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Assessment of the resistance of ventilated facade system by vacuum testing

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Abstract. The aim of this research was to determine experimentally the mechanical resistance of preset ventilated facade systems exposed to wind suction. In accordance with the European ETAG 034 Guideline, Part 1, seven facade assemblies were tested. The wind suction load was simulated in a vacuum test in the AdMaS centre using the universal vacuum loading system. The test was performed with a load increasing in increments, where after each level, the specimens were unloaded. The effect of the density of connections of load-bearing plates with the structure of subframes was demonstrated. Further, the resistance to wind suction of specimens with timber subframe was slightly higher than that of specimens with aluminium subframe.

1. Introduction

Ventilated facades have recently been coming into focus because of their use in the residential and industrial construction. The advantages of this system include protection of the building against the climate, assembly without wet processes, potential for use on uneven surfaces, high durability and easy repair of the elements. Mention should also be made of the aesthetic aspect and the variability of application of this type of façade [1].

In accordance with the Guideline for European Technical Approval of Kits for External Wall Claddings [2], these parts of the structure are mainly assessed from the point of view of safety in the case of fire, indoor environment, dampness, outdoor environment, noise protection, energy efficiency and heat retention, durability, operability and safety in use. As far as safety in use is concerned, the evaluated properties include mechanical resistance of connections, resistance to horizontal point load, impact resistance, hygrothermal behaviour, resistance to seismic action and resistance to wind action (suction and pressure) [2].

The aim of this research was to determine experimentally the mechanical resistance of preset ventilated facade systems exposed to wind suction. The tests were performed in accordance with the European ETAG 034 Guideline, Part 1 (Section 5.4.1.1, Wind suction) [3].



2. Specimens

The tests were performed on a total of seven specimens of the ventilated facade system with an area of 3.3×2.5 m. The basic difference consisted in the load-bearing subframe, which was made from aluminium in 4 assemblies and from timber in 3 assemblies. Apart from the subframe, the tested specimens differed in the layout of plates on the tested area and in the number of connections. Differences in the individual solutions of the facade systems are given in the following Figure 1. The specific differences in the number of connections are apparent from Table 1, which shows the basic spacings of screws in the load-bearing plates in the longitudinal direction.

