HGB HANDRAIL CONNECTIONS
The benefits at a glance

Construction specialists consider the Halfen HGB Handrail connections to be particularly suited for fastening railings and banisters to the thin front faces of balcony slabs

Halfen HGB Handrail connections profile
HGB E-54/33-A4

Safe and reliable
- statically verified installation
- no damage to visible surfaces of concrete slabs
- also suitable to secure mandatory safety rails during construction (Refer to: EN 795 "Guard rails")
- use with Halfen high-strength bolts to ensure a relible and statically sound connection of railing/banister components

Fast and cost-effective
- adjustable anchorage
- can also be used in slabs as thin as h ≥ 100 mm
- installed with bolts instead of welding or drilling
- pre-planning reduces on-site construction time
- all attached components remain fully adjustable or are easily replaced as required

Halfen HGB Handrail connections profile
HGB E-49/30-A4

Halfen HGB Handrail connections profile
HGB E-40/25-A4

Halfen HGB Handrail connections profile
HGB E-38/17-A4

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HALFEN HGB HANDRAIL CONNECTIONS
Application Examples

SAFETY BARRIERS IN STADIUMS

①-④: Safety barrier installation, multi purpose arena in Berlin

Fixing of safety rails, Rheinenergiestadion Cologne

Fixing of safety rails, Rheinenergiestadion Cologne

RAILINGS

Used to secure safety rails during the construction phase

Cast-in HGB Channel, residential building

HALFEN HGB HANDRAIL CONNECTION
General

Regulatory requirements

Balconies are part of the structural system. *"They must be designed, constructed, maintained and modified in such a fashion that public order and safety, especially to health or life, is not endangered"*. Model building code and construction guidelines (*Musterbauordnung MBO 2020 und Ausführungsvorschriften*).

Technical guidelines issued by public notice as technical building regulations must be observed.* Technical rules provide information on load parameters, calculation, dimensioning of structural products, construction types, structural layouts etc. A requirement of regional building codes refers to structural stability: *"All structures must, as a whole and in their individual components, be structurally self-supporting"*. This stability must be statically verifiable based on current technical standards.

A further building regulation addresses traffic loads, for example: Balconies and loggias must be fitted with safety rails to prevent falls when they border on to an area with a drop of more than one metre. For a drop height up to 12 m the minimum railing height is 0.90 m measured from the upper surface of the finished floor surface or accessible ledge. For drop heights greater than 12 m the banister height must be at least 1.10 m. For exceptions see the German federal building regulations / Deutsche LandesBauOrdnung.

Other regulations, not covered here, address the design, dimensioning, required spacings in the guard rail design, fire protection, thermal/sound insulation and rainwater drainage.

* issued by the highest construction supervision authorities of the German Federal States

Regulations, standards and directives (to be observed when designing safety rails)

Regional Building Codes §

Individual regional states have their own building codes and regulations. All current technical regulations require proof of structural safety and integrity. A static calculation or a building authority certificate is required when designing and dimensioning the fixings for guard rails.

VOB — Part B, § 4, execution of construction: §

§ 4.2 (1) It is the contractor's responsibility to provide the static documentation in accordance with the contract. He has to observe the recognized standards of practice as well as with the provisions of the law and regulatory directives. Tender and Contract Regulations for the German building industry (*VOB Vergabe- und Vertragsordnung für Bauleistungen*) Part B, § 4.3, requires the contractor to report to the customer, in writing, any obvious design flaws, which he as the expert must be able to recognize. He alone is responsible for any resulting defect and consequential expenses. If he has satisfied his reporting obligation, the responsibility for the defect passes to the customer (defect example: banister attachment mounted in a concrete slab which is too thin).

BVM Directive

Directive on metal railings/banisters/balustrades, published by Federal Association of German Metalworkers (*BVM Berufsverband Metall*).

Other applicable regulations and standards (Extract): §

- Accident Prevention Regulation "General Provisions" (DGUV Regulation 1)
- Industrial Safety Regulations
- ETB – Directive "Fall Prevention Installations", Publ. 1985
- Stainless Steels, EC3 part 1-4

EN 1992-1-1 (EC2):	Design and construction of concrete support structures; with National Annex (NA)
EN 1991 (EC1):	General effects on load structures; with National Annex (NA)
EN 1993 (EC3):	design and construction of steel structures; with National Annex (NA)

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HALFEN HGB HANDRAIL CONNECTION
Materials/Corrosion Protection

Stainless Steel A4:
Chromium is the most important alloy element in stainless steel. A specific chromium concentration ensures the generation of a passive layer on the surface of the steel that protects the base material against corrosion. This explains the high corrosion resistance of stainless steel.

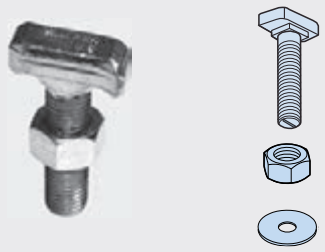
Stainless Steel

"Anchor channels in stainless steel may be used outdoors – also in an industrial and coastal environment, but may not be directly exposed to salt water".
See guidelines for "Metal railings, banisters and balustrades" issued by the German Association of Metalworkers (*BVM Bundesverband der Metallverarbeiter*).

