HP Bearing Piles

Execution details

PROFILARBED S.A.
Arcelor Group

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1. Pile head connections

1.1. Introduction

The efficiency of the H-pile system is, in many cases, affected by the costs involved for connecting the pile to the superstructure.

In cases where the superstructure is made of steel, the technical solution can be found by applying the rules and standards for steel structures (figure 1).

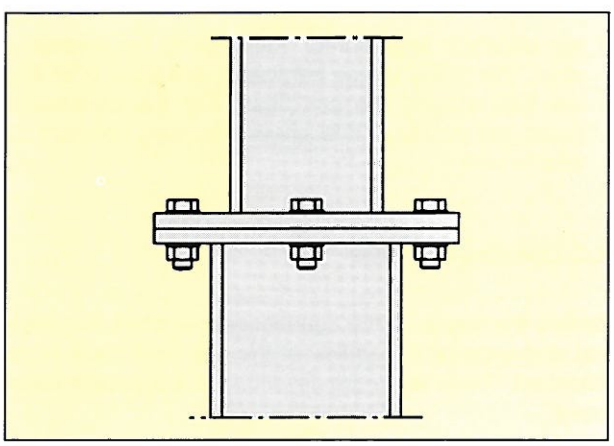


***Figure 1:* Connection between a steel structure and the H-pile**

In cases where the building loads are transferred via a concrete slab to the piles, the conventional solution consists in welding a transfer plate to the pile head in an effort not to exceed the allowable compressive strength of the concrete.

It has been shown, however, that a direct connection between the H-pile head and the concrete slab is workable, provided the H-pile is of adequate section and the concrete member is of adequate size and properly reinforced.

Laboratory compression tests showed that there is no need to provide a bearing plate or other auxiliary bearing device at the top of the pile (Shaffer et al. 1947, 1975; Lambotte 1985).

This chapter aims to show the principle of a direct connection between an H-pile and a concrete slab. It also provides tables and diagrams enabling a rapid and easy predesign.

The design method is based on the Eurocode 2 (ENV 1992-1-1) and the French Standard BAEL 91. Other national standards may be applicable, provided the philosophy of the proposed solution is safeguarded.

In the following paragraphs, compression and tension loads are considered separately, they can however be combined without problems, if required.

In cases where a combination of horizontal and tension forces occurs the connection has to be designed in bending.

The loads are taken at the ultimate limit state (ULS).

1.2. Tension piles

The transfer of tension forces is done by welding reinforcing bars to the H-section. A typical example is shown in figure 2.

Figure 3 shows the required amount A_t of reinforcement for tension loads (ULS) up to 1250 kN (concrete C25/30, steel bars in Fe E500, H-pile in Fe 510). The connection of the bars to the pile requires typically a weld 4 mm in thickness and 250 mm in length.

