ArcelorMittal Europe - Long Products
Sections and Merchant Bars

ArcelorMittal

# Steel Sections in Power Plant Construction

Figure 1: Walsum power plant

# Efficient solutions for power plants with hot rolled sections

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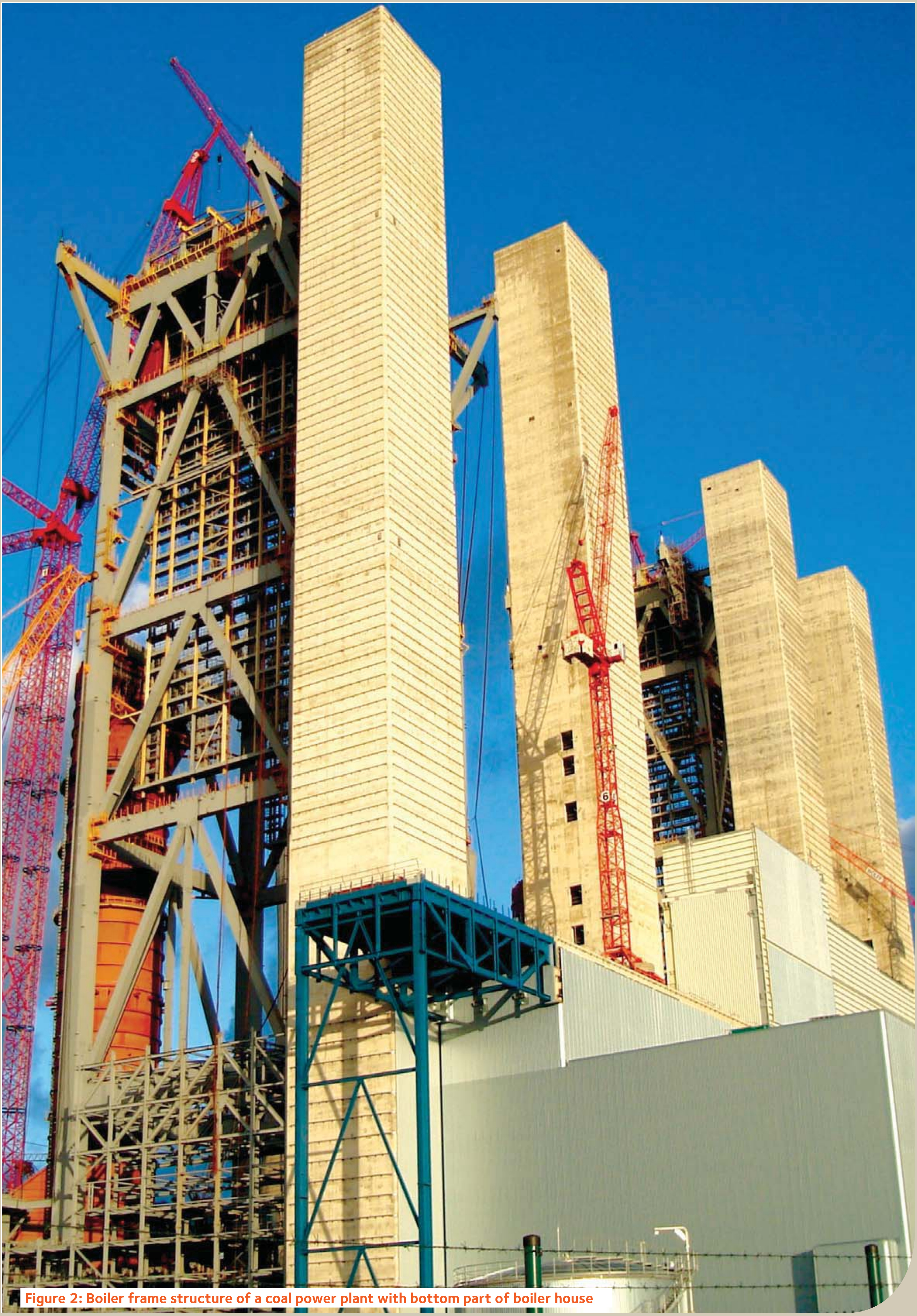