Halfen Cast-in channels, stainless steel

Description	Stainless steel		
	Materials	Standard	Corrosion resistance class according to EN 1993-1-4, table A.3
Channel profile	1.4404 or 1.4571 ■	EN 10 088	III
Ribbed-head anchor	Reinforcing steel B500B □ Reinforcing steel BSt 500 NR ■	DIN 488	

Halfen Bolts, stainless steel



Description	Stainless steel		
	Materials	Standard	Corrosion resistance class according to EN 1993-1-4, table A.3
Bolt	A4-70: 1.4404 or 1.4571 ■	EN 3506-1 and EN 10 088	III
Hexagonal nut	A4-70: 1.4404 or 1.4571 ■	EN 3506-2 and EN 10 088	III
Washer	1.4404 or 1.4571 ■	EN 10 088	III

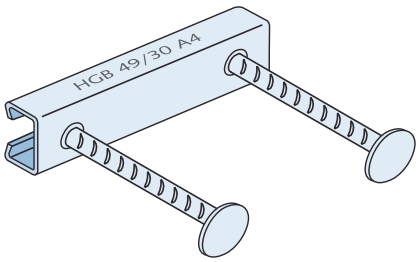
□ **WB** = Steel mill finish
■ **A4** = Stainless steel

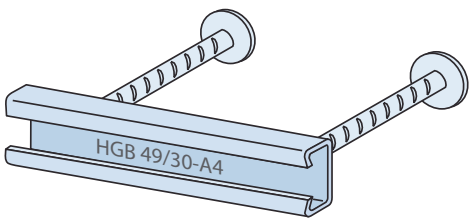
Available on request:

Galvanized material for interior, dry rooms, for instance when installing staircase railings and banisters in residential buildings, schools or commercial retail stores.

Hot-dip galvanized FV:
Dipped in a galvanizing bath, with a temperature of approx. 460 °C; this method will primarily be used for your requested channels and bolts.

Identification of Halfen HGB Cast-in channels

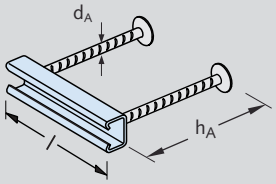
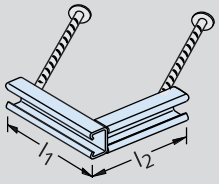
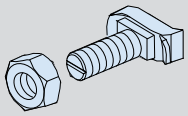
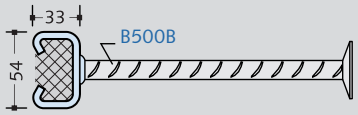
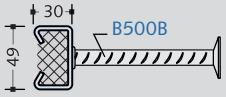
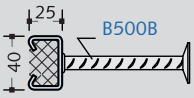




Product identification
- on channel side
- additionally inside the profile

HALFEN HGB HANDRAIL CONNECTION
Product Range

Halfen HGB Cast-in channels and bolts

Item description		Dimensions HGB-E [mm]			Dimensions HGB-EE [mm]				Halfen HS Bolts	
										
	l	d_A	h_A	Weight kg/each G	l_1 / l_2	d_A	h_A	Weight kg/each G	Type / FK	Dimensions
HGB E - 54/33-A4 	100	14	200	1.071	170/170	14	250	2.262	HS-50/30 A4-70	M12×40 M16×50
	150			1.307						
	200			1.543						
HGB E - 49/30-A4 	100	12	110	0.704	170/170	14	150	1.501	HS-50/30 A4-70	M12×40 M16×50
	150			0.855						
	200			1.007						
HGB E - 40/25-A4 	100	10	90	0.611	170/170	14	90	1.042	HS-40/22 A4-70	M12×40 M16×40
	150			0.717						
	200			0.822						
HGB E - 38/17-A4	100	10	201	0.824	170/170	12	201	1.214	HS-38/17 A4-70	M12×40 M16×40
	150			0.911						
	200			0.999						

■ **A4** = Stainless steel 1.4571/1.4404 **Alternative for interior use** (on request) ■ **FV** = Steel hot-dip galvanized 1.0038/1.0044

Ordering and materials

Ordering example HGB channel:

HGB-E-49/30 - 200 - A4
- A4 → material
- 200 → length [mm]
- HGB-E-49/30 → description

Ordering example Halfen Bolt:

HS-50/30 - M12x40 - A4-70
- A4-70 → material
- M12x40 → thread-Ø × length
- HS-50/30 → description

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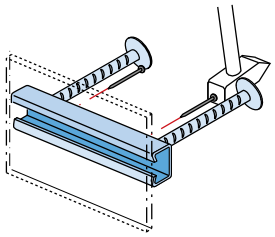
HALFEN HGB HANDRAIL CONNECTION
Installation/Assembly

