

# ICC-ES Evaluation Report


ESR-4919

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<p><b>DIVISION: 07 00 00— THERMAL AND MOISTURE PROTECTION</b></p> <p><b>Section: 07 42 05—Wall Panel Fasteners</b></p>	<p><b>REPORT HOLDER:</b></p> <p><b>KEIL BEFESTIGUNGSTECHNI K GmbH</b></p>	<p><b>EVALUATION SUBJECT:</b></p> <p><b>KEIL UNDERCUT ANCHOR KH IN CERAMIC TILE (STONEWARE)</b></p>	
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## 1.0 EVALUATION SCOPE

### Compliance with the following codes:

- 2021, 2018, 2015 and 2012 [International Building Code® \(IBC\)](#)
- 2021, 2018, 2015 and 2012 [International Residential Code® \(IRC\)](#)

### Property evaluated:

- Structural

## 2.0 USES

The KEIL Undercut Anchor KH is used for attachment of ceramic tile (a.k.a stoneware) façade panels to exterior and interior walls and soffits, as part of a cladding system similar to the one illustrated in [Figure 8](#). The anchors may be used in structures regulated under the IRC, when their use is addressed in an engineered design in accordance with IRC Section R301.1.3.

## 3.0 DESCRIPTION

### 3.1 KEIL Undercut Anchor KH:

The KEIL Undercut Anchor KH is a stainless-steel anchor consisting of a sleeve component, which is installed in an undercut hole drilled in the façade panel, and a fastener which is installed through a supporting metal component (for example a clip or an agraffe) into the sleeve, causing the sleeve to expand. The anchor sleeve has four equally spaced slots, an internal M6 thread and an anchorage depth of 0.217, 0.276 or 0.335 inch (5.5, 7.0 or 8.5 mm). The fastener may be any one of the following: a hexagonal head screw with integrated tooth lock washer (hex washer head screw); a set screw (a.k.a. a grub screw); or a threaded rod. The required fastener length must be selected based on the embedment depth of the anchor and the thickness of the supporting clip. See [Table 1](#) for model designations and dimensions. See [Figure 1](#) for a depiction of the KEIL Undercut Anchor KH components. See [Figure 2](#) for a typical installation detail.

### 3.2 Materials:

**3.2.1 KEIL Undercut Anchor KH:** All of the KEIL Undercut Anchor KH components, including sleeves and fasteners, are made from stainless steel, conforming to the specifications in the approved quality documentation. The anchor sleeves are made from stainless steel 1.4404 complying with EN 10088:2014, while the fasteners are made from stainless steel 1.4401, 1.4404 or 1.4578 complying with EN 10088:2014.

**3.2.2 Façade Panels:** Façade panel material must be Class P1, P2, E1 or E2 ceramic tile complying with ANSI A137.1-2021 or Group AI<sub>a</sub>, AI<sub>b</sub>, BI<sub>a</sub> or BI<sub>b</sub> ceramic tile complying with EN14411:2016. The tile must be free of fractures and cracks. Flexural strength of the ceramic tile must comply with [Table 2](#).

## 4.0 DESIGN AND INSTALLATION

### 4.1 Notations and Symbols:

$a$	: anchor spacing ( $a_x, a_y$ )
$a_r$	: standard anchor edge distance ( $a_{rx}, a_{ry}$ )
$a_{r,min}$	: minimum anchor edge distance
$C$	: fastener length
$d_0$	: diameter of drill hole
$h$	: minimum façade panel thickness
$h_s$	: anchor embedment depth
$N_a$	: allowable anchor tensile resistance
$N_c$	: additional normal load due to mounting constraints
$N_{load}$	: total service level tension load on a single anchor
$t_{fix}$	: support frame thickness
$T_{inst}$	: installation torque
$V_a$	: allowable shear resistance
$V_{load}$	: total service level shear load on a single anchor
$\sigma_{f,nom}$	: minimum required façade panel flexural strength

### 4.2 Design:

**4.2.1 General:** The KEIL undercut anchor KH is used to attach facade panels to the supporting façade framing system. In turn, the façade framing is installed over exterior and interior walls or wall framing capable of supporting the imposed loads, including gravity loads and transverse wind loads. The façade panel system must be securely fastened to the supporting walls or wall framing with corrosion-resistant fasteners that are compatible with both the façade system framing material and the supporting wall assembly substrate.

