PEINER
Umformtechnik

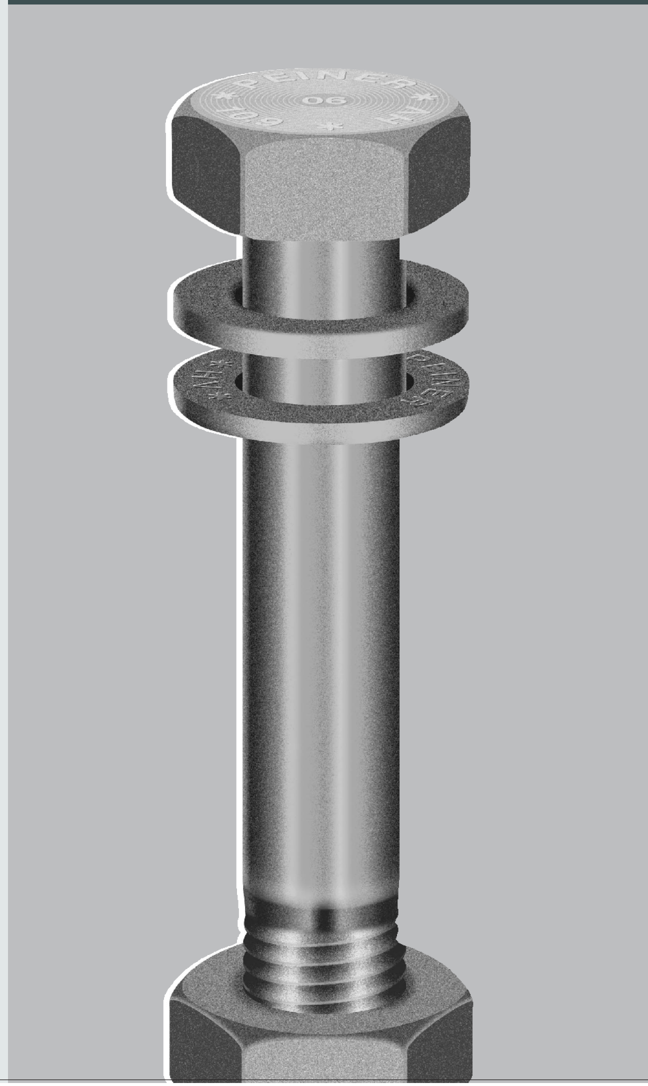
Peiner Umformtechnik GmbH
Woltorfer Straße 20-24
31224 Peine
Deutschland/Germany

Tel. No + 49 (0) 5171 545-0
Facsimile + 49 (0) 5171 545-180
e-mail info@peiner-ut.com
Internet www.peiner-ut.com

A company of
Sundram Fasteners Ltd., India

PEINER HV-

Structural bolt sets



PEINER
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Leading in steel construction
PEINER HV-bolt-sets

PEINER Umformtechnik is a company of Indian Sundram Fasteners Limited (SFL). Sundram is a member of the TVS Group, one of India's largest automotive suppliers. The Peine factory of PEINER Umformtechnik has produced bolts, nuts and other fastening elements for steel structures and bridges, fasteners for wind turbines as well as high-end automotive parts for well-known car and truck makers throughout the world for more than 80 years.

Our key accounts provide technology support for our customers on all aspects of fastening technology, from the selection of fastener elements, the design of the fastening points or calculation and installation. By cooperation with universities and colleges under research agreements and by active involvement with standardisation bodies, such as national (DIN) and international (CEN, ISO) standardization committees, we are always abreast of the state-of-the-art and help advance it. We make our customers aware of changes in product standards, calculation or installation provisions and other features in seminars and training courses.

Through wholesale channels, which provide the logistics services, PEINER Umformtechnik supplies high-strength HV-bolt-sets and HV-fit-bolt-sets complying with DIN EN 14399-4, DIN EN 14399-6 and DIN EN 14399-8 to the steel construction industry.

PEINER high-strength preloaded (HV) bolt-sets are preferably used in slip-resistant connections, flexurally rigid plate connections, shear type connections and in ring flange connections of wind turbines.

As construction elements serving a safety function, these fasteners must comply with strict quality requirements. Consequently, we have installed high-precision standards and invested heavily in quality assurance. Each Peiner HV-bolt and HV-nut carries a code – a serial number – to make the end product traceable right down to the batch of input material. This code adds transparency to the production process and, at the same time, is an expression of our quality demand. According to DIN 18800-7:2008-11, this makes test certificates 3.1 which DIN EN 10204 requires for HV-bolts, unnecessary. However, test certificates 3.1 will still be issued on request.

PEINER HV-sets are available ex stock in the standard size range from M12 to M36. Larger sizes up to M64, especially for installation in wind turbines, complying with DASt-guideline 021 and the corresponding PEINER company standard, are also available.

Corrosion protection by hot dip galvanization
Hot dip galvanizing provides efficient and long-life corrosion protection even in potentially aggressive atmospheres. Depending on the aggressive media, a zinc coat of 50 to 70 µm thickness alloyed with the base material can protect the full function of the bolted connection for many years (Figure 1).

Based on scientific findings and empirical data gained through many years in the industry, hot dip galvanizing is applied under defined conditions according to the manufacturing guideline of Deutscher Schraubenverband and Gemeinschaftsausschuss Verzinken.

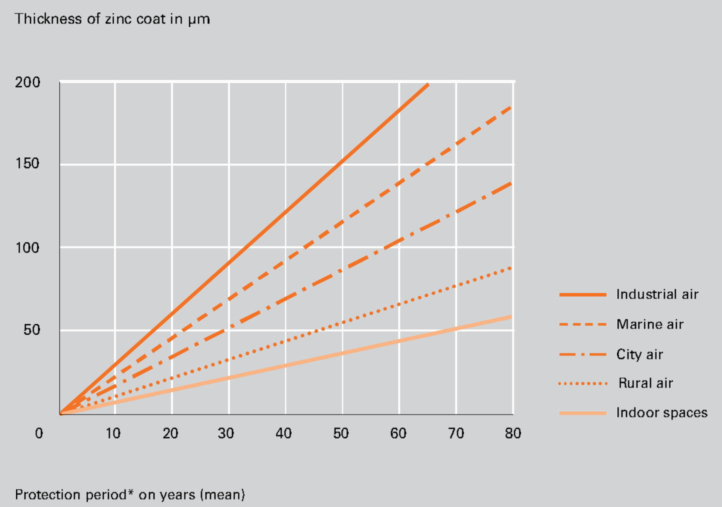
Hot dip galvanized and black, slightly oiled HV-nuts are treated with special long-time lubrication and are ready for installation. In this state, they comply with the requirements for preload force and tightening torque according to DIN 18800-7:2008-11.

The European HV-product standards are so called harmonized standards according to the Construction Product Directive of the European Community. On this basis, HV-sets are delivered with CE label. Therefore, no handicaps to trading these products should exist or be established within the European Community.

As a rule, HV-sets according to DIN EN 14399-4, DIN EN 14399-6 and DIN EN 14399-8 are shipped with CE label in k-class K1 design and, in addition, comply with DIN 18800-7 for torque controlled preloading.

The components of the HV-sets, i.e., bolts, nuts and washers, are packed separately. An HV-set is a combination of bolt, nut and washer from one manufacturer.

