

ICC-ES Evaluation Report

ESR-4297

Reissued July 2024


This report also contains:

- CBC Supplement

Subject to renewal July 2026

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<p>DIVISION: 07 00 00 THERMAL AND MOISTURE PROTECTION</p> <p>Section: 07 42 05—Wall Panel Fasteners</p>	<p>REPORT HOLDER:</p> <p>KEIL BEFESTIGUNGSTECHNIK GmbH</p>	<p>EVALUATION SUBJECT:</p> <p>KEIL UNDERCUT ANCHOR KH</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 granite façade panels to exterior and interior walls in all construction types under the IBC and on buildings constructed in accordance with the IRC.

3.0 DESCRIPTION

The KEIL undercut anchor KH is a stainless-steel anchor consisting of a crosswise slotted anchor sleeve component with an internal thread and anchorage depth of 10 or 15 mm. The anchor sleeve component is installed in an undercut hole drilled in the façade panel. A hexagon screw with integrated tooth lock washer is then threaded into the anchor sleeve component to the specified installation torque to complete a form-fitted, deformation-controlled anchorage. Alternatively, a threaded pin or threaded rod may be used instead of a hexagon screw. [Figure 1](#) depicts the KEIL undercut anchor KH components, dimensions and marking.

4.0 MATERIAL

4.1 KEIL Undercut Anchor KH

The KEIL undercut anchor KH components, including sleeves, hexagon screws, threaded pins and threaded rods are made from stainless steel, conforming to the manufacturer’s product specifications in the approved quality documentation. The material properties for the components are shown in [Table 1](#).

4.2 Granite façade panel material

Granite façade panel base materials used with KEIL undercut anchors KH must be granite complying with ASTM C615 or listed in [Table 2](#) and must be free of fractures and mechanically effective cracks.

5.0 DESIGN AND INSTALLATION:

5.1 Notations and Symbols:

$\sigma_{f,nom}$: nominal façade panel flexural strength
H	: façade panel smaller dimension
L	: façade panel greater dimension
h_{nom}	: façade panel thickness
h_s	: anchor embedment depth
t_{fix}	: support frame thickness
c	: screw length
a_r	: anchor edge distance (a_{rx}, a_{ry})
a	: anchor spacing (a_x, a_y)
e	: distance between shear center point and backside of panel
z	: distance between anchor axis and upper flange clamp
$N_{t,nom}$: nominal resistance for tensile normal loads
$N_{c,nom}$: nominal resistance for compressive normal loads
$N_{s,nom}$: nominal anchor tensile steel resistance
N_V	: additional normal load due to eccentricity/torsion
V_{nom}	: nominal resistance for vertical (shear) loads
$V_{s,nom}$: nominal anchor shear steel resistance
G	: gravity load of the panel
V_G	: gravity shear load per anchor
N_{load}	: total nominal normal load on a single anchor
V_{load}	: total nominal shear load on a single anchor
T_{inst}	: installation torque moment
γ	: partial safety factor for LRFD loads
Φ	: resistance factor for LRFD
Ω	: safety factor for ASD

5.2 General:

The KEIL undercut anchor KH is used to attach the selected facade panels to the supporting façade framing system that is installed over exterior and interior walls or wall framings capable of supporting the imposed gravity loads, including transverse wind loads. The façade panel system must be securely fastened to the supporting exterior and interior walls or wall framings with corrosion-resistant fasteners that are compatible with both the hanging seat clip of the connecting clip assembly and the wall assembly substrate.

5.3 Design:

Each façade panel must be anchored with four KEIL undercut anchors KH.

In-plane shear strengths (gravity resistance) and transverse load strengths provided in [Table 2](#) are based on shear load and transverse load testing complying with ASTM C1354 using an individual KEIL undercut anchor KH anchored to the specified façade panel base material. Nominal capacities for tensile and shear loads on KEIL undercut anchor KH are provided in [Table 2](#).

For calculating the vertical gravity load V_G on an individual KEIL undercut anchor KH, the total gravity load G of the façade panel is assumed to be supported by only two anchors:

$$V_G = \frac{G}{2} \quad (1)$$

For transverse load design, including wind loads, of exterior wall assemblies constructed with the granite panel façade systems, the applied transverse loads must be determined in accordance with IBC Chapter 16 or Section R301.2.1 of the IRC, as applicable.

For façade panels with flush anchors and horizontal load-bearing profiles, an additional transverse load component N_V due to torsion of the supporting frame profiles must be considered as shown in [Figure 8](#).

$$N_V = V_G \frac{e}{z} \quad (2)$$

The resulting applied loads N_{load} and V_{load} must be equal to or less than the corresponding ASD allowable load or LRFD design strength as provided in [Tables 2](#) and [3](#).