The wall structure, façade panels and the attachment of the façade panel system to the supporting wall structure must withstand the applied gravity and transverse loads and must be designed by a registered design professional in accordance with the IBC. The design details must be submitted to the code official for approval and are outside the scope of this report.

**4.2.2 Anchorage Requirements:** Determination of the loads applied to each anchor is outside the scope of this report. The applied loads must be determined in accordance with the IBC and applicable referenced standards, or be as certified in an ICC-ES evaluation report addressing the ICC-ES Acceptance Criteria for Façade and Wall Cladding Systems with Porcelain, Ceramic, Terra Cotta, or Slate Panels (AC504). In the absence of this guidance, follow the requirements of the latest edition of EOTA Technical Report TR 062 to determine the applied loads.

General design concepts for façade panel attachment include the following:

1. Only two anchors of the panel are taken into account to support the weight of the panel. Only one of these resists lateral load in the plane of the façade.
2. Otherwise, the support points are allowed to move, to accommodate building movement, changes in panel dimensions due to temperature changes, etc. See [Figure 3](#).
3. Applied transverse loads due to wind must be determined in accordance with IBC Chapter 16 or Section R301.2.1 of the IRC, as applicable. These loads must be increased as follows:
  - a. Due to mounting restraints an additional normal load  $N_c = 11.24$  lbf (0.05 kN) must be considered.
  - b. For façade panels with flush anchors and horizontal support framing, an additional transverse load component due to the eccentricity of the gravity load of the panel, relative to the supporting wall structure, must be considered. (Follow EOTA Technical Report TR 062, Section 3.2.3 in absence of other guidelines.)

**4.2.3 Anchorage Capacity:** The allowable in-plane shear strengths (gravity load resistance) and tension strengths (transverse load resistance) of the anchor installed into various ceramic tile materials are provided in [Table 3](#). The service level (ASD) applied loads  $N_{load}$  and  $V_{load}$  per anchor must be equal to or less than the corresponding ASD allowable load provided in [Table 3](#). For combined loading of normal and transverse loads the following interaction requirement must be fulfilled for anchoring the façade panel:

$$\left(\frac{N_{load}}{N_a}\right) + \left(\frac{V_{load}}{V_a}\right) \leq 1.0 \quad (Eq. 1)$$

**4.2.4 Anchor Placement:** Full (rectangular) façade panels must be supported by a minimum of four fasteners installed near the corners of the panel, with an edge distance,  $a_r$ , of 4 inches (100 mm) or more, to achieve the allowable design values shown in [Table 3](#). The recommended edge spacing is 1/5 of the respective panel edge length. For edge distance between 2 and 4 inches (50 and 100 mm), the allowable anchorage strengths provided in [Table 3](#) must be reduced by a ratio of  $a_r/4$  (with  $a_r$  in inches) [ $a_r/100$  (with  $a_r$  in mm)].

### 4.3 Project Specific Testing:

For each construction project, tests must be conducted by an ISO 17025 accredited testing laboratory, prior to installation of the façade panels, to verify the flexural strength of the ceramic tile façade panels used on the project and the tensile anchorage strength of the KEIL Undercut Anchor KH.

**4.3.1 Flexural Strength Testing:** A minimum of 10 specimens must be tested for flexural strength in accordance with ISO 10545-4:2014-11, with the front face on top. The dimensions of the test specimen must be 15.7 x 7.87 inches (400 x 200 mm) and the support span must be 11.8 inches (300 mm). The average test result must equal or exceed the flexural strength required by [Table 2](#), for the applicable ceramic tile strength class.

**4.3.2 Anchorage Testing:** A minimum of 10 specimens must be tested for tensile anchorage strength in accordance with ICC-ES AC547. The anchors must be installed in the center of a test specimen which is 7.8 x 7.8 inches (200 x 200 mm) in dimension, with a support diameter of 2.75 inches (70 mm). The average test result, divided by a safety factor of 4.0, must equal or exceed the allowable tensile anchorage strength,  $N_a$ , shown in [Table 3](#).

