STAFA®
Our part in every solution

HV-Preloaded Bolts

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SPECIALIST FOR HV-SYSTEM

Looking at a building of technically and architecturally demanding design nobody will think of bolts from **Friedberg** immediately. Structure and style dominate our perception. But without top-quality fasteners many constructional highlights would be beyond imagination - not to mention realization.

For many years architects and engineers of steel constructions have therefore been relying on fastening systems from **Friedberg**. Any part leaving our production has passed many severe tests in order to stand up to the more extreme strains ahead – featuring everything required to succeed: certified quality, sound development, closely monitored and documented production processes, and more than 130 years of experience.

This field manual for high-tensile fasteners provides you with necessary information as regards the technical applicability of our connecting systems for steel constructions and shall be a useful aid in your daily work with high-tensile fasteners.

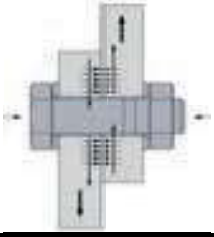
1 Design Categories, Connection Types and Design Checks according to DIN EN 1993-1-8

Category		Type	Tightening	Design Checks
A	Shear Connections	Bearing type	Hand tightened No preloading required	$F_{v,Ed} \leq \begin{cases} F_{v,Rd} \\ F_{b,Rd} \end{cases}$
B		Slip-resistant at serviceability	Preloaded to $F_{p,C}$ acc. to DIN EN 1090-2	$F_{v,Ed,ser} \leq F_{s,Rd,ser}$ $F_{v,Ed} \leq \begin{cases} F_{v,Rd} \\ F_{b,Rd} \end{cases}$
C		Slip-resistant at ultimate	Preloaded to $F_{p,C}$ acc. to DIN EN 1090-2	$F_{v,Ed} \leq \begin{cases} F_{s,Rd} \\ F_{b,Rd} \end{cases}$ $\Sigma F_{v,Ed} \leq N_{net,Rd}$
D	Tension Connections	Non-preloaded	Hand tightened No preloading required	$F_{t,Ed} \leq \begin{cases} F_{t,Rd} \\ B_{p,Rd} \end{cases}$
E		Preloaded	Preloaded to $F_{p,C}$ acc. to DIN EN 1090-2	
			Preloaded to $F_{p,C}^{*}$ acc. to DIN EN 1993-1-8/NA	

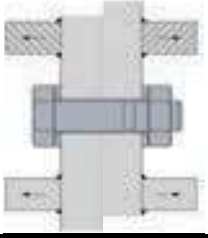
Note
If preload is not explicitly used in the design calculations for slip resistance but is required for execution purposes or as a quality measure, then the level of preload can be specified. According to the National Annex of DIN EN 1993-1-8/NA.

Category A

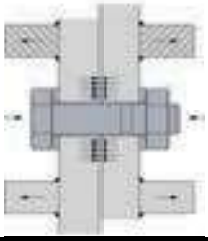
Category B/C



Category D

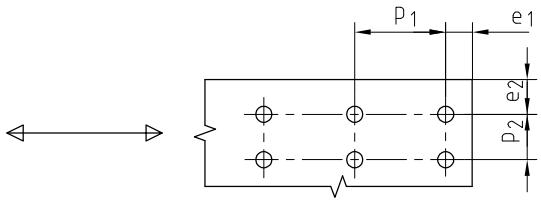


Category E



2 Edge Distances and Spacing

Plate thickness t with hole diameter d_0 for a suitable bolt



	Edge Distance		Spacing	
Min	e_1	1,2 d_0	p_1	2,2 d_0
	e_2	1,2 d_0	p_2	2,4 d_0
Max	e_1	4 t + 40 mm	p_1	min { 14 t ; 200 mm
	e_2		p_2	

3 Preloads $F_{p,C}$ and Tightening Torques for the Combined Method

according to DIN EN 1090-2:2011-10 for HV-Bolting Assemblies k-class K1

Note

For **preload level $F_{p,C}$ according to DIN EN 1090-2** FRIEDBERG HV-Assemblies have to be tightened using the Combined Method, as HV-Assemblies are manufactured in k-class K1. The torque method is not applicable for HV-Assemblies of class K1 to achieve that preload level.

