# REAR ATTACHMENT OF PANELS FOR VENITLATED CURTAIN WALLS

# RÜCKSEITIGE BEFESTIGUNG VON BEKLEIDUNGSPLATTEN FÜR VORGEHÄNGTE HINTERLÜFTETE AUßENWANDBEKLEIDUNGEN

# FIXATION ARRIERE DES PANNEAUX POUR DES FACADES RIDEAUX

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## SUMMARY

The structure and function of attachment devices at the back of panels are described.

Possible interaction of panels and substructure and the necessity of symmetrical loading are indicated.

The method of testing the load bearing capacity of the attachment elements is explained and results of tests performed are commented on.

## ZUSAMMENFASSUNG

Die Ausbildung und Wirkungsweise der rückseitigen Befestigungselemente für Bekleidungsplatten von vorgehängten Außenwandbekleidungen wird beschrieben.

Auf mögliche Wechselwirkungen zwischen Bekleidungsplatten und Unterkonstruktion und die Notwendigkeit einer symmetrischen Lasteinleitung wird hingewiesen.

Das Vorgehen bei der Erfassung des Tragverhaltens der Befestigungselemente durch Versuche wird erläutert, und es werden Ergebnisse von durchgeführten Untersuchungen mitgeteilt.

## RESUME

La géométrie et le mode d’action de fixations arrières de panneaux pour des façades rideaux sont décrits.

Des interactions possibles entre panneaux et supports et la nécessité d’un chargement symmétrique sont indiqués.

La methode expérimentale de déterminer la capacité de chargement des éléments de fixation est décrite et les résultats des essais sont présentés.

KEYWORDS: anchorage, wall panels, undercut anchor, rear attachment

## 1. GENERAL

Ventilated curtain walls consist of a wooden or metal substructure attached at a dictated distance to the external walls of a building and of panels attached on the substructure.

Panels suitable for rear attachment have to be of a minimum thickness of 8 mm and of a maximum size of about 1,5 m x 3,0 m.

High pressure laminated boards (HPL-plates), boards made of fibre cement, of crystallized glass, ceramics or natural stone are used. The boards are attached at several points to the substructure.

The easiest way of connecting is the direct attachment which will leave visible the heads of the attachment devices like nails, bolts and rivets (on board surface) or metal cramps (at board edges). This effect is often not wanted so that the more complicated method of indirect application of the load at the back of the panel is preferred.

According to Standard [1] plates of natural stone are not attached at the surface but at the board edges by use of steel spikes. Using rear attachment devices installed at the back surface of the board the structural advantage of better use of the bending load carrying capacity of the boards (cantilevers) occurs. As a result of this effect, material can be saved and the dead load of the boards can be diminished in comparison to attachment methods used previously.

## 2. FORM AND FUNCTION OF ANCHORS FOR REAR ATTACHMENT OF PANELS

The only anchors providing satisfying results at tests up to now are the so-called undercut anchors.

Fig. 1: *Longitudinal section of the back sloped bore hole.*

For this type of anchor a firstly cylindrical borehole is widened conically according to the straddling zone of the anchor (figure 1). Then an anchor is inserted into the borehole and widened to its final form in the straddling zone until touching the sloped walls of the borehole.

Due to the lower thickness of the panels the depth of anchorage is clearly smaller than the one of anchors common in concrete. Depending on the panel thickness the depth of anchorage varies from 7 to 15 mm. The main geometrical difference in comparison to concrete anchors manifests in the ratio of anchor diameter / anchorage depth of approx. 1,0 - 1,5. For concrete anchors this ratio is clearly lower than 1, i.e. the anchors used in panel boards have a wider diameter than those used in concrete.

Superposed bending loads out of deflection have a greater influence on the load bearing capacity of anchors in thin boards than in virtually stiff concrete. This is a result of high flexural stresses appearing around the attachment points of thin panel boards that superpose with tension stresses resulting from anchor loading.

Anchors officially allowed for use in various board materials are shown in figures 2 and 3. The anchors shown are produced by the companies fischerwerke [2, 3, 4] and KEIL [5] respectively. For both companies the tests required for admittance were performed at the FMPA, Referat 23, as were the tests for the so-called Quadro-System by AGROB-BUCHTAL [6] for attachment of ceramic Makropanels as shown in figure 6.

In this system a bolt is fitted into a small ceramic block so that its shaft is sticking out at one end. The ceramic block is sintered in a burning oven with special glass solder onto the back of a ceramic plate.