### 4.4 Installation:

**4.4.1 General:** Installation of the KEIL Undercut Anchor KH in façade panels must be in accordance with the report holder's published installation instructions, the approved project-specific construction documents, and this evaluation report. In the event of a conflict amongst these documents, the most restrictive requirements govern. Installation must be done by installers trained by KEIL or otherwise qualified. A copy of the installation instructions must be available on the jobsite at all times during anchor installation.

**4.4.2 Preparation of Holes for Anchors:** The KEIL Undercut Anchor KH must be installed perpendicular to the façade panels into a pre-drilled, undercut anchor hole. The hole must be drilled using a special undercut drilling tool provided by KEIL (depicted in [Figure 4](#)). The hole dimensions must comply with [Figure 5](#), with embedment depth,  $h_s$ , complying with [Table 1](#). Façade panel drilling must be done at the panel fabrication location or on site under workshop conditions in accordance with KEIL installation requirements. The drill dust must be removed from the drilled hole prior to installation of the anchor sleeve.

The support conditions (fixed and slide support) for the KEIL undercut anchors KH on the supporting frame must prevent unintended constraint against movement, as illustrated in [Figures 3](#) and [8](#).

### 4.4.3 Verification of Hole Geometry:

**4.4.3.1 Dimensions to be Checked:** The geometry of the drill hole must be checked prior to anchor installation. The following dimensions must be checked and documented according to KEIL installation and testing instructions by means of a measuring device complying with KEIL requirements (illustrated in [Figure 6](#)):

1. Hole diameter.
2. Hole depth. This is determined by measuring the distance between the lower edge of the measuring device (caliber) and the surface of the façade panel. This measurement must be between 0.0 and 0.0118 inch (0.0 and 0.3 mm).

**4.4.3.2 Inspection Frequency:** A minimum of 1 percent of all drilled holes on the project must be inspected. For example, for every 25 panels (100 anchors), a minimum of 1 hole must be inspected. If any of the hole dimension tolerances are exceeded, the inspection frequency must be increased to 25 percent of all drilled holes (at least one per panel). Then, if any additional nonconformances are found, all drilled holes on the project must be inspected.

**4.4.3.3 Remediation:** Drill holes which do not conform to the specified tolerances must be abandoned (not used), and a new hole must be drilled at a minimum distance from of the abandoned hole of  $2 * h_s$ . The new hole must be inspected for conformance with the hole geometry requirements.

**4.4.4 Installation of KEIL Undercut Anchor KH:** Between the clip and the façade panel, an elastic material (e.g. EPDM) with a thickness of 0.0394 to 0.118in (1.0 to 3.0mm) and holes matching the geometry of the predrilled holes may be placed as shown in [Figure 2](#). The anchor sleeve component is placed into the predrilled hole, taking care not to damage the ceramic tile, until the underside of the sleeve collar is in contact with the face of the panel. Then the fastener is installed through the clip and into the sleeve, until an installation torque,  $T_{inst}$ , within the range of 1.84 to 2.95 ft-lbf (2.5 to 4.0 Nm) is achieved. See [Figure 7](#) for a depiction of the typical installation sequence.

#### 4.5 Special Inspection

Special inspection of the anchor installation is required in accordance with IBC Section 1705.1.1. The inspector must verify the following:

1. Project specific testing has been conducted in accordance with Section 4.3 and the results are acceptable.
2. Dimensions of drilled holes meet the requirements. This can be determined from the inspection documentation required by Section 4.4.3.1.

### 5.0 CONDITIONS OF USE:

The KEIL Undercut Anchor KH described in this report complies with, or is a suitable alternative to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

- 5.1 The design and installation of the fasteners must be in accordance with this evaluation report and the report holder's published installation instructions.
- 5.2 The design of the wall cladding system, including resistance to fire, deflection considerations and seismic performance, is outside the scope of this report and must be justified to the satisfaction of the code official.
- 5.3 For the purpose of ensuring adequate anchorage strength, the ceramic tile façade panel material must comply with [Table 2](#). The adequacy of the façade panel to resist the applied loading is outside the scope of this report and must be justified to the satisfaction of the code official.
- 5.4 Full panels must be supported by a minimum of four fasteners. The edge distance and anchor spacing must be in accordance with [Table 3](#).
- 5.5 For small pieces of cladding material, where installation of four fasteners is not feasible, the number and position of the fasteners must be determined by the registered design professional.
- 5.6 Use where the anchors are subject to cyclic (seismic) loading is outside the scope of this report.
- 5.7 See Section 4.5 regarding special inspection.
- 5.8 Wall cladding systems qualified by testing must be addressed in an ICC-ES evaluation report under the ICC-ES Acceptance Criteria for Façade and Wall Cladding Systems with Porcelain, Ceramic, Terra Cotta, or Slate Panels (AC504) or a similar acceptance criteria. In the absence of system testing, Technical Report TR 062, published by EOTA, can be referenced for design guidance.
- 5.9 The KEIL undercut anchor KH is manufactured under a quality control program with inspections by ICC-ES.