Figure 2: Boiler frame structure of a coal power plant with bottom part of boiler house

# 1. Power plants

## Introduction

The ever growing demand for energy, and investments in new power plants which have been postponed over many years, have recently led to a remarkable boom in the construction of power plants. This requires the use of enormous amounts of steel and a considerable amount of rolled sections. In the area of coal power plants, the proportion of rolled sections accounts for approx. 60% of the total steel volume.

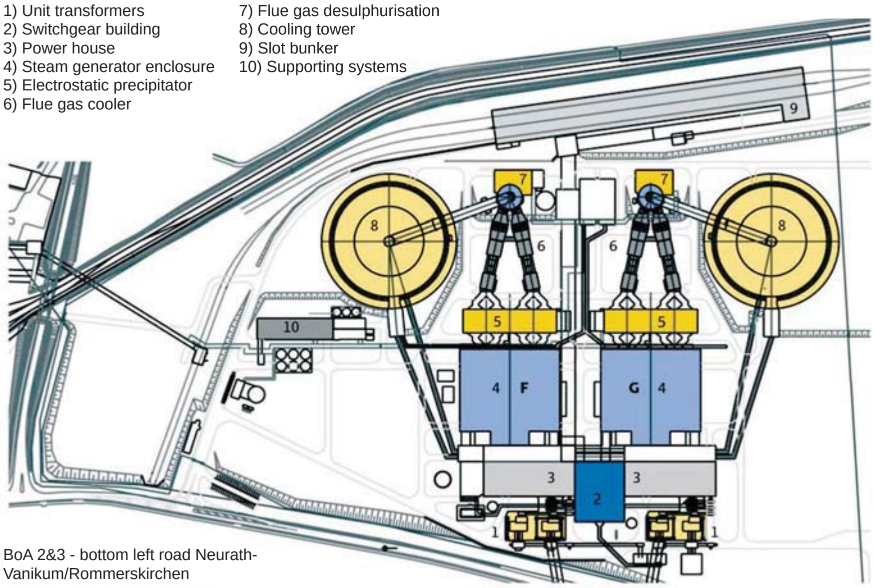
The need for short construction times and rising labour costs make the use of rolled sections attractive. With a wide range of rolled sections, ArcelorMittal offers the right solution for every opportunity.

## Coal power plants

Figure 3 shows the functional units of a coal power plant. Most notable in such power plants are the large cooling towers and the boiler frame structures, which, however, are later enclosed by the boiler house.

But not only these large structures make up a power plant. A number of dependent buildings are necessary to accommodate all the necessary units, such as the power house, in which the generators are located, and the bunker for temporary storage of coal.

Figure 2 shows the boiler frame structure of a modern coal power plant. The staircases have been designed as solid constructions and will later provide access to all areas. In the upper part of the boiler frame structure the pre-installed boiler frame trusses can be seen that will later reinforce the boiler when in operation. In the bottom section in front of the boiler frame structure, the upper structure of the boiler house can be seen which, together with the bottom part of the boiler house, will fully surround the boiler frame structure once lifted in its final position. For this, a large number of rolled sections are used.



Caption

1) Unit transformers
2) Switchgear building
3) Power house
4) Steam generator enclosure
5) Electrostatic precipitator
6) Flue gas cooler
7) Flue gas desulphurisation
8) Cooling tower
9) Slot bunker
10) Supporting systems

BoA 2&3 - bottom left road Neurath-Vanikum/Rommerskirchen

**Figure 3: Overview of coal power plant in Neurath**

Depending on the size of the steam generator, between 20 and 40 working platforms are required. For their construction, the entire range of available rolled sections is used. As can be seen in Figure 4, rolled sections are used almost everywhere for both the supports and main and secondary beams of the platforms.

