



**STEEL
CONSTRUCTION**



4TH EDITION

FIELD MANUAL HV - HIGH STRENGTH

STRUCTURAL BOLTING ASSEMBLIES FOR PRELOADING

acc. to DIN EN 1993-1-8 / DIN EN 1090-2

DIN EN 1993-1-8/NA / DIN EN 14399

- Edge Distances and Spacing
- Bearing Load Resistances
- Shear Load Resistances
- Slip Resistances
- Punching Shear Resistances
- Dimensions and Clamp Lengths
- Preload, Tightening Torque, Angle of Rotation
- Checking of Preload

GET A GRIP.

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.

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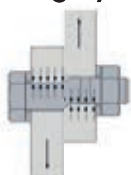
Design Categories, Connection Types and Design Checks according to DIN EN 1993-1-8

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	

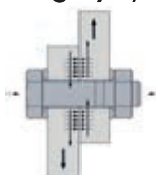
Note

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.

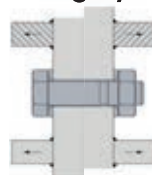
Category A



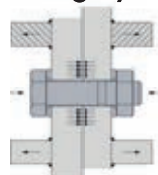
Category B/C



Category D



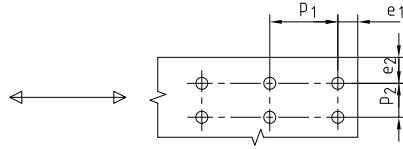
Category E



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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	$4 t + 40 \text{ mm}$	p_1	min $\left\{ \begin{array}{l} 14 t \\ 200 \text{ mm} \end{array} \right.$
	e_2		p_2	

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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	

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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.

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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	Impact Turn Method	Modified Torque Controlled Method	Modified Combined Method
	$F_{p,c}^*$	Preload $F_{v,DI}$ to be adjusted	Torque M_A to be applied	Pre-Tightening Torque $M_{A,MKV}$
	kN	kN	Nm	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

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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

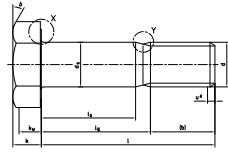
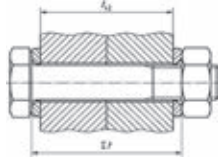
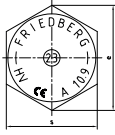
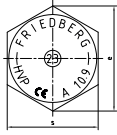
Note

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.

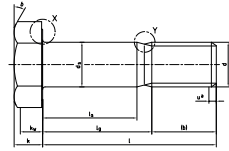
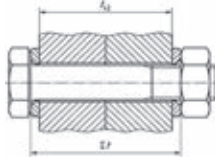
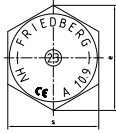
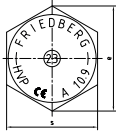
Dimensions and Clamp Lengths in mm



Bolt Size	M 12	M 16	M 20	M 22	M 24	M 27	M 30	M 36	
Thread- \varnothing	d	12	16	20	22	24	27	30	36
Shank- \varnothing HV	$d_{s, \text{nom}}$	12	16	20	22	24	27	30	36
Shank- \varnothing HVP	$d_{s, \text{nom}}$	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- \varnothing	$d_{z, \text{max}}$	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 Σl_{min} bis Σl_{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.

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- \varnothing d	12	16	20	22	24	27	30	36
Shank- \varnothing HV $d_{s, \text{nom}}$	12	16	20	22	24	27	30	36
Shank- \varnothing HVP $d_{s, \text{nom}}$	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- \varnothing $d_{2, \text{max}}$	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 $t_{s2, \text{min}}$ bis $t_{s2, \text{max}}$							
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.

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

Material acc. to DIN EN 10025 with plate thickness $t = 10\text{mm}$

Steel grade	f_u N/mm ²	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

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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





AUGUST FRIEDBERG GMBH

Achternbergstraße 38 A
45884 Gelsenkirchen

Tel.: +49 (0) 2 09-91 32-0

Fax.: +49 (0) 2 09-91 32-178

E-mail: info@august-friedberg.com

www.august-friedberg.com

**CONNECTING RENEWABLE ENERGY
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SUPPLYING GERMAN QUALITY**

For more than 130 years many companies have been trusting in products made by **Friedberg**. Starting off with a small-scale bolt production for the local mining industry our company now offers a wide range of first-class fastening systems.

Long-established like few other companies in this particular trade **Friedberg** is one of the market leaders for high-quality fastener technology. Our early bread and butter business was the production of bolts for the mining industry, the most important industry in our region at that time. Taking advantage of the industrial boom very early Friedberg gained ground in the high-tech sectors such as the automotive industry, machine and plant construction, steel construction and other industries requiring tailor-made and purpose-built fastening systems. Today **Friedberg** is also well-established and widely known as one of the leading manufacturer of bolting systems for the ground-breaking wind turbine industry. From the assembly of flange and rotor blade to the fixation of the base many wind turbine generators worldwide nowadays literally consist of our material from top to bottom.

Extensive development, carefully monitored production and heat treatment processes, quality and safety tests ranging from impact and friction tests to micrograph analysis and tensile tests guarantee maximum safety and excellent products, which have allowed **Friedberg** to become a successful player in the international market.