Bolt Size	Min. Preload $F_{p,C}$	Combined Method	
		Pre-Tightening Torque	Additional Further Angle of Rotation
M 12	59	75	according to following table
M 16	110	190	
M 20	172	340	
M 22	212	490	
M 24	247	600	
M 27	321	940	
M 30	393	1240	
M 36	572	2100	

4 Incremental Tightening and further Angle of Rotation for the Combined Method

according to DIN EN 1090-2:2011-10 for HV-Bolting Assemblies

1. Tightening Step	Applying of pre-tightening torque according to table above for all bolting assemblies in a connection. The position of the nut relative to the bolt thread shall be permanently marked.
2. Tightening Step	Visual check and adding of missing markings. Applying additional further angle of rotation depending on the clamp length.

Total Nominal Thickness Σt of parts to be connected (including all support plates and washers)	Further Angle of Rotation in the Second Step	
d=Bolt Size	Degree	Turning Factor
$\Sigma t < 2d$	60	1/6
$2d \leq \Sigma t \leq 6d$	90	1/4
$6d \leq \Sigma t \leq 10d$	120	1/3

Note

In case of bearing surface under bolt head or nut is not perpendicular to the bolt axis (taking necessary installed tapered washers under consideration), the required additional further angle of rotation should be determined with tests.

5 Preload $F_{p,C}$* and Tightening Torque for HV-Bolting Assemblies

according to DIN EN 1993-1-8/NA:2010-12 for k-class K1 according to DIN EN 14399-1

Bolt Size	Nominal Preload $F_{p,C}$* kN	Impact Turn Method	Modified Torque Controlled Method	Modified Combined Method
		Preload $F_{V,DI}$ to be adjusted kN	Torque M_A to be applied Nm	Pre-Tightening Torque $M_{A,MKV}$ Nm
		Surface Condition: HV-Assemblies hot-dip galvanized, Nut lubricated with MoS_2 HV-Assemblies as processed, Nut lubricated with MoS_2		
M 12	50	60	100	75
M 16	100	110	250	190
M 20	160	175	450	340
M 22	190	210	650	490
M 24	220	240	800	600
M 27	290	320	1250	940
M 30	350	390	1650	1240
M 36	510	560	2800	2100

6 Additional Further Angle of Rotation ϑ_{MKV} for the Modified Combined Method

Total Nominal Thickness Σt of parts to be connected (including all support plates and washers) d = Bolt Size	Further Angle of Rotation ϑ_{MKV} to be applied during the second tightening step	
	Degree	Turning Factor
$\Sigma t < 2d$	45	1/8
$2d \leq \Sigma t < 6d$	60	1/6
$6d \leq \Sigma t < 10d$	90	1/4
$10d < \Sigma t$	no recommendation	no recommendation

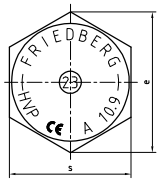
Note

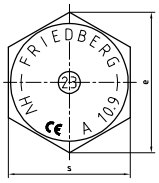
For preload level $F_{p,C}$* the Modified Torque Method is usually applied in practice.

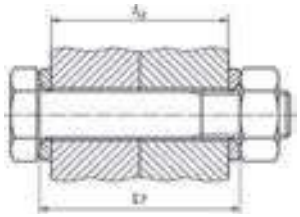
Corrosion Protection and Delivery Condition

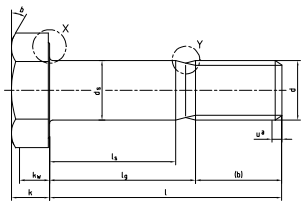
The bolts, nuts and washers are delivered in a hot-dip galvanized condition with nuts lubricated under process conditions. The internal thread of the nut is not hot-dip galvanized and merely protected against corrosion by lubrication applied. Inappropriate transport and storage conditions may cause excessive corrosion in the internal thread and may lead to a modified correlation between torque and preload.