For the storage of the coal, a bunker is required. While the bunker structure normally consists of heavy I-sections or box sections, the house structure and working platforms are normally made of rolled sections.

In the air heater house, which is attached to the boiler house, fresh air is pre-heated by the flue gas stream. Again, rolled sections are used for the house structure and working platforms.

Then there is also the power house and dependent buildings that are constructed mainly with rolled sections.

In addition to using rolled I-sections as bending beams and supports in platforms, façades and steel structures, they are also often used in bracings and trusses.

Figure 4: Working platform

## Combined gas and steam turbine power plants and alternate fuel power plants

Combined gas and steam turbine power plants and alternate fuel power plants (e.g. fired with wood chips) are being built in increasing numbers due to their high efficiency as well as their use of renewable raw materials and alternate materials. The decentralised construction of such power plants provides for short delivery routes, both for the energy carriers and the energy itself. In these kinds of power plants, rolled sections are not only profitably used for the surrounding structures, but also for internal structures (platforms and supporting framework).

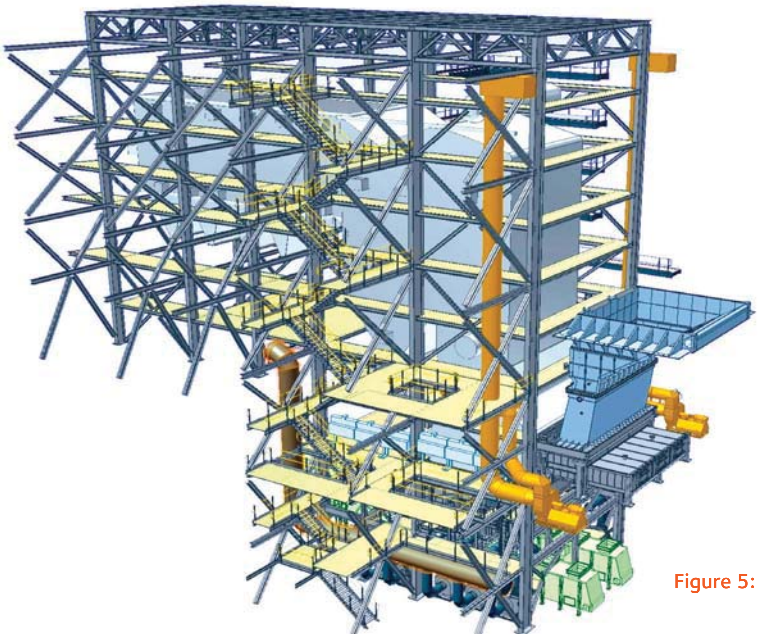


Figure 5: Steel structure of a refuse-derived fuel power plant

Figure 6: SIEMENS Combined Cycle Power Plant - steel structure of the power houses

# 2. Structural steels from ArcelorMittal Europe - Long Products

## ArcelorMittal Europe-Long Products

With plants in Luxembourg, Poland, Romania, Spain and the Czech Republic, ArcelorMittal Europe Long Products is the largest manufacturer of hot rolled steel sections and has worldwide experience in the manufacture and application of these products.

We sell I-sections, U-sections and steel angles and bars. The product range includes all dimensions of European standards and a large number of British, American, Chinese, Russian and Japanese standards. The deepest beam of the standard product range of ArcelorMittal is 1 138 mm. The heaviest rolled section currently has a flange thickness of 140 mm (HD 400x1299). Upon request, sections can also be manufactured to order or to tailor made geometry.

A chart of the entire range of dimensions of available rolled section is shown in Figure 7.