### 6.0 EVIDENCE SUBMITTED

Data in accordance with the [ICC-ES Acceptance Criteria for Fasteners for Wall Cladding Panels \(AC547\)](#), dated February 2023.

### 7.0 IDENTIFICATION

- 7.1 The ICC-ES mark of conformity, electronic labeling, or the evaluation report number (ICC-ES ESR-4919) along with the name, registered trademark, or registered logo of the report holder must be included in the product label.

7.2 In addition, each package of KEIL Undercut Anchor KH products is labeled with the model designation. The sleeve anchor and the head of KEIL hex washer head screw must be stamped with the marking shown in [Figure 1](#).

7.3 The report holder's contact information is the following:

**KEIL BEFESTIGUNGSTECHNIK GmbH**  
**POST OFFICE BOX 1127**  
**51766 ENGELSKIRCHEN**  
**GERMANY**  
**(239) 598-3737**  
[www.keilanchor.com](http://www.keilanchor.com)  
[www.keil.pro](http://www.keil.pro)

TABLE 1—KEIL UNDERCUT ANCHOR KH DIMENSIONS

ANCHOR MODEL DESIGNATION:		KH 5,5	KH 7,0	KH 8,5
Embedment depth	$h_s$	0.217 inch (5.5 mm)	0.276 inch (7.0 mm)	0.335 inch (8.5 mm)
Minimum façade panel thickness	$h$	0.315 inch (8.0 mm)	0.374 inch (9.5 mm)	0.433 inch (11.0 mm)
Fastener length	$C$	$h_s + 0.118 \text{ in.} + t_{fix}$ (inch) $[h_s + 3\text{mm} + t_{fix}]$ (mm)		
Required drill hole diameter	$d_0$	0.276 inch (7.0 mm)		