Dimensions and Clamp Lengths in mm







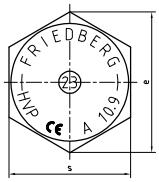


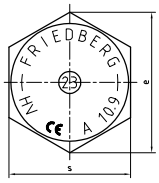
Bolt Size		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
Thread-∅	d	12	16	20	22	24	27	30	36
Shank-∅ HV	$d_{S,nom}$	12	16	20	22	24	27	30	36
Shank-∅ HVP	$d_{S,nom}$	13	17	21	23	25	28	31	37
Head Height	k_{nom}	8	10	13	14	15	17	19	23
Nut Height	m_{nom}	10	13	16	18	20	22	24	29
Wrench Size	s_{max}	22	27	32	36	41	46	50	60
Width Across Corners	e_{min}	23,91	29,56	35,03	39,55	45,20	50,85	55,37	66,44
Outer Washer-∅	$d_{2,max}$	24	30	37	39	44	50	56	66
Washer Thickness	h_{nom}	3	4	4	4	4	5	5	6
Bolt Length	ℓ_{nom}	Clamp Length Range Σt_{min} bis Σt_{max}							
35		16 - 21							
40		21 - 26	17 - 22						
45		26 - 31	22 - 27	18 - 23					
50		31 - 36	27 - 32	23 - 28	22 - 27				
55		36 - 41	32 - 37	28 - 33	27 - 32				
60		41 - 46	37 - 42	33 - 38	32 - 37	29 - 34			
65		46 - 51	42 - 47	38 - 43	37 - 42	34 - 39			
70		51 - 56	47 - 52	43 - 48	42 - 47	39 - 44	36 - 41		
75		56 - 61	52 - 57	48 - 53	47 - 52	44 - 49	41 - 46	39 - 44	
80		61 - 66	57 - 62	53 - 58	52 - 57	49 - 54	46 - 51	44 - 49	
85		66 - 71	62 - 67	58 - 63	57 - 62	54 - 59	51 - 56	49 - 54	43 - 48
90		71 - 76	67 - 72	63 - 68	62 - 67	59 - 64	56 - 61	54 - 59	48 - 53
95		76 - 81	72 - 77	68 - 73	67 - 72	64 - 69	61 - 66	59 - 64	53 - 58
100		81 - 86	77 - 82	73 - 78	72 - 77	69 - 74	66 - 71	64 - 69	58 - 63
105		86 - 91	82 - 87	78 - 83	77 - 82	74 - 79	71 - 76	69 - 74	63 - 68
110		91 - 96	87 - 92	83 - 88	82 - 87	79 - 84	76 - 81	74 - 79	68 - 73
115		96 - 101	92 - 97	88 - 93	87 - 92	84 - 89	81 - 86	79 - 84	73 - 78
120		101 - 106	97 - 102	93 - 98	92 - 97	89 - 94	86 - 91	84 - 89	78 - 83
125		106 - 111	102 - 107	98 - 103	97 - 102	94 - 99	91 - 96	89 - 94	83 - 88
130		111 - 116	107 - 112	103 - 108	102 - 107	99 - 104	96 - 101	94 - 99	88 - 93
135		116 - 121	112 - 117	108 - 113	107 - 112	104 - 109	101 - 106	99 - 104	93 - 98
140		121 - 126	117 - 122	113 - 118	112 - 117	109 - 114	106 - 111	104 - 109	98 - 103
145		126 - 131	122 - 127	118 - 123	117 - 122	114 - 119	111 - 116	109 - 114	103 - 108
150		131 - 136	127 - 132	123 - 128	122 - 127	119 - 124	116 - 121	114 - 119	108 - 113
155		136 - 141	132 - 137	128 - 133	127 - 132	124 - 129	121 - 126	119 - 124	113 - 118
160		141 - 146	137 - 142	133 - 138	132 - 137	129 - 134	126 - 131	124 - 129	118 - 123
165		146 - 151	142 - 147	138 - 143	137 - 142	134 - 139	131 - 136	129 - 134	123 - 128
170		151 - 156	147 - 152	143 - 148	142 - 147	139 - 144	136 - 141	134 - 139	128 - 133
175		156 - 161	152 - 157	148 - 153	147 - 152	144 - 149	141 - 146	139 - 144	133 - 138
180		161 - 166	157 - 162	153 - 158	152 - 157	149 - 154	146 - 151	144 - 149	138 - 143
185		166 - 171	162 - 167	158 - 163	157 - 162	154 - 159	151 - 156	149 - 154	143 - 148
190		171 - 176	167 - 172	163 - 168	162 - 167	159 - 164	156 - 161	154 - 159	148 - 153
195		176 - 181	172 - 177	168 - 173	167 - 172	164 - 169	161 - 166	159 - 164	153 - 158
200		181 - 186	177 - 182	173 - 178	172 - 177	169 - 174	166 - 171	164 - 169	158 - 163