HV-sets can be used without restriction for all bolted structural connections common in steel construction according to the German standard DIN 18800-1 and European standard DIN EN 1993-1-8.



Source: Hot dip galvanizing specifications (5.4 Corrosions behaviour of zinc coatings exposed to atmospheric), 3rd edition 1999

Figure 1

Period of protection of zinc coatings

*The period of protection is not a „warranty period."

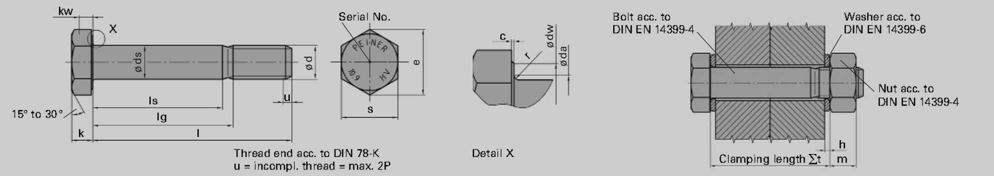


Table 1

Bolt dimensions*

Dimensions of PEINER HV-bolts with large widths across flats DIN EN 14399-4 for GV, SLV and SL connections in steel construction

***Dimensions in millimeters**

Nominal size		M12	M16	M20	M22	M24	M27	M30	M36
P[1]		1,75	2	2,5	2,5	3	3	3,5	4
c	min.	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
	max.	0,6	0,6	0,8	0,8	0,8	0,8	0,8	0,8
d_a	max.	15,2	19,2	24	26	28	32	35	41
d_s	nom.	12	16	20	22	24	27	30	36
	min.	11,3	15,3	19,16	21,16	23,16	26,16	29,16	35
	max.	12,7	16,7	20,84	22,84	24,84	27,84	30,84	37
d_w [2]	min.	20,1	24,9	29,5	33,3	38,0	42,8	46,6	55,9
e	min.	23,91	29,56	35,03	39,55	45,20	50,85	55,37	66,44
k	nom.	8	10	13	14	15	17	19	23
	min.	7,55	9,25	12,1	13,1	14,1	16,1	17,95	21,95
	max.	8,45	10,75	13,9	14,9	15,9	17,9	20,05	24,05
k_w	min.	5,28	6,47	8,47	9,17	9,87	11,27	12,56	15,36
r	min.	1,2	1,2	1,5	1,5	1,5	2	2	2
s	max.	22	27	32	36	41	46	50	60
	min.	21,16	26,16	31	35	40	45	49	58,8
h	nom.	3	4	4	4	4	5	5	6
	min.	2,7	3,7	3,7	3,7	3,7	4,4	4,4	5,4
	max.	3,3	4,3	4,3	4,3	4,3	5,6	5,6	6,6
m	nom. = max.	10	13	16	18	20	22	24	29
	min.	9,64	12,3	14,9	16,9	18,7	20,7	22,7	27,7

Note: The dimensions are for hot dip galvanized bolts, nuts and washers before galvanization

[1] P = Thread pitch (standard thread) [2] $d_{w,max.} = s_{act.}$

l	Shank lengths l_s and l_g															
	M12		M16		M20		M22		M24		M27		M30		M36	
Nominal size	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.
30	1,75	7														
35	6,75	12	1	7												
40	11,75	17	6	12												
45	16,75	22	11	17	4,5	12										
50	21,75	27	16	22	9,5	17	8,5	16	2	11						
55	26,75	32	21	27	14,5	22	13,5	21	7	16						
60	31,75	37	26	32	19,5	27	18,5	26	12	21	10	19				
65	36,75	42	31	37	24,5	32	23,5	31	17	26	15	24				
70	41,75	47	36	42	29,5	37	28,5	36	22	31	20	29	15,5	26		
75	46,75	52	41	47	34,5	42	33,5	41	27	36	25	34	20,5	31		
80	51,75	57	46	52	39,5	47	38,5	46	32	41	30	39	25,5	36	16	28
85	56,75	62	51	57	44,5	52	43,5	51	37	46	35	44	30,5	41	21	33
90	61,75	67	56	62	49,5	57	48,5	56	42	51	40	49	35,5	46	26	38
95	66,75	72	61	67	54,5	62	53,5	61	47	56	45	54	40,5	51	31	43
100	71,75	77	66	72	59,5	67	58,5	66	52	61	50	59	45,5	56	36	48
105	76,75	82	71	77	64,5	72	63,5	71	57	66	55	64	50,5	61	41	53
110	81,75	87	76	82	69,5	77	68,5	76	62	71	60	69	55,5	66	46	58
115	86,75	92	81	87	74,5	82	73,5	81	67	76	65	74	60,5	71	51	63
120	91,75	97	86	92	79,5	87	78,5	86	72	81	70	79	65,5	76	56	68
125	96,75	102	91	97	84,5	92	83,5	91	77	86	75	84	70,5	81	61	73
130	101,75	107	96	102	89,5	97	88,5	96	82	91	80	89	75,5	86	66	78
135	106,75	112	101	107	94,5	102	93,5	101	87	96	85	94	80,5	91	71	83
140	111,75	117	106	112	99,5	107	98,5	106	92	101	90	99	85,5	96	76	88
145	116,75	122	111	117	104,5	112	103,5	111	97	106	95	104	90,5	101	81	93
150	121,75	127	116	122	109,5	117	108,5	116	102	111	100	109	95,5	106	86	98
155	126,75	132	121	127	114,5	122	113,5	121	107	116	105	114	100,5	111	91	103
160	131,75	137	126	132	119,5	127	118,5	126	112	121	110	119	105,5	116	96	108
165	136,75	142	131	137	124,5	132	123,5	131	117	126	115	124	110,5	121	101	113
170	141,75	147	136	142	129,5	137	128,5	136	122	131	120	129	115,5	126	106	118
175	146,75	152	141	147	134,5	142	133,5	141	127	136	125	134	120,5	131	111	123
180	151,75	157	146	152	139,5	147	138,5	146	132	141	130	139	125,5	136	116	128
185			151	157	144,5	152	143,5	151	137	146	135	144	130,5	141	121	133
190			156	162	149,5	157	148,5	156	142	151	140	149	135,5	146	126	138
195			161	167	154,5	162	153,5	161	147	156	145	154	140,5	151	131	143
200			166	172	159,5	167	158,5	166	152	161	150	159	145,5	156	136	148
210			176	182	169,5	177	168,5	176	162	171	160	169	155,5	166	146	158
220			186	192	179,5	187	178,5	186	172	181	170	179	165,5	176	156	168
230					189,5	197	188,5	196	182	191	180	189	175,5	186	166	178
240					199,5	207	198,5	206	192	201	190	199	185,5	196	176	188
250					209,5	217	208,5	216	202	211	200	209	195,5	206	186	198
260					219,5	227	218,5	226	212	221	210	219	205,5	216	196	208