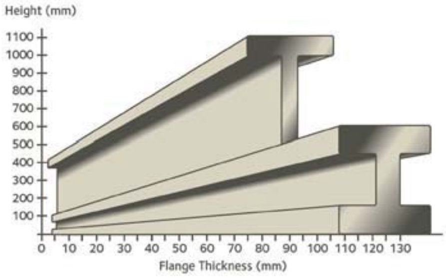


Figure 7: Range of dimensions of rolled sections

Rolled sections are sold in grades that comply with European, American, Russian and Japanese standards. Other grades (e.g. Canadian CSA standards) can be supplied upon request.

The harmonised quality standard for structural steels is EN 10025 which has been prepared on the basis of the Construction Products Directive 89/106/EC and summarises all provisions relating to the EC declaration of conformity and CE marking.

The structural steel is normally supplied with a silicon content of 0.14% - 0.25%. It is therefore suitable for forming a zinc layer during galvanising. The phosphorus content is generally below 0.035% and with respect to the aforementioned Si-values has no effect on the final thickness of the coating

Figure 8: Rolling of a HISTAR-grade beam on the Grey rolling mill of ArcelorMittal in Differdange, Luxembourg

## Thermomechanically rolled structural steel

There is an increasing demand in the market for steel grades that offer high strength values, good toughness, good weldability and a fine-grained structure. The requirements are met by thermomechanically rolled long products (as-delivered condition +M/M according to EN 10025-2 and EN 10025-4) from ArcelorMittal.

The steel grade of these products is largely determined during production in the electric arc furnace. The mechanical properties of these thermomechanically rolled steels are mainly influenced by heat control during the rolling process. This involves taking into consideration the crucial metallurgical processes and controlling the timing of the rolling processes and temperature in a systematic fashion so as to obtain the required material properties. Such treatments are referred to as "normalized rolling" and "thermomechanical rolling". In the EN 10025-2, the terms "normalized rolling" and "thermomechanical rolling" are used. The term "controlled rolling" thus applies to both methods (see Figure 9).

Thanks to the precise temperature control during the rolling process of long products, i.e. during controlled rolling, conventional construction steel with a considerably lower equivalent carbon content than comparable hot rolled or normalized steels can be manufactured. Although in the case of conventionally normalized steels, fine grain elements lead to fine-grained structures and thus high mechanical values, the addition of fine grain elements is associated with a limited loss of toughness. This disadvantage does not arise in the case of thermomechanically rolled fine-grained construction steel, since there is almost no need to add fine grain elements for the manufacture of steel with comparable toughness. Thermomechanical rolling thus enables :

- a considerable improvement of the homogeneity of the material properties,
- a significant reduction in manufacturing costs both on the manufacturing and processing side,
- the creation of a new generation of high-strength, fine-grained rolled steel beams with unprecedented properties.

In addition, thermomechanically rolled steels have good cold formability properties thanks to their grain structure. They can generally also be flame straightened without problems. As with other types of structural steels, it is important to ensure that the flame straightening temperature does not exceed certain maximum values and time intervals (700°C for brief and penetrating heating and 900°C for local surface heating). Residual stresses in the rolled sections can be eliminated by stress-relief heat treatment. This is carried out according to the treatment guidelines in accordance with the usual parameters regarding temperature range and heating time. Further processing by hot forming, which is not common practice for long products anyway, is not permitted according to EN 10025-2.

Upon agreement, grades according to EN 10025-2 and EN 10025-4 can be supplied with improved deformation properties. Such grades are characterised by a lower lamellar fracture tendency when loads are applied perpendicular to the product surface during the manufacturing process (Z-grades).