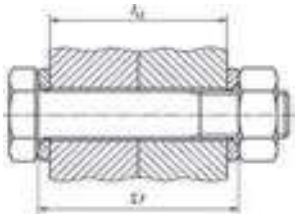
Further Bolt Sizes can be provided on request.

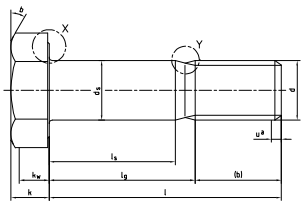
FRIEDBERG HV-Bolting Assemblies according to DIN EN 14399 - HV/HVP - Grip Length t_{s2}

Dimensions and Clamp Lengths in mm









Bolt Size		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
Thread-∅	d	12	16	20	22	24	27	30	36
Shank-∅ HV	$d_{S,nom}$	12	16	20	22	24	27	30	36
Shank-∅ HVP	$d_{S,nom}$	13	17	21	23	25	28	31	37
Head Height	k_{nom}	8	10	13	14	15	17	19	23
Nut Height	m_{nom}	10	13	16	18	20	22	24	29
Wrench Size	s_{max}	22	27	32	36	41	46	50	60
Width Across Corners	e_{min}	23,91	29,56	35,03	39,55	45,20	50,85	55,37	66,44
Outer Washer-∅	$d_{2,max}$	24	30	37	39	44	50	56	66
Washer Thickness	h_{nom}	3	4	4	4	4	5	5	6
Bolt Length	ℓ_{nom}	Grip Length Range $t_{s2,min}$ bis $t_{s2,max}$							
35		10 - 15							
40		15 - 20	9 - 14						
45		20 - 25	14 - 19	10 - 15					
50		25 - 30	19 - 24	15 - 20	14 - 19				
55		30 - 35	24 - 29	20 - 25	19 - 24				
60		35 - 40	29 - 34	25 - 30	24 - 29	21 - 26			
65		40 - 45	34 - 39	30 - 35	29 - 34	26 - 31			
70		45 - 50	39 - 44	35 - 40	34 - 39	31 - 36	26 - 31		
75		50 - 55	44 - 49	40 - 45	39 - 44	36 - 41	31 - 36	29 - 34	
80		55 - 60	49 - 54	45 - 50	44 - 49	41 - 46	36 - 41	34 - 39	
85		60 - 65	54 - 59	50 - 55	49 - 54	46 - 51	41 - 46	39 - 44	31 - 36
90		65 - 70	59 - 64	55 - 60	54 - 59	51 - 56	46 - 51	44 - 49	36 - 41
95		70 - 75	64 - 69	60 - 65	59 - 64	56 - 61	51 - 56	49 - 54	41 - 46
100		75 - 80	69 - 74	65 - 70	64 - 69	61 - 66	56 - 61	54 - 59	46 - 51
105		80 - 85	74 - 79	70 - 75	69 - 74	66 - 71	61 - 66	59 - 64	51 - 56
110		85 - 90	79 - 84	75 - 80	74 - 79	71 - 76	66 - 71	64 - 69	56 - 61
115		90 - 95	84 - 89	80 - 85	79 - 84	76 - 81	71 - 76	69 - 74	61 - 66
120		95 - 100	89 - 94	85 - 90	84 - 89	81 - 86	76 - 81	74 - 79	66 - 71
125		100 - 105	94 - 99	90 - 95	89 - 94	86 - 91	81 - 86	79 - 84	71 - 76
130		105 - 110	99 - 104	95 - 100	94 - 99	91 - 96	86 - 91	84 - 89	76 - 81
135		110 - 115	104 - 109	100 - 105	99 - 104	96 - 101	91 - 96	89 - 94	81 - 86
140		115 - 120	109 - 114	105 - 110	104 - 109	101 - 106	96 - 101	94 - 99	86 - 91
145		120 - 125	114 - 119	110 - 115	109 - 114	106 - 111	101 - 106	99 - 104	91 - 96
150		125 - 130	119 - 124	115 - 120	114 - 119	111 - 116	106 - 111	104 - 109	96 - 101
155		130 - 135	124 - 129	120 - 125	119 - 124	116 - 121	111 - 116	109 - 114	101 - 106
160		135 - 140	129 - 134	125 - 130	124 - 129	121 - 126	116 - 121	114 - 119	106 - 111
165		140 - 145	134 - 139	130 - 135	129 - 134	126 - 131	121 - 126	119 - 124	111 - 116
170		145 - 150	139 - 144	135 - 140	134 - 139	131 - 136	126 - 131	124 - 129	116 - 121
175		150 - 155	144 - 149	140 - 145	139 - 144	136 - 141	131 - 136	129 - 134	121 - 126
180		155 - 160	149 - 154	145 - 150	144 - 149	141 - 146	136 - 141	134 - 139	126 - 131
185		160 - 165	154 - 159	150 - 155	149 - 154	146 - 151	141 - 146	139 - 144	131 - 136
190		165 - 170	159 - 164	155 - 160	154 - 159	151 - 156	146 - 151	144 - 149	136 - 141
195		170 - 175	164 - 169	160 - 165	159 - 164	156 - 161	151 - 156	149 - 154	141 - 146
200		175 - 180	169 - 174	165 - 170	164 - 169	161 - 166	156 - 161	154 - 159	146 - 151