For combined loading of normal and transverse loads the following interaction requirement must be fulfilled:

$$\left(\frac{N_{load}}{N_{t,nom}/\Omega} \right) + \left(\frac{V_{load}}{V_{nom}/\Omega} \right) \leq 1.0 \quad (3a) \quad (\text{ASD})$$

$$\left(\frac{N_{load} \cdot \gamma}{N_{t,nom} \cdot \Phi} \right) + \left(\frac{V_{load} \cdot \gamma}{V_{nom} \cdot \Phi} \right) \leq 1.0 \quad (3b) \quad (\text{LRFD})$$

where $\Omega \geq 4.0$; $\Phi \leq 0.5$; $\gamma \geq 2.0$

The exterior or interior wall, wall framing and the attachment of the façade panel system to the supporting wall or wall framing 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.

The flexural strength design of granite façade panels is outside the scope of this report and must be prepared by a registered design professional when required by the statutes of the jurisdiction in which the system is to be installed.

5.4 Installation:

Installation of KEIL undercut anchor KH in façade panels must be in accordance with the manufacturer's published installation instructions, the approved project-specific construction documents, and this evaluation report. Installations must be done by qualified installers recognized by KEIL. A copy of the installation instructions must be available on the jobsite during construction.

The KEIL undercut anchors KH must be installed perpendicular to the façade panels into pre-drilled anchor holes ([Figure 3](#)) at the four corners of the façade panels with a minimum edge distance a_{rx} and a_{ry} as noted and shown in [Figure 4](#), using a special undercut drilling tool provided by KEIL. The embedment depth h_s for KEIL undercut anchor KH must be in accordance with the dimensions noted in [Table 2](#).

The support conditions (fixed and slide support) for the KEIL undercut anchors KH on the supporting frame must prevent any constraint (e.g. due to temperature expansion) as illustrated in [Figures 4](#) and [5](#).

Levelling of thickness tolerances up to 0.197 inch (5 mm) are permitted and require usage of KEIL distance washers.

Additionally, the following installation instructions must be followed:

- Façade panel drilling must be done at the fabrication location or on site under workshop conditions in accordance with KEIL installation requirements.
- Undercut drilling must be done with the KEIL drill bit ([Figure 6](#)) following KEIL installation requirements.
- The drill dust must be removed from the borehole using compressed air or vacuum.
- In the case of an abandoned hole, a new hole must be drilled at a minimum distance of twice the depth from of the abandoned hole.

- The geometry of the drill hole must be checked on 1% of all drilled holes. The following dimensions must be checked and documented according to KEIL installation instructions and testing instructions by means of a measuring device according to KEIL requirements and illustrated in [Figure 7](#).
 - Volume of the undercut drill hole
 - Depth position of the undercut; the distance between the lower edge of the measuring device and the façade panel is between 0.0 in. and 0.0118 in. (0.0 mm and 0.3 mm).

If the tolerances are exceeded, the geometry of the drill holes must be additionally checked on 25% of the drilled holes. No further drill hole may exceed the dimensional tolerances, otherwise all of the drill holes shall be checked. Drill holes exceeding the tolerances shall be rejected. Note: Checking the geometry of the drill hole on 1% of all drill holes means that on one of 25 panels (corresponding to 100 drill holes in granite façade panels each with four anchors) one drill hole shall be checked. If the tolerances given in [Figure 7](#) are exceeded, the extent of the control must be increased to 25% of the drill holes, i.e. one drill hole each shall be checked on all the 25 panels.

- During transport and storage of the façade panels on the project site, the façade panels must be protected from damage. The façade panels must be erected in a steady manner such that cracking does not occur. Façade panels with incipient cracks must not be installed.
- Between clamp (agraffe) and façade panel an elastic sandwich layer (e.g. EPDM) with a thickness of 0.0394 in. to 0.118 in. (1.0 mm to 3.0 mm) may be placed as shown in [Figure 2](#).
- Overhead installation is permitted.
- The installation torque moment T_{inst} must be within the range $1.84 \leq T_{inst} \leq 2.95$ ft-lbf. ($2.5 \leq T_{inst} \leq 4.0$ Nm).

[Figures 2, 3](#) and [5](#) provide example illustrations of a typical installation of KEIL undercut anchor KH and a façade panel system installed with KEIL undercut anchor KH, respectively. The support framing, screw connections between the connecting clamps (agraffes) and the horizontal supporting members, connections between horizontal and vertical supporting members, and connections between the vertical supporting members and the exterior and interior walls or wall framings is outside the scope of this report.