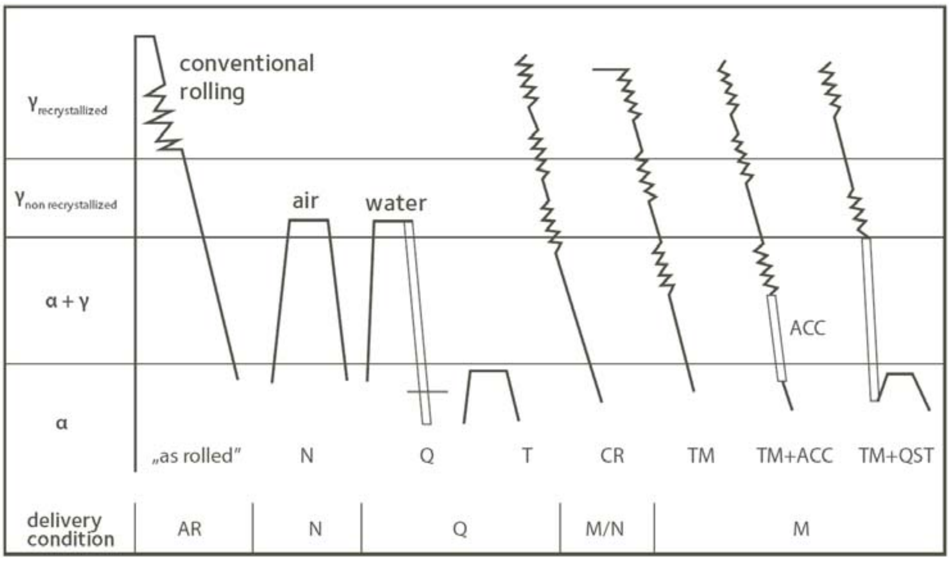


Figure 9: Relation between manufacturing and delivery conditions

## High performance structural steels HISTAR®

HISTAR® steels are more sophisticated thermomechanical structural steels that are manufactured with the in-line heat treatment process QST (Quenching and Self-Tempering) that is used by ArcelorMittal. With low alloy contents, these steels are characterised by excellent welding properties and in addition to their high strength are very tough. They are manufactured with minimum yield strengths of 355 and 460 MPa. HISTAR® steels are delivered in thermomechanically rolled condition and are in full compliance with the requirements of EN 10025-4 The use of HISTAR steels is regulated in Germany by the national technical approval Z-30.2-5, in Europe by ETA-10/0156 (ETA : European Technical Approval).

The brochure "HISTAR, Innovative High-Strength Steels for Economical Steel Structures" provides additional information including mechanical values and manufacturing advantages for all available HISTAR® brand steels. The advantages of HISTAR compared to conventional structural steels, especially for power plant construction, are presented on page 13.

## Alloyed steels for elevated service temperature 16 Mo3

Thanks to its improved mechanical properties (specified up to 500°C) and improved creep resistance, 16 Mo3 alloyed steel grade is particularly recommented for use at elevated service temperatures.

16Mo3 + AR in relation with EN10273 and EN 10028 is now also available in sections and merchant bars. Rolled sections of 16Mo3 grade are far more economical than cutting and welding plates to build up sections of 16Mo3 grade.

16Mo3 steel can be welded with all manual and automatic welding processes according to the general rules for welding.

Table1 : 16 Mo3, Mechanical properties

| Standard | Minimum yield strength $R_{eH}$ MPa | | Tensile strength $R_m$ MPa | | Minimum elongation A $L_0 = 5{,}65*\sqrt{S_0}$ % | Notch impact test | |
|---|---|---|---|---|---|---|---|
| | Nominal thickness (mm) | | Nominal thickness (mm) | | | Temperature | Min. absorbed energy |
| | ≤16 | >16<br>≤40 | ≤16 | >16<br>≤40 | | °C | J |
| EN 10028-2: 2009 + EN 10273: 2007 | 275 | 270 | 440 - 590 | | 24 | -20<br>0<br>+20 | 1)<br>1)<br>40 |