Standardized nominal length range

Additional nominal length range

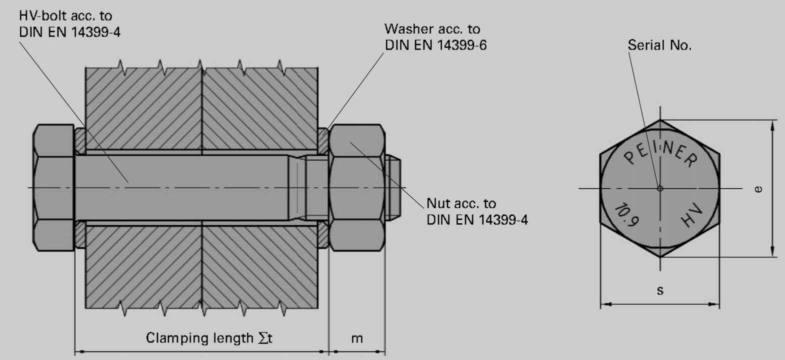
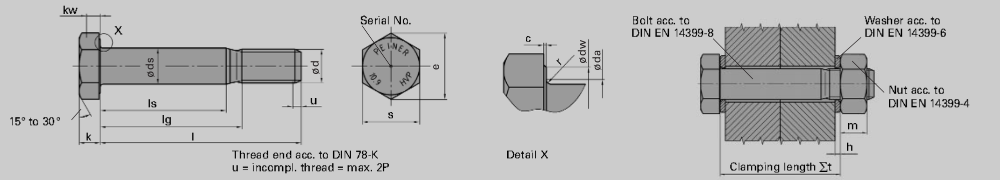


Table 1a

[1] **Clamping length Σt also includes the two washers (see figure above)**

Nominal length l	Clamping length $\Sigma t_{min.}$ and $\Sigma t_{max.}$ for HV- and HVP-bolts[1]							
	M12	M16	M20	M22	M24	M27	M30	M36
30	11 - 16							
35	16 - 21	12 - 17						
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			158 - 163	157 - 162	154 - 159	151 - 156	149 - 154	143 - 148
190			163 - 168	162 - 167	159 - 164	156 - 161	154 - 159	148 - 153
195			168 - 173	167 - 172	164 - 169	161 - 166	159 - 164	153 - 158
200			173 - 178	172 - 177	169 - 174	166 - 171	164 - 169	158 - 163
210			183 - 188	182 - 187	179 - 184	176 - 181	174 - 179	168 - 173
220			193 - 198	192 - 197	189 - 194	186 - 191	184 - 189	178 - 183
230			203 - 208	202 - 207	199 - 204	196 - 201	194 - 199	188 - 193
240			213 - 218	212 - 217	209 - 214	206 - 211	204 - 209	198 - 203
250			223 - 228	222 - 227	219 - 224	216 - 221	214 - 219	208 - 213
260			233 - 238	232 - 237	229 - 234	226 - 231	224 - 229	218 - 223



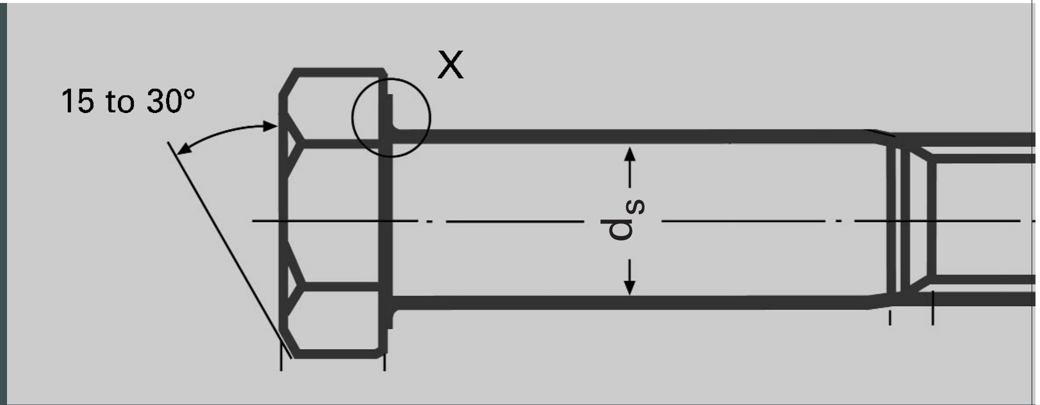


Table 2

Fit bolt dimensions*

Dimensions of PEINER HV-fit-bolts with large widths across flats DIN EN 14399-8 for GVP, SLVP and SLP connections in steel construction

The nut for HVP-sets according to DIN EN 14399-8 is identical with the HV-nut according to DIN EN 14399-4

*Dimensions in millimeters

Nominal size		M12	M16	M20	M22	M24	M27	M30	M36
P[1]		1,75	2	2,5	2,5	3	3	3,5	4
c	min.	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
	max.	0,6	0,6	0,8	0,8	0,8	0,8	0,8	0,8
d_a	max.	15,2	19,2	24	26	28	32	35	41
d_s	nom.	13	17	21	23	25	28	31	37
	min.[2]	12,74	16,74	20,71	22,71	24,71	27,71	30,67	36,67
	max.[2]	12,85	16,85	20,84	22,84	24,84	27,84	30,83	36,83
d_w[3]	min.	20,1	24,9	29,5	33,3	38,0	42,8	46,6	55,9
e	min.	23,91	29,56	35,03	39,55	45,20	50,85	55,37	66,44
k	nom.	8	10	13	14	15	17	19	23
	min.	7,55	9,25	12,1	13,1	14,1	16,1	17,95	21,95
	max.	8,45	10,75	13,9	14,9	15,9	17,9	20,05	24,05
k_w	min.	5,28	6,47	8,47	9,17	9,87	11,27	12,56	15,36
r	min.	1,2	1,2	1,5	1,5	1,5	2	2	2
s	max.	22	27	32	36	41	46	50	60
	min.	21,16	26,16	31	35	40	45	49	58,8
h	nom.	3	4	4	4	4	5	5	6
	min.	2,7	3,7	3,7	3,7	3,7	4,4	4,4	5,4
	max.	3,3	4,3	4,3	4,3	4,3	5,6	5,6	6,6
m	nom.= max.	10	13	16	18	20	22	24	29
	min.	9,64	12,3	14,9	16,9	18,7	20,7	22,7	27,7

Note:
The dimensions are for hot dip galvanized bolts, nuts and washers before galvanization
1) P = Thread pitch (standard thread) 2) Corresponds to tolerance class b11 3) $d_{w,max.} = s_{act.}$

