ASDO

ANCHORS FOR MARINE STRUCTURES

M64 – M170 in accordance with EN1993-5

CE

Since 1920

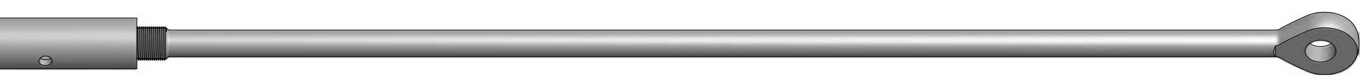
100 years steel tradition 1920–2020

ANKER SCHROEDER

ASDO steel tension members

ASDO ANCHORS FOR MARINE STRUCTURES

Anker Schroeder manufacture anchors for retaining structures such as quay walls, abutments, berths and crane runways. Our anchors range in diameter from M64 to M170 and can be supplied in grades 355, 460, 500 & 700. Anker Schroeder anchors are manufactured from round steel bar with forged or threaded ends that allow a variety of connections to be made to sheet piles, tubes, H-piles, combi-walls and diaphragm walls.



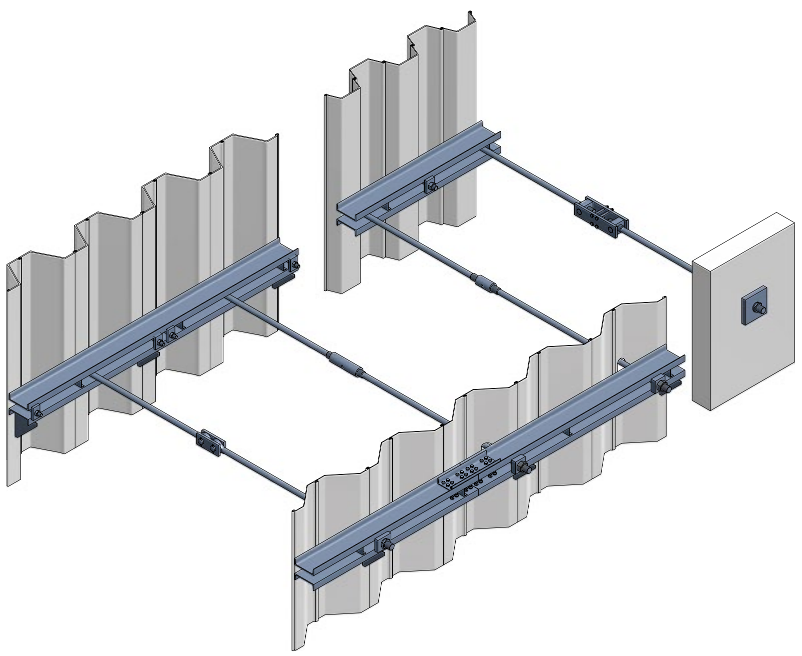
STEEL GRADES

Anker Schroeder offer 4 standard steel grades for tie bars:

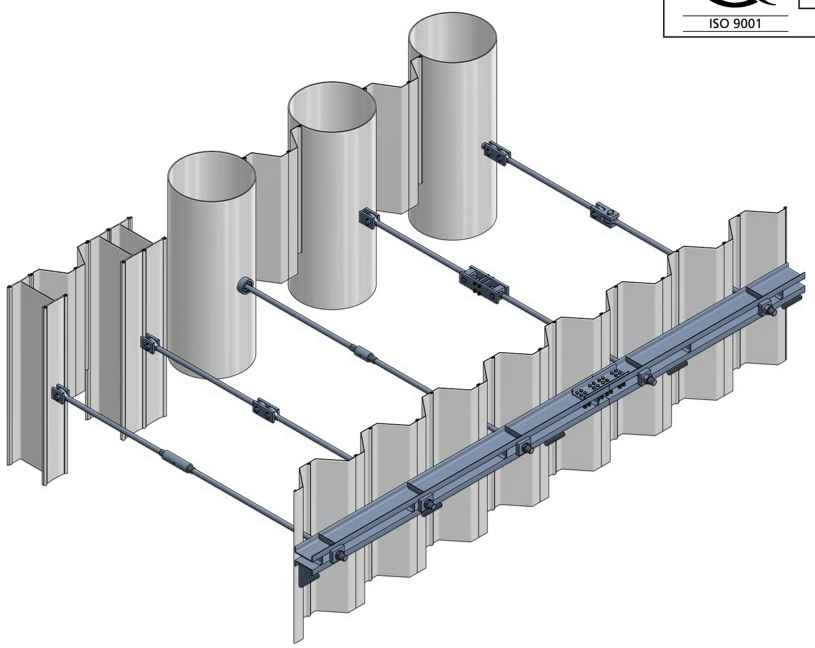
	Diameter	f_y N/mm²	f_{ua} N/mm²
ASDO355	M64 - M160	355	510
ASDO460	M64 - M165	460	610
ASDO500	M64 - M165	500	660
ASDO700	M64 - M170	700	900

The choice of steel grade depends on a number of factors, whilst the higher strength steel will always produce the lightest weight anchor this may not be suitable for stiffness requirements, onsite welding or lead-times. Other grades of steel are available please contact Anker Schroeder to discuss further.

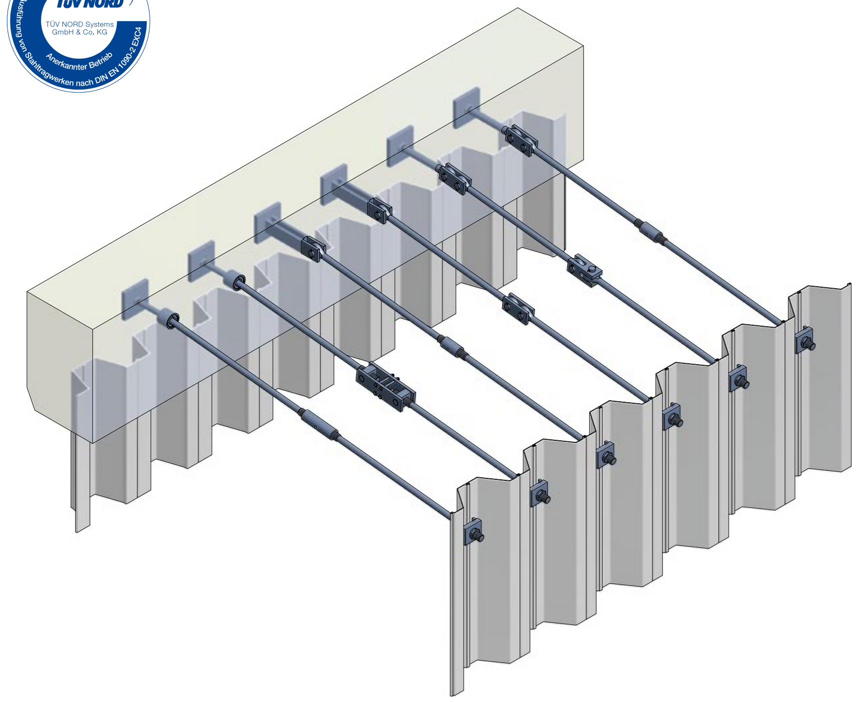
Depending on diameter and length required Anker Schroeder tie bars are manufactured using selected fine grained steel, high strength low alloy steel or quench and tempered steel. The choice of steel is dependent upon your specific project requirements but the above minimum properties will be met. All tie bars and components are manufactured to a quality system audited and accredited to ISO 9001 and meet the requirements of EN1090 and are CE marked (a legal requirement for supply into the European market).



Z-pile and U-pile solutions

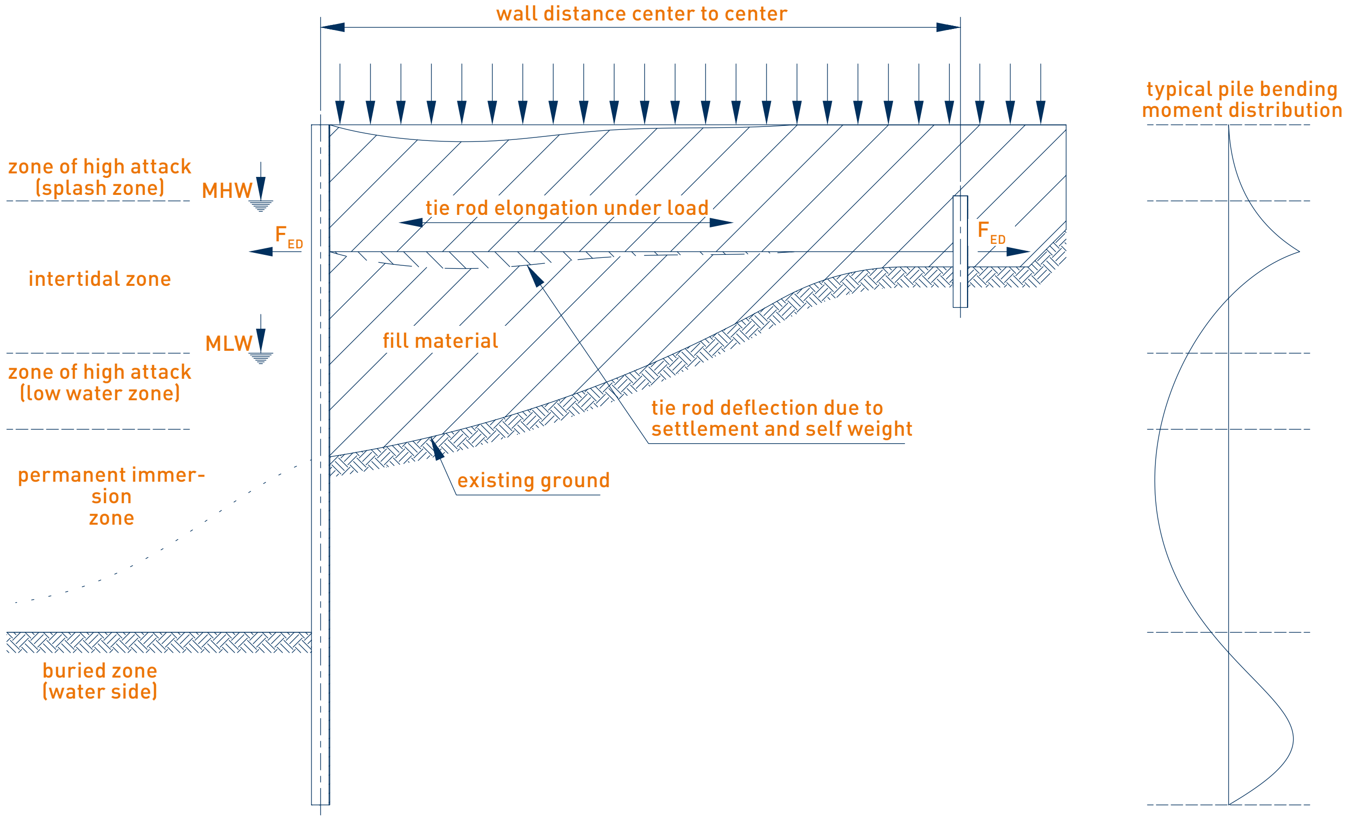


High modulus wall solutions



Concrete wall solutions

ASDO ANCHORS FOR MARINE STRUCTURES



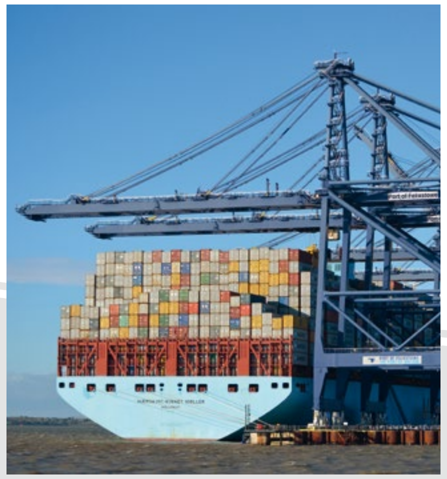
When designing anchors for retaining walls the following should be considered:

Design Resistance – the anchorage should be designed to provide sufficient design resistance to satisfy the design load required (note the design resistance is calculated differently between design codes).

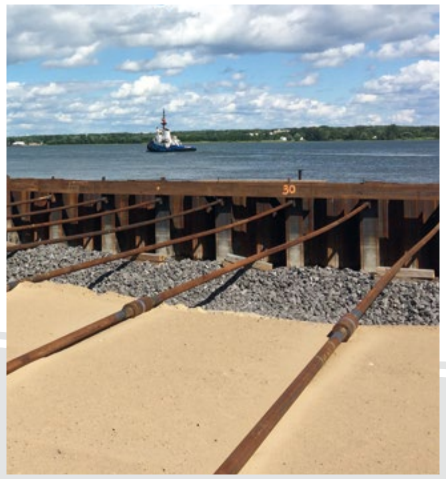
Steel Grade – there are various steel grades available today, some with very high strengths. Care should be taken when selecting a steel as grades with a nominal yield stress greater than 800N/mm^2 are not permitted according to clause 7.2.2 EN1993-5. Steels with nominal yields greater than 500N/mm^2 should be further assessed for durability according clause 3.7 EN1993-5 - please contact our technical department for more information.

