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Dimensions in mm

1 Scope

The Linde Standard (LS) specifies cases of application of anchor bolts for fastening vessels and similar equipment as well as steel structures to concrete foundations and to other concrete structures.

2 Normative references

The LS contains undated references to incorporate provisions of other publications and links to other applicable regulations for attention. The normative references are cited at the respective place in the text and the publications are listed below.

EN 1090 Series	Execution of steel structures and aluminum structures
EN 1992-4	Eurocode 2: Design of concrete structures - Part 4: Design of fastenings for use in concrete
EN 1993-1-1	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
EN 10025-2	Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
EN 10269	Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties
ACI 318-11	Building code requirements for structural concrete
LS 152-06	Insulation blocks for cold vessels
LS 201-19 Part 01	Supporting saddles for horizontal vessels and heat exchangers with fixed bundles Construction sheet and allowable loads
LS 201-19 Part 02	Supporting saddles for horizontal heat exchangers with removable bundles Construction sheet and allowable loads
LS 201-20	Supporting skirts for vertical vessels
LS 201-21	Templates holding anchor bolts in place
LS 443-01	Anchor bolts - Dimensions, materials and certification
LS 518-02	Anchoring of structural columns with shim

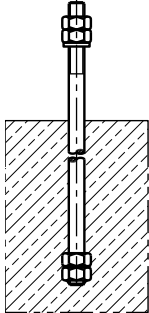
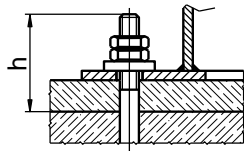
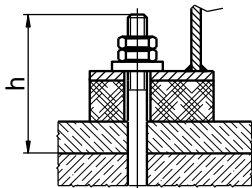
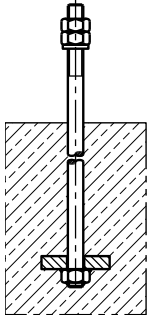
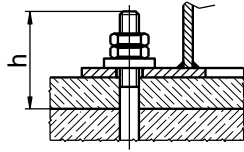
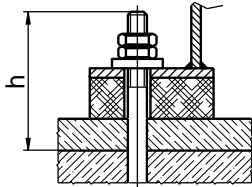
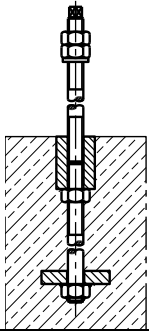
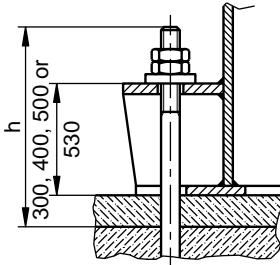
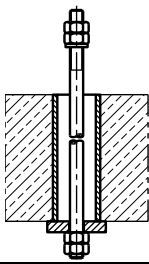
3 General

- All allowable loads are given in this standard are applicable to select the bolt dimensions only and are applicable for temperature $T < 100^{\circ}\text{C}$. (Please consider the note in Para. 6.1)
- The transmission of allowable anchor forces to the concrete structure shall be verified in a foundation analysis separately. All relevant fail causes for anchors shall be considered (steel failure, pullout, concrete breakout, side-face blowout, concrete splitting, concrete pry-out) and to counteract by an adequate reinforcement design
- Concrete Capacity Design (CCD) approach is the basis for the design of anchorages in ACI 318-11, appendix D 'Anchoring to concrete' and in EN 1992-4 (45° cone failure model, anchor groups, near-edge anchoring). Reinforcement is required to transfer the anchor loads into the concrete.
- For horizontal forces a shear lug shall be used, if necessary.

4 Types of anchor bolts with cases of application

(Dimensions of bolts according to LS 443-01)

Table 1: Types of bolts and cases of application

Type of bolt	Cases of application	Subdivision according to projection h above foundation before grouting	
<p>Type K</p> 	<p>a) Horizontal vessels</p> <p>b) Small vertical vessels with single base ring</p> <p>c) Light steel structure</p> <p>Bolt size \leq M30</p>	 <p>Case 1 Without insulation</p>  <p>Case 2 With insulation of 95 mm thickness for horizontal vessels according to LS 152-06</p>	
<p>Type K</p> 	<p>a) Large vertical vessels with single or with double base ring</p> <p>b) Columns</p> <p>c) Heavy steel structures</p> <p>Bolt size $>$ M30</p>	 <p>Case 1 Without insulation</p>  <p>Case 2 With insulation of 95 mm thickness for horizontal vessels according to LS 152-06</p>	
<p>Type KR</p> 	<p>In case, when bolts projecting above the foundation must be avoided (equipment erection at a later stage).</p>	 <p>Case 3 Vertical vessels and columns with double base ring 300, 400, 500 mm or 530 mm high according to LS 201-20 without insulation</p>	
<p>Type G</p> 	<p>Type G is used in concrete slabs and concrete beams, the thickness of which is not sufficient for anchoring according to type K.</p>	<p>All 3 cases are possible (see above). Additionally, there is an elongation required below the concrete.</p>	