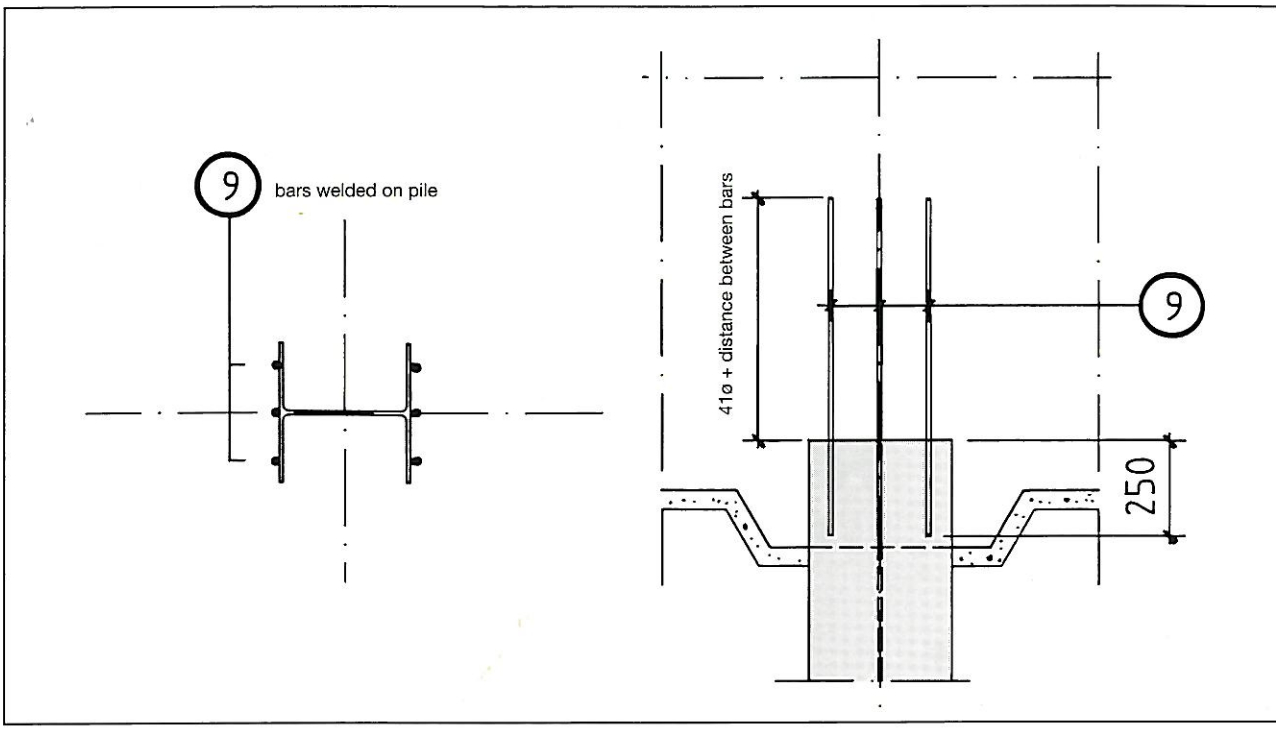


Figure 2: **Typical connection for tension loads**

For ULS loads beyond 1250 kN, the required length of weld has to be checked.

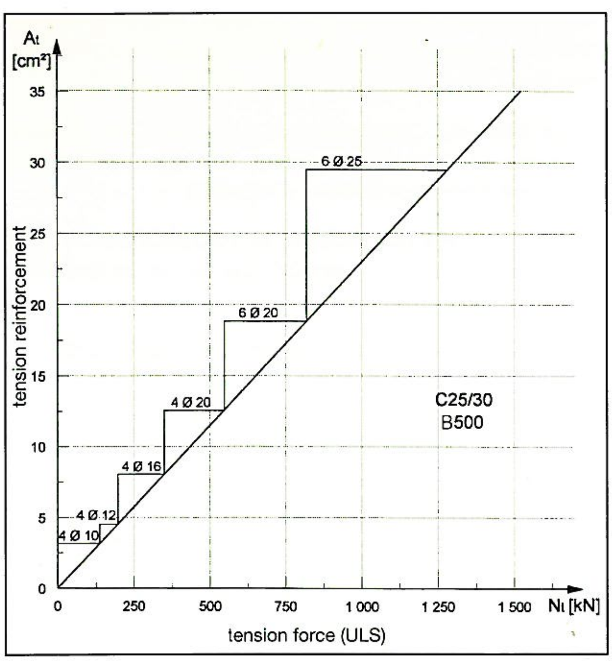


Figure 3:
Determination of reinforcement in tension

The anchorage length of the bars is the sum of 2 parts:

- the basic anchorage length = 41 diameters of the bar (EC2).

  In case the anchoring is done by bars with hooks or loops, the required anchorage length has to be determined for the specific situation.

- the distance required for transmitting by means of struts the tension force between the welded bars and the bars around the pile head. For the considered loads and sections, this length may vary between 20 and 35 cm.

1.3. Compression piles

Before the design of the connection is started, the internal and external capacities of the pile itself have to be checked. These steps are described in a separate document.