l	Shank lengths l_s and l_g															
	M12		M16		M20		M22		M24		M27		M30		M36	
Nominal size	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.	l_s min.	l_g max.
50	20,5	27	14,5	22	8,5	17										
55	25,5	32	19,5	27	13,5	22	12,5	21	6	16						
60	30,5	37	24,5	32	18,5	27	17,5	26	11	21	9	19				
65	35,5	42	29,5	37	23,5	32	22,5	31	16	26	14	24	9,5	21		
70	40,5	47	34,5	42	28,5	37	27,5	36	21	31	19	29	14,5	26		
75	45,5	52	39,5	47	33,5	42	32,5	41	26	36	24	34	19,5	31		
80	50,5	57	44,5	52	38,5	47	37,5	46	31	41	29	39	24,5	36		
85	55,5	62	49,5	57	43,5	52	42,5	51	36	46	34	44	29,5	41	20	33
90	60,5	67	54,5	62	48,5	57	47,5	56	41	51	39	49	34,5	46	25	38
95	65,5	72	59,5	67	53,5	62	52,5	61	46	56	44	54	39,5	51	30	43
100	70,5	77	64,5	72	58,5	67	57,5	66	51	61	49	59	44,5	56	35	48
105	75,5	82	69,5	77	63,5	72	62,5	71	56	66	54	64	49,5	61	40	53
110	80,5	87	74,5	82	68,5	77	67,5	76	61	71	59	69	54,5	66	45	58
115	85,5	92	79,5	87	73,5	82	72,5	81	66	76	64	74	59,5	71	50	63
120	90,5	97	84,5	92	78,5	87	77,5	86	71	81	69	79	64,5	76	55	68
125	95,5	102	89,5	97	83,5	92	82,5	91	76	86	74	84	69,5	81	60	73
130	100,5	107	94,5	102	88,5	97	87,5	96	81	91	79	89	74,5	86	65	78
135	105,5	112	99,5	107	93,5	102	92,5	101	86	96	84	94	79,5	91	70	83
140	110,5	117	104,5	112	98,5	107	97,5	106	91	101	89	99	84,5	96	75	88
145	115,5	122	109,5	117	103,5	112	102,5	111	96	106	94	104	89,5	101	80	93
150	120,5	127	114,5	122	108,5	117	107,5	116	101	111	99	109	94,5	106	85	98
155	125,5	132	119,5	127	113,5	122	112,5	121	106	116	104	114	99,5	111	90	103
160	130,5	137	124,5	132	118,5	127	117,5	126	111	121	109	119	104,5	116	95	108
165	135,5	142	129,5	137	123,5	132	122,5	131	116	126	114	124	109,5	121	100	113
170	140,5	147	134,5	142	128,5	137	127,5	136	121	131	119	129	114,5	126	105	118
175	145,5	152	139,5	147	133,5	142	132,5	141	126	136	124	134	119,5	131	110	123
180	150,5	157	144,5	152	138,5	147	137,5	146	131	141	129	139	124,5	136	115	128
185					143,5	152	142,5	151	136	146	134	144	129,5	141	120	133
190					148,5	157	147,5	156	141	151	139	149	134,5	146	125	138
195					153,5	162	152,5	161	146	156	144	154	139,5	151	130	143
200					158,5	167	157,5	166	151	161	149	159	144,5	156	135	148
210					168,5	177	167,5	176	161	171	159	169	154,5	166	145	158
220					178,5	187	177,5	186	171	181	169	179	164,5	176	155	168
230					188,5	197	187,5	196	181	191	179	189	174,5	186	165	178
240					198,5	207	197,5	206	191	201	189	199	184,5	196	175	188
250					208,5	217	207,5	216	201	211	199	209	194,5	206	185	198
260					218,5	227	217,5	226	211	221	209	219	204,5	216	195	208

Standardized nominal length range

Additional nominal length range

Table 2a

Weights of PEINER HV-bolts DIN EN 14399-4, PEINER HVP-bolts DIN EN 14399-8, PEINER HV-nuts DIN EN 14399-4 and PEINER HV-washers DIN EN 14399-6

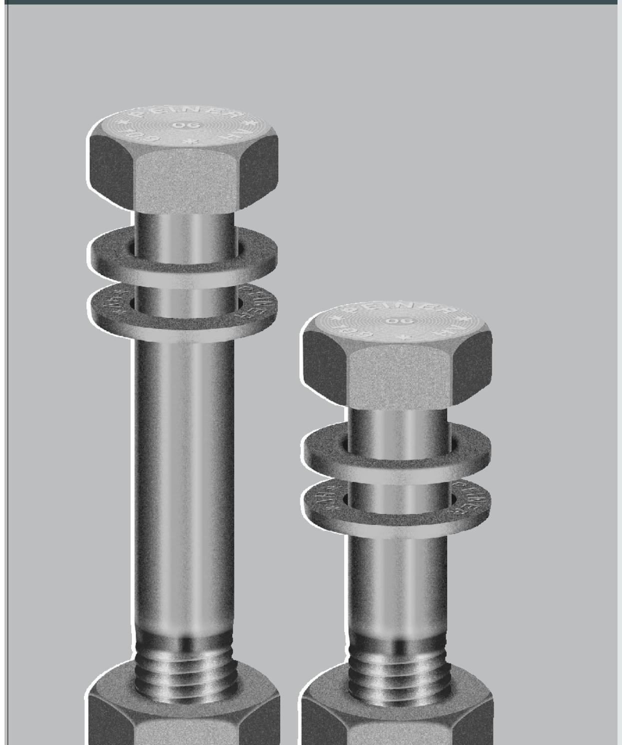
* All weights are for guidance only

Thread d	M12	M16	M20	M22	M24	M27	M30	M36
Nominal length l	Weight* in kg/100 bolts with 7.85 kg//dm³							
30	4,50							
35	4,94	9,19						
40	5,39	9,98						
45	5,83	10,77	17,83					
50	6,28	11,56	19,07	24,60	30,60			
55	6,72	12,35	20,30	26,09	32,38			
60	7,16	13,14	21,53	27,58	34,15	45,90		
65	7,61	13,92	22,77	29,08	35,93	48,15	61,63	
70	8,05	14,71	24,00	30,57	37,70	50,39	64,40	
75	8,50	15,50	25,23	32,06	39,48	52,64	67,17	
80	8,94	16,29	26,46	33,55	41,25	54,89	69,95	110,50
85	9,38	17,08	27,70	35,04	43,03	57,14	72,72	114,50
90	9,83	17,87	28,93	36,54	44,81	59,38	75,50	118,49
95	10,27	18,66	30,16	38,03	46,58	61,63	78,27	122,49
100	10,71	19,45	31,40	39,52	48,36	63,88	81,05	126,48
105	11,16	20,24	32,63	41,01	50,13	66,13	83,82	130,48
110	11,60	21,03	33,86	42,50	51,91	68,37	86,60	134,47
115	12,05	21,82	35,10	44,00	53,68	70,62	89,37	138,47
120	12,49	22,61	36,33	45,49	55,46	72,87	92,14	142,46
125	12,93	23,39	37,56	46,98	57,23	75,11	94,92	146,46
130	13,38	24,18	38,80	48,47	59,01	77,36	97,69	150,45
135	13,82	24,97	40,03	49,96	60,79	79,61	100,47	154,45
140	14,27	25,76	41,26	51,46	62,56	81,86	103,24	158,44
145	14,71	26,55	42,49	52,95	64,34	84,10	106,02	162,44
150	15,15	27,34	43,73	54,44	66,11	86,35	108,79	166,43
155	15,60	28,13	44,96	55,93	67,89	88,60	111,57	170,43
160	16,04	28,92	46,19	57,42	69,66	90,85	114,34	174,42
165	16,49	29,71	47,43	58,92	71,44	93,09	117,11	178,42
170	16,93	30,50	48,66	60,41	73,22	95,34	119,89	182,41
175	17,37	31,29	49,89	61,90	74,99	97,59	122,66	186,41
180	17,82	32,08	51,13	63,39	76,77	99,83	125,44	190,40
185		32,86	52,36	64,88	78,54	102,08	128,21	194,40
190		33,65	53,59	66,38	80,32	104,33	130,99	198,39
195		34,44	54,83	67,87	82,09	106,58	133,76	202,39
200		35,23	56,06	69,36	83,87	108,82	136,53	206,38
205		36,02	57,29	70,85	85,64	111,07	139,31	210,38
210		36,81	58,52	72,34	87,42	113,32	142,08	214,37
215		37,60	59,76	73,84	89,20	115,57	144,86	218,37
220		38,39	60,99	75,33	90,97	117,81	147,63	222,36
225			62,22	76,82	92,75	120,06	150,41	226,36
230			63,46	78,31	94,52	122,31	153,18	230,35
235			64,69	79,80	96,30	124,55	155,96	234,35
240			65,92	81,30	98,07	126,80	158,73	238,35
245			67,16	82,79	99,85	129,05	161,50	242,34
250			68,39	84,28	101,63	131,30	164,28	246,34
255			69,62	85,77	103,40	133,54	167,05	250,33
260			70,86	87,26	105,18	135,79	169,83	254,33

Note: The weights of HVP-bolts according to DIN EN 14399-8 in the table should be increased by approximately 6%.