Further Bolt Sizes can be provided on request.

9 Design Bearing Resistance $F_{b,Rd}$ in kN

for plate thickness t = 10 mm of steel grade S235 (f_u = 360 N/mm²)

Nominal Clearance for **Normal Round Holes** acc. to DIN EN 1090-2
Distances Perpendicular to Load Direction e_1 = **1,2** d_0 and p_2 = **2,4** d_0

HV-Assemblies	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm	13	18	22	24	26	30	33	39
Hole Spacing p_1 in Load Direction mm								
p_1 = 30	29,8							
35	37,1							
40	44,5	37,5						
45	51,9	44,6						
50	57,4	51,7	48,5					
55	57,4	58,8	55,8	54,0				
60	↓	65,9	63,0	61,4	59,6			
65		73,0	70,3	68,7	66,9			
70		76,5	77,5	76,0	74,3	68,1		
75		76,5	84,8	83,3	81,6	75,3	72,8	
80		↓	92,0	90,6	89,0	82,5	80,0	
85			95,6	97,9	96,4	89,6	87,3	
90			95,6	105,2	103,7	96,8	94,5	89,4
95			↓	105,2	111,1	104,0	101,8	96,7
100				↓	114,7	111,2	109,0	104,1
105					114,7	118,3	116,3	111,4
110					↓	125,5	123,5	118,8
115						129,1	130,7	126,1
120						129,1	138,0	133,5
125						↓	143,4	140,8
130							143,4	148,2
135							↓	155,6
140								162,9
145								170,3
150								172,1
155								172,1