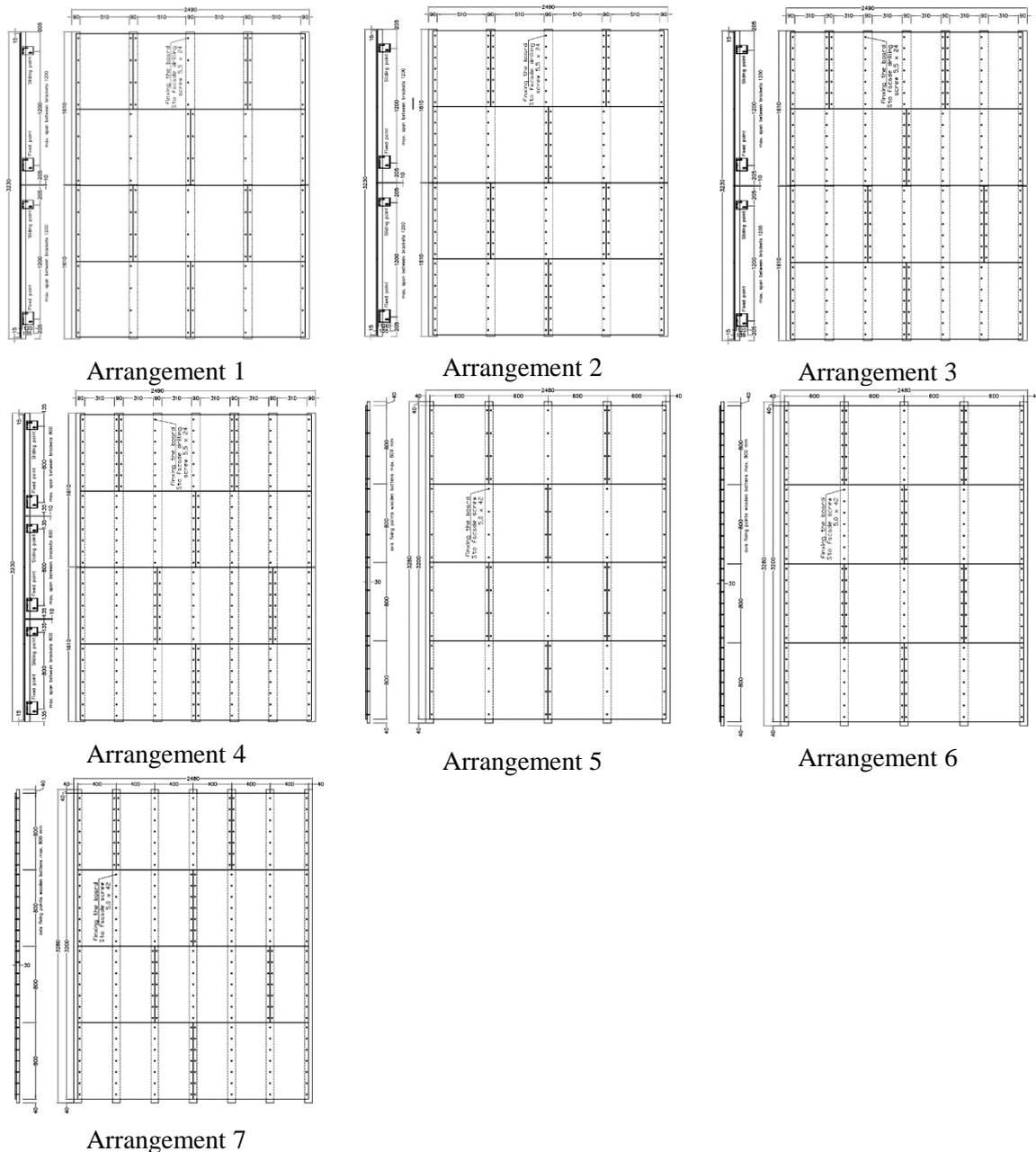


Figure 1. Diagrams of facade systems for vacuum testing with layouts of plates and screws.

Table 1. Spacings between screws in the load-bearing plates of the facade system specimens in the longitudinal direction.

Specimen	1	2	3	4	5	6	7
Longitudinal distance of screws [mm]	233.3	117.0	117.0	117.0	233.3	117.0	117.0

The facade systems with aluminium frame (Figure 2) consisted of supporting plates StoVentec Carrier Board Verotec 12 (basic full dimension of 1200×800 mm) made from glass granulate reinforced with mesh on both sides, the plates are screwed to aluminium subframes made of T-profiles ($90 \times 52.7 \times 2.7$ mm) using Sto facade drilling screws (5.5×24 mm). The aluminium supporting beams were placed to Sto Wall Bracket GP a FP/GP (both with a length of 120 mm, width of 2.5 mm, stainless steel 1.4301) and fastened with self-tapping screws (5.5×19 mm) [4]. These wall brackets were screwed to timber crossbeams (160×160 mm), which represent the base structure here, using self-tapping screws (5.0×42 mm). The crossbeams were fastened to the longitudinal timber beams (160×160 mm) with self-tapping screws (8×280 mm). Unlike setups 1 to 3, the specimen of setup 4 was equipped with two rows of local wall brackets, see Figure 1.

A facade system with a timber subframe (Figure 3) consists of supporting plates StoVentec Carrier Board Verotec 12 (basic full dimension of 1200×800 mm) attached to wooden laths (80×30 mm, class S 10 according DIN [5]) using Sto facade screws (5.0×42 mm).

**Figure 2.** Preparation of the facade system specimen (including the assembly wooden frame) intended for vacuum testing – aluminium subframe arrangement 1.



Figure 3. Preparation of the facade system specimen (including the assembly wooden frame) intended for vacuum testing – timber subframe arrangement 6.