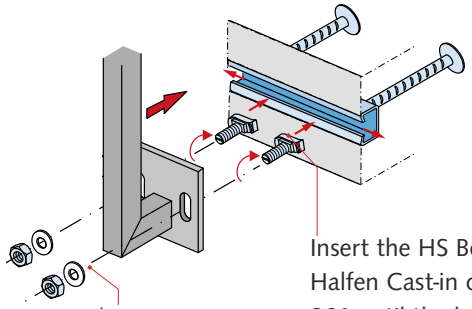
1 Nail the Halfen Cast-in channel to the formwork



Where possible, use stainless steel nails to avoid corrosion.
After striking the formwork remove the foam filler from the Halfen Cast-in channels.

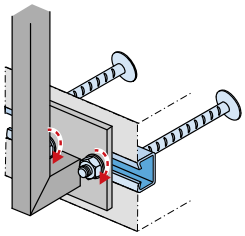
Nail the Halfen Cast-in channel to the formwork

2 Installation and adjustment of balustrades



Insert the HS Bolts into the Halfen Cast-in channel (turn 90° until the bolt locks into place).

3 Tighten the bolts

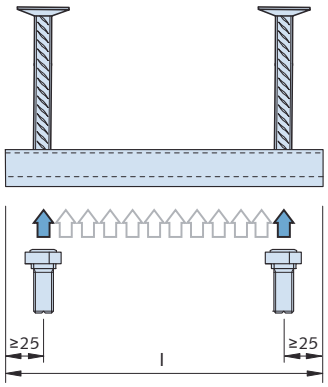


Tighten the nuts using a torque wrench. See table on the right for torque values

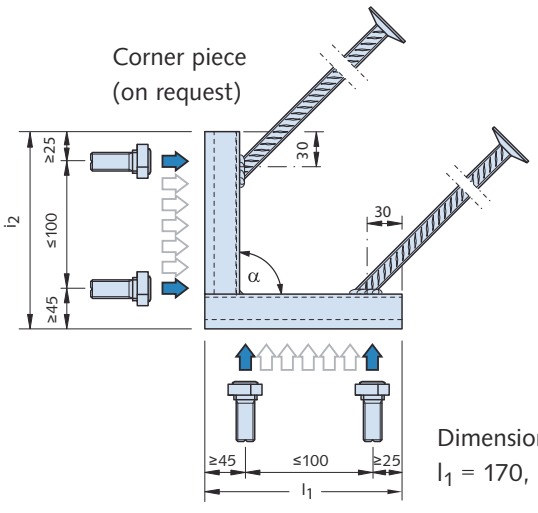
Railing bolts			
Stainless steel Material grade A4-70		**Torque [Nm]**	
HS 50/30		M16	60
for profile 49/30 and 54/33		M12	25
HS 40/22		M16	45
for profile 40/25		M12	25
HS 38/17		M16	40
for profile 38/17		M12	25

Fixing position of the bolts

Short piece



Corner piece
(on request)

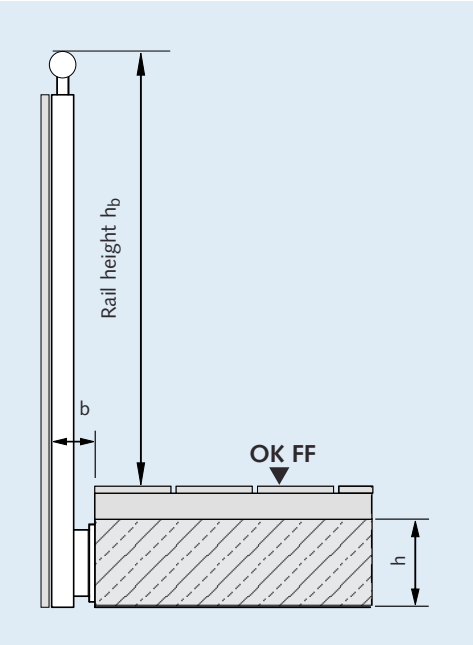


Dimensions [mm]:
l_1 = 170, l_2 = 170, α = 90°

HALFEN HGB HANDRAIL CONNECTION
Dimensioning Fundamentals

Railing height
The minimum height h_b of a railing is 0.90 m from the top surface of the finished floor or accessible ledge to the upper edge of the rail. For drop heights of more than 12.0 m the railing must be at least 1.10 m in height. (Exceptions; as specified in regional building codes)

It would be advisable to have one uniform minimum height of 1.00 m as has already been mandated in the commercial sector and in a number of European countries.