Table 2 : 16 Mo3, Mechanical properties at elevated temperatures

| Standard | 0,2% proof strength at temperature, min. N/mm2 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nominal thickness | 50°C | 100°C | 150°C | 200°C | 250°C | 300°C | 350°C | 400°C | 450°C | 500°C |
| EN 10028-2: 2009 + EN 10273: 2007 | ≤16 mm | 273 | 264 | 250 | 233 | 213 | 194 | 175 | 159 | 147 | 141 |
| | 16 mm< t ≤40 mm | 268 | 259 | 245 | 228 | 209 | 190 | 172 | 156 | 145 | 139 |

Table 3 : 16 Mo3,Chemical composition

| Standard | Cast analysis | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C % | Si max. % | Mn % | P max. % | S max. % | Al total min. % | N max. % | Cr max. % | Cu max. % | Mo % | Ni max. % |
| EN 10028-2: 2009 + EN 10273: 2007 | 0,12 - 0,20 | 0,35 | 0,40 - 0,90 | 0,025 | 0,010 | 2) | 0,012 | 0,30 | 0,30 | 0,25 - 0,35 | 0,30 |

1) A value may be agreed at the time of enquiry and order.

2) The Al content of the cast shall be determined and given in the inspection document.

# 3. Hot rolled sections and their advantages

Due to the enormous time pressure under which construction projects are carried out these days, it is necessary to use rolled sections as much as possible. Several factors influence the decision whether to use rolled sections or welded sections.

## Advantages for the operator

For the operator of a power plant it is very important that the construction takes place as quickly and smoothly as possible, because the sooner the construction work is completed, the sooner the power plant can be put into operation. The use of rolled sections has the advantage that their higher degree of fabrication considerably reduces the construction time. This advantage is also important for the construction company, since shorter construction times have economic advantages

## Advantages for the builder of the power plant

*Influencing factor : workshop capacity*

The commissioned steel construction company must obviously check its workshop capacity before commencing large projects, under which the construction of power plants certainly falls. Since only very large welded sections (mainly box sections) can be used for the boiler frame structure with its extremely high loads, large capacities are required in the workshop areas “assembly” and “welding”. For rolled sections, far fewer capacities are required which is why it makes sense to use rolled sections to utilise capacities more effectively and manufacture in a timely and economical fashion.

*Influencing factor: cost effectiveness*

One of the most important factors in decision-making is cost effectiveness. It is therefore necessary to define the area in which rolled sections are more cost effective than welded sections. Variables such as costs for plates and welding as well as for rolled sections play a role in this respect.

It becomes clear that not only the material price speaks for the use of rolled sections, but in particular the very low costs for cutting and welding rolled sections compared to welded sections

*Influencing factor: flexibility*

For the builder of the power plant it is very important that the products needed for the construction are available at the desired location, on the desired date and the desired quality. In this respect ArcelorMittal can meet all customer requirements since the availability of rolled sections is very high. Thanks to the wide range of rolled products, suitable and flexible solutions can be found for all requirements. Quality control measures ensure that only products of the highest quality are delivered and arrive on time at the desired location. For documentation purposes, all required certificates can be provided.