	M12	M16	M20	M22	M24	M27	M30	M36
+ 2 HV-washers	1,4	3,0	3,8	4,8	6,0	10,6	12,6	21,2
+ 1 HV-nut	2,3	4,5	6,9	9,8	14,5	20,7	26,2	46,0
Σ	3,7	7,5	10,7	14,6	20,5	31,3	38,8	67,2

Calculation of steel construction fastenings using HV-bolts according to DIN 18800-1:2008-11 and DIN EN 1993-1-8:2005



Categories of stuctural bolted joints
The classification of bolted connections in DIN 18800-1 was revised and a new classification adopted by DIN EN 1993-1-8. The new classification is based on the direction of force transmission in relation to the bolt longitudinal axis. Tables 3 and 4 below illustrate the performance criteria, which will be explained later, and the respective classification according to DIN 18800-1, each for the serviceability limit state (GdG) and the ultimate limit state of load-bearing capacity (GdT).

Calculation of HV-bolted connections
Verification of the performance capacity of HV-connections using HV-bolts will, for some time, still be based on the German standard DIN 18800-1 and also the European standard DIN EN 1993-1-8 and DIN EN 1993-1-9. So it is reasonable to consider both verification formats and expose technically relevant differences where such differences exist.

1. Verification of bolt shear
1.1. The design value of the ultimate limit state, V_a, must not exceed the limit shear forces $V_{a,R,d}$ in DIN 18800-1:2008-11.

$$\frac{V_a}{V_{a,R,d}} \leq 1$$

The limit shear force, $V_{a,R,d}$ is

$$V_{a,R,d} = A \cdot \tau_{a,R,d} = A \cdot \alpha_a \cdot f_{u,b,k} / \gamma_M$$

A Shank diameter A_{Sch}, if the smooth shank is located in the shear joint. Stressed cross section A_{Sp}, of the thread part of the shank is located in the shear joint.

α_a 0,55 for HV-bolts of property class 10.9, if the smooth shank is located in the shear joint.

0,44 for HV-bolts of property class 10.9, if the threaded part is located in the shear joint.

$f_{u,b,k}$ Typical tensile strength of the bolt material, for HV-bolt: 1000 N/mm²

γ_M = 1,1 partial safety factor for resistance

Additional requirements must be met for the method of proving plastic-plastic and for unsupported single-shear connections.

1.2 According to DIN EN 1993-1-8:2005, the acting shear force $F_{v,Ed}$ must not exceed the respective limit $F_{v,Rd}$, which is calculated as follows:

$$F_{v,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}}$$

- if the shank is in the shear joint:
  A shank cross section α_v = 0,6
- if the thread is in the shear joint:
  A shank cross section A_s
  α_v = 0,5
  f_{ub} for property class 10.9 = 1000 N/mm²
  γ_{M2} = 1,25 partial safety factor for resistance

Despite these differences in the coefficients of the verification formats, the resistance capacity according to DIN 18800-1 and to DIN EN 1993-1-8 calculated on this basis are almost identical. The service resistance values are identical if the bolt thread is in the shear joint.

Table 3

Force transmission transversal to the bolt axis

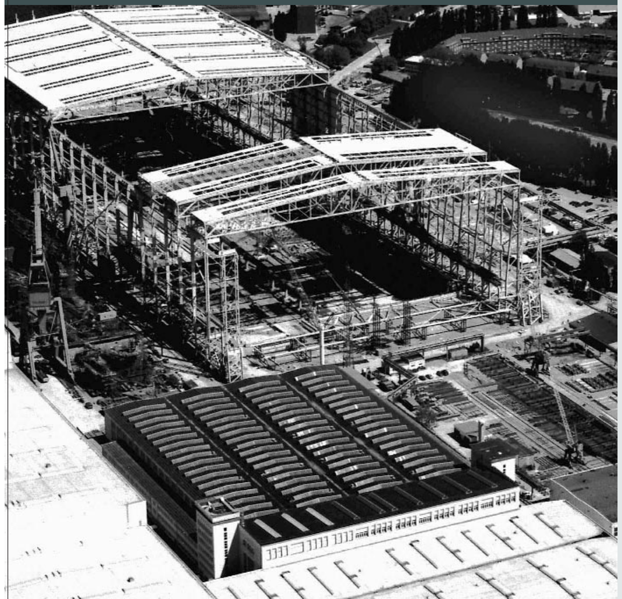
Shear type and slip-resistant connections				
Category	Criterion	Note	Compared with DIN 18800-1	
			GdG	GdT
A. Shear type connection	$F_{v,Ed} \leq F_{v,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$	No preload required but of advantage in some cases, property class 4.6 to 10.9	SL and SLP, resp.	SL and SLP, resp.
B. Slip-resistant connection (GdG)	$F_{v,Ed,ser} \leq F_{s,Rd,ser}$ $F_{v,Ed} \leq F_{v,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$	High-strength bolts property class 8.8 or 10.9 preloaded	GV and GVP, resp.	SL and SLP, resp.
C. Slip-resistant connection (GdT)	$F_{v,Ed} \leq F_{s,Rd}$ $F_{v,Ed} \leq F_{b,Rd}$ $F_{v,Ed} \leq N_{net,Rd}$	High-strength bolts property class 8.8 or 10.9 preloaded; $N_{net,Rd}$ according to DIN EN 1993-1-1	GV and GVP, resp.	GV and GVP, resp. (net)

Table 4

Force transmission along the bolt axis

Tensile loaded connections			
Category	Criterion	Note	Compared with DIN 18800-1
D. No preload	$F_{t,Ed} \leq F_{t,Rd}$ $F_{t,Ed} \leq B_{p,Rd}$ [1]	No preload required, property class 4.6 to 10.9	Not categorized, but specify verification criterion
E. Preloaded	$F_{t,Ed} \leq F_{t,Rd}$ $F_{t,Ed} \leq F_{p,Rd}$	High-strength bolts property class 8.8 or 10.9	

[1] Design value of the shear resistance of the bolt head and the bolt nut (DIN EN 1993-1-8:2005 section 3.6.1 table 3.5)



2. Verification of bearing resistance

2.1 According to DIN 18800-1:2008-11, the design values of bearing resistance V_l must not exceed the ultimate bearing strength $V_{l,R,d}$.

$$\frac{V_l}{V_{l,R,d}} \leq 1$$

The ultimate bearing strength $V_{l,R,d}$ is

$$V_{l,R,d} = t \cdot d_{Sch} \cdot \sigma_{l,R,d}$$
$$= t \cdot d_{Sch} \cdot \alpha_l \cdot f_{y,k} / \gamma_M$$

Where

t	Thickness of the part
d_{Sch}	Shank diameter of the bolt
α_l	Factor for determining the bearing strength, depending on the hole pattern (Figure 2)
$f_{y,k}$	Typical yield stress of the part material
γ_M	= 1,1 partial safety factor for resistance