Serviceability – the elongation of the anchors under the serviceability load may be the limiting factor rather than design resistance particularly where large crane loads have to be accommodated. Stiffness of an anchor is a function of the shaft diameter and subsequently a higher grade tie bar (e.g. ASDO700) may not be the most suitable. Movement under imposed loads may be reduced in many cases by pre-loading the anchors at the time of installation to develop the passive resistance of the ground.

Pre-loading of the anchor is most easily achieved at a threaded end of the anchor by means of a hydraulic jack, consideration to the practicality of this should be made at design stage.



Felixstowe Docks, UK



Port de Trois-Rivières, Canada

Stressing operation

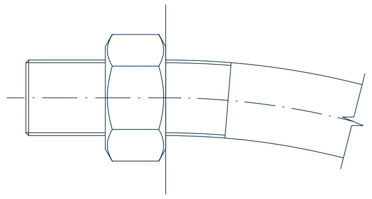
DESIGN CONSIDERATIONS

Settlement – the effect of sag of the anchor and forced deflection due to settlement of fill may induce significant bending stresses at a fixed anchorage and increase the tensile stress in the tie rod locally. Shear stresses may also be induced into the thread if a tie rod is displaced when the fill settles causing compound stresses which must be allowed for in the detailed design. This can often be overcome by provision of articulated joints at connections to the wall.

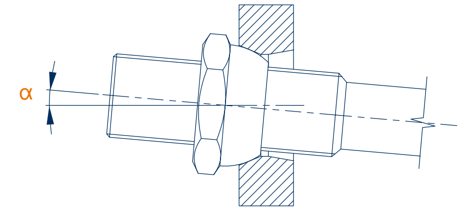
Whether a connection is articulated or fixed will affect the design resistance of the tie bar. If connections are fixed then a greater thread size must be used to accommodate any bending introduced to the anchor.

Settlement ducts can also be installed to reduce bending at the connection however these can be difficult and expensive to install and, if not aligned correctly, will not prevent settlement bending being introduced. If settlement ducts are used articulation at the wall connection is recommended to prevent bending due to the self weight of the bar as the duct moves. Further corrosion protection systems (such as wrapping) are essential particularly where there is a possibility of the duct acting as a conduit for seawater. Please contact our technical department for more information.

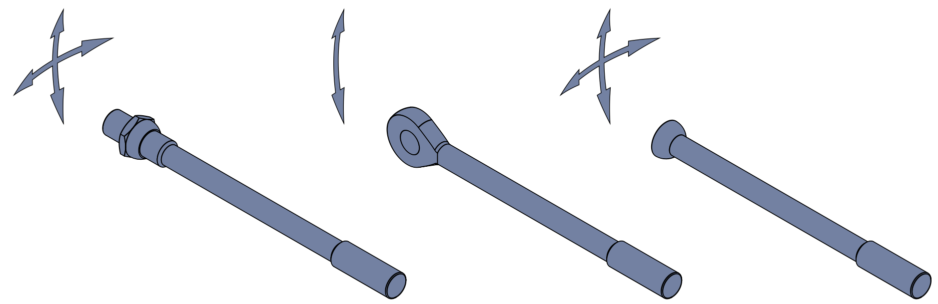
Corrosion protection system
Anchor ties are typically used in aggressive environments and consequently corrosion protection factors influencing effective life must be considered. Consideration of the corrosion protection of the anchors at design stage and in particular the connection to the front wall is important as the anchor is typically subjected to the most aggressive environment at this point. Options include sacrificial steel, protective tape or coating systems. In most cases sacrificial steel provides the more economic and robust form of corrosion protection – see page 24 for more detail.



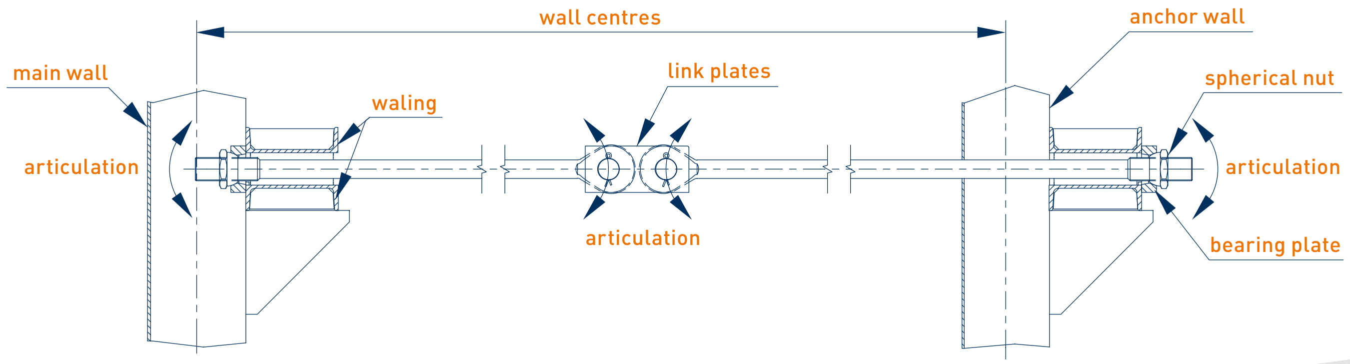
Bending stress induced by settlement or misalignment



Articulation removes bending stress at connection α < 7°



Typical articulated end solutions by Anker Schroeder: Thread and spherical nut | Forged eye | Forged spherical end

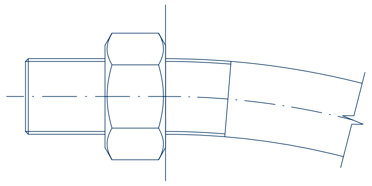


TENSILE RESISTANCE OF TIE BARS

In accordance with EN1993-5 the tensile resistance $F_{t,Rd}$ of an anchor is calculated as the lesser of the tensile resistance of the thread, $F_{tt,Rd}$ or the tensile resistance of the shaft, $F_{tg,Rd}$ at any time during the life of the structure.

$$F_{t,Rd} = \text{lesser of:} \quad F_{tg,Rd} = A_g \times f_y / \gamma_{M0} \qquad F_{tt,Rd} = k_t \times f_{ua} \times A_S / \gamma_{M2}$$

A_s = tensile stress area of thread
A_g = gross cross sectional area of anchor
f_y = yield strength of anchor material
f_{ua} = tensile strength of anchor material
k_t = a reduction factor allowing for combined bending and tension in the thread (typically 0.6 where bending at the connection must be considered and 0.9 where structural detailing eliminates bending at the connection)
γ_{M0} & γ_{M2} = partial factors accord. EN1993 typically 1.0 & 1.25 respectively



Bending stress in thread induced by settlement or misalignment

It is important to note that the thread capacity of an anchor is reduced by the factor k_t. According to EN1993-5 this is to allow for additional stresses that may be introduced due to settlement of fill or installation in less than ideal conditions.

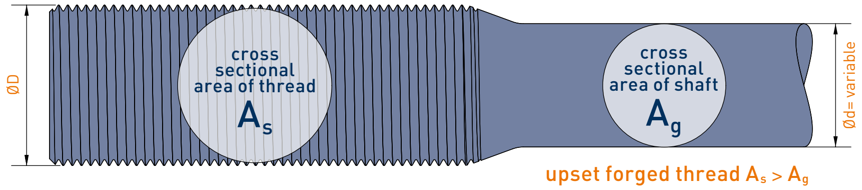
In accordance with many EN1993-5 National Annexes a conservative k_t value of 0.6 should be used unless structural detailing at the connection eliminates any possible bending when 0.9 can be used. However fully eliminating bending can be difficult, often settlement ducts are used but typical site conditions hinder proper installation of these as well as failing to provide restraint to the bending introduced by the self weight of the anchor as the duct moves with the fill.

Alignment of anchors, especially for diaphragm walls, is also difficult along with accurate prediction of settlement. Therefore Anker Schroeder recommend that a k_t factor of k_t 0.6 is used in combination with articulated connections, this can also have benefits for corrosion resistance – see page 24.

It is for this reason Anker Schroeder have developed a full range of upset forged ends for tie bars. Upset forging allows threads to be increased in size with little additional weight being added to the anchor. By increasing the thread diameter bending stresses can be minimised and sacrificial steel can be easily added to the threaded portion, often the most vulnerable part of an anchor.

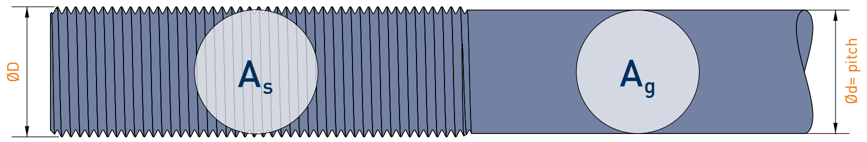
Only upset forged threads ensure that the shaft is the weakest part of a tiebar anchor. This has benefits as, in the unfortunate event of structural failure, the shaft will realise it's full elongation capacity giving greater warning of serviceability failure of the pile wall.

Upset threads can also have benefit for seismic design giving greater safety factor to connections and ensuring maximum elongation takes place along the whole tie rod length during a seismic event.



upset forged thread $A_s > A_g$
variable ratio A_s / A_g

Upset forged thread advantage – stress area of thread > stress area of shaft



standard rolled thread $A_s = A_g$
fixed ratio A_s / A_g

DESIGN CONSIDERATIONS

Upset forging

Unlike traditional forging in which a parent metal is heated and forged into a smaller dimension upset forging is a process by which parent metal is increased in sectional area. In the case of anchors this allows the ends of a bar to be increased in section and threads cut or rolled onto the forged cylinder. The same process can also be used to form articulated ends such as eyes or spherical ends.

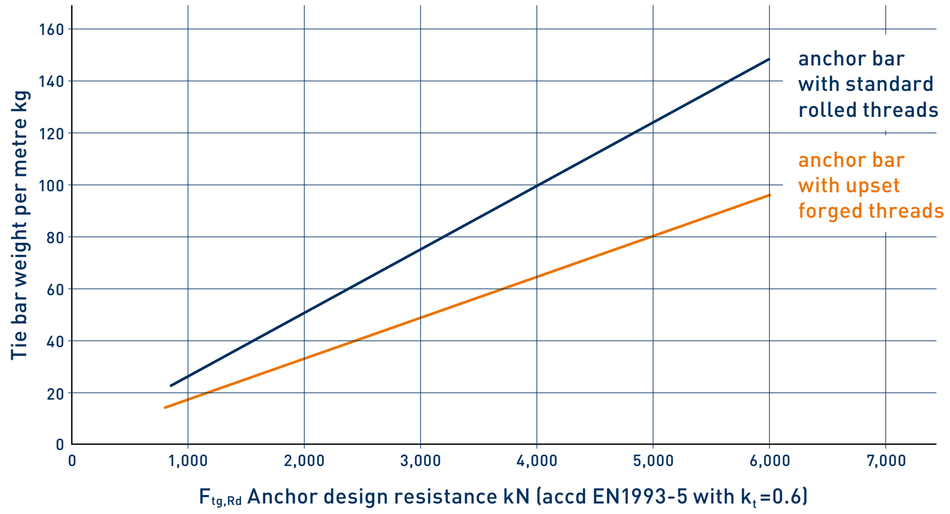
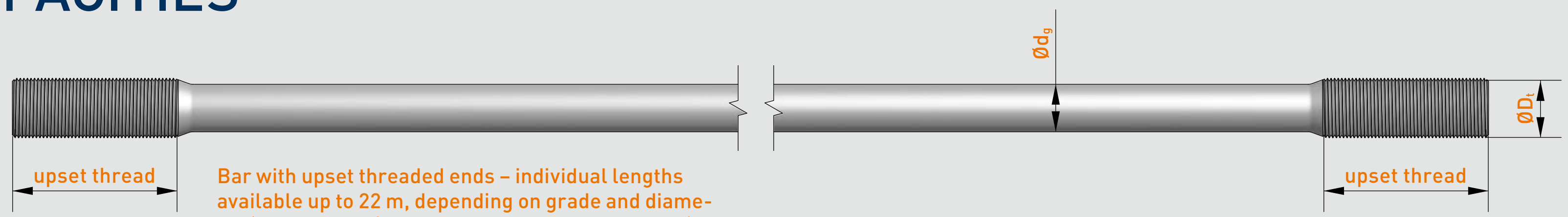


Chart showing the weight per metre advantage for upset forged anchors compared to standard threaded anchors.

ASDO ANCHOR DESIGN CAPACITIES



Bar with upset threaded ends – individual lengths available up to 22 m, depending on grade and diameter (turnbuckles/couplers used for longer lengths).