5 Projections, spacing of anchor bolts

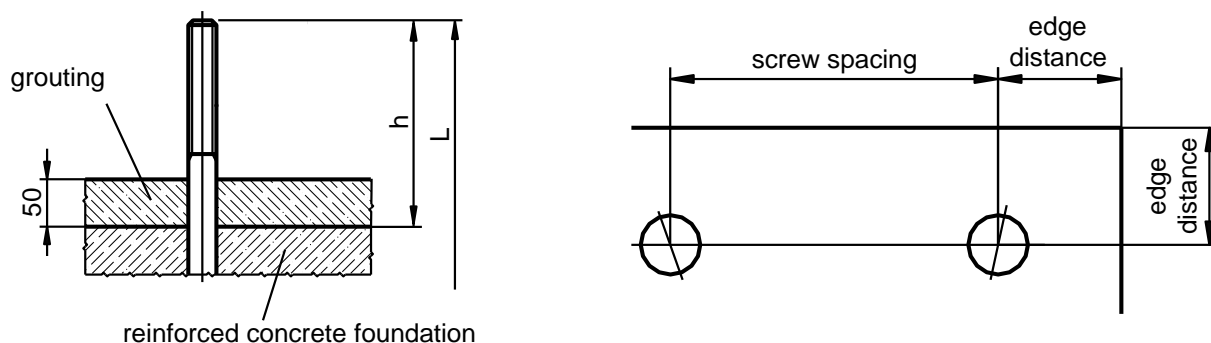


Figure 1: Definition of projecting length, spacing and edge distance of anchor bolts

5.1 Projections and recommended spacing of anchor bolts

Table 2: Projections, recommended spacing and lengths of anchor bolts

Bolt size	Projection h ¹⁾ above ungrounded concrete foundation for bolts type K, KR and G			Bolt projections for type G downward	Recommended spacing		Length of anchor bolts L	max. base plate thickness t _{max.} ²⁾
	Case 1	Case 2	Case 3		between 2 bolts	to the edge		
M 16	140	240	-	55	140	120	acc. to LS 443-01	30
M 20	150	250	430	60	160	150		30
M 24	160	260	435	65	200	150		35
M 30	190	290	460	75	250	200		50
M 36	210	310	470	92	300	250		60
M 42	230	330	490	102	340	300		60
M 48	250	-	510	115	390	300		70
M 56	270	-	530	125	450	400		70
M 64	-	-	650	-	520	400		80
M 72 x 6	-	-	670	-	590	500		-
M 80 x 6	-	-	800	-	640	500		-
M 90 x 6	-	-	820	-	720	600		-
M 100 x 6	-	-	880	-	800	600		-

¹⁾ For structural columns the indicated specified projections refers to a thickness of grouting of 50 mm (details see Figure 1).
²⁾ Design of anchoring of structural columns according to LS 518-02.

5.2 Minimum recommended spacing of bolts, minimum anchoring lengths

Follow minimum spacing and minimum anchoring lengths shall be used in the normal case:

- minimum anchoring lengths 12 x bolt diameters
- minimum edge distance 6 x bolt diameters
- minimum bolt spacing ³⁾ 8 x bolt diameters

³⁾ Exception: Supporting saddles for horizontal vessels when using 4 anchor bolts.
 Spacing between anchor bolts shall be kept according to LS 201-19 Part 01 and Part 02 supporting saddles for horizontal-type vessels.

Smaller bolt spacing is acceptable, if the necessary static analyses is provided.

6 Permissible tensile forces (design of values) for design of partial security concept (limit state)

6.1 Material

Table 3: Characteristically strength

Steel grade and property class	Standard	Bolt size	Yield strength resp. 0.2% proof strength, [N/mm ²]	Tensile strength, [N/mm ²]
S355	EN10025-2	≤ M16	355	470
		> M16 ≤ M 40	345	
		> M40 ≤ M56	335	
		> M56 ≤ M80	325	
		> M80 ≤ M100	315	
25CrMo4	EN 10269	≤ M100	440	600

With a loss of strength of concrete and elasticity of steel all characteristic yield strength loads in Table 3 shall be reduced for high temperature $T \geq 100 \text{ }^{\circ}\text{C}$.