For $e_2 \geq 1{,}5\ d_L$ and $e_3 \geq 3{,}0\ d_L$ is
$\alpha_l = 1{,}1\ e_1/d_L - 0{,}30$ (end bolt)
$\alpha_l = 1{,}08\ e/d_L - 0{,}77$ (inner bolt)

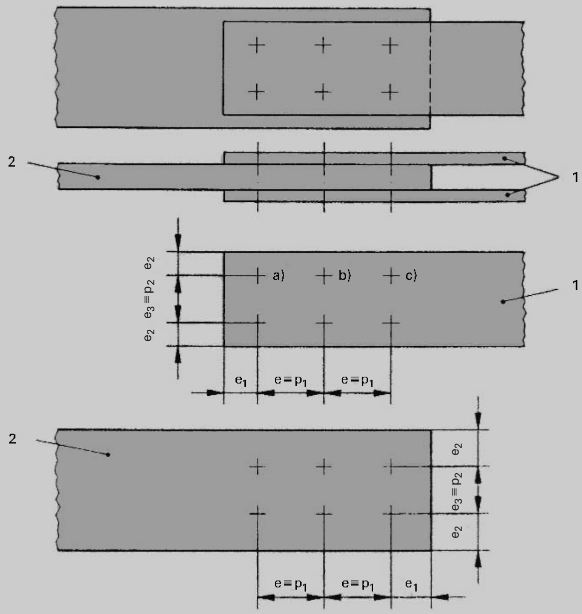
For $e_2 = 1{,}2\ d_L$ and $e_3 = 2{,}4\ d_L$ is
$\alpha_l = 0{,}73\ e_1/d_L - 0{,}20$ (end bolt)
$\alpha_l = 0{,}72\ e/d_L - 0{,}51$ (inner bolt)

with
e_1 = Edge distance in direction of force
e = Hole pitch in direction of force
e_2 = Edge distance vertical to the direction of force
e_3 = Hole pitch vertical to the direction of force
d_L = Hole diameter

2.2 The ultimate bearing strength according to DIN EN 1993-1-8 is calculated as:

$$F_{b,Rd} = \frac{k_1 \cdot \alpha_b \cdot f_u \cdot d \cdot t}{\gamma_{M2}}$$

Where α_b min. (α_d; f_{ub}/f_u;1,0)
for edge bolts:
$\alpha_d = e_1/3 \cdot d_0$
for inner bolts:
$\alpha_d = p_1/3 \cdot d_0 - 0{,}25$



k_1	for edge bolts: min. ($2{,}8 \cdot e_2/d_0 - 1{,}7$; 2,5)
k_1	for inner bolts: min. ($1{,}4 \cdot p_2/d_0 - 1{,}7$; 2,5)
f_u	Tensile stress of the part material
d	Bolt nominal diameter
t	Part thickness
$\gamma_{M2} = 1{,}25$	partial safety factor for resistance

Notes:
$F_{b,Rd}$ for oblong holes with longitudinal axis transversal to the direction of force with coefficient 0,6 reduced in comparison with normal hole clearance.
In this case, d_0 is the hole diameter; p_1 is the hole pitch in the direction of force and p_2 the hole pitch vertical to the direction of force.
The calculation uses the material property f_u instead of $f_{y,k}$ for verification according to DIN 18800-1.
The approach to the calculation of the ultimate bearing strength according to DIN 18800-1 and DIN EN 1993-1-8 is different. Therefore, no simple comparison is possible and a new calculation must be made.

Figure 2

Double-plate shear connection with edge distances e_1 and e_2 and hole pitches e and e_3.
For tensile shear resistance, of the connection

bolts a and c are end bolts

bolts b are inner bolts

For compressive shear resistance of the connection, bolts a, b and c are inner bolts.

1 outer plates
2 inner plate

3. Verification of the tensile stress of HV-bolts by calculating the ultimate tensile force based on very similar approaches (Table 5).

For HV-bolts, the following equation applies:

$$\frac{F_{t,Rd}}{N_{R,d}} = 0{,}99$$

so that the resistance capacity according to the old and the new norm can be assumed to be the same.

4. Combination of tension and shear
According to DIN 18800-1, the verification of the following interaction must be provided:

$$\left(\frac{N}{N_{R,d}}\right)^2 + \left(\frac{V_a}{V_{a,R,d}}\right)^2 \leq 1$$

Where
N, V_a Design values of tension and ultimate limit states
$N_{R,d}$ see 3
$V_{a,R,d}$ see 1.1

No verification of interaction is required if $N / N_{R,d}$ or $V_a / V_{a,R,d}$ is smaller than 0,25.

According to DIN EN 1993-1-8, the interaction term is obtained form the analysis of experimental results as

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1{,}4\ F_{t,Rd}} \leq 1{,}0$$

Thus, interactions between both loads are rated differently (Figure 3).

Table 5

Calculation of ultimate tensile force to prove the tensile load of HV-bolts

DIN 18800-1:2008-11	DIN EN 1993-1-8:2005
$N_{R,d} = \frac{A_{Sp} \cdot f_{u,b,k}}{1{,}25 \cdot \gamma_M}$	$F_{t,Rd} = \frac{k_2 \cdot f_{ub} \cdot A_S}{\gamma_{M2}}$
A_{Sp} Tension cross section	A_S Tension cross section
$f_{u,b,k}$ for property class 10.9 = 1000 N/mm²	f_{ub} for property class 10.9 = 1000 N/mm²
1,25 = Coefficient for higher safety against tensile strength	k_2 = 0,9
γ_M = 1,1	γ_{M2} = 1,25

5. Verification of slip-resistant connections: (GV und GVP)
5.1 According to DIN 18800-1, the stresses V_g decisive for serviceability the following limit slip loads $V_{g,R,d}$.

$$\frac{V_g}{V_{g,R,d}} \leq 1$$

The limit slip load $V_{g,R,d}$ is

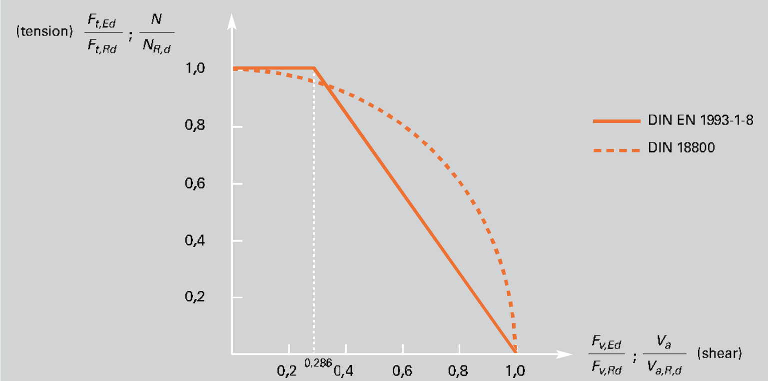
$V_{g,R,d} = \mu \cdot F_v / (1{,}15 \cdot \gamma_M)$, if no external tensile force acts on the HV-bolt,
$V_{g,R,d} = \mu \cdot F_v (1 - N / F_v) / (1{,}15 \cdot \gamma_M)$, if an external tensile force acts on the HV-bolt.

Where
μ the coefficient of friction after pretreatment of the friction surfaces according to DIN 18800-7
F_v the preload force according to DIN 18800-7
N the tensile force prorated for the bolt
γ_M = 1,0

In addition to this, verification of structural safety must be provided for GV and GVP connections as for SL and SLP connections.