The concept of straddling used by the fischer panel anchor (figures 2a, 2c, 2d) consists of a festoon shaped straddling element that is slid over the tampered top of a threadbold sitting on the bottom of the borehole. Usually this is done by simultaneously screwing down a nut and pressing the anchor against the bottom of the hole. Regarding ceramic anchors the nut is pressing on a plastic sleeve adjacent to the straddling festoon, regarding natural stone anchors on a steel sleeve.

Fig. 2: *fischer-Zykon panel anchors*

Fig. 3: *KEIL-back sloped anchors*

The subsequently annexed part is fixed with an additional nut (figure 4). The projecting length of the steel sleeve of the natural stone anchor over the stone surface can be varied (figure 4b). Consequently, varying thickness of stone plates can be adjusted up to about 4 mm by appropriate choice of depth of anchorage. In this way the visible surface of the stone plate can be provided plane even for differing thickness of the stone plates.

Alternatively, natural stone anchors can be placed flush to the stone surface by a purpose-built impact tool (figure 2d).

The rivet anchor made by fischer (figure 2b) consists of a cylindrical slit sleeve with integrated blind rivet [4]. As soon as the anchor is stayed up the widening of the straddling head of the rivet widens the sleeve and simultaneously jams the annex part (flush installation analogical to figure 5).

Fig. 4: *Spaced installation*.

Fig. 5: *Flush installation.*

The KEIL anchor [5] (figure 3) consists of a slit sleeve with an internal thread of a conical form at its lower part according to the borehole geometry. For installation the sleeve is compressed at its lower end (figure 5). The sleeve is placed into the borehole and widened to its original shape by screwing down a fixation screw holding the annex part (figure 5).

An existing grip between the head of the fixing screw and the upper end of the anchorage sleeve is important for this system. Otherwise, e.g. in case of cavity (the annex element props up to the side of the anchor) undefined tension strain is put on the anchor when the fixation screw is tightened.

Regarding the Quadro-system [6] in figure 6 the necessary annex parts are attached with a nut to the screw sticking out of the ceramic block.

Fig. 6: *Quadro-system by AGROB-BUCHTAL displaying a sintered ceramic block incl. agrafe and substructure*

## 3. SUSPENDING STRUCTURES

There are two different possibilities:

Either single agrafes are screwed on the anchors and during assembly of the panels are hooked into horizontal fixing rails attached to the building (figure 4a, 5 and 6) or fixing rails are connected with 2 or more aligned anchors (figure 4b) and subsequently attached to the building. In the licences [2 to 6] the use of single agrafes is limited to 6 to max. 8 agrafes per board out of reasons of safety of assembly.

For both single agrafes and fixing rails it has to be observed that the anchorage forces are applied and transferred centrally, i.e. normally symmetrical sections with adequate flexural and torsion rigidity are to be used. Using agrafes that can be hooked in only on one side or angle sections that can contort and are supported by the panels only with short lever arms to the anchor axis, the anchors may be loaded due to the lever action with a multiple of the calculated wind suction.

In the panel plane a widely unrestricted room for displacement due to expansion of the panel with changing temperature and / or humidity must be given. This can be achieved by fixing only one support and leaving the other supports in board plane free. Using hooking-agrafes (e.g. figure 6) it normally suffices to cancel the moveability given at an agrafe and so form a fixed-point. In fixing rails oblong holes have to be provided at the sliding points.

## 4. INTERACTION BETWEEN PANELS AND SUBSTRUCTURE

Especially for panels with more than 4 attachment points the actual stress of the anchors can differ largely from the stress estimated for a restrained support of the panel. This occurs as a result of the varying deformation of each fixing point of the substructure. As a consequence of this ‘joint displacement’ at the attachment points the loads can be changed up to 100 % compared to restricted supports [7].

As the stiffness of the panel board and the substructure, possible yielding of the anchor zone, twisting of the sections of the substructure and the distances and situation of the anchor points have to be taken into consideration, a reliable estimation of the performance of the total structure is only possible by testing elements under actual conditions.

# 5. TESTS FOR ESTIMATION OF THE PERFORMANCE OF REAR ATTACHMENT ELEMENTS ON PANELS

## 5.1 Aptitude tests

To determine the principal aptitude of an undercut anchor the tolerances of fabrication of boreholes have to be determined. Back sloped boreholes are made with specific drills, resp. drilling techniques so that additional influences to the fabrication of cylindrical boreholes have to be taken into account.

