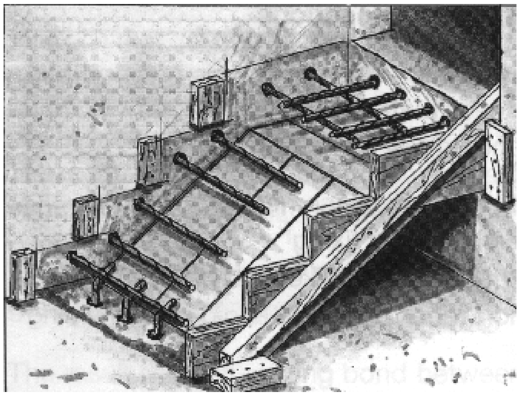
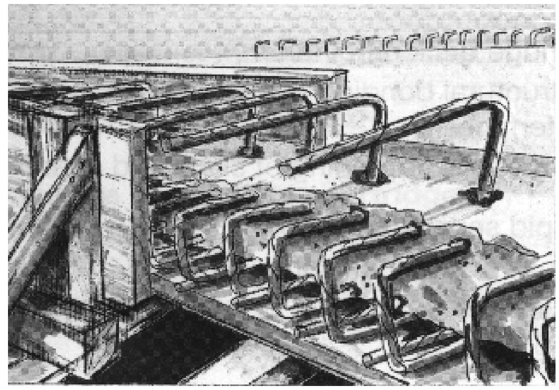
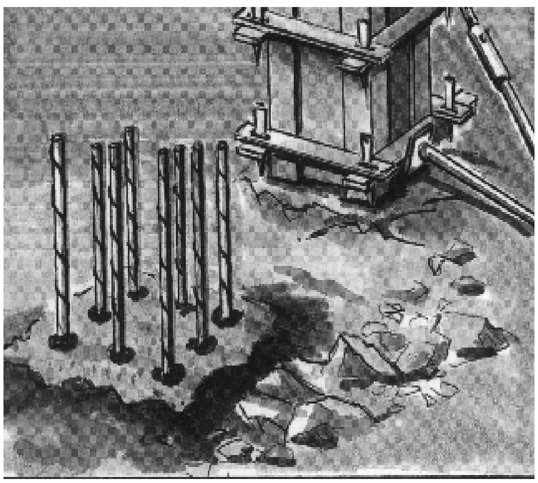
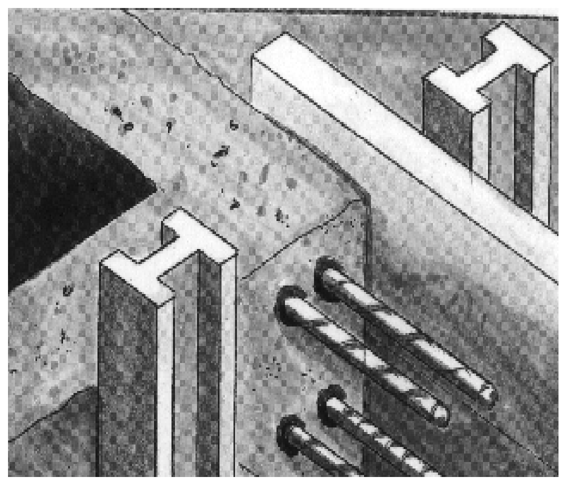
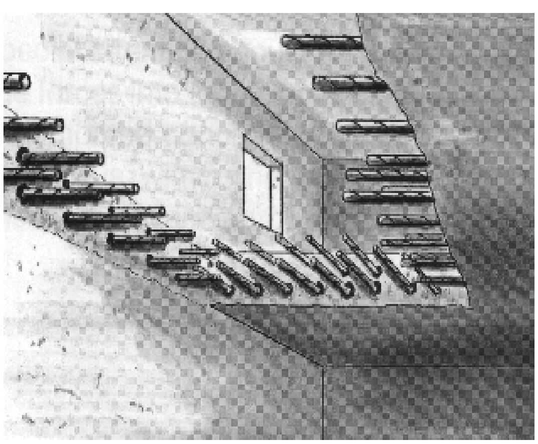
HILTI HY 150 REBAR DESIGN GUIDE