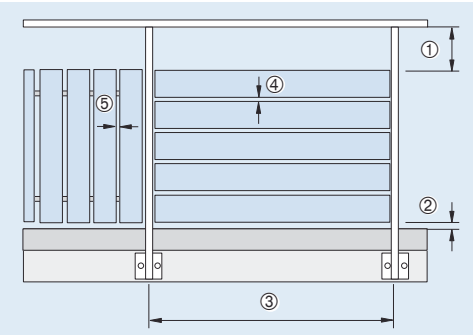


b = clear distance between the back of the balcony cladding and the front face of the balcony slab or gutter / kick plate

Balcony slab
Anchor channels or dowel installations require concrete of at least C 20/25 grade. A case-by-case decision must be made if the concrete grade is less than C 20/25 grade or is unknown.

The thickness of the balcony slab must be at least h = 100 - 150 mm when the HGB is cast in the slab edge (depends on channel profile and according to the German HGB approval). Other types of installation and systems require a thicker slab. All weather-exposed concrete-embedded installations (e.g. for balconies) must be made of stainless steel.

Spacings
Any structural design must take all basic requirements for railings and banisters into account. As a general rule, all railings and banisters must be designed so that personal injury is ruled out, for instance with correct spacing of rails, lattice bars or panels. They should also be designed so as not to entice but instead to discourage anyone from climbing over. The specific requirements for guard rail design are determined by the intended use (residential, public, commercial) and the drop height involved. Also observe the building codes of each country or region, the ETB guide-lines "Fall Protection Components" and DIN 18065 (Stairs in Buildings — definition, rules, key measurements) and guard rail regulation applicable at the construction site. In Germany these are the Guardrail regulations 2020 set by the German Association of Metalworkers, (*"Geländer-Richtlinie 2020, BVM Berufsverband Metall"*) .



① clear distance between bottom edge of hand rail and top edge of facing / lower structure
② clear distance between the top edge of the finished floor and the bottom edge of the facing lower structure
③ axis spacing between posts
④ clear distance between horizontal facings
⑤ clear distance between vertical facings

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HALFEN HGB HANDRAIL CONNECTION
Dimensioning

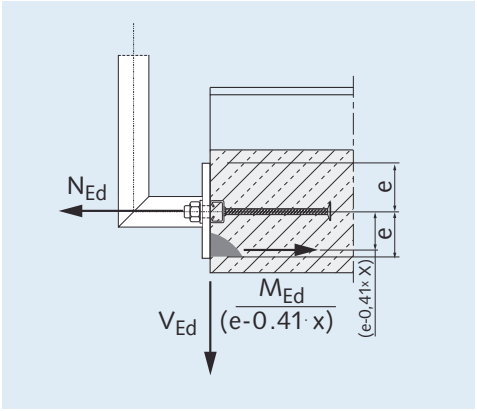
Dimensions

The forces acting on the railing must be transferred into the main building structure. It is necessary to verify that the forces

a) are wholly supported by the railing and

b) can be transferred via the connecting elements into the balcony slab.

$$N_{Ed} = \frac{M_{Ed}}{(e - 0.41 \cdot x)} + H_{Ed}$$



N_{Ed} = tensile force on the anchor
e = distance between channel axis and outer edge of the railing base plate
x = maximum concrete pressure zone level according to annex 8, table 8a and 8b

Railing heights

Drop height	Minimum height of rails (recommended)	Note
Less than 12 m	90 cm (100 cm)	Relevant regional building regulations and if necessary other regulations e.g. for civil constructions must be observed.
Greater than 12 m	110 cm	

Calculation

1. Railing/banister load h according to EN 1991-1-1/NA Table 6.12 DE

"Calculation must assume 100% traffic load in drop direction and 50 % of traffic load (but not less than 0.5 kN/m) in the opposite direction."

for example: residential buildings and communal areas with low foot traffic	**q_k = 0.5 kN/m**
for example: rooms for mass assembly, commercial sales spaces, corridors	**q_k = 1.0 kN/m**
for example: areas for large gatherings of people, factories, workshops	**q_k = 2.0 kN/m**

2. Vertical loads v according to BVM* guidelines

Load assumptions to calculate vertical loads are according to the BVM guidelines for guard rails/banisters.

from dead weight of structure including any renders	**v_1 = 0.40 kN/m**
from window box	**v_2 = 0.35 kN/m**
support capacity	**v_3 = 0.15 kN/m**

3. Wind loads

F_w according to EN 1991-1-4 and EN 1991-1-4/NA

Velocity force q in kN/m² and total wind pressure F_w are calculated according to EN 1991-1-4 with EN 1991-1-4/NA.