The according applies to the fabrication tolerances of anchors.

With the aptitude tests derivations exceeding the planned ones, e.g. an enlargement/amplification of the borehole-diameter or a diminuition of the back slope are checked. These tests are performed to determine that the performance of an anchor does not change significantly for slight discrepancies from the specifications of the setting depth.

Furthermore the influence of a deviation of the planned setting depth on assembly and / or performance of the anchors is analysed. Taking into account the worst combination of given tolerances to be anticipated tests with swelling loads and constant long-term loads as well as tests following alternate freeze-thaw-tests of anchors installed in panel segments are performed.

## 5.2 Collapse load testing to determine allowable stress of anchors

The majority of collapse load tests is performed by applying a centric tension force to the anchor. For each test anchor is fixed centrally (at the intersection of the diagonals) onto a panel section and loaded thereafter. The reaction forces are applied in a circle around the anchor using a ring. The panel section is placed on the support in a way that the anchor sits in the centre of the ring support.

The influence of superposed bending stress from panel bending in the anchorage zone is determined by use of different diameters of support rings. If necessary, the influence of different given panel thicknesses and / or depths of anchorage is analysed. The effect of small distances to the panel edges on the performance of the anchors is recorded by testing the anchors in panels with side dimensions equal to twice the value of the margin provided.

Furthermore, transverse tension tests are performed loading the anchor orthogonal to its axis and where appropriate adding a bending moment - created by a shearing force applied at a defined distance to the panel surface - as well as angular tension tests with an angle of 45° to the anchor axis.

## 6. SOME RESULTS OF THE TESTS PERFORMED

Figures 7 to 9 show the results of tests made with anchors in HPL-panels.

Fig. 7: *Influence of depth of anchorage on failure loads of undercut anchors fixed to a*

*HPL-panel of 14 mm thickness*

Figure 7 shows the decrease of failure loads of anchors in HPL-panels depending on the depth of anchorage.

For a tested panel thickness of 14 mm and a ring support of 55 mm the performance is not influenced worth mentioning by a superposed flexural load out of panel bending. It can be noticed that a decrease of approx. 80 % (from 9 mm to 2 mm) of the depth of anchorage results in a diminuition of approx. 95 % of the failure load (from approx. 7.5 kN to approx. 0.5 kN).

Fig. 8: *Influence of panel thickness and superponed flexural loading on performance of undercut anchors in HPL-panels*

Figure 8 shows the influence of superponed flexural loading resulting from panel bending. With diminishing panel thickness the failure load decreases; namely stronger for a ring diameter of 347 mm than for a diameter of 135 mm.

Figure 9 clarifies the influence of flexural load on the performance of anchors for different panel thicknesses and on different setting depths of the anchors according to the panel thickness.

The failure load decreases stronger for 14 mm panels and a ring diameter of 50 mm to 150 mm than for larger ring diameters. This can be put down to the fact that in this range the failure mode ‘conical fracture’ is ruling and that the fracture load is reduced by flexural tension stresses in the panel more strongly for this failure mode than in ranges of higher flexural loading that are ruled by the failure mode of bending failure of the panels.

Fig. 9: *Influence of superponed flexural load on the performance of undercut anchors in HPL-panels of varying thickness*

Figure 10 shows a graph according to figure 9 for 2 different kinds of granite called W an G with 3 different thicknesses of 25, 20 and 15 mm. First, it has to be noted that the graphs are similar for both kinds of stone but the failure load of the anchors in stone G with a lower flexural strength compared to stone W is smaller.

In the support diameter range from 55 to 135 mm a significantly higher decrease of failure loads (out of superponed bending stress for failure mode 'conical fracture') can be observed than for HPL-panels according to figure 9 that show an approx. 15 times higher flexural strength than the granites tested.

Fig. 10: *Decrease of the failure load of undercut anchors in granite plates of varying thicknesses subject to the ring diameter (d)*

In figure 11 the failure loads for different support diameters are shown in relation to the panel thickness. The numbers next to the letters W and G respectively state the diameter of the ring supports. It can be seen that up to a diameter of 135 mm the test values follow the graph as theoretically expected for the failure mode rupture of the plate and that they start to deviate at diameter 55 mm for stone G starting with a thickness of 20 mm and with a thickness of 15 mm for stone W.

*varying*

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