6.0 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:

- 6.1 Installation must comply with this report, the manufacturer's published installation instructions, and the applicable code. In the event of a conflict between the manufacturer's published installation instructions and this report, this report governs.
- 6.2 Drawings, design details, and calculations verifying the adequacy of the anchoring to connect the façade attachment system to the supporting wall must be prepared by a registered design professional and submitted to the code official for approval.
- 6.3 The granite façade panel material must be selected in accordance with Section 4.2 of this report.
- 6.4 Design of granite façade panels to resist flexural loading is outside the scope of this report and must be prepared by a registered design professional.
- 6.5 Full panels must be supported by a minimum of four fasteners installed near the corners of the panel, with a minimum edge distance of 2 inches (50 mm). For small pieces of cladding material, where installation of four fasteners is not feasible, the number and position of the fasteners shall be determined by the registered design professional.
- 6.6 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.
- 6.7 Wall cladding systems qualified by testing must be addressed in an ICC-ES evaluation report under 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.
- 6.8 The KEIL undercut anchor KH is manufactured in Engelskirchen, Germany under a quality control program with inspections by ICC-ES.

7.0 EVIDENCE SUBMITTED

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

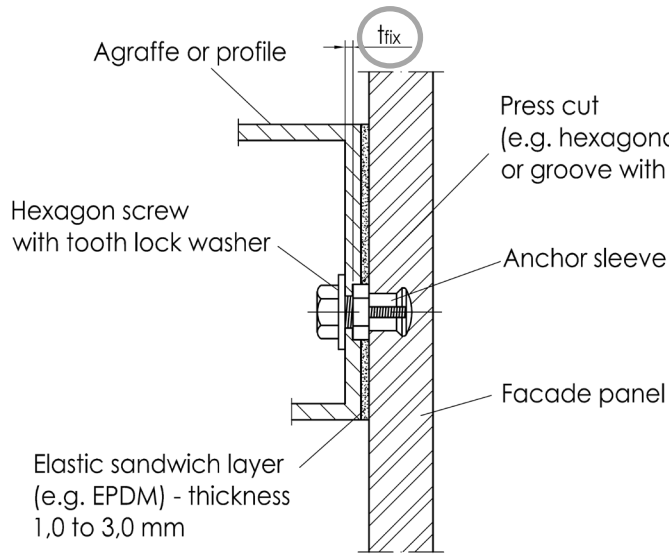
8.0 IDENTIFICATION

- 8.1 The ICC-ES mark of conformity, electronic labeling, or the evaluation report number (ICC-ES ESR-4297) along with the name, registered trademark, or registered logo of the report holder must be included in the product label.
- 8.2 In addition, each package of KEIL undercut anchor KH is labeled with the undercut anchor KH model designation, with the head of KEIL ratchet screws stamped with a marking shown in [Figure 1](#).
- 8.3 The report holder's contact information is the following:

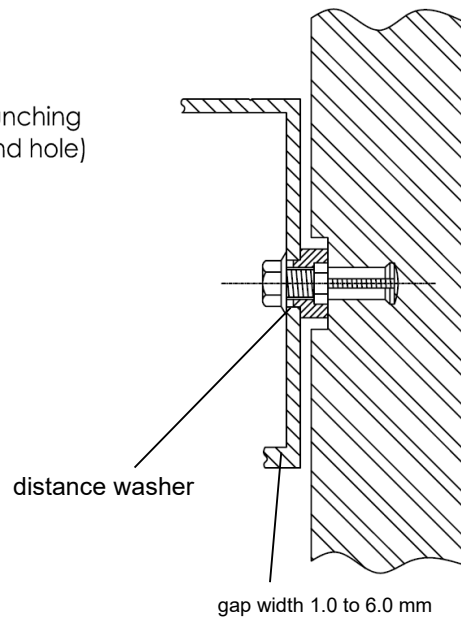
KEIL BEFESTIGUNGSTECHNIK GmbH
POST OFFICE BOX 1127
51766 ENGELSKIRCHEN
GERMANY
(239) 598-3737
www.keilanchor.com
www.keil-fixing.de