In the most general case, the H-piles are not located in the axis of the loads from the superstructure. As such, the concrete member has to be designed for resisting both the concentrated force at the pile head and the transverse forces. For the latter, supplementary reinforcement has to be provided which is capable of resisting the balance between the total transverse force at the considered pile and the one developed by the concrete.

In the case where the axes of the H-pile and of the load from the superstructure coincide, no transverse reinforcement is required.

For the present proposal, the following assumptions are made:

- characteristic cylinder compressive strength of the concrete: fck = 25 MPa
- characteristic yield strength of the reinforcing bars: fyk = 500 MPa
- yield strength σe of the H-pile steel in function of the steel grade
- the design shear strength of the concrete = 0,10 fck
- maximum stress in the H-pile at the limit state = 0,75 fy
- pile head penetration in the concrete = 10 cm in compression and 25 cm + concrete cover in tension
- the minimum distance between the piles is taken as 3 times the height/width of the section.

The first design step is made by checking the maximum internal capacity of the connection in relation with the design force N_C (ULS).

The diagram from figure 4 is helpful here.

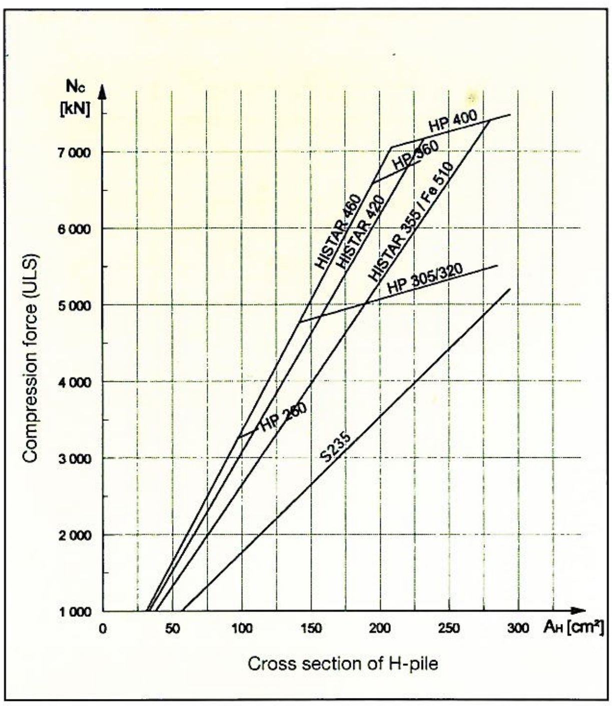


Figure 4: **Check of the maximum internal capacity of the connection**

Then, the required thickness h of the concrete member is determined in function of the design force N_C (figure 5).

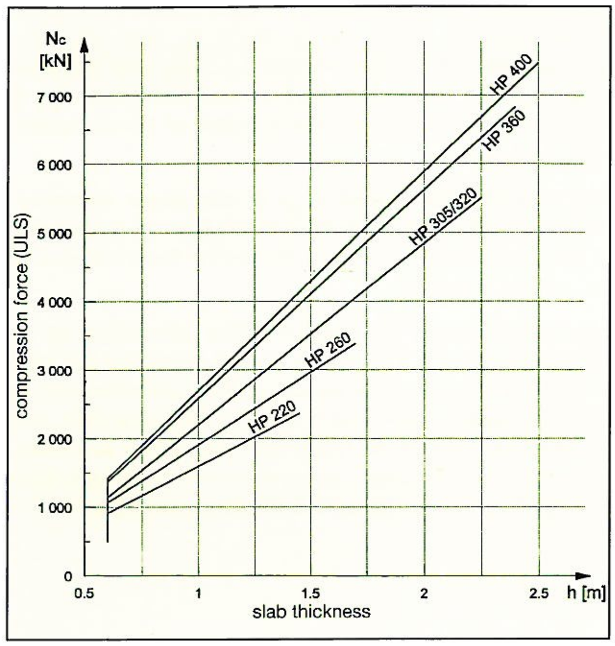


Figure 5: **Determination of the slab thickness**

The reinforcement above the pile head can be read in figure 6.