Table 2 – Anchors with upset forged threads

Nominal upset thread diameter	$ØD_t$	Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	$ØD_t$
Thread tensile stress area	A_s	mm²	2,676	3,055	3,460	3,889	4,344	4,948	5,591	6,273	6,995	7,755	8,556	9,395	10,274	11,191	12,149	13,145	14,181	15,256	16,370	17,524	18,716	19,948	21,220	A_s
Shaft diameters available*	All grades	mm	48-56	52-60	52-64	56-68	60-72	64-76	68-80	72-86	76-90	80-95	85-100	85-105	95-110	95-115	100-120	105-125	105-130	110-135	115-140	120-145	125-150	125-155	130-160	All grades

ASDO355 – Tensile resistance (EN1993-5)

ASDO355		Anchor code		ASDO355 -																							
	k_t = 0.6	Anchor code		ASDO355 -	M64/48	M68/52	M72/56	M76/60	M80/64	M85/68	M90/72	M95/75	M100/80	M105/85	M110/90	M115/90	M120/95	M125/100	M130/105	M135/110	M140/115	M145/115	M150/120	M155/125	M160/130	M165+	
		Optimum shaft diameter	$Ød_g$	mm	48	52	56	60	64	68	72	75	80	85	90	90	95	100	105	110	115	115	120	125	130		$Ød_g$
		Shaft gross area	A_g	mm²	1,810	2,124	2,463	2,827	3,217	3,632	4,072	4,418	5,027	5,675	6,362	6,362	7,088	7,854	8,659	9,503	10,387	10,387	11,310	12,272	13,273		A_g
		Shaft yield capacity	F_y	kN	642	754	874	1,004	1,142	1,289	1,445	1,568	1,784	2,014	2,258	2,258	2,516	2,788	3,074	3,374	3,687	3,687	4,015	4,357	4,712	larger diameters at request	F_y
		Shaft ultimate capacity	F_{ua}	kN	923	1,083	1,256	1,442	1,641	1,852	2,076	2,253	2,564	2,894	3,244	3,244	3,615	4,006	4,416	4,847	5,297	5,297	5,768	6,259	6,769		F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	642	748	847	952	1,063	1,211	1,369	1,536	1,712	1,899	2,094	2,258	2,515	2,740	2,974	3,218	3,471	3,687	4,007	4,290	4,582		$F_{t,Rd}$
	k_t = 0.9	Anchor code		ASDO355 -	M64/56	M68/60	M72/64	M76/68	M80/72	M85/75	M90/80	M95/85	M100/90	M105/95	M110/100	M115/105	M120/110	M125/115	M130/120	M135/125	M140/130	M145/135	M150/140	M155/145	M160/150	M165+	
		Optimum shaft diameter	$Ød_g$	mm	56	60	64	68	72	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150		$Ød_g$
		Shaft gross area	A_g	mm²	2,463	2,827	3,217	3,632	4,072	4,418	5,027	5,675	6,362	7,088	7,854	8,659	9,503	10,387	11,310	12,272	13,273	14,314	15,394	16,513	17,671		A_g
		Shaft yield capacity	F_y	kN	874	1,004	1,142	1,289	1,445	1,568	1,784	2,014	2,258	2,516	2,788	3,074	3,374	3,687	4,015	4,357	4,712	5,081	5,465	5,862	6,273	larger diameters at request	F_y
		Shaft ultimate capacity	F_{ua}	kN	1,256	1,442	1,641	1,852	2,076	2,253	2,564	2,894	3,244	3,615	4,006	4,416	4,847	5,297	5,768	6,259	6,769	7,300	7,851	8,422	9,012		F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	847	952	1,063	1,211	1,369	1,536	1,712	1,899	2,258	2,515	2,740	2,974	3,218	3,687	4,007	4,290	4,582	4,883	5,465	5,846	6,186		$F_{t,Rd}$

ASDO460 – Tensile resistance (EN1993-5)

ASDO460																											
	k_t = 0.6	Anchor code		ASDO460 -	M64/48	M68/52	M72/52	M76/56	M80/60	M85/64	M90/68	M95/72	M100/76	M105/80	M110/85	M115/90	M120/90	M125/95	M130/100	M135/105	M140/110	M145/115	M150/115	M155/120	M160/125	M165/130	M170+
		Optimum shaft diameter	$Ød_g$	mm	48	52	52	56	60	64	68	72	76	80	85	90	90	95	100	105	110	115	115	120	125	130	$Ød_g$
		Shaft gross area	A_g	mm²	1,810	2,124	2,124	2,463	2,827	3,217	3,632	4,072	4,536	5,027	5,675	6,362	6,362	7,088	7,854	8,659	9,503	10,387	10,387	11,310	12,272	13,273	A_g
		Shaft yield capacity	F_y	kN	832	977	977	1,133	1,301	1,480	1,671	1,873	2,087	2,312	2,610	2,926	2,926	3,261	3,613	3,983	4,372	4,778	4,778	5,202	5,645	6,106	larger diameters at request F_y
		Shaft ultimate capacity	F_{ua}	kN	1,104	1,295	1,295	1,502	1,725	1,962	2,215	2,484	2,767	3,066	3,461	3,881	3,881	4,324	4,791	5,282	5,797	6,336	6,336	6,899	7,486	8,097	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	784	895	977	1,133	1,272	1,449	1,637	1,837	2,048	2,271	2,505	2,751	2,926	3,261	3,557	3,849	4,152	4,467	4,778	5,131	5,480	5,841	$F_{t,Rd}$
	k_t = 0.9	Anchor code		ASDO460 -	M64/56	M68/60	M72/64	M76/68	M80/72	M85/76	M90/80	M95/85	M100/90	M105/95	M110/100	M115/105	M120/110	M125/115	M130/120	M135/125	M140/130	M145/135	M150/140	M155/145	M160/150	M165/155	M170+
		Optimum shaft diameter	$Ød_g$	mm	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	$Ød_g$
		Shaft gross area	A_g	mm²	2,463	2,827	3,217	3,632	4,072	4,536	5,027	5,675	6,362	7,088	7,854	8,659	9,503	10,387	11,310	12,272	13,273	14,314	15,394	16,513	17,671	18,869	A_g
		Shaft yield capacity	F_y	kN	1,133	1,301	1,480	1,671	1,873	2,087	2,312	2,610	2,926	3,261	3,613	3,983	4,372	4,778	5,202	5,645	6,106	6,584	7,081	7,596	8,129	8,680	larger diameters at request F_y
		Shaft ultimate capacity	F_{ua}	kN	1,502	1,725	1,962	2,215	2,484	2,767	3,066	3,461	3,881	4,324	4,791	5,282	5,797	6,336	6,899	7,486	8,097	8,731	9,390	10,073	10,780	11,510	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	1,133	1,272	1,449	1,637	1,837	2,048	2,271	2,505	2,926	3,261	3,557	3,849	4,152	4,778	5,131	5,480	5,841	6,584	6,992	7,399	7,817	8,680	$F_{t,Rd}$

ASDO500 – Tensile resistance (EN1993-5)

ASDO500																											
	k_t = 0.6	Anchor code		ASDO500 -	M64/48	M68/52	M72/52	M76/56	M80/60	M85/64	M90/68	M95/72	M100/76	M105/80	M110/85	M115/90	M120/90	M125/95	M130/100	M135/105	M140/110	M145/110	M150/115	M155/120	M160/125	M165/130	M170+
		Optimum shaft diameter	$Ød_g$	mm	48	52	52	56	60	64	68	72	76	80	85	90	90	95	100	105	110	110	115	120	125	130	$Ød_g$
		Shaft gross area	A_g	mm²	1,810	2,124	2,124	2,463	2,827	3,117	3,632	4,072	4,536	5,027	5,675	6,362	6,362	7,088	7,854	8,659	9,503	9,503	10,387	11,310	12,272	13,273	A_g
		Shaft yield capacity	F_y	kN	905	1,062	1,062	1,232	1,414	1,559	1,816	2,036	2,268	2,513	2,837	3,181	3,181	3,544	3,927	4,330	4,752	4,752	5,193	5,655	6,136	6,637	larger diameters at request F_y
		Shaft ultimate capacity	F_{ua}	kN	1,194	1,402	1,402	1,626	1,866	2,057	2,397	2,687	2,994	3,318	3,745	4,199	4,199	4,678	5,184	5,715	6,272	6,272	6,855	7,464	8,099	8,760	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	848	968	1,062	1,232	1,376	1,559	1,771	1,987	2,216	2,457	2,710	2,976	3,181	3,544	3,849	4,164	4,492	4,752	5,186	5,551	5,929	6,320	$F_{t,Rd}$
	k_t = 0.9	Anchor code		ASDO500 -	M64/56	M68/60	M72/64	M76/68	M80/72	M85/76	M90/80	M95/85	M100/90	M105/95	M110/100	M115/105	M120/110	M125/115	M130/120	M135/125	M140/130	M145/135	M150/140	M155/145	M160/150	M165/155	M170+
		Optimum shaft diameter	$Ød_g$	mm	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	$Ød_g$
		Shaft gross area	A_g	mm²	2,463	2,827	3,217	3,632	4,072	4,536	5,027	5,675	6,362	7,088	7,854	8,659	9,503	10,387	11,310	12,272	13,273	14,314	15,394	16,513	17,671	18,869	A_g
		Shaft yield capacity	F_y	kN	1,232	1,414	1,608	1,816	2,036	2,268	2,513	2,837	3,181	3,544	3,927	4,330	4,752	5,193	5,655	6,136	6,637	7,157	7,697	8,256	8,836	9,435	larger diameters at request F_y
		Shaft ultimate capacity	F_{ua}	kN	1,626	1,866	2,123	2,397	2,687	2,994	3,318	3,745	4,199	4,678	5,184	5,715	6,272	6,855	7,464	8,099	8,760	9,447	10,160	10,899	11,663	12,454	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	1,232	1,376	1,567	1,771	1,987	2,216	2,457	2,710	3,181	3,544	3,849	4,164	4,752	5,186	5,551	5,929	6,320	7,138	7,565	8,005	8,836	9,400	$F_{t,Rd}$

ASDO700 – Tensile resistance (note - according to clause 3.7 of EN1993-5 : 2007 grades with $f_{y,spec}$ > 500N/mm² should be corrosion protected)

ASDO700																												
	k_t = 0.6	Anchor code		ASDO700 -	M64/48	M68/52	M72/52	M76/56	M80/60	M85/64	M90/68	M95/72	M100/76	M105/80	M110/85	M115/85	M120/90	M125/95	M130/100	M135/105	M140/105	M145/110	M150/115	M155/120	M160/125	M165/125	M170/130	
		Optimum shaft diameter	$Ød_g$	mm	48	52	52	56	60	64	68	72	76	80	85	85	90	95	100	105	105	110	115	120	125	125	130	$Ød_g$
		Shaft gross area	A_g	mm²	1,810	2,124	2,124	2,463	2,827	3,217	3,632	4,072	4,536	5,027	5,675	5,675	6,362	7,088	7,854	8,659	8,659	9,503	10,387	11,310	12,272	12,272	13,273	A_g
		Shaft yield capacity	F_y	kN	1,267	1,487	1,487	1,724	1,979	2,252	2,542	2,850	3,176	3,519	3,972	3,972	4,453	4,962	5,498	6,061	6,061	6,652	7,271	7,917	8,590	8,590	9,291	F_y
		Shaft ultimate capacity	F_{ua}	kN	1,629	1,911	1,911	2,217	2,545	2,895	3,269	3,664	4,083	4,524	5,107	5,107	5,726	6,379	7,069	7,793	7,793	8,553	9,348	10,179	11,045	11,045	11,946	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	1,156	1,320	1,487	1,680	1,877	2,137	2,415	2,710	3,022	3,350	3,696	3,972	4,438	4,835	5,248	5,679	6,061	6,590	7,072	7,570	8,085	8,590	9,167	$F_{t,Rd}$
	k_t = 0.9	Anchor code		ASDO700 -	M64/56	M68/60	M72/64	M76/68	M80/72	M85/76	M90/80	M95/85	M100/90	M105/95	M110/100	M115/105	M120/110	M125/115	M130/120	M135/125	M140/130	M145/135	M150/140	M155/145	M160/150	M165/155	M170/160	
		Optimum shaft diameter	$Ød_g$	mm	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	$Ød_g$
		Shaft gross area	A_g	mm²	2,463	2,827	3,217	3,632	4,072	4,536	5,027	5,675	6,362	7,088	7,854	8,659	9,503	10,387	11,310	12,272	13,273	14,314	15,394	16,513	17,671	18,869	20,106	A_g
		Shaft yield capacity	F_y	kN	1,724	1,979	2,252	2,542	2,850	3,176	3,519	3,972	4,453	4,962	5,498	6,061	6,652	7,271	7,917	8,590	9,291	10,020	10,776	11,559	12,370	13,208	14,074	F_y
		Shaft ultimate capacity	F_{ua}	kN	2,217	2,545	2,895	3,269	3,664	4,083	4,524	5,107	5,726	6,379	7,069	7,793	8,553	9,348	10,179	11,045	11,946	12,882	13,854	14,862	15,904	16,982	18,096	F_{ua}
		Tensile resistance	$F_{t,Rd}$	kN	1,680	1,877	2,137	2,415	2,710	3,022	3,350	3,972	4,438	4,835	5,248	6,061	6,590	7,072	7,570	8,590	9,167	9,733	10,316	11,533	12,167	12,818	13,486	$F_{t,Rd}$

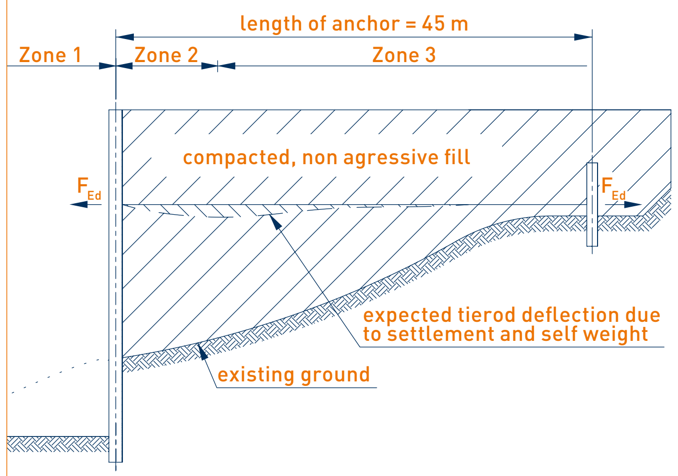
*Note: The above sizes are standardised, other shaft and thread ratios can be adapted to suit your project requirements, e.g. for sacrificial steel requirements or smaller design loads, design resistance calculated as per EN1993-5 with γ_{M0} = 1.0 & γ_{M2} = 1.25 and k_t as noted.