3. Methods

The tests were performed in the AdMaS centre on a universal vacuum loading system (see Fig. 4) developed by prof. Melcher and prof. Karmazínová. The dimensions of the air-tight chamber used for this test were 3.7 x 4.1 x 0.5 m. The specimens were placed into the upper part of the chamber and covered by a transparent plastic film. The unused rest of the chamber space was filled with extruded polystyrene and covered with black plastic film. During the test, air was sucked from the chamber using the Mivalt RT 83130 air blower (output 11 kW, suction power 576 m³h⁻¹). The level of loading was given by a difference between the air pressure in the chamber and the ambient atmospheric pressure. [2]

During the test, deflections were measured using the 1-WA/100 MM-T HBM inductance transducers (with a measuring base of 100 mm) in 11 appropriately selected points of facade element specimens and the deflections of the supporting frame in the middle of its span (see Figure 4). The displacement of the supporting frame was measured by a 1-WA/50 MM-T HBM transducer (with a measuring base of 50 mm). The transducers were attached to an auxiliary independent steel frame using universal magnetic stands, and the deformations were measured from the upper side of the specimen. The inductance transducers were connected to two synchronized QuantumX MX840 systems (each with eight channels). Data from the systems were collected by catman@easy software (V3.5.1) in a computer and subsequently exported into a file in the *.txt format. The pressure in the chamber was regulated by a separate computer with LabVIEW software.

The testing of specimens was carried out in accordance with the procedure described in ETAG 034 [3]. Loading was applied gradually in increments, at first, two increments to 0.3 kNm⁻², one increment to 0.5 kNm⁻², one increment to 1.0 kNm⁻² and then every subsequent increment by 0.2 kNm⁻² higher than the previous one. After each increment, the specimen was unloaded to 0.0 kNm⁻². The load was gradually increased to the appearance of apparent irreversible deformations or up to a failure. Each level of loading was maintained for at least 10 seconds and until the stabilization of deformations. Figure 5 shows an example of a real loading of specimen 1 with aluminium subframe.

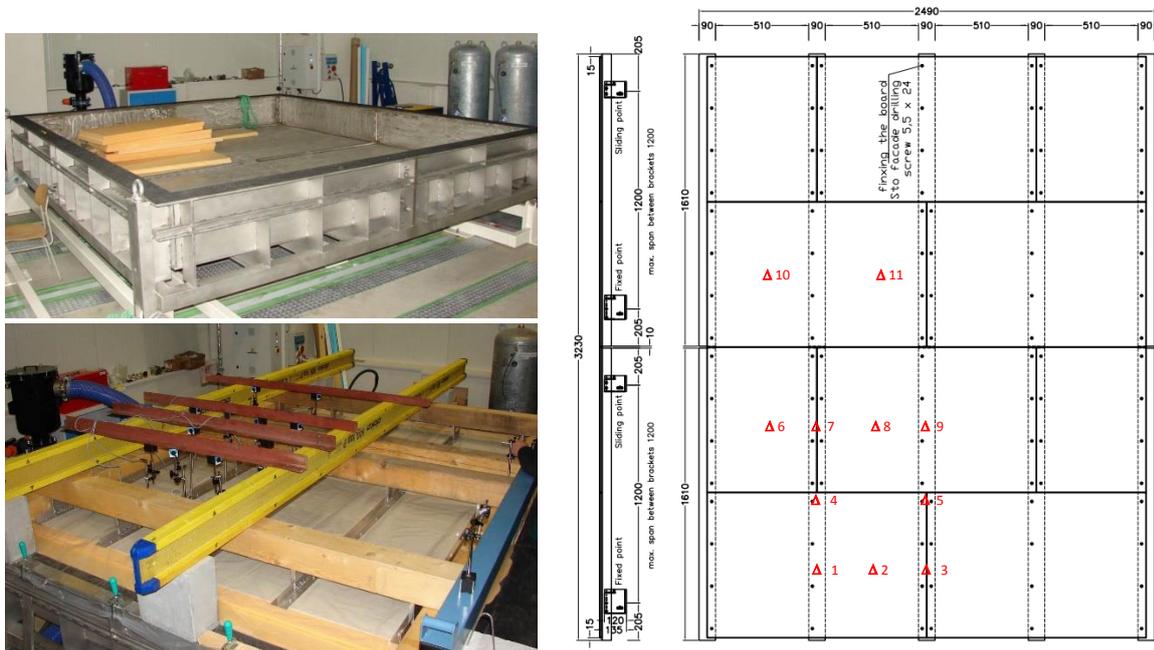


Figure 4. Universal vacuum loading steel chamber (upper left), example of specimen 1 placement on the vacuum chamber incl. location of inductance transducers (lower left), diagram of inductance transducers location of specimen 1 (right).