*German Association of Metalworkers (BVM Bundesverband der Metallverarbeiter)

HALFEN HGB HANDRAIL CONNECTION
Dimensioning

Extract from HGB approval Z-21.4-1912, page 6

3.2.2 Actions and required verifications

The actions H_{Ed}, V_{Ed}, M_{Ed} and N_{Ed} have to be determined according to the calculation basics as in annex 7.
The ratio in the design calculation between horizontal action and bending moment is limited to:

$$\frac{H_{Ed}}{M_{Ed}} \leq 1.5\ [1/m] \qquad H_{Ed}\ [kN];\ M_{Ed}\ in\ [kNm]$$

It has to be verified that the design action value E_d does not exceed the design resistance value R_d:

$E_d \leq R_d$ see table 3.1 and 3.2 below
E_d = Design action value (N_{Ed}, V_{Ed}, M_{Ed})
R_d = Design resistance value (N_{Rd}, V_{Rd}, M_{Rd})

For a standard case the following equation for the design action value applies
(permanent load and variable load acting in the same direction):

$E_d = \gamma_G \cdot G_k + \gamma_Q \cdot Q_k$
$G_k; Q_k$ = characteristic value of permanent load or variable load according to recoqnized standards for load assumptions
$\gamma_G; \gamma_Q$ = partial safety factors for permanent and variable action

Extract from HGB approval no. Z-21.4-1912, page 7

Table 3.1 Required verifications for tensile loads	
Steel failure	$N_{Ed} \leq N_{Rd,s}$ $\leq N_{Rd,s,s}$ (for single-bolt fixing) $\leq 2\ N_{Rd,s,s}$ (for two-bolt fixing)
Pull out failure	
Concrete failure with anchor reinforcement	
Spalling	

Table 3.2 Required verifications for shear loads	
Steel failure	$V_{Ed} \leq V_{Rd,s}$ $\leq V_{Rd,s,s}$ (for single-bolt fixing) $\leq 2\ V_{Rd,s,s}$ (for two-bolt fixing)
Concrete failure with anchor reinforcement	
Concrete edge failure with anchor reinforcement	$V_{Ed} \leq V_{Rd,c}$
	$M_{Ed} \leq M_{Rd,c}$

With combined loads the following interactions must be verified:

1. $\max.\ (\ N_{Ed} / N_{Rd,s}\ )^2 + \max.\ (\ V_{Ed} / V_{Rd,s}\ )^2 \leq 1.0$
   or
   $\max.\ (\ N_{Ed} / N_{Rd,s}\ ) + \max.\ (\ V_{Ed} / V_{Rd,s}\ ) \leq 1.2$

2. $M_{Ed} / M_{Rd,c} + 1.5\ V_{Ed} / V_{Rd,c} \leq 1.5$ for $0.333 \leq V_{Ed} / V_{Rd,c} \leq 1.0$

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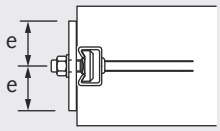
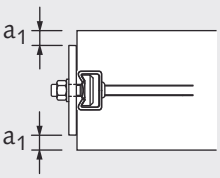
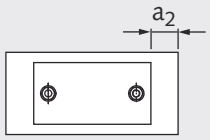
HALFEN HGB HANDRAIL CONNECTION
Dimensioning

Extract from HGB-approval no. Z-21.4-1912, annex 6

Table 6: Installation and anchor parameters

Description	Illustration	Anchor channels profiles			
		38/17	40/22 40/25	50/30 49/30	52/34 54/33
A) Profile shape and bolt positioning					
Minimum channel length required for a two-bolt fixing [mm]	annex 2	150	150	150	150
Minimum bolt distance p [mm]	see next page	80	80	80 (100) ①	80 (100) ①
B) Building element dimensions and anchor position in the element					
Minimum thickness of concrete element h [mm]	annex 8	100	120	140	150
Minimum edge distance c_1 [mm] (channel axis to the upper and the lower edge of the concrete element)	annex 8	50	60	70	75
Minimum distance a_e [mm] to edge of concrete element (from end of channel)	see next page	40	45	50	50
C) Size and position of anchor plate					
Minimum distance e [mm] from the channel axis to the upper and the lower edge of the anchor plate		30	30	35	37.5
Minimum distance a_1 [mm] from the upper and lower edge of the anchor plate to the upper and lower edge of the concrete element ②		10	10	10	10
Minimum distance a_2 [mm] from the outer edge of the anchor plate to the edge of the concrete element		40	45	45	45

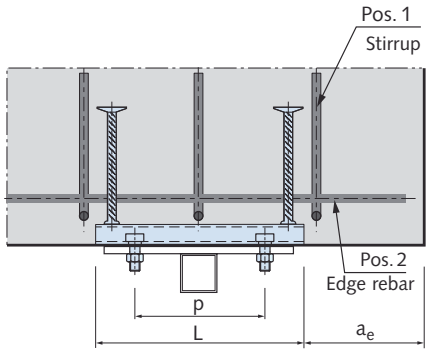
① The values in brackets apply when using M20 bolts
② In components with a weather groove, the bottom of the groove is regarded as the concrete element edge

HALFEN HGB HANDRAIL CONNECTION
Dimensioning

Extract; HGB approval no. Z-21.4-1912, annex 6

Table 7: Size and position of required minimum reinforcement				
Description	Anchor channels			
	38/17	40/25	49/30	54/33
Stirrup / Quantity	3 Ø 8 l_b = 200 mm	3 Ø 8 l_b = 250 mm	3 Ø 10 l_b = 300 mm	3 Ø 12 l_b = 400 mm
Edge rebar, top and bottom [mm]	Ø 8	Ø 8	Ø 10	Ø 12

Required minimum reinforcement:
One stirrup is placed centrally between the channel anchors and one stirrup directly next to each anchor at the channel ends (if positioned near to the edge, between the anchor and component edge).