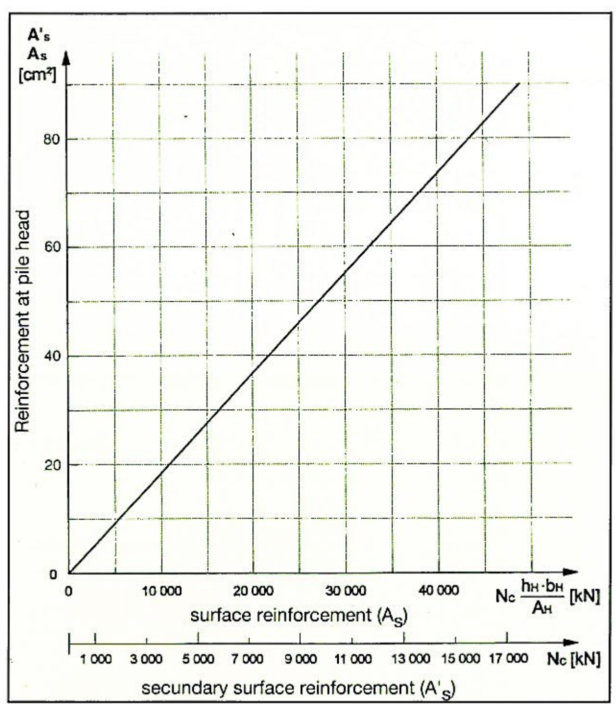


Figure 6: **Determination of the reinforcement at the pile head**

The surface reinforcement A_S is determined in function of the product of the design force N_C and the ratio between the total H-pile section h_H x b_H and the steel area A_H. The secundary surface reinforcement A'_S is found in the same diagram in function of the compression force N_C.

The cross-sectional area A_{SW} of the shear reinforcement is determined in figure 7 in function of the square of the compression force N_C divided by the thickness of the concrete slab h.

Figure 8 shows a typical layout of the connection for an HP360x84.3 in Fe 510 with a design compression load of 2840 kN (ULS). The layout of the reinforcement is done in such a way that it can be prefabricated and installed as a whole on top of the pile. Other solutions, for instance with continuous surface reinforcement from one pile head to the other, are of course possible.