ASDO ANCHOR DESIGN CAPACITIES

Table 3 – Forged eye (all grades)

Nominal shaft diameter	$Ød_s$	mm	48	52	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	$Ød_s$
Eye ref		inches	2 1/2	2 3/4	3	3	3 1/4	3 1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2	
Eye thickness	T_e	mm	42	47	50	50	55	60	60	63	66	72	75	80	85	90	95	100	105	115	120	T_e
Eye length	L_e	mm	162	177	204	207	214	227	227	248	262	289	312	332	340	357	370	382	412	440	460	L_e
Eye width	W_e	mm	125	135	155	155	165	180	180	190	210	230	240	255	270	275	290	300	310	330	340	W_e
Pin diameter		mm	50	55	60	60	64	72	72	75	80	85	90	95	100	100	110	115	120	125	130	

Design example



Design criteria:
Design ultimate load for anchor, F_{Ed} = 2,200 kN

Tie bar length = 45 m (calculated in accordance with EN1997)

Serviceability characteristic load, $F_{t,ser}$ = 1,600 kN

Tie bar extension limit = 100 mm

Design life structure = 50 years

Thread notch factor - use recommended value k_t = 0.6
(see EN1993-5 National UK Annex)

Size selection
Minimum Anchor size required – Clause 7.2.3 EN1993-5

From table 2 grade ASDO500, k_t = 0.6 select M100/76 anchor

Design tensile resistance $F_{t,Rd}$ = 2,216 kN > 2,200 kN ∴ OK

Thread = M100 (stress area, A_s = 6,995 mm²)
Shaft = 75 mm diameter (stress area A_g = 4,536 mm²)
f_y = 500 N/mm², f_{ua} = 660 N/mm²

Note: Clause 7.2.3(4) EN1993-5 states that the design provisions given do not cover the occurrence of bending in the thread. It is recommended by EN1993 & EAU that connections to the wall be articulated to provide sufficient rotation tolerance (further articulation at points of maximum bending along the bar should also be considered).

Further checks may be required for combined bending and axial load checks in both the thread and shaft due to settlement of the fill. The use of upset threads and a k_t factor of 0.6 will give greater capacity in the areas of likely bending giving a greater safety factor. For the above example the tie bar arrangement in the figure opposite can be made.

Serviceability check
Elongation under axial characteristic loading

$F_{t,ser}$ = 1,600 kN

Stress in shaft = $\dfrac{1{,}600 \times 10^3}{4{,}536}$ = 353 N/mm²

Elongation = $\dfrac{353 \times 45{,}000}{210 \times 10^3}$ = 76 mm < 100 mm ∴ OK

Where elastic modulus = 210 kN/m²

Hint – if the elongation is too great try a larger diameter of a lesser grade.

Serviceability limit state – Clause 7.2.4 EN1993-5

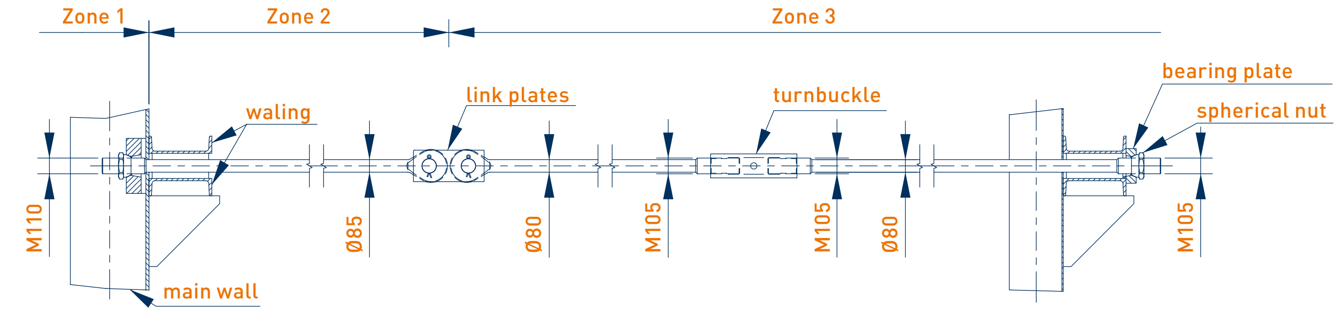
The required additional check for serviceability in this example is already implied in the resistance check $F_{Rd} < F_{Ed}$ as a k_t factor of 0.6 has been used, however it is performed here for information.

$F_{t,ser} \leq \dfrac{f_y A_s}{\gamma M_{t,ser}}$ where A_s is the lesser of shaft area or thread area

$1{,}600 \text{ kN} \leq \dfrac{500 \times 4{,}536}{1.1 \times 10^3} \leq 2{,}062 \text{ kN}$ ∴ OK

Corrosion resistance – for robustness and simplicity in handling and installation use sacrificial steel. The tie bar is split into zones
as per the diagram below. The corrosion rate assumed for each
zone depends on local conditions, or the guidance given in EN1993-5 can be considered. The rates given below are for example only.

Each zone is considered in turn and the expected corrosion rate added to the minimum size, as per the table below. Note the corrosion rate assumed for zone one can be reduced considerably by placing the anchor connection head behind the sheet pile pan as shown on page 12 and detail Z page 20.



Zone	Description	Environment	Corrosion allowance	Min. size including corrosion allowance		Nearest standard size	
				Thread	shaft	Thread	shaft
1	Anchor head	Splash zone, aggressive	3.75 mm (from table 4.2 EN1993-5)	107.5	83.5 mm	M110	85 mm
2	Immediately behind wall	Non-aggressive compacted fill, possibility of seawater entering through connection to front wall	2.0 mm (assumed)	-	80 mm	-	85 mm (same bar as zone 1)
3	Remainder of tie bar	Non-aggressive compacted fill	1.2 mm (from table 4.1 EN1993-5, compaction reduction ignored for conservatism)	102.4	78.4 mm	M105	80 mm

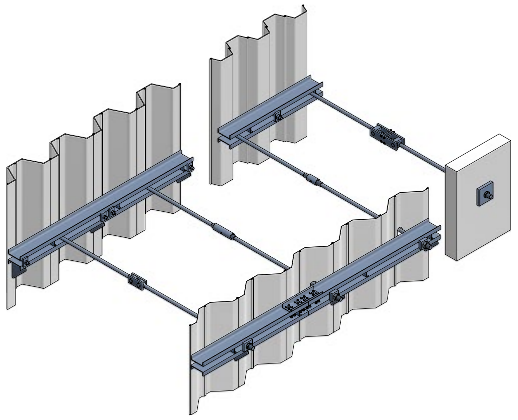
Final specification
As a minimum the following information is required in order to specify the anchors correctly.

Anchors:

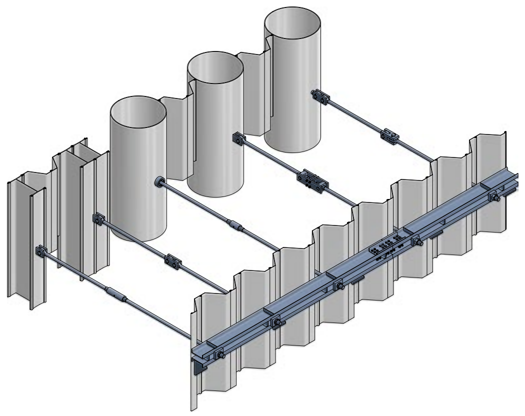
Grade ASDO500 - M110/85, M105/80 with articulated connections, turnbuckles and length as indicated on drawing
Minimum design resistance, $F_{t,Rd}$ = 2,200 kN (after corrosion losses)
k_t = 0.6 (in accordance with EN1993-5)
f_y = 500 N/mm²
f_{ua} = 660 N/mm²
Corrosion protection = sacrificial steel to all bars and components as indicated

TYPICAL CONNECTIONS

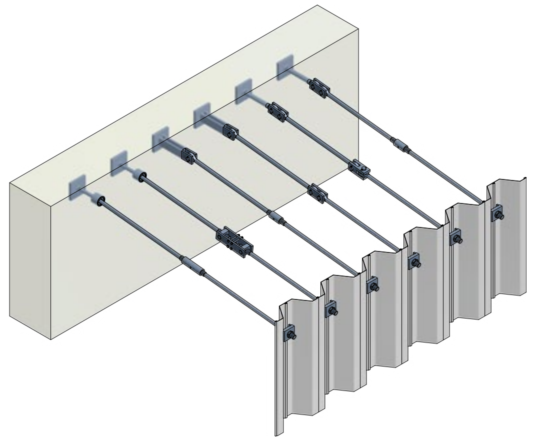
Connections to sheet piles
Forces are transferred from the sheet pile to the anchor bar through waling sections that run the length of the wall. At the front wall these are normally placed behind the wall (i.e. earth side) and at the anchor wall the non-bearing side.



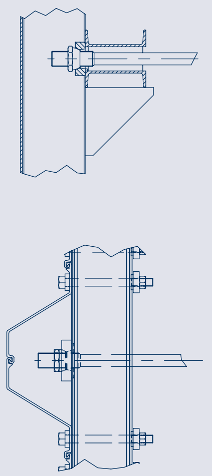
Connections to high modulus piles
Anchor forces are generally high and articulated connections are recommended to minimize bending at the connection. Articulation can be provided that allows movement in the vertical direction or in all directions.



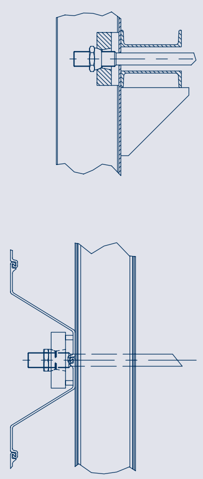
Connections to concrete walls
Alignment between the front wall and anchor wall connection points is critical. Simple articulated connections allow easy casting into the wall without difficult interruption to formwork and allow easy connection once the wall has cured. Articulated joints are strongly recommended to aid installation.



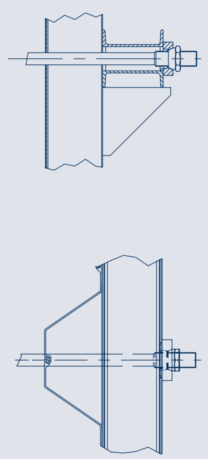
Steel Z-pile with spherical nut (articulated)



Anchor connection to inside of pile pan
Sheet pile loads are transferred to the waling via waling bolts, then to the anchor by a spherical bearing plate and nut. The connection is placed inside the pan giving greater corrosion protection.

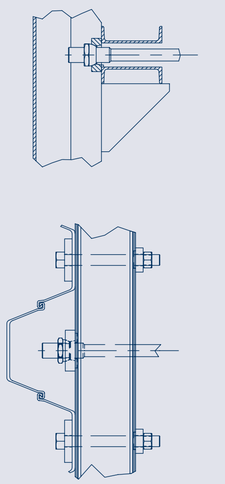


Anchor connection to outside of pile pan
Sheet pile loads are transferred directly to the anchor. This has the advantage that less waling bolts are required, but the anchor connection is placed outside the wall in the aggressive corrosion zone.

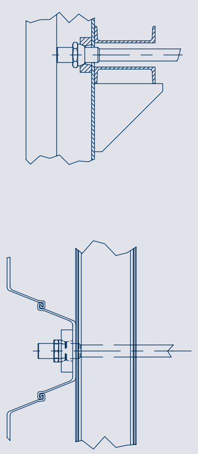


Anchor wall connection
Anchor forces are transferred directly to the anchor wall via the waling. Generally waling bolts are not required.

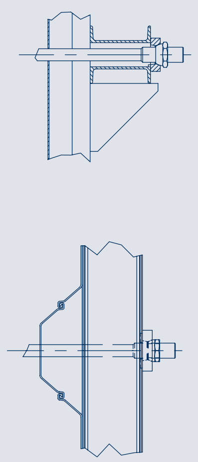
Steel U-pile with spherical nut (articulated)



Anchor connection to inside of pile pan
Sheet pile loads are transferred to the waling via waling bolts, then to the anchor by a spherical bearing plate and nut. The connection is placed inside the pan giving greater corrosion protection.

