based on this data, the tensile adhesion σ_{adh} was calculated according to Formula (1). Statistical evaluation was performed for all the calculated parameters in the form of calculating the standard deviation s_x and the coefficient of variation v_x. The tensile test results can be seen in Table 1.

Table 1. Results of tensile adhesion σ_{adh} (in MPa) and force F (in N), standard deviation s_x (in MPa for σ_{adh}, in % for ε) and coefficient of variation v_x (in %) when acting on different areas.

	125 mm^2	250 mm^2	500 mm^2	1000 mm^2	2000 mm^2
σ_{adh}	0.519	0.518	0.543	0.433	0.300
s_x	0.069	0.081	0.023	0.013	0.022
v_x	13.346	15.711	4.193	3.065	7.414
F	64.79	128.92	270.88	432.89	600.49
s_x	8.61	20.26	11.33	13.22	44.52
v_x	13.29	15.72	4.18	3.05	7.41

[1] The average values are a summary of six measurements conducted for each tested combination.

4 Discussion

The aim was to verify the influence of the size of the bonded joint on the overall load-bearing capacity of the bonding technology of sheet metal elements on facades with ETICS. Partial results without thermal insulation have already been published under normal laboratory conditions, where the joint had a load bearing capacity of 0.694 MPa on a target area of 2500 mm^2 [3].

The closest to this result were the 125 mm^2, 250 mm^2 and 500 mm^2 targets, but these were also affected by an approximate 24% reduction in tensile adhesion. A significant decreasing trend was seen for the larger targets. This trend can be explained by the significant influence on the cohesive strength by the thermal insulation, which has a strength only one sixth compared to the strength of the acrylic plaster itself.

As the area increases, there is more interaction with the thermal insulation, which extends more deeply and more elongation can be seen.

5 Conclusions

Measured tensile adhesive strengths were the highest for the measured surfaces 125 mm^2 0.519 MPa, 250 mm^2 0.518 MPa, 500 mm^2 0.543 MPa and further decreased linearly or slightly exponentially for individual surfaces. The smallest measured tensile adhesion was measured at the largest area of 2000 mm^2. On the other side, the measured tensile forces decreased gradually due to increasing area and the difference between the smallest area and the largest area was decreased by 42%.

The following conclusions were drawn based on the results obtained:

- The dependence of force on area is not linear
- The tensile strength is decreasing with increasing area and is limiting towards the weakest layer of ETICS, i.e. thermal insulation with a strength of 0.1 MPa.
- For the overall load-bearing capacity of the joint, a larger amount of smaller joints is preferable due to the limitation of the joint interaction only to the plaster with a high load-bearing capacity, not the thermal insulator

It is obvious that the load-bearing capacities of the individual base layers significantly influence the overall load-bearing capacity of the bonded joint by their interaction. For a complete verification of the load capacity, the shear adhesion test to the substrate must be additionally carried out, which, as expected, should not be affected as much as in the tensile test.[7]

This research has been funded by an Internal Grant Programmes of the Brno University of Technology under No. FAST-J-22-7871 and No. FAST-J-23-8230.

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