6.2 Permissible tensile forces (N R, d) of anchor bolts and threaded bolts

The specified values in Table 4 are the design values of permissible tensile forces N R, d for bolts only according to EN 1993-1-1 (please consider the note in Para. 6.1).

All anchorage loads in concrete shall be verified separately and can reduce all permissible tensile forces.

Table 4: Permissible tensile forces ^{4) 5)}

Size	Area stress [mm ²]	Permissible tensile forces N R, d of material ¹⁾²⁾		Initial prestress forces F _v and tightening torques M _A ³⁾			
		S355	25CrMo4	S355		25CrMo4	
		[kN]	[kN]	F _{vmax} [kN]	M _A [Nm]	F _{vmax} [kN]	M _A [Nm]
M16	157	46	57	16.7	39.8	21.2	50.4
M20	245	70	89	25.4	75	33.1	97.8
M24	353	101	129	36.5	129	47.7	169
M30	561	160	206	58.1	259	75.7	337
M36	817	235	300	84.6	449	110	586
M42	1120	322	411	113	698	151	938
M48	1470	423	540	148	1050	194	1380
M56	2030	583	745	204	1680	268	2210
M64	2680	769	982	261	2420	353	3280
M72x6	3460	995	1270	338	3480	457	4710
M80x6	4340	1248	1593	424	4800	560	6350
M90x6	5590	1607	2052	528	6710	721	9160
M100x6	7000	2013	2570	661	9330	903	12736

- ¹⁾ For the alternative materials the same values shall be used, if no separate proof of materials properties can be provided.
- ²⁾ All permissible tensile forces can increase by 15% if anchor bolts are manufactured according to EN 1090
- ³⁾ The initial stress forces and tightening torques are calculated with the following parameters:
Utilization of the yield strength 30%; tightening factor = 1.6; coefficient for friction for the thread = 0.16; coefficient of friction for the support = 0.20.
- ⁴⁾ The specified allowable loads apply for bolts without horizontal loads only.
- ⁵⁾ Please consider the note in Para. 6.1

7 Installation

7.1 Installation of the anchor bolts for concreting

The anchor bolts shall be placed in the form work precisely in position, in elevation and in exactly vertical position, according to the form work drawings. The bolts shall be secured against movement during casting of concrete.

Any heat input on anchor bolts e.g. by welding or tack welding for the purpose of positioning or any other purpose shall be strictly omitted.

For the supply and the details of templates holding the anchor bolts in place during concreting see LS 201-21.

7.2 Tolerance

Final deviation of the anchor bolts from the position specified in the form work drawings, horizontally and vertically, shall not exceed ± 3 mm.

7.3 Specials

In the case of a large number of anchor bolts (12 or more) for vessels or columns the anchor bolts shall be installed in staggered elevations, to facilitate the placing of the vessel base ring over the anchor bolts. For this purpose, 4 anchor bolts which are offset from each other by 90° on the bolt circle will be installed 20 mm higher than shown in the form work drawing.

Where the foundation plate is substantially wider than the plinth carrying the vessel (e.g. in the case of tall columns), extension of the anchor bolts into the foundation plate shall be avoided, see Figure 2. For support of large diameter anchor bolts see LS 201-21.

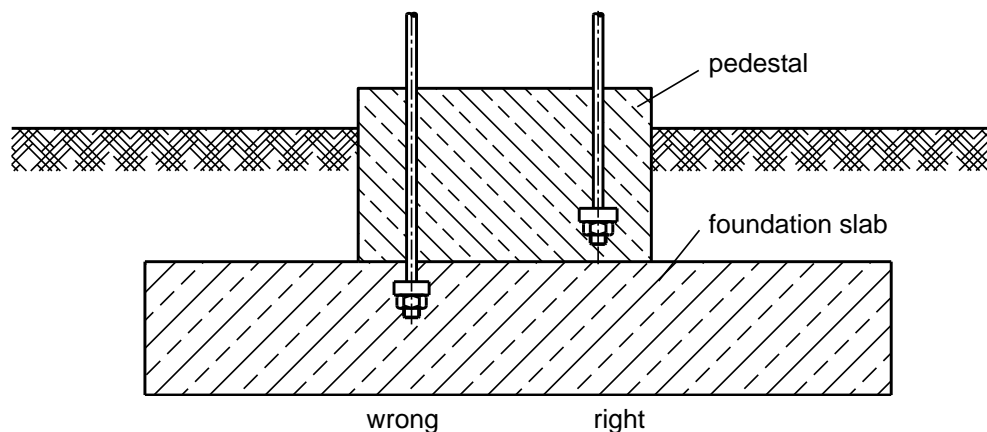


Figure 2: Anchor bolt positioning