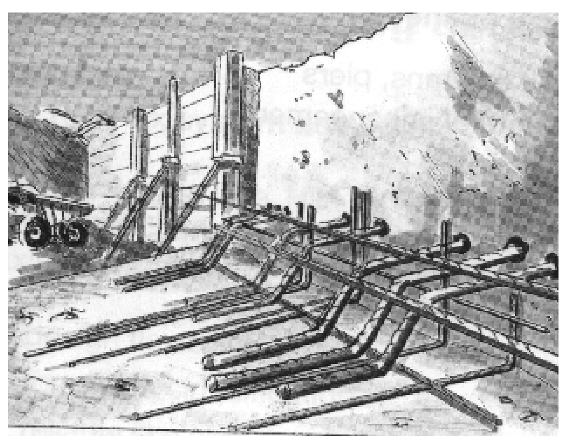










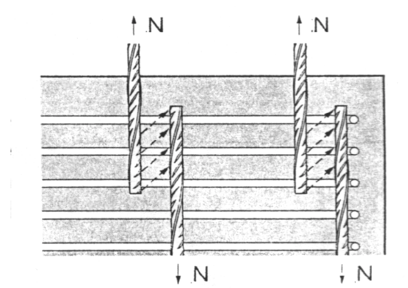


HY150 Rebar Dowelling using Limit States Concrete Design (A23.3-94)

The design method presented here was originally based on Eurocode 2: ENV 1992-1-1 "Design of Concrete Structures, Part 1, General rules and rules for buildings". The formulas have been converted to incorporate the load and reduction factors of A23.3-94. Consequently, **this method only applies to reinforced concrete.** In the case of non-reinforced concrete, - *or if the reinforcement is not known* - anchor theory must be used.
This anchor theory is the basis of the design principles described in the HILTI Engineering Manual i.e. Req'd spacing and edge distances.

HILTI'S internal and external testing including a full scale beam test has shown that the performance characteristics of rebar fastenings with HILTI HIT HY150 correspond to those of cast-in rebars. All construction rules outlined in A23.3-94 apply; **in particular, the transmission of the anchoring forces into the connecting building components must be ensured in accordance with the principles of reinforced concrete construction (e.g. transverse reinforcement, concrete cover etc.).**

In the case of reinforced concrete, the edge distance and spacing are not of primary importance because the tensile force is transmitted by the connection rebars to the cast-in rebars via the concrete bond between them.



General Rules:

To transfer shear loads the surface of the existing concrete should be roughened.

The performance characteristics of HIT HY150 correspond to those of cast-in rebars. All construction rules of A23.3 apply; **in particular, the transmission of the anchoring forces into the connecting building components must be ensured in accordance with the principles of reinforced concrete construction (e.g. transverse reinforcement, concrete cover etc.).**

If the rebar connection is to be loaded before the concrete reaches its 28 day compressive strength, the strength at the time of installation should be used with the given formulae. However, special attention should be given to concrete creep.

The formulas used in this guide are based on extensive testing of HILTI HY150 adhesive and can only be used for HY150. Other adhesive or epoxy products will have different bond strengths, ductility and load displacement characteristics which would result in different formulas.