Extract; HGB approval no. Z-21.4-1912, annex 8

Table 9: Design resistance for each bolt				
Tensile				
Bolts Ø		M12	M16	M20
$N_{Rd,s,s}$ [kN]	4.6	16.9	31.4	49.0
	8.8	44.9	83.7	130.7
	A4-, HC-50	14.8	27.4	42.8
	A4-70*	31.6	58.8	91.7
Shear				
$V_{Rd,s,s}$ [kN]	4.6	12.1	22.6	35.2
	8.8	27.0	50.2	78.4
	A4-, HC-50	10.6	19.8	30.9
	A4-70*	22.7	42.2	66.0

* Values also apply for all stainless steels of strength class 70 (see also HGB approval, annex 4)

Design resistance of concrete pressure zone

$$M_{Rd,c} = 0.81 \cdot x \cdot b \cdot \frac{f_{ck}}{\gamma_{Mc}} \cdot (e - 0.41 \cdot x)$$

where:
x = maximum height; concrete pressure zone (see table 8a and 8b)
b = width of pressure zone = width of anchor plate b_p
f_{ck} = characteristic compression strength of concrete in accordance with EN 206-1:2001-07, for concrete strength ≥ C30/37 only calculate using f_{ck} = 30 N/mm²
e = distance between anchor channel axis and outer edge of the anchor plate (see illustration on page 67, table 8)
γ_{Mc} = 1.5 (partial safety factor)

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HALFEN HGB HANDRAIL CONNECTION
Dimensioning

Extract, HGB-approval no. Z-21.4-1912, annex 8

Table 8a: Design resistance of the channel using single-bolt fixing

Channel type		38/17	40/25	49/30	54/33
Minimum thickness of component h [mm]		100	120	140	150
Steel failure (single-bolt fixing)					
Tension	$N_{Rd,s}$ [kN]	10.0	11.1	17.2	30.6
Shear	$V_{Rd,s}$ [kN]	10.0	11.1	17.2	30.6
Concrete failure (single-bolt fixing)					
$V_{Rd,c}$ [kN]		6.7	9.0	11.7	12.7
Maximum height of concrete pressure zone x		0.25 · e ①	0.25 · e ①	0.30 · e ①	0.40 · e ①

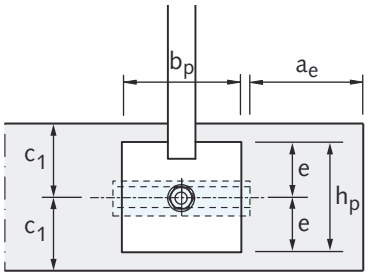
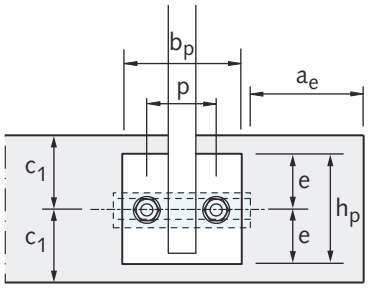


Table 8b: Design resistance of the channel using a two-bolt fixing

Profile		38/17	40/25	49/30	54/33
Minimum thickness of component h [mm]		100	120	140	150
Steel failure (two-bolt fixing)					
Tension	$N_{Rd,s}$ [kN]	15.0	16.7	25.8	45.8
Shear	$V_{Rd,s}$ [kN]	15.0	16.7	25.8	45.8
Concrete failure (two-bolt fixing)					
$V_{Rd,c}$ [kN]		6.7	9.0	11.7	12.7
Maximum height of concrete pressure zone x		0.25 · e ①	0.25 · e ①	0.30 · e ①	0.40 · e ①

① e = distance between the anchor channel axis and outer edges of the anchor plate. For asymmetrical anchor plates the smallest distance to the outer edge of the anchor plate is used for calculation.



Dimensioning example Halfen HGB Guard rail fittings

M_{Ed} = used to calculate applicable moment relative to the channel axis

e_{V1}, e_{V2}, e_{V3} = distance of the vertical loads to the front edge of the channel

e_{h1}, e_{Fw} = distance of the horizontal loads to the front edge of the channel