5.2 According to DIN EN 1993-1-8, verification of slip-resistant HV-connection can be submitted by calculating the slip resistance both at serviceability limit state (GdG) and ultimate limit state of load-bearing capacity (GdT). Slip resistance $F_{s,Rd}$ is calculated as:

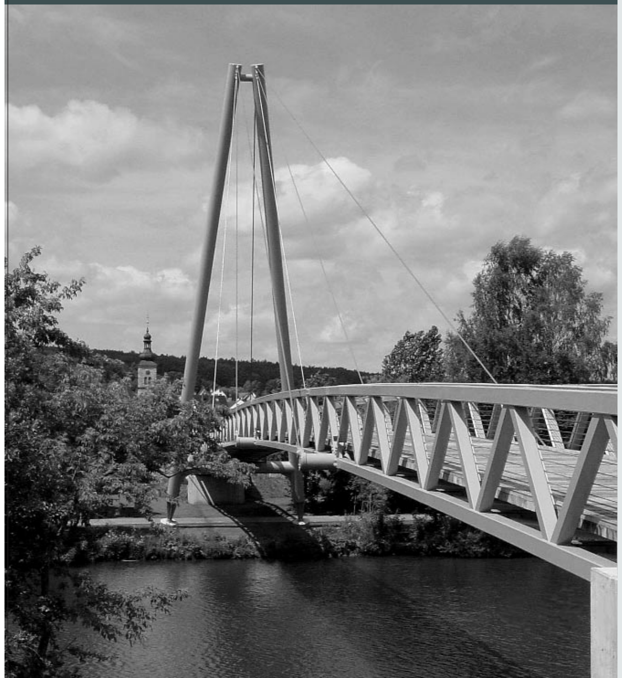
$$F_{s,Rd} = \frac{k_s \cdot n \cdot \mu}{\gamma_{M3}} \cdot F_{p,C}$$



Source: Acquired from Univ.-Prof. Dr. Ing. Ungermann and Dipl.-Ing. Schmidt, Dortmund University

Figure 3

Interaction between tension and shear: DIN 18800-1:2008-11 DIN EN 1993-1-8:2005



Where

k_S Hole coefficient, depends in hole configuration and clearance, e.g., for normal hole clearance: $k_S = 1$

n Number of contact surfaces

μ Coefficient of fiction in the contact surfaces, grouping according to preloading forces and tightening classes, e.g., for class A: $\mu = 0{,}5$

$F_{p,C}$ $= 0{,}7 \cdot f_{ub} \cdot A_s$ $(= 1{,}11 \cdot F_v)$

γ_{M3} = 1,25 partial safety factor for GdT

$\gamma_{M3,ser}$ = 1,1 partial safety factor for GdG

In the ultimate state of serviceability (category B acc. to DIN EN 1993-1-8), this value is about 16 % higher than the ultimate slip force according to DIN 18800-1. It should be noted, however, that the assumed preloading force $F_{p,C}$ is about 11% higher than the preloading force F_v according to DIN 18800-7 and cannot safely be obtained with torque methods because the effect of friction acting in that case is subject to a certain scatter.
For this reason, the combined preload method according to DIN EN 1090-2 should be applied here. The preliminary tightening torques and the additional angle of rotation of PEINER HV-bolts are given as manufacturer recommendations in Table 8.

5.3 A simple comparison of the resistance capacity of slip-resistant connections according to DIN EN 1993-1-8 and DIN 18800-1 under combined shear and tensile stress by a ratio or specification of a percentage difference is not possible because the resistance capacity depends on the relation between tensile stress and preloading force.

Table 6 contains the calculation equations for the resistance capacity in the respective standard. Only DIN EN 1993-1-8 contains information on slip-resistant connections in the ultimate limit state of load-bearing capacity (GdT, category C).

To make a comparison in the ultimate state of serviceability (GdG), the external tensile stress is equated and the preloading force according to DIN EN 1993-1-8 expressed as a function of the preloading force according to DIN 18800-7.

Where
$F_{p,C} = 1{,}11 \cdot F_v$ and $F_{t,Ed,ser} = N$ and $\mu = 0{,}5$ as well as F_v according to DIN 18800-7, transformation of the equations according to Euro code 3 and DIN yields

$$F_{s,Rd,ser} = 0{,}836 \cdot V_{g,R,d} + 0{,}141 \cdot F_v$$

This is the equation of a straight line of the general shape.

$$y = mx + n$$

6. Verification of fatigue strength
According to DIN 18800-1, the required verifications for bolts subjected to tension or shearing must be established according to section 7.5.1, element 741 or section 8.2.1.5, element 811 of DIN 18800-1:2008-11. A suitable verification format is available in DIN EN 1993-1-9. Fundamentally, this is based on a damage calculation by a modified damage accumulation hypothesis by Palmgren-Miner.

Table 6

Slip-resistant connection exposed to combined shear and tensile stress

DIN 18800-1:2008-11	DIN EN 1993-1-8:2005
Ultimate slip resistance $V_{g,R,d} = \frac{\mu \cdot F_v \left(1 - \frac{N}{F_v}\right)}{1{,}15 \cdot \gamma_M}$ μ the coefficient of friction after pretreatment of the friction surfaces according to DIN 18800-7 F_v the preload force according to DIN 18800-7 N the tensile force prorated for the bolt $\gamma_M = 1{,}0$ Coefficients of friction $\mu > 0{,}5$ can be used if they can be proved.	Slip resistance for high-strength connections applies generally $F_{s,Rd} = \frac{k_s \cdot n \cdot \mu}{\gamma_{M3}} \cdot F_{p,C}$ where k_s a coefficient n the number of shear joints μ the coefficient of friction Combined shear and tensile stress applies to category B connections $F_{s,Rd,ser} = \frac{k_s \cdot n \cdot \mu}{\gamma_{M3,ser}} \left(F_{p,C} - 0{,}8 \cdot F_{t,Ed,ser}\right)$ with category C connections $F_{s,Rd} = \frac{k_s \cdot n \cdot \mu}{\gamma_{M3}} \left(F_{p,C} - 0{,}8 \cdot F_{t,Ed}\right)$

Notes to DIN 18800-1:2008-11:

1) It follows for bolts not exposed to tensile stress:

$$V_{g,R,d} = \frac{\mu \cdot F_V}{1{,}15 \cdot \gamma_M}$$

2) Tensile forces in preloaded connections reduce the clamping force between the contact faces which also reduces the slip loads.

3) Factor 1,15 is for correction. By calculation, the tensile stress from external loads is exclusively assigned to bolts. This means that the actual decrease of the clamping force in the contact faces of the parts connected and the higher compression in the support areas of the bolt head and the nut are ignored.

Preloading
PEINER HV-bolt connections

1. Provisions in DIN 18800-7:2008-11
For a specified preload, HV-bolt-sets shall be preloaded to the preload F_v specified in Table 7. The specified preload is obtained as the product of nominal tension cross section of the thread (A_{Sp}) x 0,7 x yield point ($f_{y,b,k}$ = 900 N/mm² for 10.9).
The preferred method of preloading by turning, normally by turning the nut, is the torque method. The specified preload F_v is produced by a tightening torque M_A.
For HV-bolt-sets of k-class K1, a uniform tightening torque M_A in Table 7 applies irrespective of the surface condition.
This method enables a stepwise preloading of connections with many bolts and retightening for checking or as compensation for preload loss after a few days.