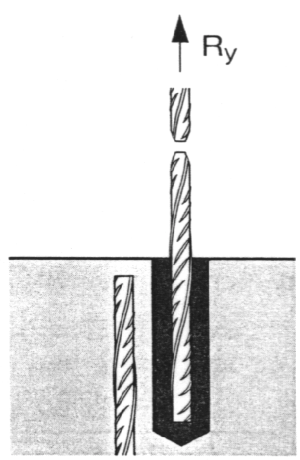
Definitions:

The following definitions are used in this design method:

d = Nominal diameter of rebar (mm)
D = Hole diameter (mm)
l_b = Basic development length (mm)
$l_{b,\ inst}$ = Installed anchorage length (mm)
$l_{b,\ min}$ = Minimum anchorage length (mm)
e = Distance between reinforcing bar and nearest connection rebar (mm)
a = Distance between reinforcing bar and farthest connection rebar (mm)
ϕ_e = Epoxy bond factor = 0.7 (epoxy coated bars) or 1.0 (plain reinforcing)
f_y = Yield stress of rebar (MPa)
ϕ_s = Resistance factor for rebar = 0.85
f'_c = Concrete compressive strength (MPa)
ϕ_c = Resistance factor for adhesive bond to concrete = 0.6
ϕ_b = Resistance factor for adhesive bond to steel = 0.6
γ_D = Dead load factor = 1.25
γ_L = Live load factor = 1.50
R_{yd} = Design value of rebar strength (N)
R_{bd} = Design value of adhesive bond to steel (N)
R_{cd} = Design value of adhesive bond to concrete (N)
F_d = Factored resistance (kN) = MIN{R_{yd}; R_{bd}; R_{cd}}

Limit to rebar utilization

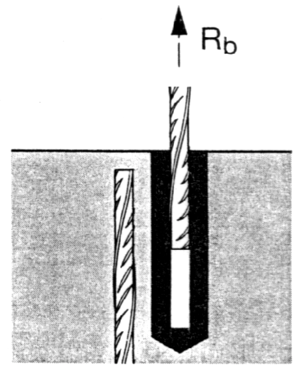
The design tensile force, R_{yd}, at which the rebar steel is fully utilized, results from the product of the cross sectional steel area times the yield strength times the steel factor.



$R_{yd} = 1/4 \times d^2 \times \pi \times f_y \times \phi_s$ [N]
This value is crucial when the installed anchorage length is greater than the basic development length.

Limit to adhesive to steel bond utilization

The adhesive bond to steel increases linearly with the anchorage length, but only with the square root of the rebar diameter.

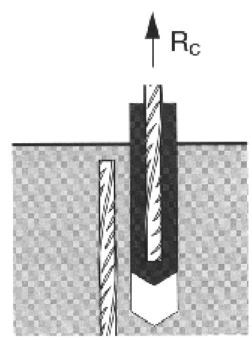


$R_{bd} = 25 \times \pi \times l_{b\,inst} \times d^{1/2} \times \phi_b \times \phi_e$ [N]

Doubling the diameter only results in a 40% increase of the bond strength.
Formula applies to a maximum bar diameter of 25M
The factor "25" in the formula is unique to HY150 and was determined after review of comprehensive test data.

Limit to adhesive to concrete bond utilization

The adhesive bond to concrete increases linearly with anchorage depth, but only with the square root of the concrete strength times the hole diameter.



$R_{cd} = 4.5 \times \pi \times l_{b\,inst} \times (f'_c \times D)^{1/2} \times \phi_c$ [N]

The factor "4.5" in the formula is unique to HY150 and was determined after review of comprehensive test data.

Basic development length

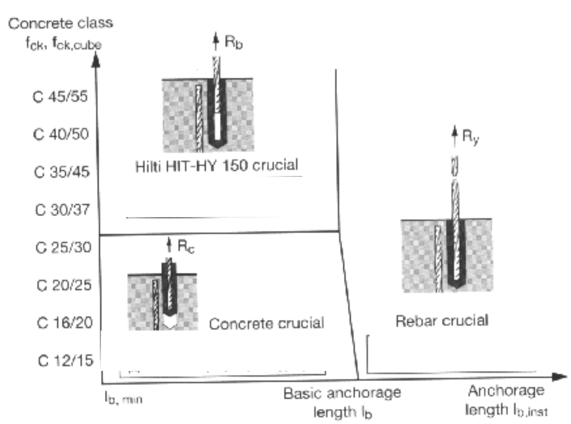
If this length is exceeded, the steel is fully utilized.