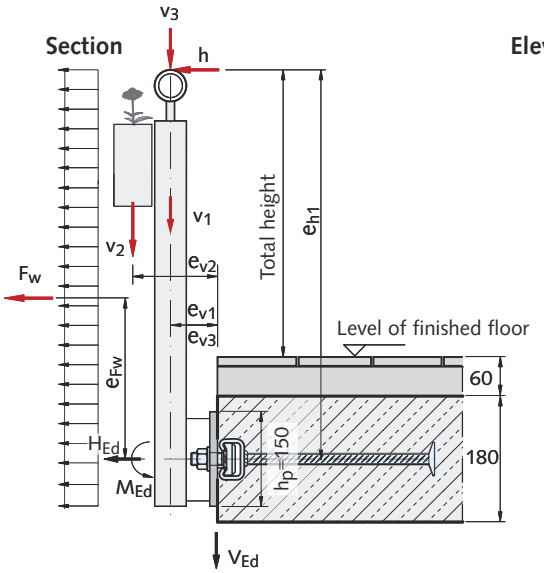
H_{Ed} = used to calculate the applicable horizontal effect

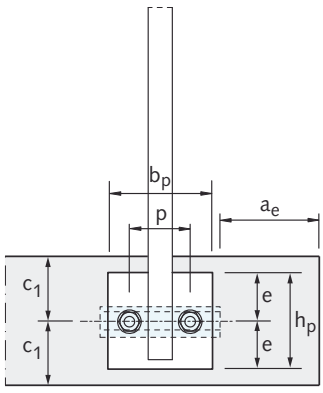
V_{Ed} = used to calculate the applicable vertical effect

h, F_w = horizontal load effects

v_1, v_2, v_3 = vertical load effects

b_p, h_p = anchor plate width and height





HALFEN HGB HANDRAIL CONNECTION
Calculation Example

Calculation example

Post spacing	1.5 m
Post height from FFL	1.0 m
Structure height	9.0 m < 25.0 m
Railing/banister load	0.5 kN/m (residential buildings)
Concrete slab thickness	180 mm

Distance of channel axis to component edge	c_1 = 90 mm
Width of railing/banister anchor plate	b_p = 150 mm
Height of railing/banister anchor plate	h_p = 150 mm

Bolt spacing	p = 80 mm
Concrete strength	C30/37

Load

Vertical loads:

Dead load, railing/banister including siding	v_1 = 0.40 kN/m
Dead load, flower box	v_2 = 0.35 kN/m
Vertical traffic load on the railing/banister	v_3 = 0.15 kN/m

Horizontal loads:

Railing/banister load	h = 0.50 kN/m
Wind force	q = 0.50 kN/m²

(according to EN 1991-1-4 NA. B. 3)
(assumption: building height 9.0 m < 10:0 m, not prone to resonance frequency, inland wind zone 1)

Cantilevers:

$$e_{h1} = 1.0 + 0.06 + \frac{0.18}{2} = 1.15\,m$$

$$e_{Fw} = \frac{(1.15 + 0.075)}{2} - 0.075 = 0.53\,m$$

e_{v1} = 0.10 m
e_{v2} = 0.20 m
e_{v3} = 0.10 m

Wind load bearing zone:

$$A = (1.00 + 0.06 + \frac{0.18}{2} + \frac{0.15}{2}) \cdot 1.5 = 1.84\,m^2$$

External pressure coefficient (acc. to table 7.1 EN 1991-1-4):
h/d = 1, area B
$c_{pe,1}$ = −1.1 (wind-suction)
$c_{pe,10}$ = −0.8 (wind-suction)
according to EN 1991-1-4 chapter 7.2.1
the following is valid:
1 m² < A ≤ 10 m²

$c_{pe} = c_{pe,1} + (c_{pe,10} - c_{pe,1}) \cdot \lg A =$
$-1.1 + (-0.8 + 1.1) \cdot \lg 1.84 = -1.02$

Wind suction:
$F_w = c_{pe} \cdot q \cdot A = -1.02 \cdot 0.50 \cdot 1.84 = -0.94$ kN

Action per support:

Wind load	$F_{w,Ed} = -0.94 \cdot 1.5 = -1.41$ kN (suction) with γ_F = 1.5
Railing/banister	$H_{Ed} = 0.5 \cdot 1.5 \cdot 1.5 = 1.13$ kN with γ_F = 1.5
Dead load railing/banister	$V_{1Ed} = 0.40 \cdot 1.5 \cdot 1.35 = 0.81$ kN with γ_F = 1.35
Load from flower box	$V_{2Ed} = 0.35 \cdot 1.5 \cdot 1.35 = 0.71$ kN with γ_F = 1.35
Vertical load on railing/banister	$V_{3Ed} = 0.15 \cdot 1.5 \cdot 1.5 = 0.34$ kN with γ_F = 1.5

Determining bearing reactions H_{Ed}, V_{Ed} and M_{Ed}

Not classed as an utility (escape-route) balcony therefore combination with wind load is not required.