Installed anchor

Example without distance washer

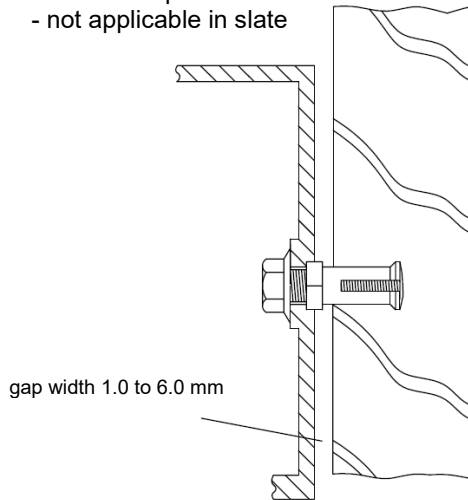


Example with distance washer



Example Stand-off fixing

- for facade panel
- not applicable in slate



Example Flush fixing

- for reveal panel

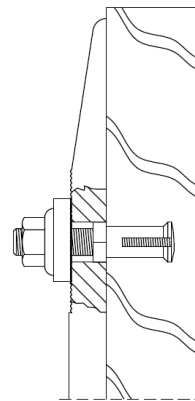


FIGURE 2—FAÇADE PANEL SYSTEM INSTALLED WITH KEIL UNDERCUT ANCHOR KH USING DISTANCE WASHER AND STAND-OFF FIXING

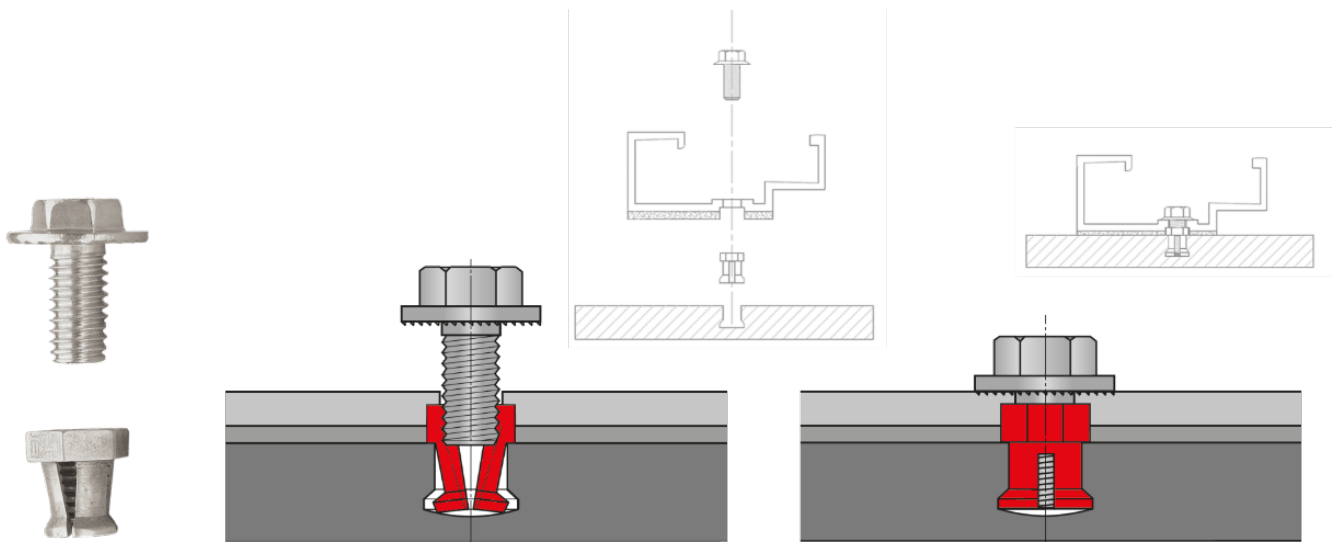


FIGURE 3—KEIL UNDERCUT ANCHOR KH INSTALLATION

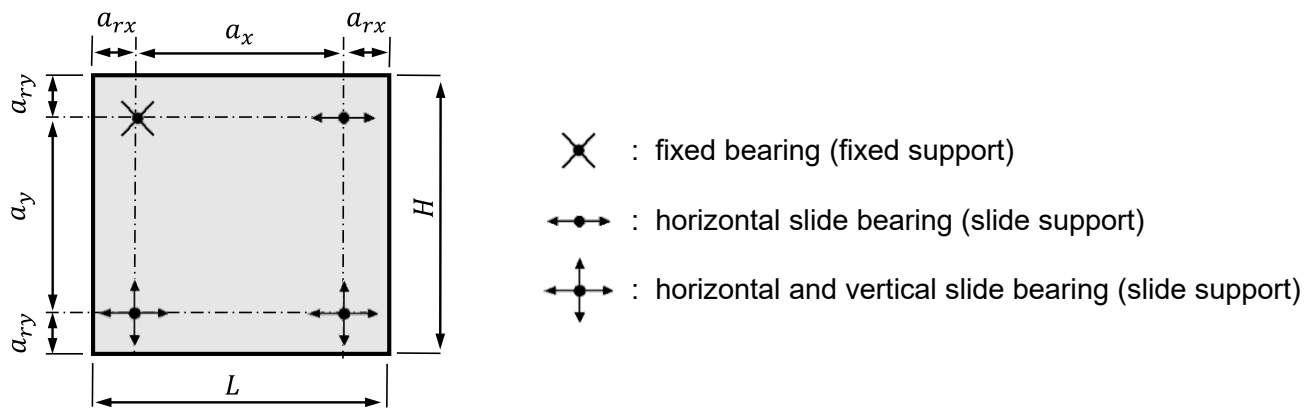


FIGURE 4—FAÇADE PANEL EDGE DISTANCES, SPACING AND SUPPORT CONDITIONS USING KEIL UNDERCUT ANCHORS KH