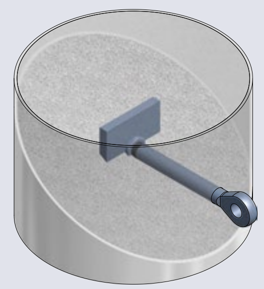


Anchor connection to outside of pile pan
Sheet pile loads are transferred directly to the anchor. This has the advantage that less waling bolts are required, but the anchor connection is placed outside the wall in the aggressive corrosion zone.

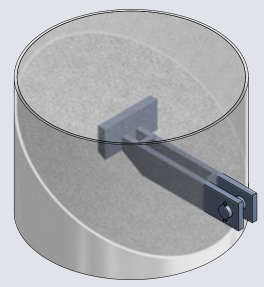


Anchor wall connection
Anchor forces are transferred directly to the anchor wall via the waling. Generally waling bolts are not required.

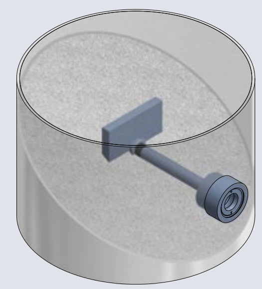
Combi & diaphragm wall connections (articulated)



Combi wall – cast-in forged eye
A forged eye bar is cast into the tube transferring forces to the centre of the tube. The anchor bars are attached to the cast-in bar via link plates allowing articulation in the vertical direction.

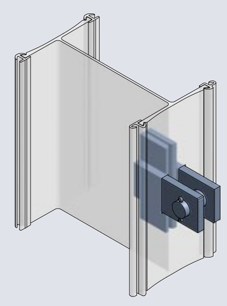


Combi wall cast-in T-Plate
A fabricated T-Plate is cast into the tube transferring forces to the centre of the tube. Forged eye anchor bars are attached to the T-connector via a pin allowing articulation in the vertical direction. See table 7 for more detail.

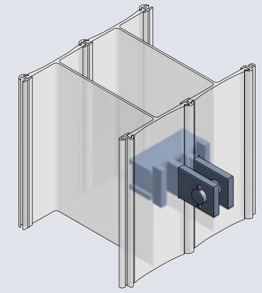


Combi & D-wall cast-in spherical box
A machined ´spherical box is cast into the tube transferring forces to the centre of the tube. Forged spherical anchor bars are connected to the box allowing articulation in both the vertical & horizontal directions.

HZ-M-pile connections (articulated)



HZ-M wall tension plates
Machined and factory welded tension plates are placed either side of the HZ-M web and passed through burnt holes in the flange. Forces are transferred from the transition radius of the HZ-M to the forged eye anchor bar through a pin connection and articulation in the vertical plane is possible. See table 6 for more detail.



Double HZ-M wall tension beam
A factory welded tension beam is placed bearing on HZ-M flanges close to the web and tension plates passed through burnt holes in the flange. Forces are transferred to the anchor bar through a pin connection and articulation in the vertical plane is possible.

CONNECTIONS

Table 4 – Standard bearing plates (ASDO500, $k_t = 0.6$)

Nominal thread diameter			Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	
Spherical plate against waling	Width	w_{PW}	mm	160	160	180	180	180	200	200	200	210	220	220	230	240	250	260	270	280	290	290	310	310	w_{PW}
	Breadth	b_{PW}	mm	210	220	230	230	240	250	260	270	270	280	300	300	300	330	330	340	350	370	370	390	390	b_{PW}
	Thickness	t_{PW}	mm	30	30	35	40	40	50	55	55	65	70	70	80	80	90	95	100	100	110	120	120	130	t_{PW}
	Max. dist. between waling[2]	W_{dist}	mm	100	100	120	120	120	140	140	140	140	160	160	160	160	180	180	180	180	200	200	200	200	W_{dist}

Nominal thread diameter			Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	
Standard plate against waling	Width	w_{PW}	mm	160	160	180	180	180	200	200	200	200	220	220	220	220	240	240	240	240	260	260	260	260	w_{PU}
	Breadth	b_{PW}	mm	170	180	200	200	200	210	210	220	220	230	240	240	240	260	270	270	280	290	300	310	310	b_{PU}
	Thickness	t_{PW}	mm	30	30	35	40	40	50	55	55	65	70	70	80	80	90	95	100	100	110	120	120	130	t_{PU}
	Max. dist. between waling[2]	W_{dist}	mm	100	100	120	120	120	140	140	140	140	160	160	160	160	180	180	180	180	200	200	200	200	W_{dist}

Nominal thread diameter			Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	
Spherical plate against concrete	Width	w_{PC}	mm	220	240	250	260	290	300	330	340	350	360	390	410	420	450	460	490	500	520	540	550	580	w_{PC}
	Breadth	b_{PC}	mm	220	240	250	260	290	300	330	340	350	360	390	410	420	450	460	490	500	520	540	550	580	b_{PC}
	Thickness	t_{PC}	mm	30	35	35	35	35	40	40	45	50	50	55	55	60	60	65	65	70	70	75	80	80	t_{PC}

Nominal thread diameter			Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	
Standard plate against concrete	Width	w_{PC}	mm	220	240	250	260	280	300	330	340	350	370	390	410	420	450	460	490	500	520	540	550	580	w_{PC}
	Breadth	b_{PC}	mm	220	240	250	260	280	300	330	340	350	370	390	410	420	450	460	490	500	520	540	550	580	b_{PC}
	Thickness	t_{PC}	mm	30	35	35	35	40	40	45	45	50	50	55	55	60	60	65	70	70	70	75	80	80	t_{PC}

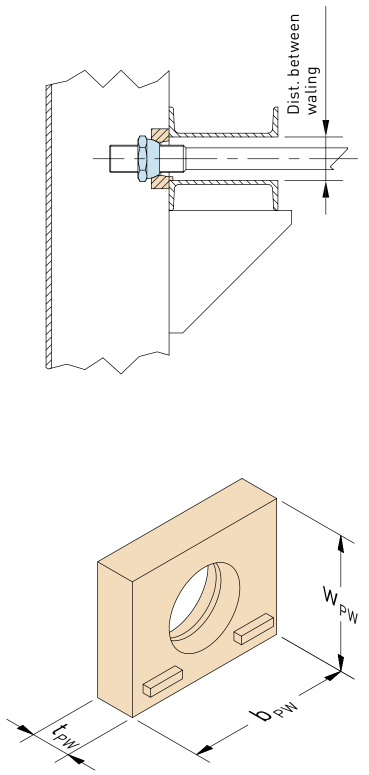
Notes: 1. All plates grade S355 and based on the maximum thread capacity for ASDO500, $k_t = 0.6$. For other grades or where $k_t = 0.9$ different plates are required.*
2. A waling gap greater than this distance will reduce the capacity of the plate.*
3. Concrete grade assumed at C35/45, plate dimensions will change for different grades of concrete.*

***Please contact our technical department for further information.**

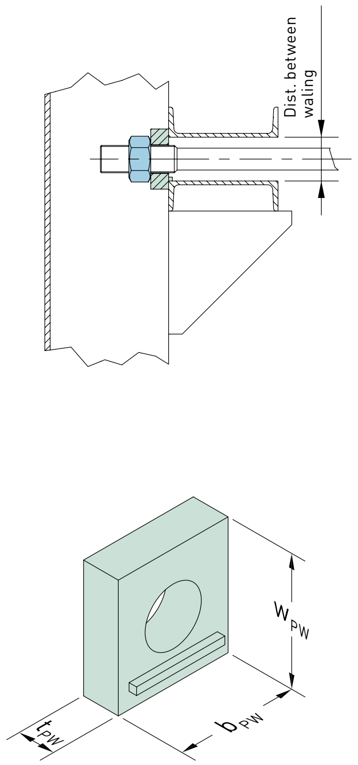
Table 5 – Hexagon and spherical nuts (ASDO500, $k_t = 0.6$)

Nominal thread diameter		Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160
Hexagon Flat Nuts	Across corners	mm	106	111	117	123	128	134	145	151	162	173	179	191	196	208	214	219	231	242	242	254	266
	Across flats	mm	95	100	105	110	115	120	130	135	145	150	155	165	170	180	185	190	200	210	210	220	230
Spherical Nuts	Across corners	mm	106	111	117	123	128	134	145	151	162	196	208	219	225	237	242	254	266	271	283	294	300
	Across flats	mm	95	100	105	110	115	120	130	135	145	170	180	190	195	205	210	220	230	235	245	255	260
	Depth	mm	51	54	58	61	64	68	72	76	80	107	107	117	117	127	127	137	137	147	147	157	157

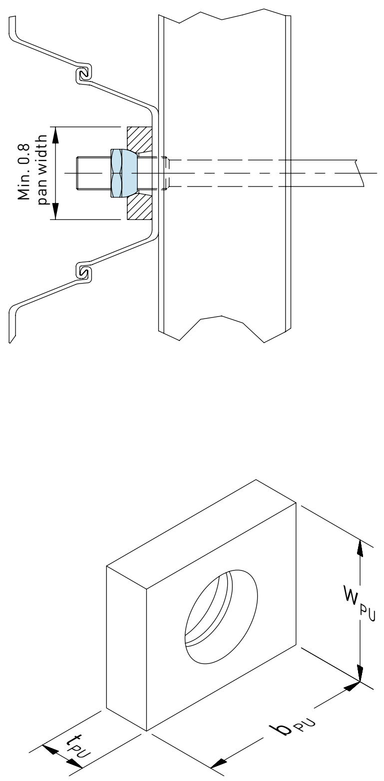
Standard bearing plates



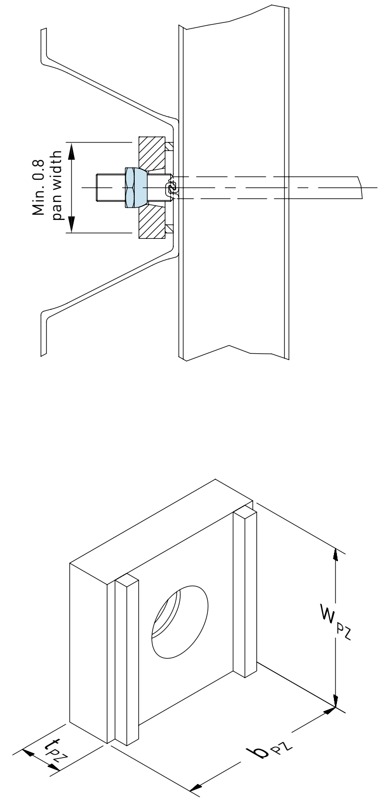
Spherical plate against waling



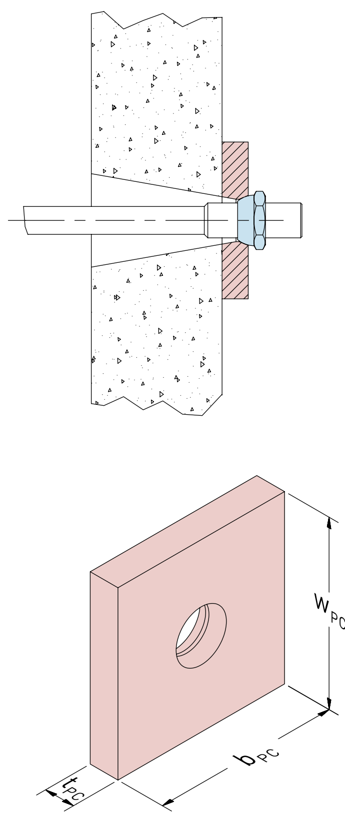
Standard plate against waling



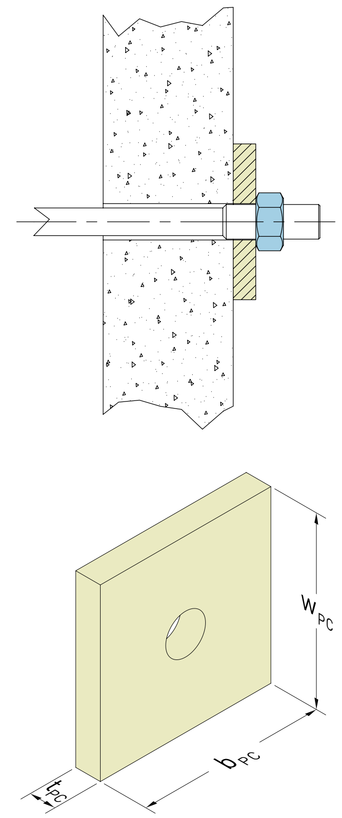
Spherical / standard plate against U-pile (contact Anker Schroeder for dimensions)



Spherical / standard plate against Z-pile (contact Anker Schroeder for dimensions)

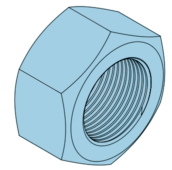


Spherical plate against concrete

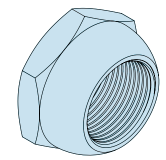


Standard plate against concrete

Hexagon and spherical nuts



Hexagon



Spherical

CONNECTIONS

Table 6 – T-Plates for HZ-M-piles (ASDO500, k_t = 0.6)

Nominal shaft diameter		mm	48	52	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	
Eye ref		inches	2 1/2	2 3/4	3	3	3 1/4	3 1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2	
Tension plates breadth	b_{TP}	mm	130	145	160	170	170	190	190	195	225	245	270	285	290	300	320	330	345	365	370	b_{TP}
Tension plates thickness	t_{TP}	mm	30	30	30	30	35	40	40	40	40	40	40	45	50	50	55	60	60	60	65	t_{TP}
Bearing plates breadth	b_{PP}	mm	110	115	140	140	140	170	170	190	190	205	240	250	265	265	290	310	330	350	370	b_{PP}
Bearing plates thickness	t_{PP}	mm	15	20	25	25	25	25	25	30	30	30	35	35	35	35	40	40	40	40	40	t_{PP}
Bearing plates length	l_{PP}*	mm	400	400	440	440	470	550	570	590	610	670	700	760	810	860	880	940	990	1060	1110	l_{PP}*
Pin diameter		mm	50	55	60	60	64	72	72	75	80	85	90	95	100	100	110	115	120	125	130	

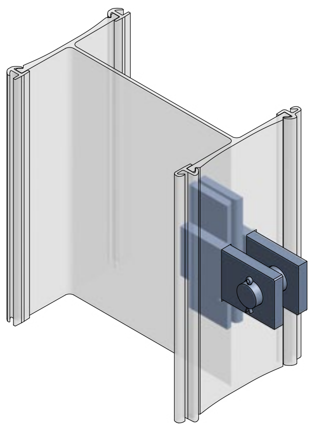
*l_{PP} based on a HZM profile quality S240GP with f_y 219 N/mm².