Load case 1: V + railing/banister load
M_{Ed} = 0.81 · 0.10 + 0.71 · 0.20 + 0.34 · 0.10 + 1.13 · 1.15
= **1.56 kNm**
V_{Ed} = 0.81 + 0.71 + 0.34 = **1.86 kN**
H_{Ed} = **1.13 kN**

Load case 2: V + wind
M_{Ed} = 0.81 · 0.10 + 0.71 · 0.20 + 1.41 · 0.53 = **0.97 kNm**
V_{Ed} = 0.81 + 0.71 = **1.52 kN**
H_{Ed} = **1.41 kN**

Selected:
HGB-E 49/30, l = 200 mm, A4 stainless steel
Bolt spacing p = 80 mm
2 bolts HS 50/30 M12, A4-70,
Required minimum reinforcement:
Stirrups 3 Ø 10, l_b = 300 mm
(see page 66 approval extract→ annex 6, table 7),
Edge rebar 2 Ø 10

Splitting the moment into a load pair

$$N_{Ed} = \frac{M_{Ed}}{(e - 0.41 \cdot x)} + H_{Ed}$$

$$e = \frac{h_p}{2} = 75\,mm$$ (see approval no. Z-21.4.1912 annex 7)

x = 0.30 · e = 0.30 · 75 = 22.5 mm
see page 67 (approval extract → annex 8 / table 8b)
e − 0.41 · x = 75 − 0.41 · 22.5 = 65.8 mm

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HALFEN HGB HANDRAIL CONNECTION
Calculation Example

Load case 1: V + railing/banister load

$N_{Ed} = \frac{1.56\,kNm}{0.0658\,m} + 1.13\,kN = \mathbf{24.84\,kN} \rightarrow \mathbf{decisive}$

$V_{Ed} = \mathbf{1.86\,kN} \rightarrow \mathbf{decisive}$

Load case 2: V + wind

$N_{Ed} = \frac{0.98\,kNm}{0.0658\,m} + 1.41\,kN = 16.30\,kN$

$V_{Ed} = 1.52\,kN$

Verifications

Geometrical boundry conditions according to approval Z-21.4-1912 annex 6, table 6 have been met.

Verification of steel capacity

Design resistance (steel) channel HGB 49/30 using 2 bolt fixing

$N_{Rd,s} = 25.8\,kN$ see page 67 (approval extract → annex 8, table 8b)
$V_{Rd,s} = 25.8\,kN$

Channel, centric pull load

$\frac{N_{Ed}}{N_{Rd,s}} = \frac{24.84}{25.8} = 0.96 < 1$ ✓

Channel, shear load

$\frac{V_{Ed}}{V_{Rd,s}} = \frac{1.86}{25.8} = 0.07 < 1$ ✓

Channel, interaction

$\left(\frac{N_{Ed}}{N_{Rd,s}}\right)^2 + \left(\frac{V_{Ed}}{V_{Rd,s}}\right)^2 = \left(\frac{24.84}{25.8}\right)^2 + \left(\frac{1.86}{25.8}\right)^2$

$= 0.93 + 0.01 = 0.94 < 1$ ✓

Design resistance (steel) **bolt M12, A4-70**

$\mathbf{N_{Rd,s,s} = 31.6\,kN}$ see page 66 (approval extract → annex 8, tab. 9)
$\mathbf{V_{Rd,s,s} = 22.7\,kN}$

Bolt, centric pull load

$\frac{0.5 \cdot N_{Ed}}{N_{Rd,s,s}} = \frac{0.5 \cdot 24.84}{31.6} = 0.39 < 1$ ✓

Bolt, shear load

$\frac{0.5 \cdot V_{Ed}}{V_{Rd,s,s}} = \frac{0.5 \cdot 1.86}{22.7} = 0.04 < 1$ ✓

Bolt, interaction

$\left(\frac{0.5 \cdot N_{Ed}}{N_{Rd,s,s}}\right)^2 + \left(\frac{0.5 \cdot V_{Ed}}{V_{Rd,s,s}}\right)^2 = 0.39^2 + 0.04^2 = 0.15 < 1$ ✓

Verification of concrete capacity

Design resistance concrete

$\mathbf{V_{Rd,c}} = 11.7\,kN$

see page 67 (annex 8, table 8b)

$\mathbf{M_{Rd,c}} = 0.81 \cdot x \cdot b \cdot \frac{f_{ck}}{\gamma_{Mc}} \cdot (e - 0.41 \cdot x)$

$\mathbf{M_{Rd,c}} = 0.81 \cdot 22.5 \cdot 150 \cdot \frac{30}{1.5} \cdot 65.8 = 3\,597\,615\,Nmm$

$= \mathbf{3.60\,kNm}$

Concrete edge failure

$\frac{V_{Ed}}{V_{Rd,c}} = \frac{1.86}{11.7} = 0.16 < 1$ ✓

$\frac{M_{Ed}}{M_{Rd,c}} = \frac{1.56}{3.60} = 0.43 < 1$ ✓

$\frac{V_{Ed}}{V_{Rd,c}} = 0.16 < 0.333$ → According to the approval verification of interaction is not required, see page 64 (approval extract / page 7).

Verifying the ratio between horizontal action and bending moment

$\frac{H_{Ed}}{M_{Ed}} = \frac{1.13\,kN}{1.56\,kNm} = 0.72 < 1.5$

→ Design model is applicable
see page 64 (approval extract / page 6)