HV-Assemblies	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm	13	18	22	24	26	30	33	39
Edge Distance e_1 in Load Direction mm								
e_1 = 20	29,4							
25	36,8	35,4						
30	44,1	42,5	43,5	43,8				
35	51,5	49,6	50,7	51,1	51,5			
40	57,4	56,7	57,9	58,4	58,8	57,4	57,9	
45	57,4	63,7	65,2	65,7	66,2	64,5	65,2	
50	↓	70,8	72,4	73,0	73,6	71,7	72,4	73,6
55		76,5	79,7	80,3	80,9	78,9	79,7	80,9
60		76,5	86,9	87,6	88,3	86,1	86,9	88,3
65		↓	94,2	95,0	95,6	93,2	94,2	95,6
70			95,6	102,3	103,0	100,4	101,4	103,0
75			95,6	105,2	110,3	107,6	108,7	110,3
80			↓	105,2	114,7	114,7	115,9	117,7
85				↓	114,7	121,9	123,1	125,0
90					↓	129,1	130,4	132,4
95						129,1	137,6	139,7
100						↓	143,4	147,1
105							143,4	154,5
110							↓	161,8
115								169,2
120								172,1
125								172,1

10 Design Shear Resistance $F_{v,Rd}$ in kN for each Shear Plane

A_s mm²	84,3	157	245	303	353	459	561	817
A_{Shank} mm²	113	201	314	380	452	573	707	1018
$F_{v,Rd}$ kN shear plane through thread	33,7	62,8	98,0	121	141	184	224	327
$F_{v,Rd}$ kN shear plane through shank	54,2	96,5	151	182	217	275	339	489

11 Design Tension Resistance $F_{t,Rd}$ in kN

A_s mm²	84,3	157	245	303	353	459	561	817
$F_{t,Rd}$ kN	60,7	113	176	218	254	330	404	588

12 Design Bearing Resistance $F_{b,Rd}$ in kN

for plate thickness t = 10 mm of steel grade S235 (f_u = 360 N/mm²)

Nominal Clearance for **Normal Round Holes** acc. to DIN EN 1090-2
Distances Perpendicular to Load Direction $e_2 \geq$ **1,5** d_0 and $p_2 \geq$ **3** d_0

HV-Assemblies	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm	13	18	22	24	26	30	33	39
Hole Spacing p_1 in Load Direction mm								
p_1 = 30	44,9							
35	55,9							
40	67,0	56,5						
45	78,1	67,2						
50	86,4	77,9	73,1					
55	86,4	88,5	84,0	81,4				
60	↓	99,2	94,9	92,4	89,7			
65		109,9	105,8	103,4	100,8			
70		115,2	116,7	114,4	111,9	102,6		
75		115,2	127,6	125,4	123,0	113,4	109,6	
80		↓	138,5	136,4	134,0	124,2	120,5	
85			144,0	147,4	145,1	135,0	131,5	
90			144,0	158,4	156,2	145,8	142,4	134,6
95			↓	158,4	167,3	156,6	153,3	145,7
100				↓	172,8	167,4	164,2	156,7
105					172,8	178,2	175,1	167,8
110					↓	189,0	186,0	178,9
115						194,4	196,9	190,0
120						194,4	207,8	201,0
125						↓	216,0	212,1
130							216,0	223,2
135							↓	234,3
140								245,4
145								256,4
150								259,2
155								259,2

HV-Assemblies	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm	13	18	22	24	26	30	33	39
Edge Distance e_1 in Load Direction mm								
e_1 = 20	44,3							
25	55,4	53,3						
30	66,5	64,0	65,5	66,0				
35	77,5	74,7	76,4	77,0	77,5			
40	86,4	85,3	87,3	88,0	88,6	86,4	87,3	
45	86,4	96,0	98,2	99,0	99,7	97,2	98,2	
50	↓	106,7	109,1	110,0	110,8	108,0	109,1	110,8
55		115,2	120,0	121,0	121,8	118,8	120,0	121,8
60		115,2	130,9	132,0	132,9	129,6	130,9	132,9
65		↓	141,8	143,0	144,0	140,4	141,8	144,0
70			144,0	154,0	155,1	151,2	152,7	155,1
75			144,0	158,4	166,2	162,0	163,6	166,2
80			↓	158,4	172,8	172,8	174,5	177,2
85				↓	172,8	183,6	185,5	188,3
90					↓	194,4	196,4	199,4
95						194,4	207,3	210,5
100						↓	216,0	221,5
105							216,0	232,6
110							↓	243,7
115								254,8
120								259,2
125								259,2