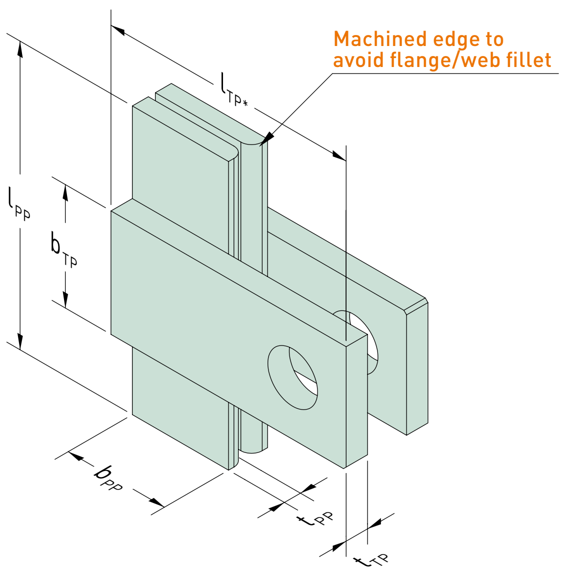
Table 7 – T-Anchors for combi-walls (ASDO500, k_t = 0.6)

Nominal shaft diameter		mm	48	52	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	
Eye ref		inches	2 1/2	2 3/4	3	3	3 1/4	3 1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2	
Tension plates width	b_1	mm	130	145	160	170	170	190	190	195	225	245	270	285	290	300	320	330	345	365	370	b_1
Tension plates thickness	t_1	mm	30	30	30	30	35	40	40	40	40	40	40	45	50	50	55	60	60	60	65	t_1
Bearing plates height & width*	l_2 x b_2	mm	230	250	270	290	310	330	340	360	380	400	430	460	480	490	530	550	570	590	610	l_2 x b_2
Bearing plates thickness	t_2	mm	35	40	45	45	50	50	55	55	60	65	70	70	75	75	80	90	90	95	95	t_2
Pin diameter		mm	50	55	60	60	64	72	72	75	80	85	90	95	100	100	110	115	120	125	130	

Note concrete grade assumed at C35/45, plate dimensions will change for different grades – please contact our technical department for information.
All plates grade S355 and based on maximum thread capacity for ASDO500, k_t = 0.6. For other grades and k_t = 0.9 contact our technical team.

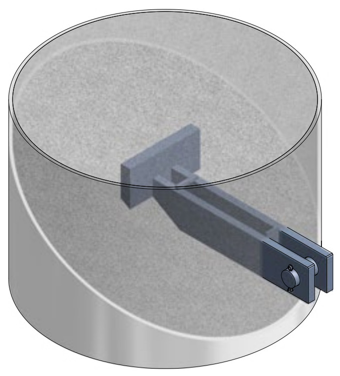
T-Plates for HZ-piles

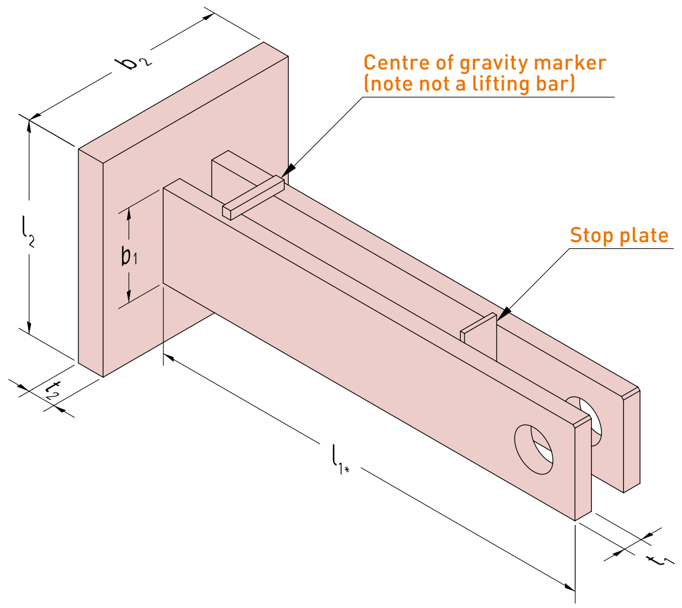




*l_{TP} depending on H-pile and nominal size

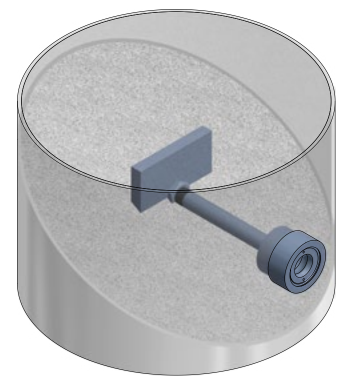
T-Anchors for combi-walls

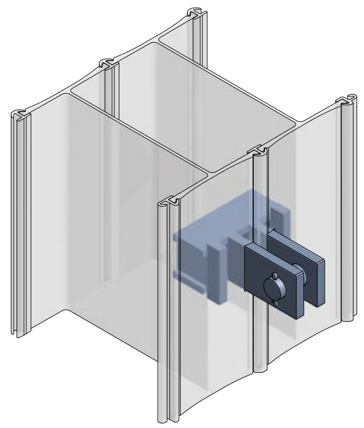




*l_1 depending on tube diameter and nominal size

Other connectors





CONNECTIONS

Table 8 – Turnbuckle & coupler (ASDO500, k_t = 0.6)

Nominal thread diameter		Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	
Diameter	$ØD_t$ & $ØD_{cp}$	mm	95	102	102	108	114	121	127	133	146	152	159	165	168	178	191	191	203	203	216	216	229	241	$ØD_t$ & $ØD_{cp}$
Standard turnbuckle length	L_t	mm	280	290	295	305	310	320	330	340	350	360	370	380	400	410	420	430	440	450	460	475	485	495	L_t
Standard turnbuckle adjustment	+/-	mm	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	+/-
Long turnbuckle length	L_t	mm	480	490	495	505	510	520	530	540	550	560	570	580	600	610	620	630	640	650	660	675	685	695	L_t
Long turnbuckle adjustment	+/-	mm	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	+/-
Coupler length	L_{cp}	mm	130	140	145	155	225	235	245	255	275	285	295	305	320	330	340	350	360	370	380	395	405	415	L_{cp}

Turnbuckles with longer adjustment are possible - please contact our sales department for more information.

Table 9 – Articulated turnbuckle (ASDO500, k_t = 0.6)

Nominal thread diameter		Metric	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	
Length	L_{AT}	mm	500	510	540	650	670	680	690	720	760	790	810	850	870	910	900	940	940	970	970	1010	1030	1050	L_{AT}
Adjustment	+/-	mm	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	+/-
Width	W_{AT}	mm	175	180	185	190	195	215	235	240	255	260	265	275	280	305	320	325	350	360	370	380	380	415	W_{AT}
Height	H_{AT}	mm	140	155	165	175	190	195	200	215	240	260	270	295	305	325	320	345	340	365	365	390	400	410	H_{AT}

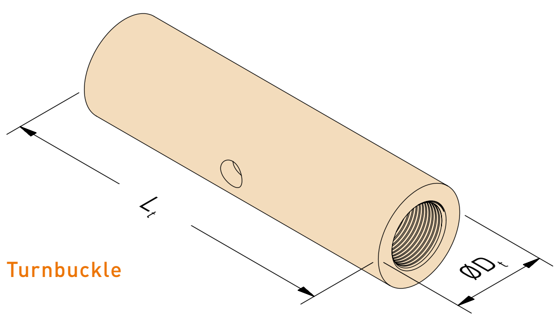
Table 10 – Link plates (ASDO500, k_t = 0.6)

Nominal shaft diameter	$Ød_g$	mm	48	52	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	$Ød_g$
Eye ref		inches	2 1/2	2 3/4	3	3	3 1/4	3 1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2	
Thickness	W_{LP}	mm	30	30	30	30	35	40	40	40	40	40	40	45	50	50	55	60	60	60	65	W_{LP}
Length	L_{LP}	mm	300	335	390	390	405	440	440	475	510	570	625	660	675	705	730	750	795	840	860	L_{LP}
Height	h_{LP}	mm	130	145	160	170	170	190	190	195	225	245	270	285	290	300	320	330	345	365	370	h_{LP}
Pin diameter		mm	50	55	60	60	64	72	72	75	80	85	90	95	100	100	110	115	120	125	130	

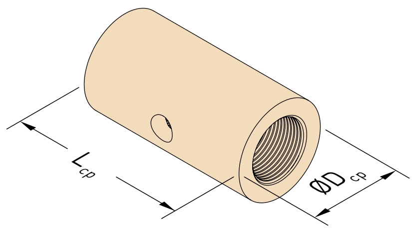
Table 11 – Cardan joint (ASDO500, k_t = 0.6)

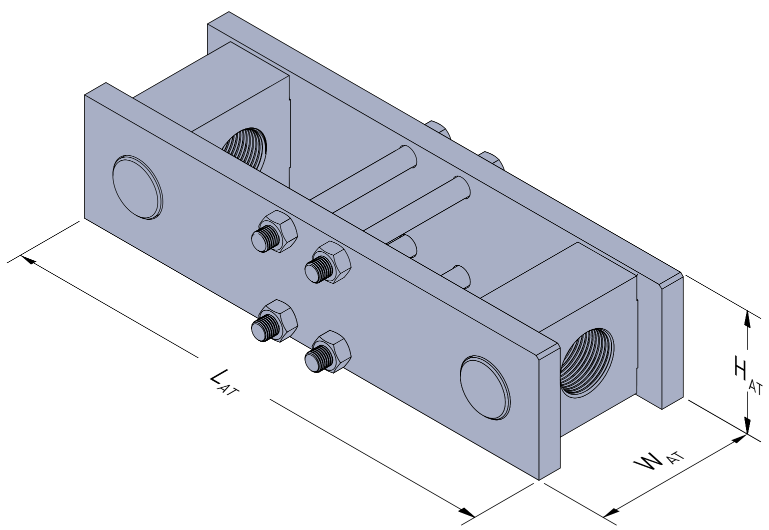
Nominal shaft diameter	$Ød_g$	mm	48	52	56	60	64	68	72	76	80	85	90	95	100	105	110	115	120	125	130	$Ød_g$
Eye ref		inches	2 1/2	2 3/4	3	3	3 1/4	3 1/2	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2	
Length	L_{CJ}	mm	330	360	410	410	440	480	480	500	540	570	610	660	680	700	750	780	810	870	910	L_{CJ}
Width	W_{CJ}	mm	120	130	140	140	150	170	170	180	190	200	210	220	240	250	260	270	280	290	300	W_{CJ}
Height	h_{CJ}	mm	120	130	140	140	150	170	170	180	190	200	210	220	240	250	260	270	280	290	300	h_{CJ}
Pin diameter		mm	50	55	60	60	64	72	72	75	80	85	90	95	100	100	110	115	120	120	130	

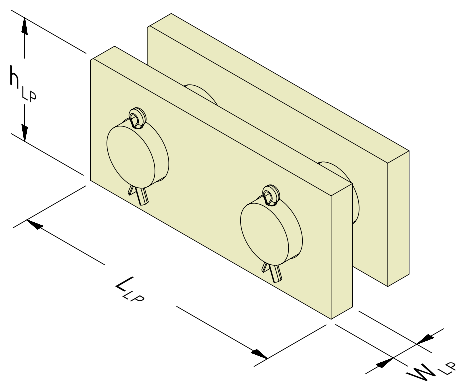
All plates grade S355 and based on maximum thread capacity for ASDO500, k_t = 0.6. For other grades and k_t = 0.9 contact our technical team.