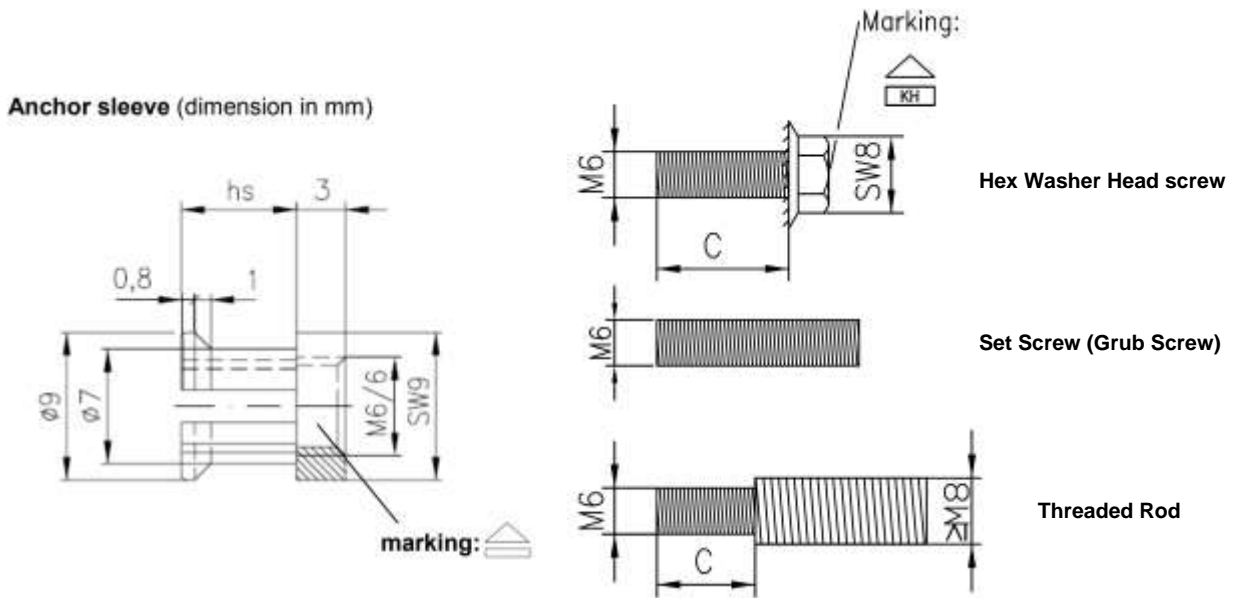


FIGURE 1—KEIL UNDERCUT ANCHOR KH COMPONENTS, DIMENSIONS AND MARKING

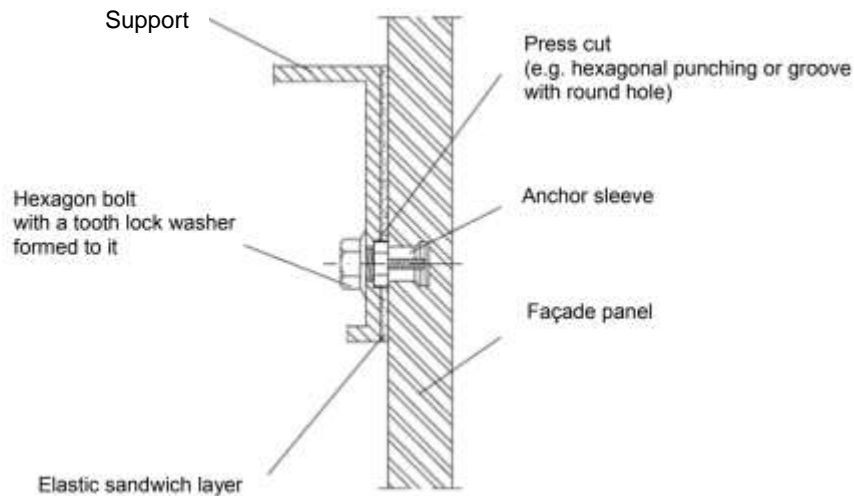


FIGURE 2—TYPICAL FAÇADE PANEL SYSTEM INSTALLED WITH KEIL UNDERCUT ANCHOR KH

**TABLE 2—CERAMIC TILE STRENGTH CLASSES AND REQUIRED FLEXURAL STRENGTH<sup>1</sup>**

CERAMIC TILE STRENGTH CLASS:	Class A	Class B	Class C
Minimum required flexural strength, $\sigma_{f,nom}$	5,800 psi (40 N/mm <sup>2</sup> )	6,525 psi (45 N/mm <sup>2</sup> )	7,250 psi (50 N/mm <sup>2</sup> )
Minimum façade panel thickness, $h$	0.315 inch (8.0 mm)	0.374 inch (9.5 mm)	0.433 inch (11.0 mm)

**TABLE 3—ALLOWABLE (ASD) ANCHORAGE STRENGTHS AND REQUIRED EDGE DISTANCE AND ANCHOR SPACING FOR THE KEIL UNDERCUT ANCHOR KH<sup>1,2</sup>**

KEIL UNDERCUT ANCHOR KH MODEL DESIGNATION:		KH 5,5	KH 7,0	KH 8,5
Anchor embedment depth, $h_s$		0.217 inch (5.5 mm)	0.276 inch (7.0 mm)	0.335 inch (8.5 mm)
Standard edge distance, $a_r$		4 inches (100 mm)		
Minimum edge distance, $a_{r,min}$		2 inches (50 mm)		
Minimum anchor spacing, $a$		8 inches (200 mm)		
<b>Allowable Tensile Strength, <math>N_a</math> (transverse outward)</b>				
Ceramic Tile Strength Class	A	70 lbf (0.31 kN)	n/a	n/a
	B	73 lbf (0.33 kN)	130 lbf (0.58 kN)	n/a
	C	79 lbf (0.35 kN)	140 lbf (0.62 kN)	209 lbf (0.93 kN)
<b>Shear load <math>V_a</math> (gravity)</b>				
Ceramic Tile Strength Class	A	144 lbf (0.64 kN)	157 lbf (0.70 kN)	169 lbf (0.75 kN)
	B	150 lbf (0.67 kN)	164 lbf (0.73 kN)	176 lbf (0.78 kN)
	C	156 lbf (0.69 kN)	170 lbf (0.75 kN)	182 lbf (0.81 kN)

<sup>1</sup>See [Figure 3](#) for a depiction of edge distance and spacing terminology.