13 Design Bearing Resistance $F_{b,Rd}$ in kN

for plate thickness t = 10 mm of steel grade S235 (f_u = 360 N/mm²)

Normal Holes with **Tolerance H11** according to ISO 286-2 for Fit Bolts
Distances Perpendicular to Load Direction e_2 = **1,2** d_0 und p_2 = **2,4** d_0

HVP-Fit Bolt Assemblies		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm		13	17	21	23	25	28	31	37
Hole Spacing p_1 in Load Direction mm	p_1 = 30	32,3							
	35	40,2							
	40	48,2	43,4						
	45	56,2	51,4						
	50	62,2	59,4	54,6					
	55	62,2	67,3	62,5	60,2	57,8			
	60	↓	75,3	70,5	68,1	65,7			
	65		81,3	78,5	76,1	73,7	70,1		
	70		81,3	86,5	84,1	81,7	78,1	74,5	
	75		↓	94,4	92,0	89,6	86,1	82,5	
	80			100,4	100,0	97,6	94,0	90,4	
	85			100,4	108,0	105,6	102,0	98,4	91,2
	90			↓	110,0	113,5	110,0	106,4	99,2
	95				110,0	119,5	117,9	114,3	107,2
	100				↓	119,5	125,9	122,3	115,1
	105					↓	133,9	130,3	123,1
	110						133,9	138,2	131,1
	115						↓	146,2	139,0
	120							148,2	147,0
	125							148,2	155,0
	130							↓	162,9
	135								170,9
	140								176,9
	145								176,9
	150								↓
	155								

HVP-Fit Bolt Assemblies		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm		13	17	21	23	25	28	31	37
Edge Distance e_1 in Load Direction mm	e_1 = 20	31,9							
	25	39,8	39,8						
	30	47,8	47,8	47,8	47,8	47,8			
	35	55,8	55,8	55,8	55,8	55,8	55,8		
	40	62,2	63,7	63,7	63,7	63,7	63,7	63,7	
	45	62,2	71,7	71,7	71,7	71,7	71,7	71,7	71,7
	50	↓	79,7	79,7	79,7	79,7	79,7	79,7	79,7
	55		81,3	87,6	87,6	87,6	87,6	87,6	87,6
	60		81,3	95,6	95,6	95,6	95,6	95,6	95,6
	65		↓	100,4	103,6	103,6	103,6	103,6	103,6
	70			100,4	110,0	111,6	111,6	111,6	111,6
	75			↓	110,0	119,5	119,5	119,5	119,5
	80				↓	119,5	127,5	127,5	127,5
	85					↓	133,9	135,5	135,5
	90						133,9	143,4	143,4
	95						↓	148,2	151,4
	100							148,2	159,4
	105							↓	167,3
	110								175,3
	115								176,9
	120								176,9
	125								↓

14 Design Shear Resistance $F_{v,Rd}$ in kN for each Shear Plane

A_{Shank} mm²	133	227	346	415	491	616	755	1075
$F_{v,Rd}$ kN	63,7	109	166	199	236	296	362	516

15 Design Tension Resistance $F_{t,Rd}$ in kN

A_s mm²	84,3	157	245	303	353	459	561	817
$F_{t,Rd}$ kN	60,7	113	176	218	254	330	404	588

16 Design Bearing Resistance $F_{b,Rd}$ in kN

for plate thickness t = 10 mm of steel grade S235 (f_u = 360 N/mm²)

Normal Holes with **Tolerance H11** according to ISO 286-2 for Fit Bolts
Distances Perpendicular to Load Direction e_2 ≥ **1,5** d_0 und p_2 ≥ **3** d_0