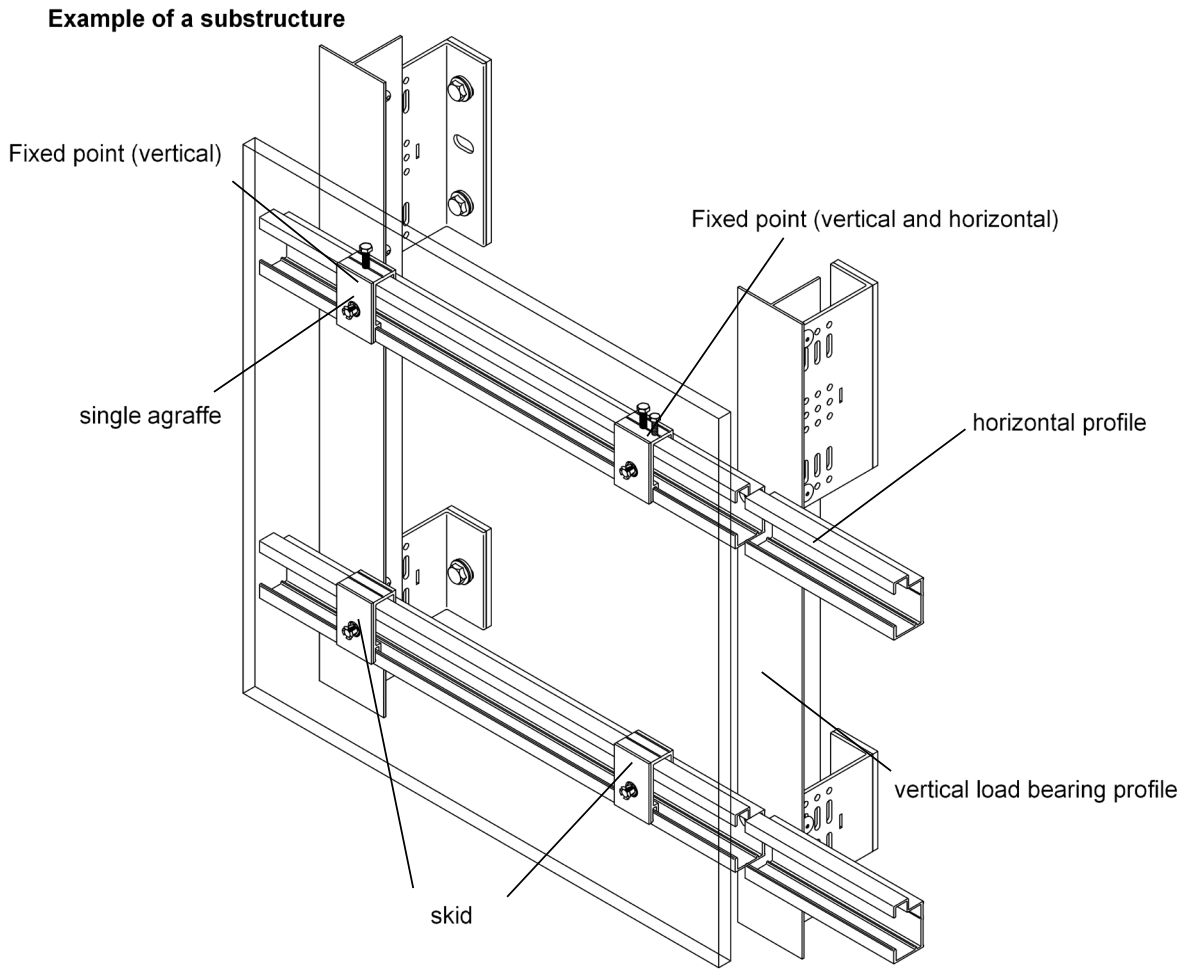


FIGURE 5—EXAMPLE FOR FAÇADE PANEL SUBSTRUCTURE INSTALLED WITH KEIL UNDERCUT ANCHORS KH

Geometry of the facade drill

for KEIL facade drill bit 7/9

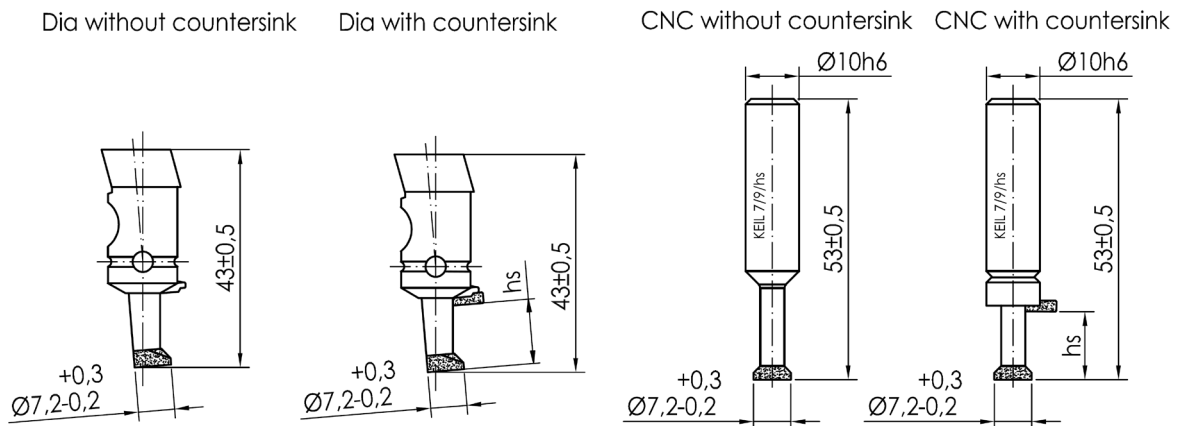
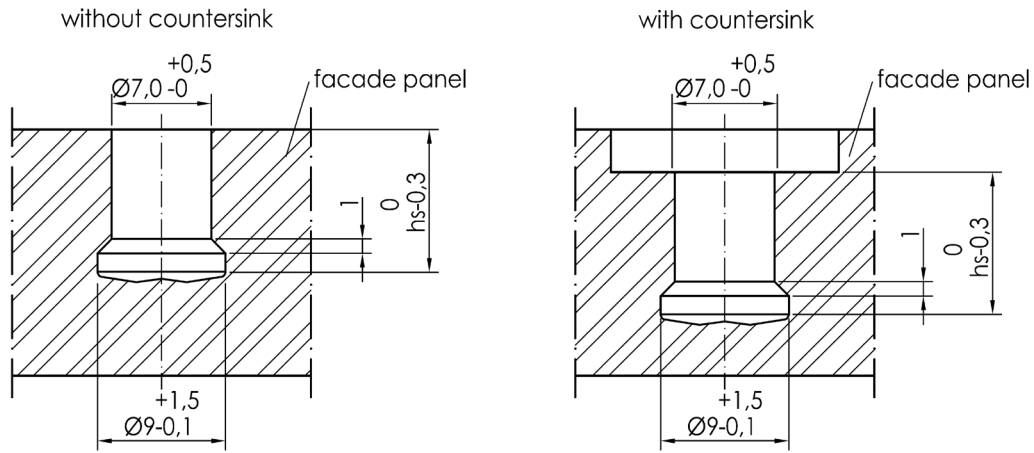
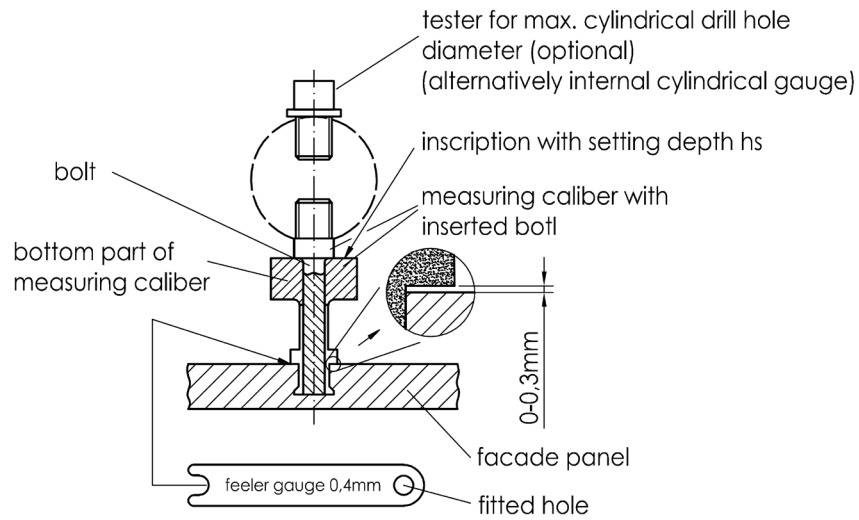