The basic anchorage length is derived by selecting an anchorage length that ensures that the bond strengths are greater than the steel strength.

l_b = MAX{$d^{3/2}$ x f_y x ϕ_s /(100 x ϕ_b x ϕ_e);d^2 x f_y x ϕ_s /(18 x (f'_c x D)$^{1/2}$ x ϕ_c)}

Up to and including 25 MPa concrete it is the bond of the adhesive to the concrete which is crucial, but for concretes greater than 30 MPa it is the bond of the adhesive to the bar that is decisive.

Schematic presentation of limits to utilization:



Minimum anchorage length

Nothing is gained by setting the rebar deeper than the basic development length but it is often useful to work with a larger diameter rebar, but a shallower hole. The design value of the connection force F_d is the minimum of R_{yd}, R_{bd} & R_{cd}.

To ensure that the force acting on the connection rebar is transmitted to the cast-in rebar the principles of reinforced concrete must be checked and the following minimum lengths must be followed. Minimum anchorage lengths vary from A23.3-94 since the rebars are post-installed not cast-in.

For anchorages in tension:

$l_{b,min}$ = MAX(0.3 x l_b; 10 x d; 100 mm)

For anchorages in compression:

$l_{b,min}$ = MAX(0.6 x l_b; 10 x d; 100 mm)

When rebars in tension or compression are lapped the minimum overlap is:

$l_{b,min}$ = MAX (0.6 x l_b;15 x d; 200 mm)

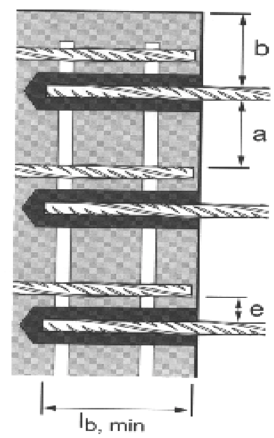


Table 1
Summary Table of Minimum Embedments and Overlaps

Rebar Size	Rebars in tension in 20 MPa concrete (mm)	Rebars in tension in concrete > 30 MPa (mm)	Rebars in compression in 20 MPa concrete (mm)	Rebars in compression in concrete > 30 MPa (mm)	Overlaps in 20 MPa concrete (mm)	Overlaps in concrete > 30 MPa (mm)
10M	115	115	145	130	200	200
15M	160	160	240	220	240	240
20M	195	195	325	300	320	300
25M	255	255	510	435	510	435

Distance between cast-in rebars and new rebars

If the clear space between the connection rebars and the nearest cast-in rebar is ...

e > 4 x d

the overlap must be increased by an amount

e - 4 x d

Table 2

Overlap Increase Required (mm)

Rebar Size	Spacing between existing bars = 150 mm	Spacing between existing bars = 200 mm	Spacing between existing bars = 300 mm	Spacing between existing bars = 400 mm
10M	30	55	105	155
15M	15	35	85	135
20M	0	25	75	125
25M	0	0	50	100

The minimum distance between cast-in rebars and farthest away connection rebars should be:

a > MAX(2 x d; 20 mm)

Transmissible forces

According to the given formulae and good bond conditions, the following values result depending on the load level and the installed anchorage length.