<sup>2</sup>For edge distances between 2 and 4 inches (50 and 100 mm), the connection capacity must be reduced in accordance with Section 4.2.



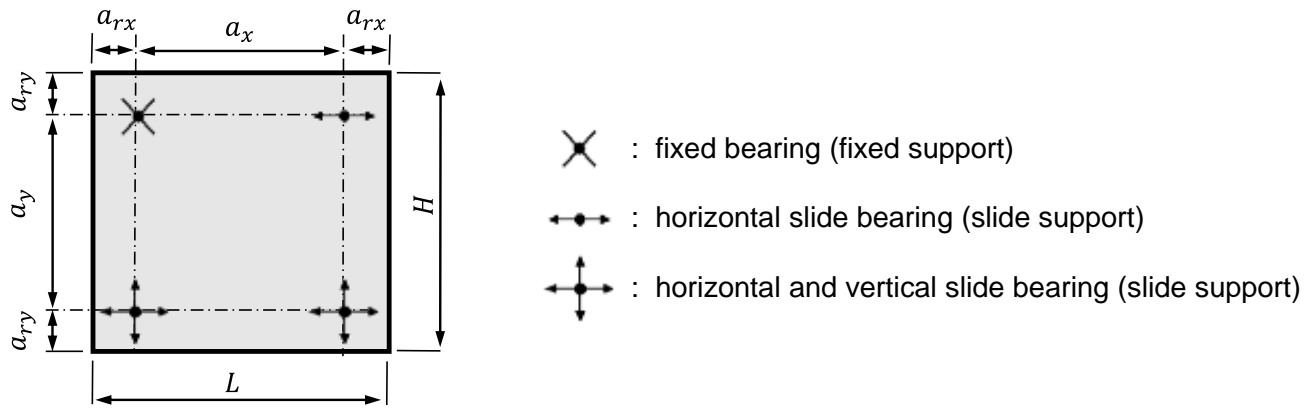


FIGURE 3—FAÇADE PANEL EDGE DISTANCES, SPACING AND SUPPORT CONDITIONS USING KEIL UNDERCUT ANCHORS KH

### Geometry of the facade drill

for KEIL facade drill bit 7/9