FIGURE 6—KEIL UNDERCUT ANCHOR KH DRILL BITS

Geometry of the drill hole



KEIL measuring device



Drawing scale not true to real scale

FIGURE 7—KEIL UNDERCUT ANCHOR KH DRILLED HOLE GEOMETRY, TOLERANCES AND MEASURING DEVICE

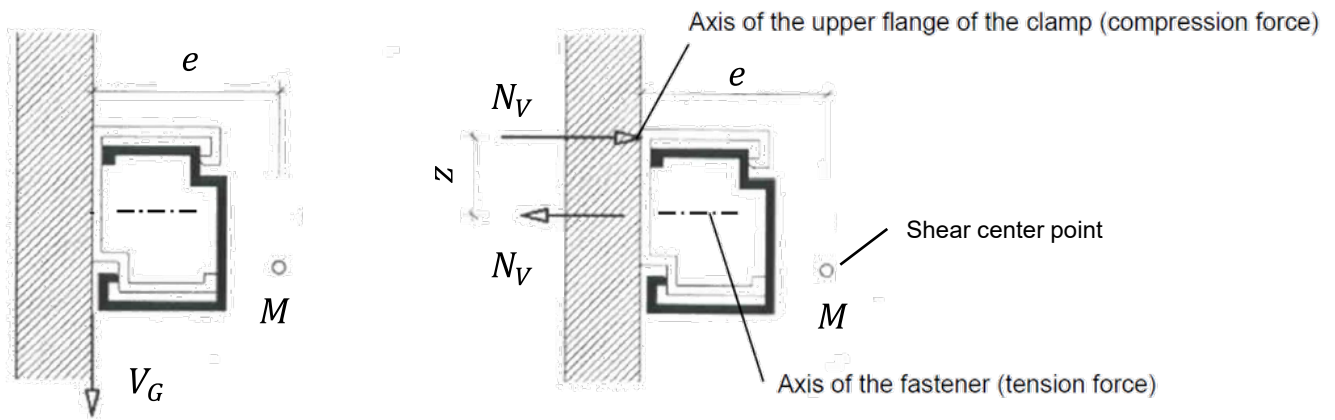


FIGURE 8—FREE BODY DIAGRAM CONSIDERING ADDITIONAL NORMAL FORCE N_V DUE TO TORSION OF THE SUPPORTING SUB-STRUCTURE UNDER FAÇADE PANEL GRAVITY LOAD V_G

TABLE 2—KEIL UNDERCUT ANCHOR KH ANCHORING TO GRANITE - NOMINAL CONNECTION CAPACITIES, EDGE AND ANCHOR SPACING AND REQUIRED FLEXURAL STRENGTH OF GRANITE FAÇADE PANELS ^{1, 2, 3}

Natural stone	Granite (ASTM C615)		Epprechtstein Yellow Granite (Germany)	Padang Light Granite (China)	
maximum façade panel area	2750 in ² (1.8 m ²)		2750 in ² (1.8 m ²)	2750 in ² (1.8 m ²)	
maximum façade panel length or width	64 in. (1650 mm)		64 in. (1650 mm)	64 in. (1650 mm)	
minimum façade panel thickness h_{nom}	0.78 in. (20 mm)		0.78 in. (20 mm)	0.78 in. (20 mm)	
Anchor embedment depth h_s	0.39 in. (10 mm)	0.59 in. (15 mm)	0.59 in. (15 mm)	0.39 in. (10 mm)	0.59 in. (15 mm)
minimum edge distance a_r	2 in. (50 mm)	4 in. (100 mm)	4 in. (100 mm)	2 in. (50 mm)	4 in. (100 mm)
maximum edge distance a_r	0.25L or 0.25H	0.25L or 0.25H	0.25L or 0.25H	0.25L or 0.25H	0.25L or 0.25H
minimum anchor spacing $a = 8 h_s$	3.15 in. (80 mm)	4.72 in. (120 mm)	4.72 in. (120 mm)	3.15 in. (80 mm)	4.72 in. (120 mm)
minimum flexural strength of façade panel $\sigma_{f,nom}$	1200 psi (8.3MPa)		2650 psi (18.27 MPa)	1961 psi (13.52 MPa)	
Tensile load $N_{t,nom}$ (transverse outward) ⁴	360 lbs (1.60 kN)	670 lbs (2.98 kN)	1129 lbs (5.02 kN)	589 lbs (2.62 kN)	1095 lbs (4.87 kN)
Compressive load $N_{c,nom}$ (transverse inward) in case of stand-off anchorage	360 lbs (1.60 kN)	for $h_{nom} \geq 1.18$ in. 670 lbs (2.98 kN)	for $h_{nom} \geq 1.18$ in. 1129 lbs (5.02 kN)	589 lbs (2.62 kN)	for $h_{nom} \geq 1.18$ in. 1095 lbs (4.87 kN)
Shear load V_{nom} (gravity) ⁵	600 lbs (2.67 kN)	788 lbs (3.51 kN)	1275 lbs (5.67 kN)	980 lbs (4.36 kN)	1288 lbs (5.73 kN)