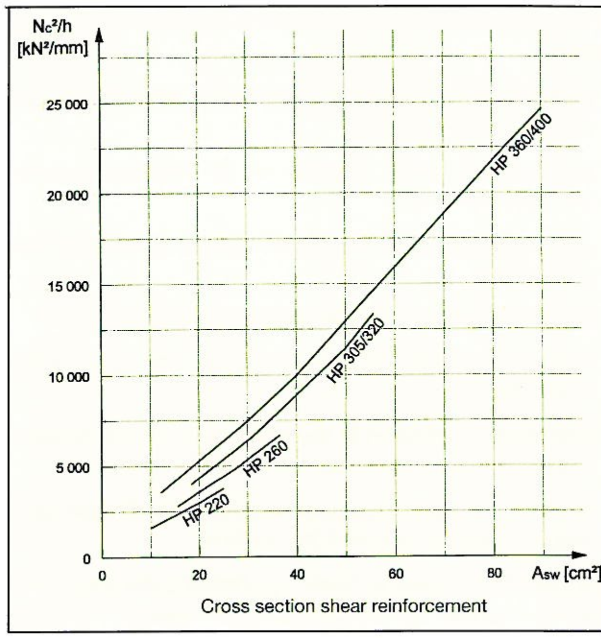
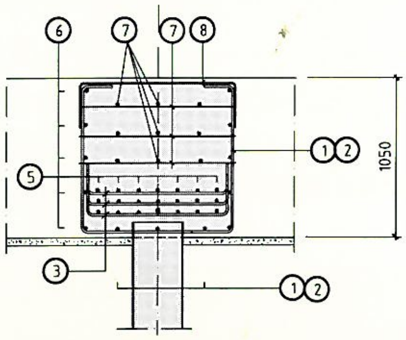
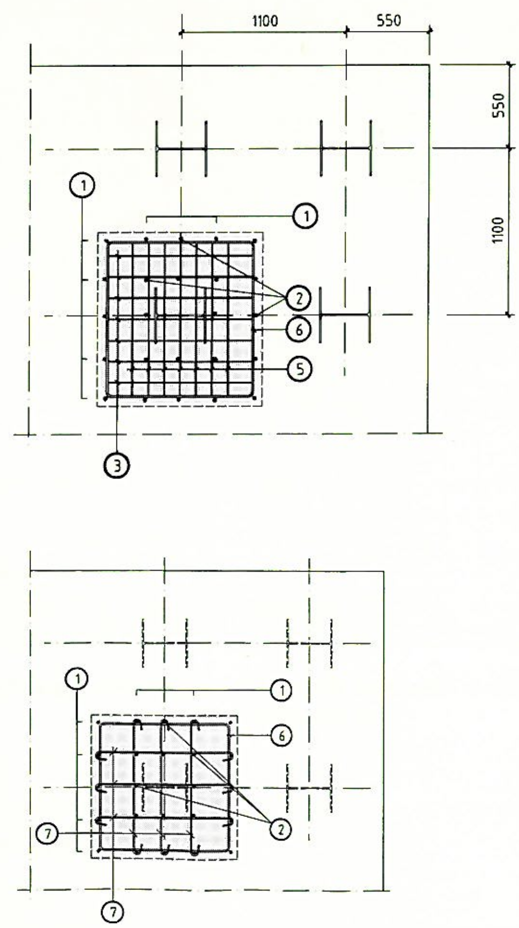


Figure 7: **Determination of the cross-sectional area of shear reinforcement**





Pos.	N	ø		Designation
1	6	14		Shear reinforcement A_{SW}
2	12	14		Shear reinforcement A_{SW}
3	21	14		Surface reinforcement A_S
5	21	14		Surface reinforcement A_S
6	10	12		
7	18	10		Secundary surface reinforcement A'_S
8	7	10		

Figure 8: **Example of reinforcement for the connection of an HP 360x84.3 pile in Fe510**

2. Pile point reinforcement

Over the last years, pile loads and working stresses have continuously increased.

Consequently, it is essential for every pile to be safely driven into the resistant layer.

As a result, hard driving which is sometimes combined with the necessity of penetrating through intermediary hard layers or layers with cobbles, increase the risk of pile damage.

Also, piles driven to sloping hard rock may be subject to distortion of the bottom of the pile. Especially the ends of the flanges are likely to buckle locally when hitting an obstacle.

In order to avoid these problems, preboring is sometimes performed; this is however an expensive solution. In most cases where driving problems are expected, pile point reinforcements can be foreseen.

The risk of pile toe distortion is substantially reduced when the tip is reinforced by plates (figure 9) or by special cast points (figure 10).

These reinforcements improve the width to flange thickness ratio and they distribute the load more uniformly over the cross section of the pile, regardless of what part first encounters resistance.

The pile points are usually larger than the H-section itself. Caution is therefore recommended in the following situations:

- friction is greatly reduced on the surface above the point so that mainly toe resistance can be counted upon.
- in case reinforced piles penetrate hard pan or soft rock, the enlarged bottom may cause premature refusal so that the required combination of point resistance and skin friction cannot develop efficiently.

3. Pile splicing

The pile length is governed by the soil conditions and the loads from the superstructure. For some projects, the piles cannot be driven in one length due to fabrication, transport and/or handling limitations. In those cases, the piles have to be spliced at the job site.

H-pile splices have to be designed to develop the full strength of the section, both in bending and axial loading. Experience shows that the 100 percent buttwelded splice is the most efficient one.

In case the pile segments can be spliced prior to installation, downhand welding in the horizontal position is performed. Here, V-shaped bevels (2 x 30°) are recommended for thicknesses below 16 mm and X-shaped bevels beyond 16 mm (figure 11).