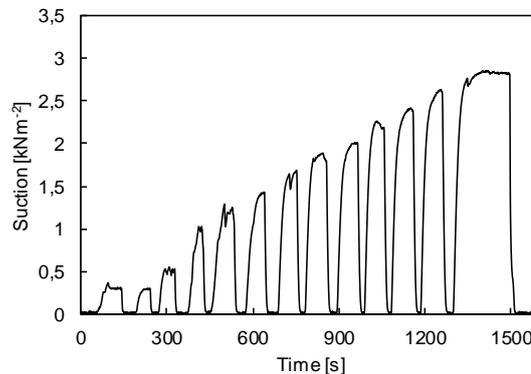


Figure 5. Actual diagram of loading during vacuum testing – Example of specimen 1.

4. Results

The test of ventilated facades by vacuum loading various assemblies using the same load-bearing plates showed differences in the use of load-bearing systems and in their anchoring. The experiment results are summarized in Table 2, which shows the values of suction $Q_{failure}$ [kNm⁻²] at which the failure occurred, the maximum deflection measured at failure $d_{Q_{failure}}$ [mm], and it also describes the way of damaging the loaded specimens. In the systems with timber subframes, resistances to wind suction ranged from 3.14 to 7.87 kNm⁻². All these assemblies were damaged due to failure of the cladding plates at the point of fixing with a screw. Example of a specimen failure caused by tearing off of the plate at the screw is shown in Figure 6.

The facade systems with aluminium subframes displayed various types of failures, see Table 2. Aluminium T-profiles were tilted, load-bearing facade plates were damaged at the point of plate anchoring to the T-profile, or a combination of both occurred. The load capacities ranged from 2.87 to 7.32 kNm⁻². An example of a failure caused by tilting of the aluminium profile and tearing off of the plate at the screw is shown in Figure 6.

Table 2. Suction $Q_{failure}$ at the moment of facade system failure, including the type of failure.

Specimen	Subframe	$Q_{failure}$ [kNm ⁻²]	Failure	$d_{Q_{failure}}$ [mm]
1	aluminium	2.87	T-profile failure (buckling), cladding elements failure in fixing (tearing the slab off)	35.74
2	aluminium	2.61	T-profile failure (buckling)	15.53
3	aluminium	4.43	T-profile failure (buckling)	30.93
4	aluminium	7.32	cladding elements failure at fixing (tearing the slab off)	9.95
5	wooden	3.14	cladding elements failure at fixing (tearing the slab off)	25.81
6	wooden	4.88	cladding elements failure at fixing (tearing the slab off)	20.73
7	wooden	7.87	cladding elements failure at fixing (tearing the slab off)	7.44

**Figure 6.** Examples of specimen failures recorded during vacuum testpmg – T-profile buckling of specimen 1 (left), cladding elements failure at a fixing of specimen 1 (middle) and cladding elements failure at a fixing of specimen 6 (right).

5. Conclusion

The research focused on ventilated facade systems and their resistance to the action of wind suction. The loading was simulated by the so-called vacuum test where air is sucked from the chamber and the loading is given by the difference between the pressure in the chamber and the atmospheric pressure. The results of facade system tests showed the dependence of the load-bearing capacity of the elements on the structure of the load-bearing frame of the plates and on the density of connections of the load-bearing plates with the structure of subframes. Specimens with a higher number of screws had a higher load capacity. The load-capacity of specimens with a comparable number of plate anchoring elements to the subframes loaded by vacuum were slightly higher in the case of timber subframe than that of specimens anchored to the aluminium subframe.

Acknowledgement

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