Diamond tipped facade drill bit

Diamond tipped facade drill bit CNC

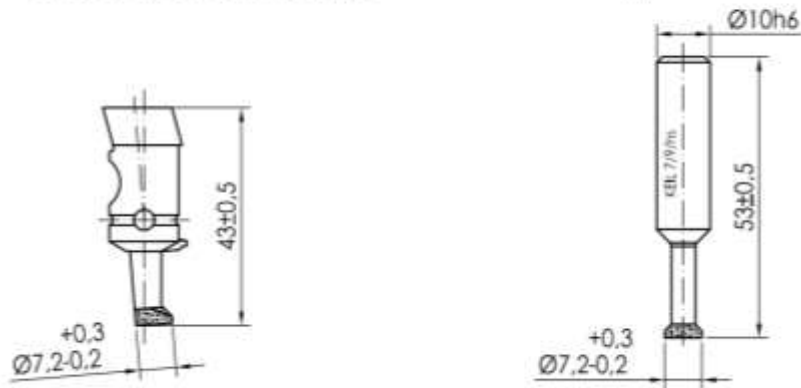


FIGURE 4—KEIL UNDERCUT ANCHOR KH DRILL BITS

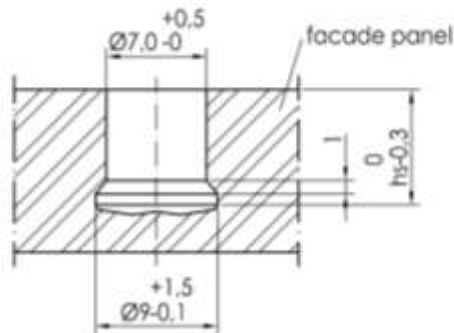


FIGURE 5—REQUIRED UNDERCUT HOLE GEOMETRY FOR KEIL UNDERCUT ANCHOR KH