HVP-Fit Bolt Assemblies		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm		13	17	21	23	25	28	31	37
Hole Spacing p_1 in Load Direction mm	p_1 = 30	48,6							
	35	60,6							
	40	72,6	65,4						
	45	84,6	77,4						
	50	93,6	89,4	82,2					
	55	93,6	101,4	94,2	90,6	87,0			
	60	↓	113,4	106,2	102,6	99,0			
	65		122,4	118,2	114,6	111,0	105,6		
	70		122,4	130,2	126,6	123,0	117,6	112,2	
	75		↓	142,2	138,6	135,0	129,6	124,2	
	80			151,2	150,6	147,0	141,6	136,2	
	85			151,2	162,6	159,0	153,6	148,2	137,4
	90			↓	165,6	171,0	165,6	160,2	149,4
	95				165,6	180,0	177,6	172,2	161,4
	100				↓	180,0	189,6	184,2	173,4
	105					↓	201,6	196,2	185,4
	110						201,6	208,2	197,4
	115						↓	220,2	209,4
	120							223,2	221,4
	125							223,2	233,4
	130							↓	245,4
	135								257,4
	140								266,4
	145								266,4
	150								↓
	155								

HVP-Fit Bolt Assemblies		M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
d_0 in mm		13	17	21	23	25	28	31	37
Edge Distance e_1 in Load Direction mm	e_1 = 20	48,0							
	25	60,0	60,0						
	30	72,0	72,0	72,0	72,0	72,0			
	35	84,0	84,0	84,0	84,0	84,0	84,0		
	40	93,6	96,0	96,0	96,0	96,0	96,0	96,0	
	45	93,6	108,0	108,0	108,0	108,0	108,0	108,0	108,0
	50	↓	120,0	120,0	120,0	120,0	120,0	120,0	120,0
	55		122,4	132,0	132,0	132,0	132,0	132,0	132,0
	60		122,4	144,0	144,0	144,0	144,0	144,0	144,0
	65		↓	151,2	156,0	156,0	156,0	156,0	156,0
	70			151,2	165,6	168,0	168,0	168,0	168,0
	75			↓	165,6	180,0	180,0	180,0	180,0
	80				↓	180,0	192,0	192,0	192,0
	85					↓	201,6	204,0	204,0
	90						201,6	216,0	216,0
	95						↓	223,2	228,0
	100							223,2	240,0
	105							↓	252,0
	110								264,0
	115								266,4
	120								266,4
	125								↓

17 Design Punching Shear Resistance $B_{p,Rd}$ in kN

Material acc. to DIN EN 10025 with plate thickness t = 10mm

Steel grade	f_u N/mm²	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
S235	360	122	151	179	202	231	260	283	340
S275	430	146	181	214	242	276	311	338	406
S355	490	167	206	244	275	315	354	386	463

18 Design Slip Resistance $F_{s,Rd}$ in kN

Limit State	Preload	Class of Friction Surfaces	Slip Factor μ	Bolt Size							
				M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36
Serviceability	$F_{p,C}$	A	0,5	26,8	50,0	78,2	96,4	112	146	179	260
		B	0,4	21,5	40,0	62,5	77,1	89,8	117	143	208
		C	0,3	16,1	30,0	46,9	57,8	67,4	87,5	107	156
		D	0,2	10,7	20,0	31,3	38,5	44,9	58,4	71,5	104
	$F_{p,C}$*	A	0,5	22,7	45,5	72,7	86,4	100	132	159	232
		B	0,4	18,2	36,4	58,2	69,1	80,0	105	127	185
		C	0,3	13,6	27,3	43,6	51,8	60,0	79,1	95,5	139
		D	0,2	9,1	18,2	29,1	34,5	40,0	52,7	63,6	92,7
Ultimate	$F_{p,C}$	A	0,5	23,6	44,0	68,8	84,8	98,8	128	157	229
		B	0,4	18,9	35,2	55,0	67,8	79,0	103	126	183
		C	0,3	14,2	26,4	41,3	50,9	59,3	77,0	94,3	137
		D	0,2	9,4	17,6	27,5	33,9	39,5	51,4	62,9	91,5
	$F_{p,C}$*	A	0,5	20,0	40,0	64,0	76,0	88,0	116	140	204
		B	0,4	16,0	32,0	51,2	60,8	70,4	92,8	112	163
		C	0,3	12,0	24,0	38,4	45,6	52,8	69,6	84,0	122
		D	0,2	8,0	16,0	25,6	30,4	35,2	46,4	56,0	81,6