Factored Resistance Tables

Factored Resistance must be greater than Factored Load

Table 3 Factored Resistance for Dowels in 20 MPa Concrete

Bar Diameter (mm)	Bar Size	Hole Diameter (mm)	Factored Resistance of Connection Force Fd (kN) for 20 MPa Concrete											Development Length (mm)
			Anchorage Length (mm)											
			115	160	200	255	300	400	500	600	700	800	900	
11.3	10M	14	16.3	22.7	28.3	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	240
16	15M	20		27.1	33.8	43.2	50.8	68.0	68.0	68.0	68.0	68.0	68.0	400
19.5	20M	25			37.8	48.2	56.8	75.7	94.6	102.0	102.0	102.0	102.0	540
25.2	25M	28				51.1	60.1	80.1	100.1	120.1	140.2	160.2	170.0	850

Notes:

1. Rebar: f_y = 400 MPa; If epoxy coated bars are used embedment must be increased by 30%
2. Holes must be drilled with Hilti rotary hammer drills or if core drilled they must be conditioned with Hilti conditioning bits
3. For bars in compression or overlap bars the minimum embedments are shown in Table 1. To fully develop a lap splice use the development length plus the overlap increase shown in Table 2.

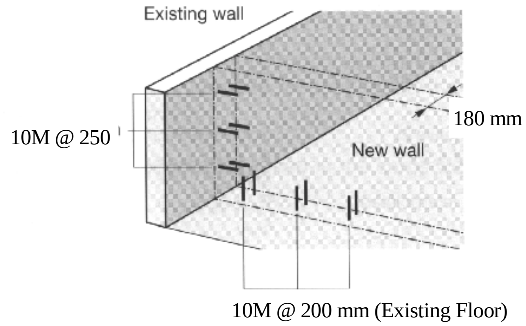
Table 4 Factored Resistance for Dowels in Concrete > 30 MPa

Bar Diameter (mm)	Bar Size	Hole Diameter (mm)	Factored Resistance of Connection Force Fd (kN) for Concrete > 30 MPa										Development Length (mm)
			Anchorage Length (mm)										
			115	160	200	255	300	400	500	600	700	800	
11.3	10M	14	18.2	25.3	31.6	34.0	34.0	34.0	34.0	34.0	34.0	34.0	215
16	15M	20		30.1	37.6	47.9	56.4	68.0	68.0	68.0	68.0	68.0	365
19.5	20M	25			41.5	52.9	62.3	83.0	102.0	102.0	102.0	102.0	495
25.2	25M	28				60.2	70.8	94.4	118.0	141.6	165.2	170.0	720

Notes:

1. Rebar: f_y = 400 MPa; If epoxy coated bars are used embedment must be increased by 30%
2. Holes must be drilled with Hilti rotary hammer drills or if core drilled they must be conditioned with Hilti conditioning bits
3. For bars in compression or overlap bars the minimum embedments are shown in Table 1. To fully develop a lap splice use the development length plus the overlap increase shown in Table 2.

Examples:



Example 1) Wall connection

A vertically compressed new wall is dimensioned as follows:

f'_c = 20 MPa
f_y = 400 MPa
New wall thickness = 180 mm
Vertical bars in new wall - 10M @ 200 mm
Horizontal bars in new wall - 10M @ 250 mm

A) Floor connection: Req'd load = 34.0 kN @ 200 mm both sides
Therefore use 10M @ 200 mm both sides with hole depth = l_b = 240 mm & D = 14 mm (from Table 3)

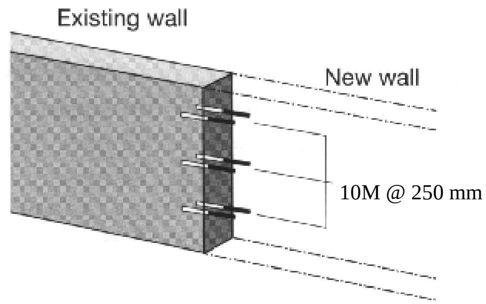
Alternate 1: Try 15M @ 200 mm both sides; $F_{d,req'd} = R_{yd}(10M)$ = 34.0 kN
Interpolating from Table 3: @ $l_{b,inst}$ = 205 mm F_d = 34.6 kN > 34.0 kN
but from Table 1 $l_{b,min}$ = 240 mm (Rebars in compression in 20 Mpa concrete)
Since $l_{b,min}$ = 240 mm there is no reduction in embedment realized by using a larger bar.