The details of the splice for welding in vertical position are shown in figure 12.

The bevels are performed by oxy-cutting; milled ends are unnecessary.

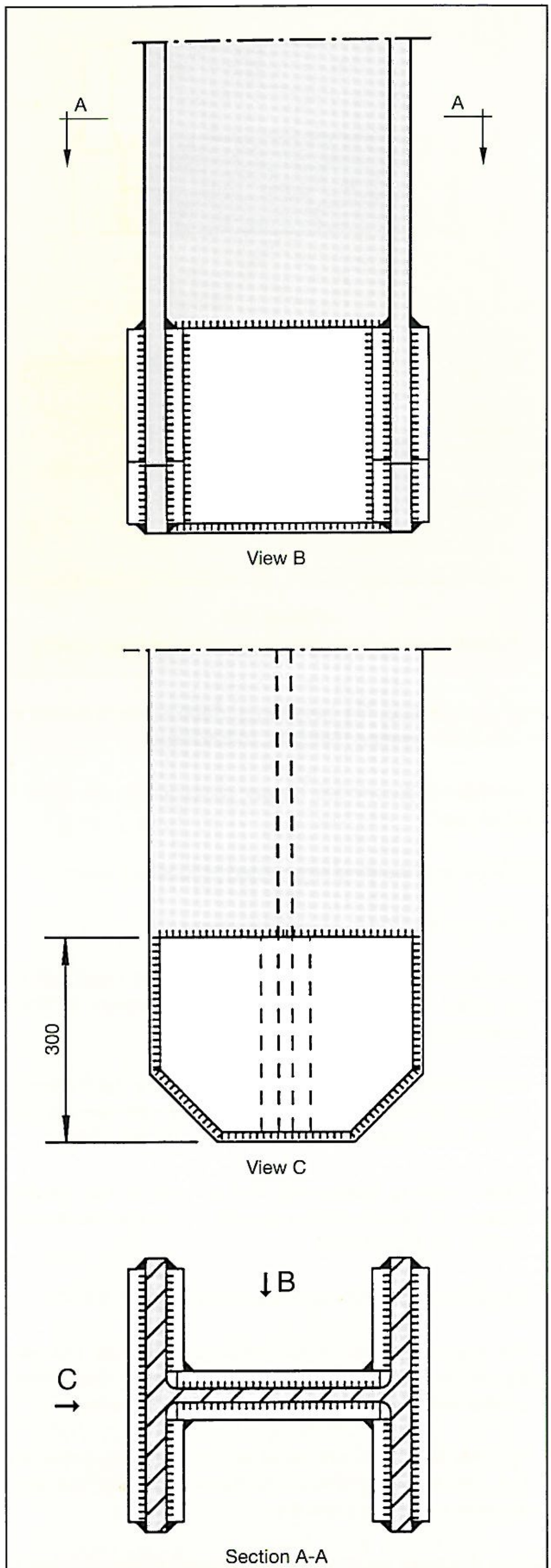


Figure 9:
Typical pile toe reinforcement by plates

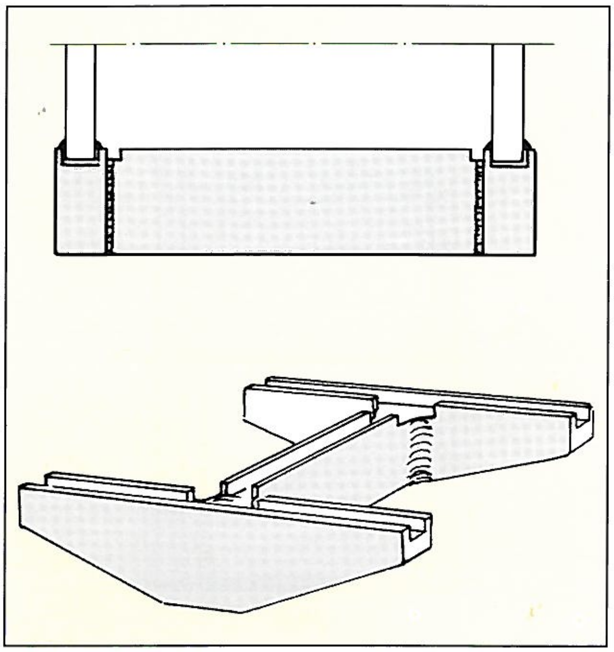


Figure 10:
Typical pile toe reinforcement by precast shoes

Prior the welding, the bevelled surfaces should however be free from grease, humidity, mill scale etc.