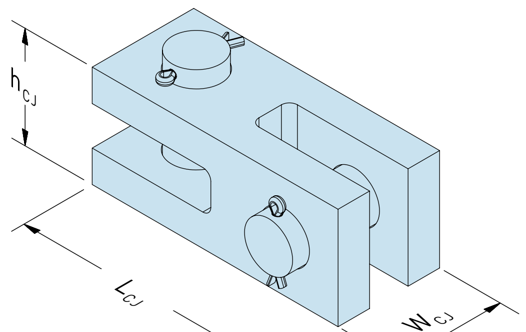


Turnbuckle









Coupler
Couplers and turnbuckles are used to connect bars to make longer lengths. A turnbuckle can be used for length adjustment.

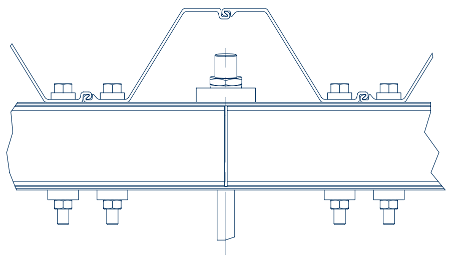
Articulated turnbuckle
An adjustable turnbuckle allows length adjustment and articulation in one plane.

Link plates
Together with forged eyes link plates provide the most economic articulated joint and the simplest connection to achieve in site conditions.

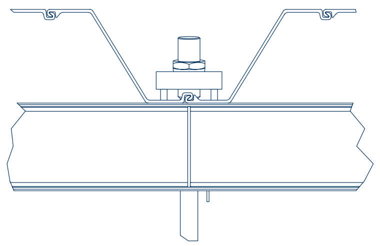
Cardan joint
The cardan joint allows bars with forged eyes to articulate in both vertical and horizontal planes.

WALINGS

Anker Schroeder can supply complete waling systems to suit a variety of wall configurations. Waling usually comprises of two rolled steel channel sections placed back to back and spaced to allow the tie rods to pass between the channels. This spacing must allow for the diameter of the tie rod and the thickness of any protective material applied to the rod and take into account any additional space required if the tie rods are inclined and need to pass between the walings at an angle.

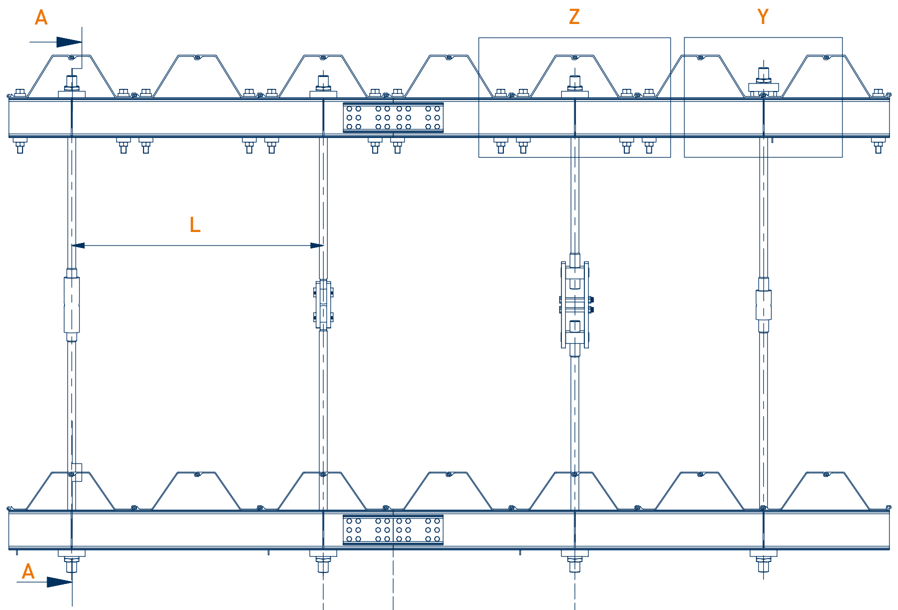


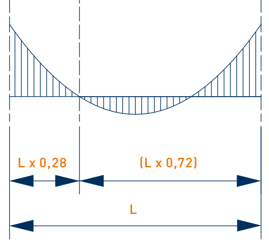
Detail Z
Tie bar connection inside sheet pile pan for additional corrosion protection



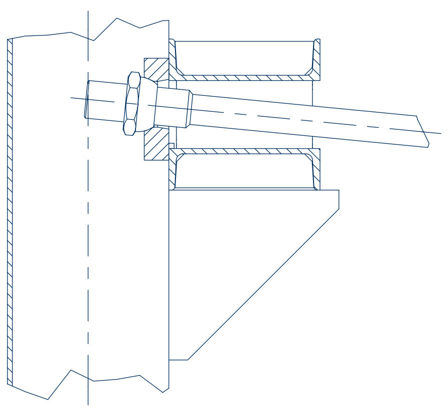
Detail Y
Tie bar connection outside sheet pile

Note: The combination of anchor head connections to the outside and inside of the sheet pan is shown for example only and would not normally be used in practice.

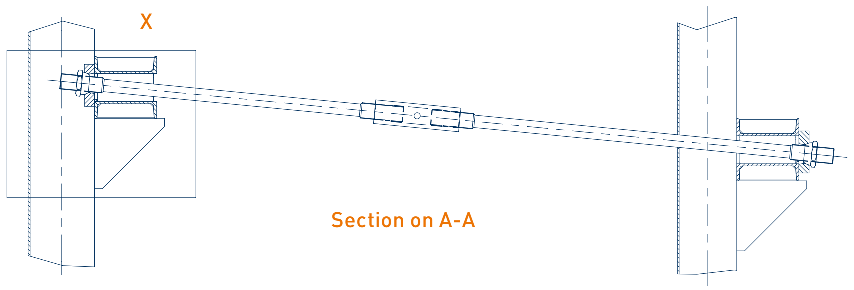




Typical bending moment profile for waling



Detail X



Section on A-A

DESIGN CONSIDERATIONS

Anchor connections to a sheet pile wall can be made in two ways – outside the wall or inside as shown opposite. Generally walings placed inside the retaining wall are preferred both for aesthetic reasons and, in the case of a wall in tidal or fluctuating water level conditions, to prevent damage to the waling by floating craft or vice versa.

Placing the waling inside the wall also allows the anchor bar to be connected inside the wall within the pan of a sheet pile. This greatly increases the corrosion protection to the main tie bar connection, see detail Z.

When the waling is placed behind the front wall, it is necessary to use waling bolts and plates at every point of contact between the piles and the waling to ensure load is transferred fully to the waling.

Anker Schroeder supply a complete range of waling bolts to suit project applications. Bolt heads are forged on to the bar and if these are placed on the outside of the wall provide greater corrosion protection than exposed threads such as hexagon nut connections.

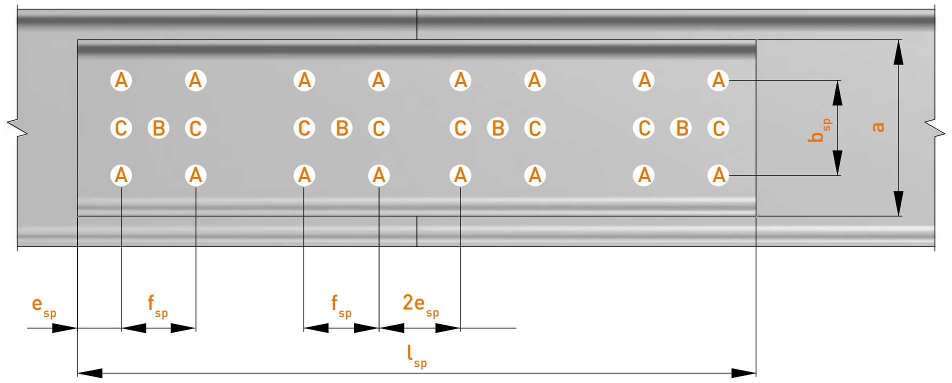
For design purposes the waling can be considered as continuous with allowance being made for end spans. Although the waling is then statically indeterminate, it is usual to adopt a simplified approach where the bending moment is assumed to be $wL^2/10$, being the calculated load to be supplied by the anchorage system acting as a uniformly distributed load and L is the span between anchors.

When checking the anchorage system for the loss of a single anchor, the load in the anchorage system is assessed on the basis of the requirements for a serviceability limit state analysis with no allowance being made for overdig at excavation level. The resulting bending moments and tie forces are considered to be ultimate values and are applied over a length of waling of 2L.

In this extreme condition, it can be demonstrated that, with the exception of the anchors at either end of the external spans, the bending moment in a continuous waling resulting from the loss of any tie rod will not exceed $0.3\ wL^2$ where w is the support load calculated for this condition expressed as a UDL and, for simplicity, L is the original span between anchors.

Typical waling sizes and grades along with theoretical bending capacities are given in table 12. It is intended that these values are used for estimation only and provide an initial assessment to which waling section may be suitable. For complete assessment of structural requirements a more rigorous analysis taking into account factors such as torsion, axial loading, vertical loading and high shear loads should be made.

WALINGS AND SPLICE CONNECTIONS



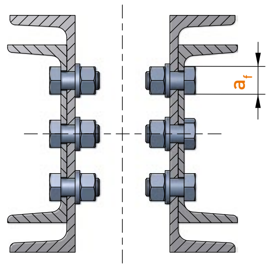
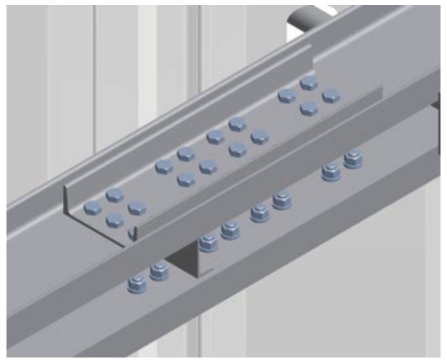


Table 12 – Waling splice connections

Walings		Splice connections								
Section	Section Modulus cm³	Section	l_{sp} mm	hole pattern	b_{sp} mm	e_{sp} mm	f_{sp} mm	Quantity	Bolts Min. 5.6 to DIN EN ISO 898-1	Hex across flat mm
UPN180	300	UPN140	560	A	60	40	60	32	M20 x 45	30
UPN200	382	UPN140	640	A	60	40	60	32	M20 x 45	30
UPN220	490	UPN160	680	A	80	40	60	32	M20 x 45	30
UPN240	600	UPN180	740	A	90	50	75	32	M24 x 50	36
UPN260	742	UPN200	800	A	110	50	75	32	M24 x 50	36
UPN280	896	UPN220	840	AB	120	50	90	40	M24 x 55	36
UPN300	1070	UPN220	920	AB	120	50	90	40	M24 x 55	36
UPN320	1358	UPN240	1000	AB	130	60	110	40	M30 x 65	46
UPN350	1468	UPN260	1000	AB	140	60	110	40	M30 x 65	46
UPN380	1658	UPN300	1000	AC	180	60	90	48	M30 x 65	46
UPN400	2040	UPN300	1000	AC	180	60	90	48	M30 x 65	46

The above sizes are the most common used – other sections can be provided on request.



Waling splice detail

Port, Reykjavik

For longer lengths, walings can be joined by splice sections. These should be located at a distance of 0.28 of the anchor spacing from an anchor location as this will be close to the position of minimum bending moment in the waling (nb this should also be checked for the load case of one tie bar failing in which the anchor spacing will double). The walings should be ordered 100 mm longer than the theoretical dimensions to allow for any creep which may develop in the wall as the piles are driven. Splice connections can be welded or bolted, if bolted only one end of the waling length is drilled for splicing to match the splice hole pattern. The other end is supplied plain for cutting and drilling on site, after the actual length required has been determined. Where inclined ties are used, the vertical component of the anchor load must not be overlooked and provision must be made to support the waling, usually in the form of brackets or welded connections. Where sheet pile anchor walls are used, similar walings to those at the retaining wall are required. These are always placed behind the anchor piles and consequently no waling bolts are required. Where higher waling loads are found, e.g. for combi-walls, Anker Schroeder can offer walings fabricated from higher inertia sections, e.g. H sections – please contact our sales department for more information.

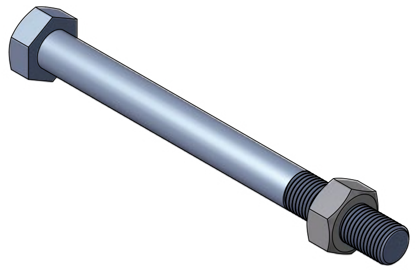
Where walings form part of the permanent structure they can be supplied with protective coatings or often more economical a sacrificial steel allowance made. If coatings are supplied then further coatings are recommended on site after installation.