B) Side wall connection: $F_{d, req'd}$ = 34.0 kN @ 250 mm both sides
Therefore use 10M @ 250 mm both sides with hole depth = l_b = 240 mm, D = 14 mm (from Table 3)

Alternate 1: Try 15M @ 250 mm both sides; $F_{d, req'd}$ = 34.0 kN
Interpolating from Table 3 @ $l_{b,inst}$ = 205 mm F_d = 34.6 kN > 34.0 kN
From Table 1: Check $l_{b,min}$ = 160 mm < $l_{b,inst}$ O.K. (Rebars in tension in 20 MPa concrete

It is simple to vary the hole depth by using the load table.

Example 2) Wall extension



The existing wall is reinforced by 10M bars at 250 mm both sides and shall be extended by a new wall with the following characteristics:

f'_c = 20 MPa
f_y = 400 MPa
Wall thickness = 200 mm

Lap connection: 10M @ 250 mm both sides
Hole depth = l_b = 240 mm (Table 3)
D = 14 mm

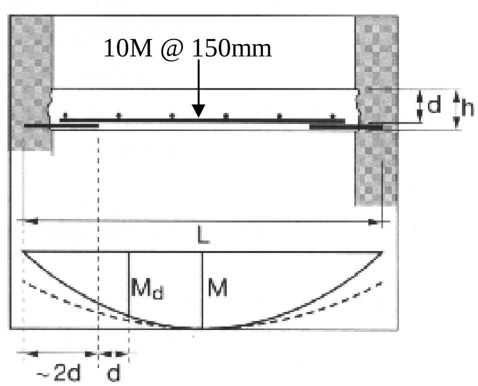
Nothing is gained by rebars of larger diameter because the force acting on the connection must be transmitted to the cast-in reinforcement via the overlap.

If the position of the existing rebar is not known it is advisable to assume the worst case regarding the proximity of the nearest cast-in rebar. Since e > 4 x d, the overlap must be increased by e - 4 x d.

Therefore $l_{b,inst}$ = 240 + (250/2 - 4 x 11.3) = 320 mm

If this is a large installation it is recommended that the existing rebar be located with a Hilti Ferroscan and the overlap of 240 mm can be used.

Example 3) Installation of an intermediate floor



Details:
Slab thickness = h = 160 mm
f'_c = 20 MPa
f_y = 400 MPa
Rebar in new slab - 10M @ 150 mm

The anchorage to the walls is done using connection rebars having the same diameter and spacing as those in the slab.
Only the minimum anchorage depth is required for rebars at supports.

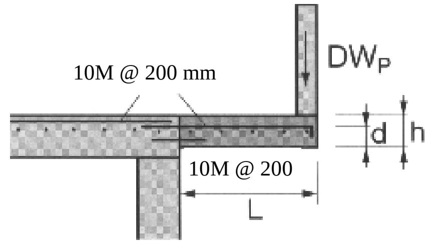
Connection: 10M @ 150 mm
From Table 1 $l_{b,min}$ = 115 mm
Therefore, embedment = $l_{b,min}$ = 115 mm & D = 14 mm

The connection surfaces must be roughened to take up the shear force.

Example 4) Connection of a balcony

Details:

Slab thickness = h = 150 mm
f'_c = 20 MPa
f_y = 400 MPa
Rebar in existing slab = 10M @ 200 mm both ways
Rebar in new slab = 10M @ 200 mm both ways



The bars in the top of new slab should be embedded into the existing slab at least equal to the basic development length for a 10M bar, l_b = 240 mm. D = 14 mm

If the existing rebar locations are not determined using the Hilti Ferroscan the embedment must be increased by

200/2 - 4 x 11.3 = 55 mm to a total length of 295 mm.

The connection surfaces must be roughened to take up the shear force.
In the bottom layer, 10M bars @ 200 mm should also be installed to the minimum embedment for a 10M of 115 mm for reasons of good detailing.