Conventional electrodes as per classification in table 1 can be used.

Some general welding recommendations are given:

- only dry electrodes should be used
- low alloy rutile and cellulosic electrodes need not to be dried provided they have been stored in their undamaged packing
- basic electrodes should always be dried, for instance 2 hours at 250°C when welding steel with low carbon content and with a yield strength up to 355 MPa.

  When welding steels with higher mechanical values, heating of the electrodes should be performed during 2 hours at 300°-350°C.
- the diameter of the electrodes is typically 4-5 mm
- the manufacturers of the electrodes usually indicate the optimum electrical power requirements depending on the weld position and the quality of the weld.
- HISTAR steels do not need any preheating, provided the ambient temperature is above 0°C and the surfaces to be welded are dry.

As the piles are usually highly stressed during driving, it is recommended to perform the splices only by experienced welders. The quality of the welds can be checked at site by ultrasonic testing.

Table 1: Choice of electrode depending on the steel grade

STEEL GRADE	CLASSIFICATION DIN 1913 (1984)	ISO 2560	Electrode
S235 JR S235 JO	E 43 22 R(C) 3 E 43 32 C4	E 43 2 R 12 E 43 3 C 19	R C
S275 JR S275 JO	E 43 22 R(C) 3 E 43 32 C4 E 43 32 R(C) 3	E 43 2 R 12 E 43 3 C 19 E 43 3 R 12	R C R
S355 JR S355 JO/ HISTAR 355	E 51 32 RR 11 160 E 51 43 B 12 160	E 51 3 RR 160 32 E 51 4 B 150 36	R B
HISTAR 420	E 51 43 B 12 160 (1)	E 51 4 B 150 36 (1)	B
HISTAR 460	E 51 43 B 12 160 (1)	E 51 4 B 150 36 (1)	B

R = rutil C = cellulosic B = basic

(1) - The tensile strength of the electrodes has to be higher than the nominal strength of the base material.

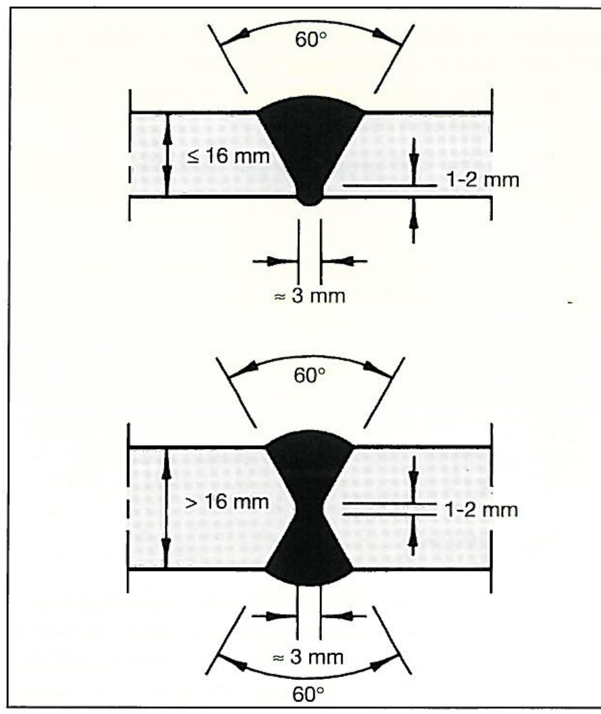


Figure 11: **Typical detail for welds performed in horizontal position of the pile**