ASDO

WALING BOLTS

PRODUCT DATA

Waling bolts are made from the same grades of steel as ASDO355 & ASDO500. Bolts can be made with forged hexagon heads or threaded each end, lengths are made to order. Standard hexagon nuts are provided.



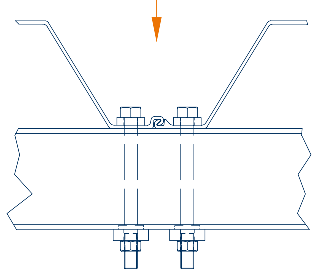
Waling bolt with forged head and hexagon nut.

Table 13 – Waling Bolts

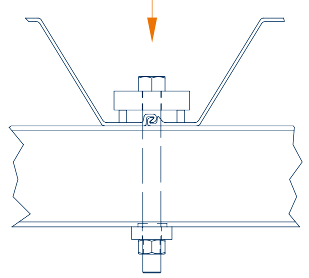
Thread	Thread pitch P	Stress area A_{sp}	Width Across Flats*	Grade ASDO	Tensile Resistance accd. EN1993-5
Metric	mm	mm²	mm		kN
36	4,0	817	55	355	200
				500	259
42	4,5	1.121	65	355	274
				500	355
45	4,5	1.306	70	355	320
				500	414
48	5,0	1.473	75	355	361
				500	467
52	5,0	1.758	80	355	430
				500	557
56	5,5	2.030	85	355	497
				500	643
60	5,5	2.362	90	355	578
				500	748
64	6,0	2.676	95	355	655
				500	848

*can be increased to allow for sacrificial corrosion

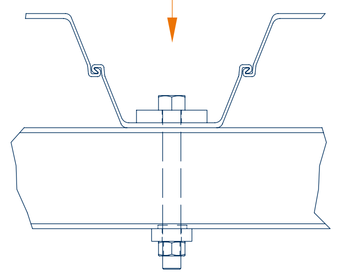
Forged head of waling bolt placed to outside of sheet pile for increased corrosion resistance



Waling bolts to Z-piles



Waling bolts to Z-piles



Waling bolts to U-piles

ANKER SCHROEDER
ASDO steel tension members

CORROSION PROTECTION

Marine structures inherently operate in aggressive environments and selection of robust protection systems for tie bars is key to the longevity of a structure. It is very important to consider the corrosion protection of the anchors at design stage and of particular importance is the connection to the front wall as the anchor is typically subjected to the most aggressive environment at this point and this is the most common area of failure for an anchorage.

Tables 4-1 & 4-2 of EN1993-5 give guidance to corrosion allowances for steel sheet piles, it is accepted practice to use these same rates for tie bars.

Corrosion protection for anchors can be provided in several ways.

Sacrificial steel
Anker Schroeder consider sacrificial steel to be the most practical and robust corrosion protection. The anchor shaft and thread size are increased in diameter to allow for corrosion steel loss during the life of the structure. No additional coating is required.

The figure below shows how the threaded part of the anchor in the splash zone has been increased in diameter to allow for the anticipated corrosion loss. This system is robust as no special transport or site considerations are required.

By calculation use Grade ASDO500

Shaft diameter required	76 mm
Thread diameter required	M100
Sacrificial corrosion allowance in fill	1.2 mm
Sacrificial corrosion allowance at head	3.75 mm

Anchor shaft size required = 83.5 mm (nearest standard size = 85 mm) and thread size M110.

Therefore use ASDO500 M110/85.

Note: The shaft and thread can be reduced as the corrosion rate decreases (see page 11) .

Table 14 – Corrosion allowances for steel anchors

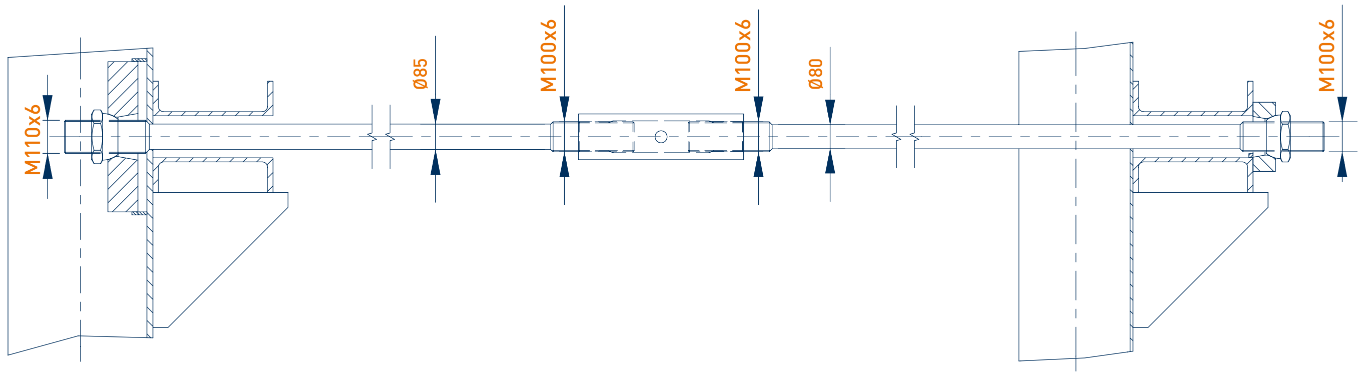
EN1993-5 Table 4-1 – Recommended value for the loss of steel thickness (mm) due to corrosion in soils with or without groundwater

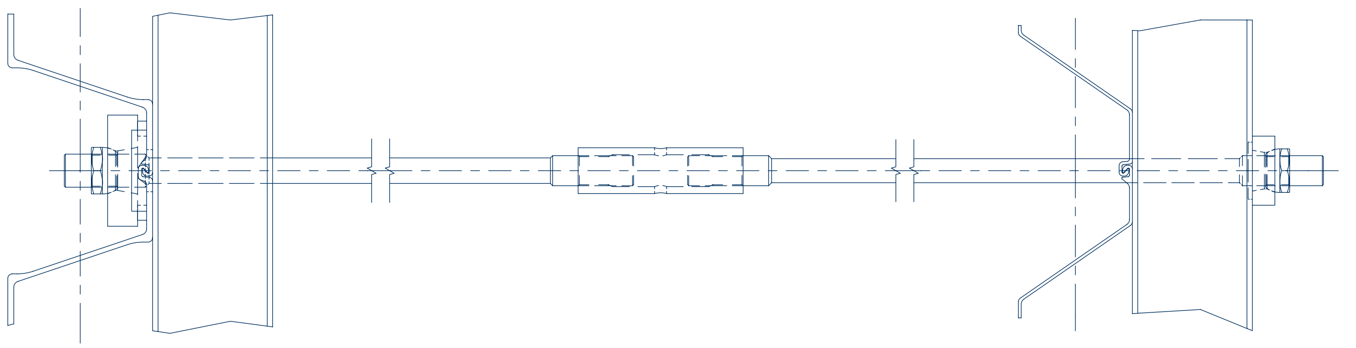
Required design working life	5 years	25 years	50 years	75 years	100 years
Non-compacted and non-aggressive fills (clay, schist, sand, silt ...)	0.18	0.7	1.2	1.7	2.2

Note: For compacted fills EN1993-5 allows the corrosion rates above to be halved but Anker Schroeder recommend this is ignored for conservatism.

EN1993-5 Table 4-2 – Recommended value for the loss of steel thickness (mm) due to corrosion in water

Required design working life	5 years	25 years	50 years	75 years	100 years
Common fresh water (river, ship canal ...) in the zone of high attack (water line)	0.15	0.55	0.9	1.15	1.4
Very polluted fresh water (sewage, industrial effluent ...) in the zone of high attack (water line)	0.3	1.3	2.3	3.3	4.3
Sea Water in temperate climate in the zone of high attack (low water and splash zones)	0.55	1.9	3.75	5.6	7.5
Sea Water in temperate climate in the zone of permanent immersion or in the intertidal zone	0.25	0.9	1.75	2.6	3.5





Wrapping systems
The most commonly used wrapping system is to cover the anchors in a protective barrier such as petrolatum tape (e.g. Denso).

Anker Schroder can offer factory petrolatum wrapped bar, but it should be remembered, that connections cannot be wrapped until installed on site and can increase installation time considerably.

The vulnerable anchor head can only be fully protected once installed and this is often difficult to achieve in site conditions.

It is important to ensure that protection to connections and the anchor head are correctly performed during installation, any damaged or unprotected areas must be repaired before backfilling.

Galvanising
With the exception of ASDO700 bar Anker Schroeder tie bars and components can be hot dip galvanised to EN ISO 1461 but consideration should be given to threads which are unable to have more than a nominal coating of zinc. Please contact our technical department for further detail.

Painting
Anchors can have any suitable paint system applied as required by the client. Consideration should be given to likely damage that will occur to the paint system during transport and installation as any break in the protective system could lead to pitting corrosion.

Please contact our technical department for further detail.

General Note
Any breaks in the protective system could lead to aggressive pitting corrosion and premature failure of the anchor. To discuss these issues further, please contact our technical department.


Factory wrapping of anchors


Storage of wrapped anchors

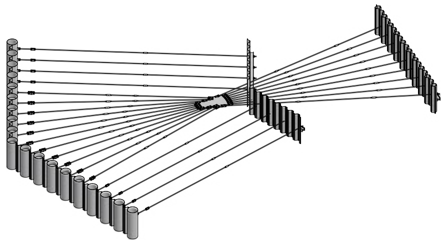

Site wrapping of connections

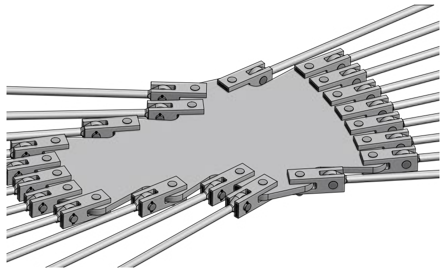

Galvanised T-plates


Galvanised anchors


Painted anchor

Anchorage Fabrications
Anker Schroeder can also supply anchorage distribution units for more complex constructions.





SITE INFORMATION

Storage of anchors
Tie rods and accessories shall be stored and handled in such a way as to avoid excessive deformation, corrosion, exposure to heat (e.g. flame cutting), bending or damage of any kind being caused on the rods, threaded ends, turnbuckles or nuts.

All threaded parts must be carefully protected from dust, dirt and damage. Clean and check all threads thoroughly before use.

No welding or flame cutting shall be carried out on the tie rods and/or accessories (turnbuckles, couplers, nuts) without written approval of ASDO. All tie bars and accessories should be protected from any exposure to heat processes on site such as welding or flame cutting.

Assembly
Container or road shipping restrictions generally mean that anchors are delivered in sections of typically 12-18 m or less, however Anker Schroeder have direct rail links and convenient access to docks where longer lengths can be shipped – please contact our technical team for further detail. Sections are assembled on site to design lengths. Assembly on a clear hard-standing with roller trestles is recommended. Great care should be taken in ensuring threads are clean and free of dirt and damage prior to assembling. All threaded connections must be made with minimum engagement of at least 1 x diameter of the thread.

Installation
Anchors should be installed as close as possible to the line of force that they will experience during service. Account should be taken of the additional forces that will be introduced to the bar by settlement of the fill, particularly bending at the wall connection.

Long anchors should be lifted by use of a stiff lifting beam with supports at approximately every 4-6 m.

Site services & training
Anker Schroeder are able to offer training for assembly, installation and stressing either at your site or at our factory in Dortmund. Please contact our technical department for more information.



Stock and availability
Anker Schroeder hold over 4,000 tonnes of raw material enabling many projects to be quickly supplied with initial needs. However most major projects will require the bulk of raw material to be rolled to the specific project diameter which can be adapted to the nearest millimetre to ensure the most economical solution. Please contact our sales department to discuss your project requirements.


OTHER PRODUCTS

ASDO Stainless Architectural tie bars

Diameter M12 to M56

ASDO Structural Architectural tie bars

Diameter M12 to M160

ASDO Micro Piles

Diameters up to M160 and working loads > 3,000 kN

ASDO Forged Shackles and flange shafts

Working load capacities up to 1,500 tonnes

This publication provides information and technical details currently used by Anker Schroeder in the manufacture of its products.

Although we have taken great care in the preparation of the data within this publication, we cannot assume responsibility for the completeness and accuracy of all the details given. Each customer should satisfy themselves of the product suitability for their requirements. The publication of this data does not imply a contractual offer.

In line with Anker Schroeder's policy of continuous improvement the company reserves the right to change or amend details. Please contact our technical department for further information or to ensure these details are current.

Sustainability
Steel is the most recycled material in construction. All anchorage material supplied by Anker Schroeder is sourced from reputable steel mills and, where possible, up to 90% of melt is recycled steel. Once a structure has reached the end of it's design life Anker Schroeder Bars are 100% recyclable as scrap material but the economics and environmental impact of extraction from the structure need to be considered.

Anker Schroeder ASDO GmbH
Hannöversche Straße 48
44143 Dortmund
Germany

Phone +49 231 51701-30
sales@anker.de
www.asdo.com

100 years steel tradition 1920-2020

Printed July 2020, see www.asdo.com for the latest version