For preloading to the level in Table 7, DIN 18800-7 offers several other methods, which will be touched upon only briefly because they are rarely applied in practice. The detailed procedures are described in the standard.

With the turning impact wrench method, the preload is produced by rotary impacts, i.e., by tangential rotary strokes. The tightening tool should be set to the preload specified for this method in DIN 18800-7 with a suitable setting device.

The turning angle method provides for preloading in 2 stages. At first, a fairly low pretightening torque is applied which, in practice, involves a certain risk that the parts to be joined do not make full contact with each other at this stage. The additional angle of rotation then to be applied should be determined after a method check. Lack of full contact of the joined parts before the additional angle of rotation is applied can cause high scatter of preload forces.

The combined method also provides for 2 preloading steps. The pretightening torque in the table in DIN 18800-7 is distinctly higher, which is to increase the probability of obtaining a full-face contact of the joined parts already at this stage. After that, an additional angle of rotation specified in DIN 18800-7 is applied but this angle of rotation is smaller than that in DIN EN 1090-2 because the preloading level is higher there.

2. Provisions in DIN EN 1090-2
A preloading level $F_{p,C}^*$ below the level of $F_{p,C}$ according to the European standard DIN EN 1993-1-8 is also permitted for preloaded connections in which the preload is not considered for stability calculation, i.e., for all cases which do not require verification of the slip resistance of the connection. Therefore, preloading to

$$F_{p,C}^* = 0{,}7 \cdot f_{yb} \cdot A_s$$

is permitted for reasons other than verification of the slip resistance of the connection, which agrees with the approach in DIN 18800-7. The tightening torque method can therefore be applied without restriction in all such cases.

For preloading to bolt force

$$F_{p,C} = 0{,}7 \cdot f_{ub} \cdot A_s$$

which exploits 70 % of the tensile strength of the bolt, PEINER Umformtechnik recommends the combined method according to DIN EN 1090-2 with the specified pretightening torque M_A and additional angles of rotation (Table 8).

Table 7

Preloads and tightening torques for tightening torque preloading methods for HV-bolt-sets of k-class K1 for preloading according to DIN 18800-7

	Sizes	Specified preload F_v [kN] (complies with $F_{p,C}^* = 0{,}7 \cdot f_{yb} \cdot A_s$)	Tightening torque method: Tightening torque M_A to be applied for obtaining the specified preload F_v [Nm] – Surface hot dip galvanized and lubricated[a] and as processed and lubricated[a]
1	M 12	50	100
2	M 16	100	250
3	M 20	160	450
4	M 22	190	650
5	M 24	220	800
6	M 27	290	1250
7	M 30	350	1650
8	M 36	510	2800

[a] Nuts as delivered by the manufacturer are treated with molybdenum disulfide or equivalent lubricant. In contrast with earlier requirements, the tightening torque is always the same, whatever the state when delivered.

Table 8

Required preloads, preloading torques and additional angles of rotation and values of rotation, resp. for the combined preloading method for HV-sets of k-class K1 for preloading according to DIN EN 1090-2

Combined method								
Sizes	M12	M16	M20	M22	M24	M27	M30	M36
Preload $F_{p,C} = 0{,}7 \cdot f_{ub} \cdot A_s$ [kN]	59	110	172	212	247	321	393	572
Pretightening torque M_A [Nm]	75	190	340	490	600	940	1240	2100

	Additional angle of rotation/value of rotation for total clamping length Σt		
	Total nominal thickness Σt of the parts joined (including all filler plates and washers)	Additional angle of rotation	Value of rotation
1	$\Sigma t < 2d$	60°	1/6
2	$2d \leq \Sigma t < 6d$	90°	1/4
3	$6d \leq \Sigma t < 10d$	120°	1/3

User guide for HV-bolt-sets

To ensure the standardized tightening performance and, in case of hot dip galvanized fastening elements also the thread fit, PEINER HV-bolts must only be assembled with PEINER HV-nuts and PEINER HV-washers.
PEINER HV-nuts are lubricated ready for assembly. Additional lubrication of the bolts, nuts or washers changes the preload characteristics and is a cause of assembly failure.

All fasteners of the same nominal size can be combined into sets but should have the same surface state (no „mixed applications", e.g., a as processed bolt and a hot dip galvanized nut).

Storage of HV-sets
The parts of a bolt-set for systematic preloading should be stored in such a way that their surface conditions and therefore the functional properties cannot be impaired (for example, due to corrosion or dirt/dust).
A set consists of any combination of a bolt, a nut and a washer from one manufacturer.

Arrangement of fastening elements
Washer: Face with the identification code showing towards the part chamfers towards the bolt head and the nut, respectively
Nut: Face with the identification code showing visibly outwards

Notes specifically for bolt connections of specified preload:

- When preload is applied by turning the bolt head, the specified preload should be obtained, for example, by checking the method for the preloading behavior by suitable lubrication of the bolt head-end washer or the contact area of the bolt head.
- For coatings of contact faces of SLV and SLVP connections, observe DIN 18800-7:2008-11, table 4. Preload losses can be compensated by retightening the bolted connection.
- If a specified preload set is opened, it should be removed and a new set installed. If for opened sets preloaded by the torque or impact wrench method it is shown that no permanent damage was done to the bolt during first preloading, that bolt can be preloaded with a new nut and a new washer from the same manufacturer. Our recommendation is: In case of opening an installed bolt tightened up to the full preload one usually does not know and cannot identify which tightening procedure has been applied before and whether the bolt sat perfectly in place or even has already got some plastic deformation. Therefore it is advisable to completely replace it anyway.

Bolt projection
In bolt connections with specified preload and in SL and SLP connections with additional tensile stress, at least one full thread should project beyond the nut after it is tightened fully.
According to DIN 18800-7:2008-11 it is sufficient for bolt connections without specified preload and without exposure to tensile stress if the bolt end is flush with the outer face of the nut.

Use of several washers on one side
To compensate the clamping length, up to three washers of a total thickness not exceeding 12 mm can be installed on the end which is not turned.

Permitted tilt of the supporting faces at the part against supporting faces of the bolt head and/or the nut
(Sum total of specified and production induced tilt)
With predominantly static load ≤ 4% (≈2°) (when tightened at the nut end), with not predominantly static load ≤ 2% (≈1°).
If the limits are exceeded, suitable wedge washers of sufficient hardness should be installed as compensation.
When U or I sections are bolted, suitable wedge washers according to DIN 6917 or DIN 6918 should be used (in addition to or instead of round washers according to DIN EN 14399-6).

Locking of bolted connections
Bolt connections of specified preload do not require additional safety precautions even under not predominantly static load.
(For a clamping length ratio $\sum t/d < 5$, possible transversal shifts should sufficiently be limited by design measures).

Oblong holes
Oblong holes and holes with specified oversize and shims (in addition to the washers) shall strictly be made to the specification of the original designer. Normally, special stability verification is required for these.

Use of HV-bolts in parts with female thread
Define the required depth of engagement according to DIN 18800-1:2008-11, El. (504).
Also consult VDI guideline 2230, if required.
To ensure a good thread fit of hot dip galvanized HV-bolts, make the female thread with oversize of tolerance class 6AZ in DIN EN ISO 10684. (Contact us, if necessary).