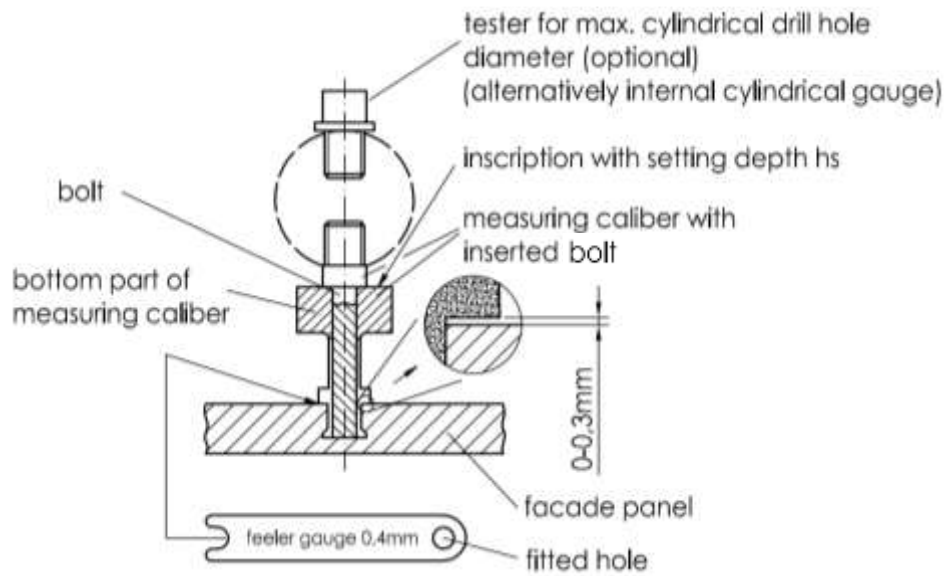


FIGURE 6—KEIL DRILLED HOLE MEASURING DEVICE

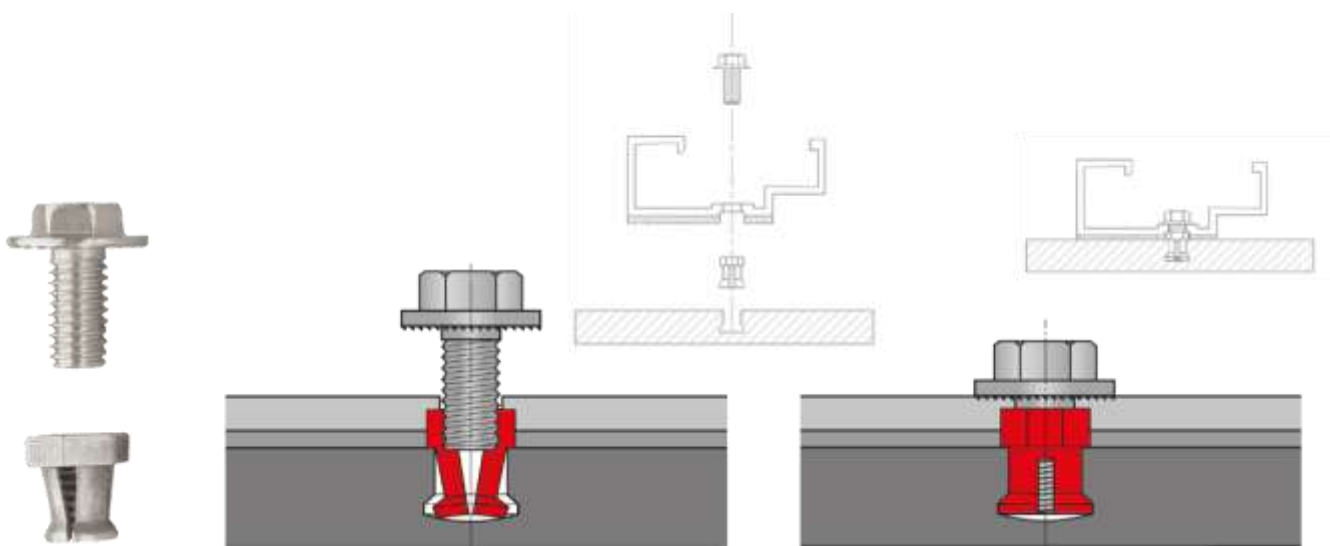
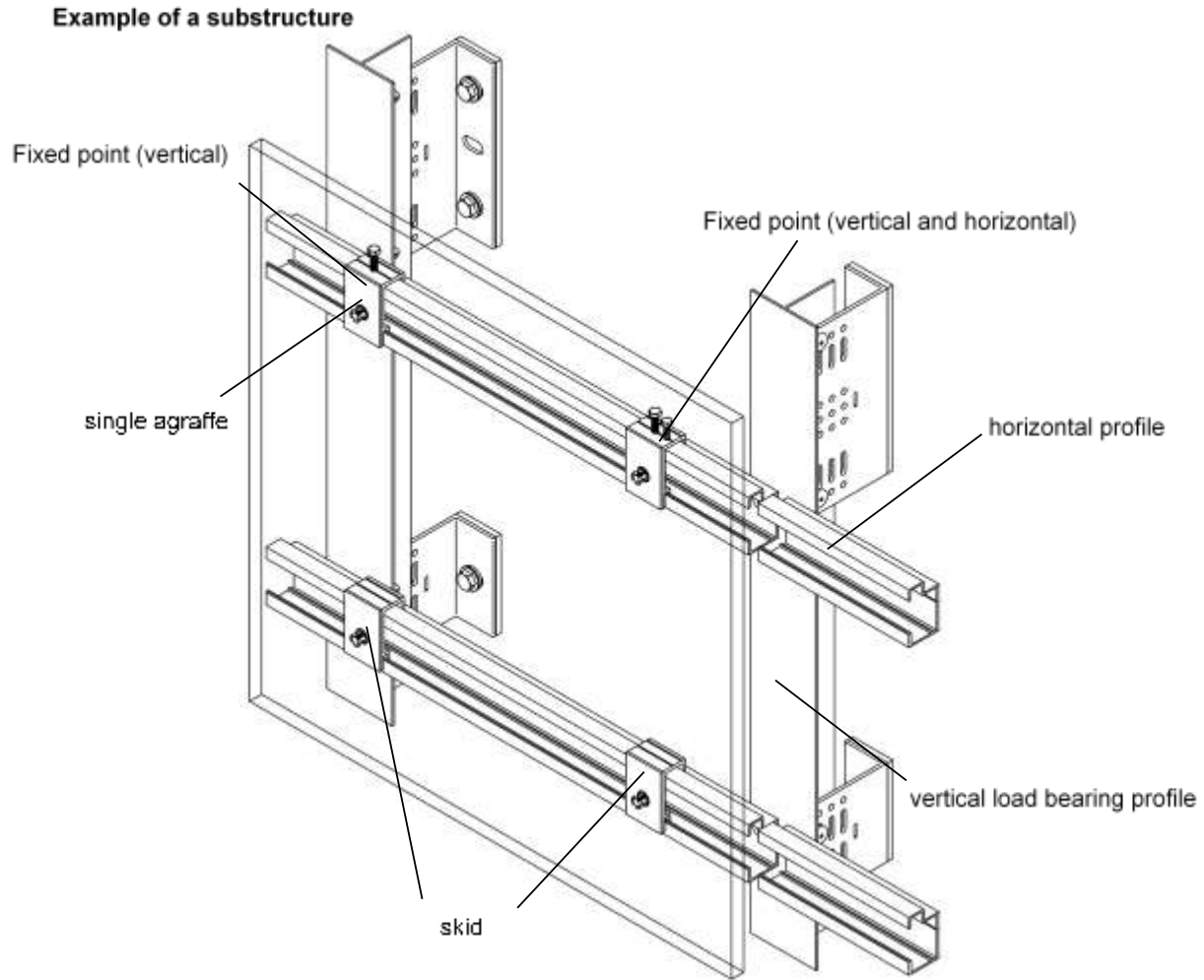


FIGURE 7—KEIL UNDERCUT ANCHOR KH SLEEVE INSTALLATION WITH HEX WASHER HEAD SCREW



**FIGURE 8—EXAMPLE FOR FAÇADE PANEL SUBSTRUCTURE INSTALLED WITH KEIL UNDERCUT ANCHOR KH**