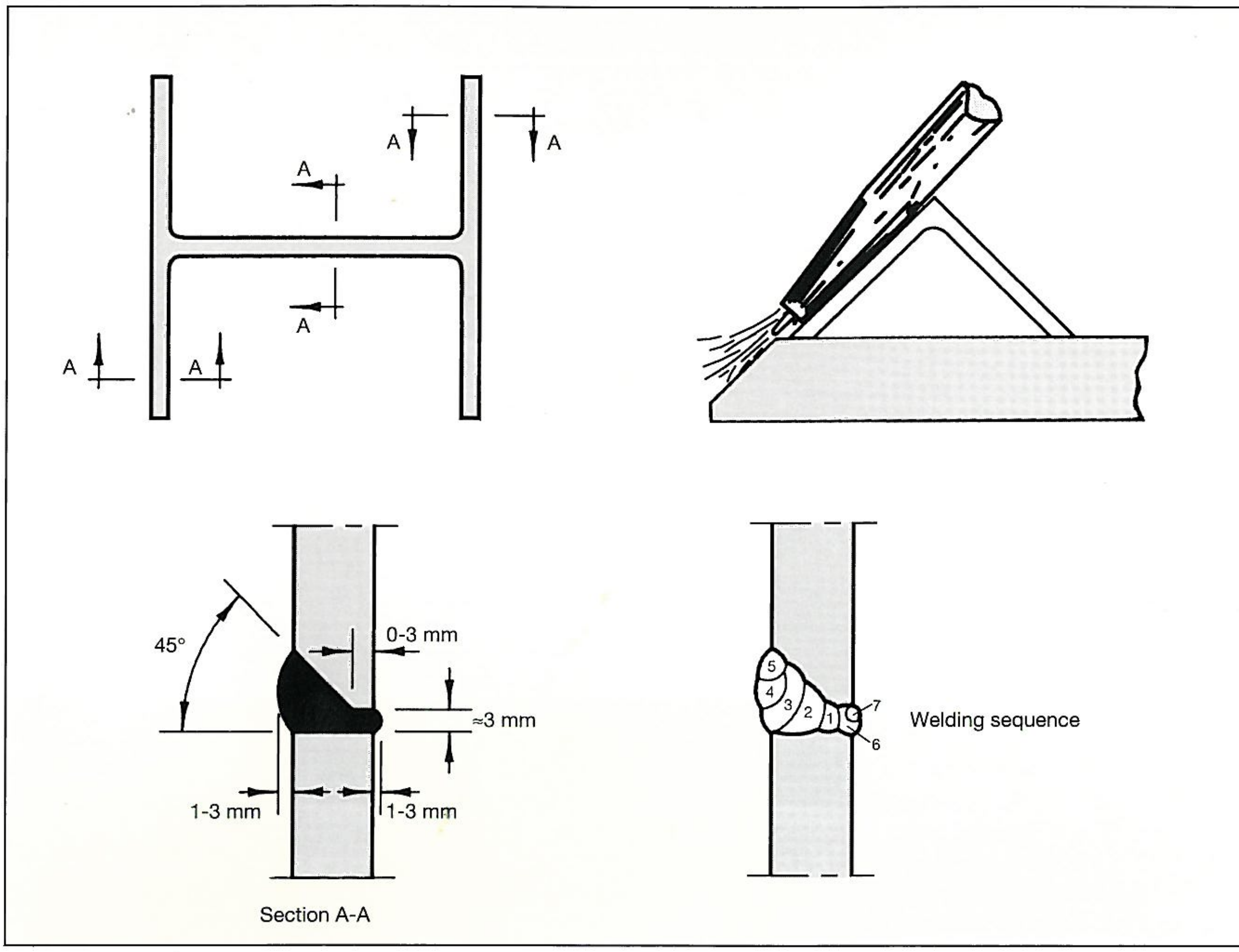


Figure 12: **Typical details for welds performed in vertical position of the pile**

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