For SI: 1 inch = 25.4 mm and 1 lbf = 4.448 N.

¹To calculate allowable shear loads and transverse loads, divide the tabulated nominal load values by ASD safety factor, $\Omega = 4.0$.

²To calculate design shear strength and design transverse strength, multiply the tabulated load values by LRFD strength reduction factor $\phi = 0.50$.

³Countersunk and stand-off anchor installation (see [Figure 2](#)) in granite façade panels is permitted, except for panels with $h_{nom} \leq 1.18$ in. (30 mm) with an anchor depth $h_s = 0.59$ in. (15 mm).

⁴Evaluated using minimum edge distance.

⁵Evaluated including a 0.118-0.197 in. (3-5 mm) washer between panel and clamp (stand-off fastening) and minimum edge distance.

TABLE 3—KEIL UNDERCUT ANCHOR KH STEEL CAPACITIES

Load Direction	Nominal Steel Capacity ^{1, 2}
Tensile (transverse) steel load $N_{s,nom}$	3170 lbs (14.1 kN)
Shear steel load $V_{s,nom}$	1573 lbs (7.0 kN)

For SI: 1 inch = 25.4 mm and 1 lbf = 4.448 N.

¹Nominal steel capacities are based on the mean tensile (transverse) loads and mean shear loads determined through testing.

To calculate allowable shear or tensile (transverse) strengths, divide tabulated values by ASD safety factor $\Omega = 4.0$.

²To calculate LRFD design strength, multiply tabulated values by the LRFD strength reduction factor $\phi = 0.50$.

DIVISION: 07 00 00 THERMAL AND MOISTURE PROTECTION
Section: 07 42 05—Wall Panel Fasteners

REPORT HOLDER:

KEIL BEFESTIGUNGSTECHNIK GmbH

EVALUATION SUBJECT:

KEIL UNDERCUT ANCHOR KH

1.0 REPORT PURPOSE AND SCOPE**Purpose:**

The purpose of this evaluation report supplement is to indicate that Keil Undercut Anchor KH, described in ICC-ES evaluation report ESR-4297, has also been evaluated for compliance with the codes noted below.

Applicable code editions:

- 2019 *California Building Code (CBC)*

For evaluation of applicable Chapters adopted by the California Office of Statewide Health Planning and Development (OSHPD) AKA: California Department of Health Care Access and Information (HCAI) and the Division of State Architect (DSA), see Sections 2.1.1 and 2.1.2 below.

- 2019 *California Residential Code (CRC)*

2.0 CONCLUSIONS**2.1 CBC:**

The Keil Undercut Anchor KH, described in Sections 2.0 through 7.0 of the evaluation report ESR-4297, complies with CBC Chapter 14, provided the design and installation are in accordance with the 2018 *International Building Code*® (IBC) provisions noted in the evaluation report and the additional requirements of CBC Chapters 14 and 16, as applicable.

2.1.1 OSHPD: The applicable OSHPD Sections and Chapters of the CBC are beyond the scope of this supplement.

2.1.2 DSA: The applicable DSA Sections and Chapters of the CBC are beyond the scope of this supplement.

2.2 CRC:

The Keil Undercut Anchor KH, described in Sections 2.0 through 7.0 of the evaluation report ESR-4297, complies with CRC Chapters 7, provided the design and installation are in accordance with the 2018 *International Residential Code*® (IRC) provisions noted in the evaluation report.

This supplement expires concurrently with the evaluation report, reissued July 2024.