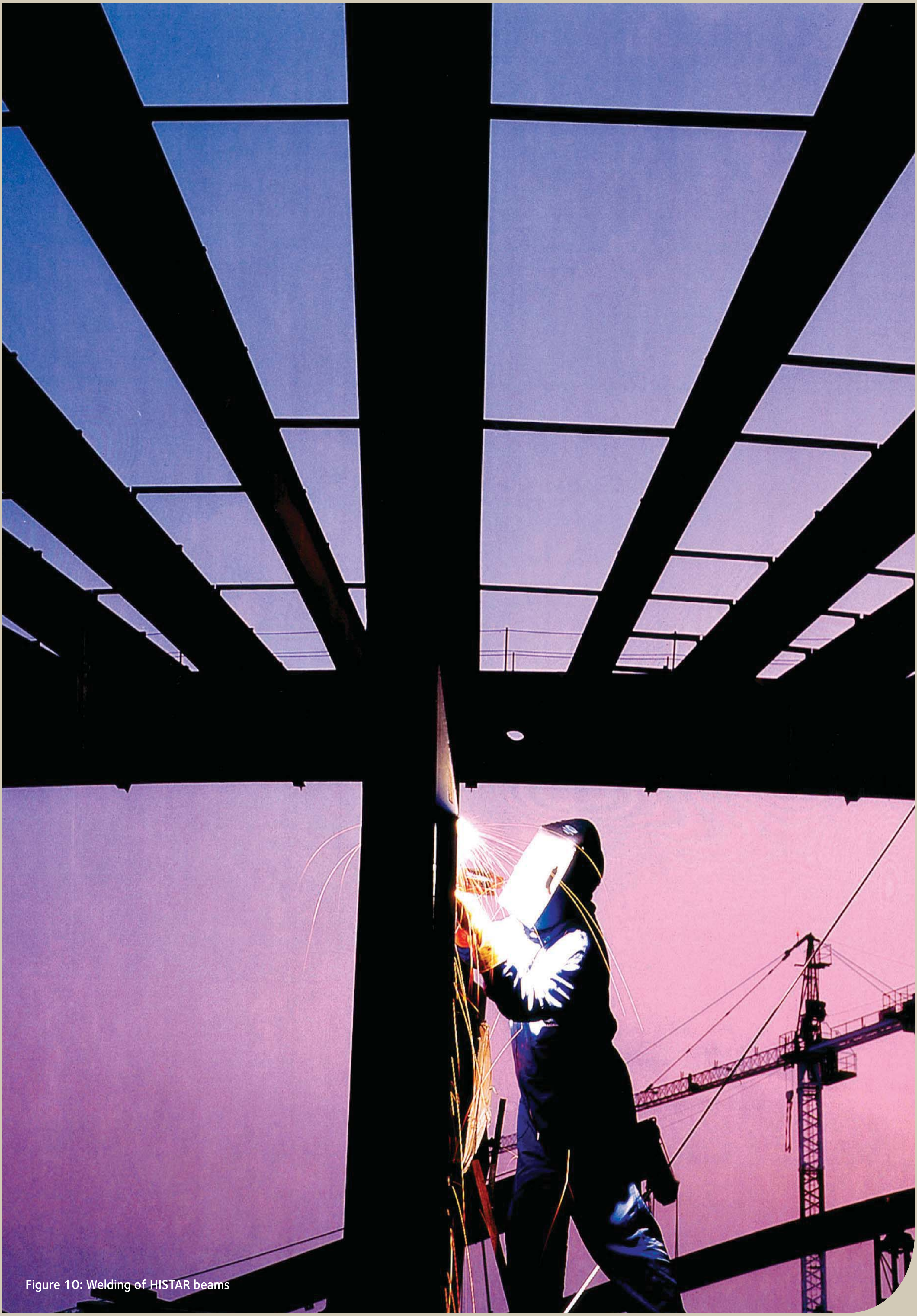


Figure 10: Welding of HISTAR beams

# 4. Advantages of HISTAR® steels compared to conventional steels

HISTAR® steels are low-alloy, high-strength thermomechanical fine-grained construction steels with excellent weldability and good toughness values. The yield strengths of HISTAR® grades are superior across the entire range of material thickness compared to standard structural steels (see Figure 11).

By using HISTAR steels with higher strength values, cost savings of up to 50% compared to S235 are possible with regard to construction elements. Due to the high yield strength, the steel tonnage can be reduced by around 50% – in some cases even more. Since the material price for HISTAR 460 is only slightly higher (10-15%) than for S235, cost savings of 30-40% are possible on material costs.

Additional savings are possible at processing in the workshop. The volume of weld deposits can generally be significantly reduced. When smaller sections are used, the surface area to protect against corrosion is reduced. Thanks to the lighter construction, transportation costs are lowered. Depending on the location and availability of equipment on the construction site, smaller cranes or hoists can be used.

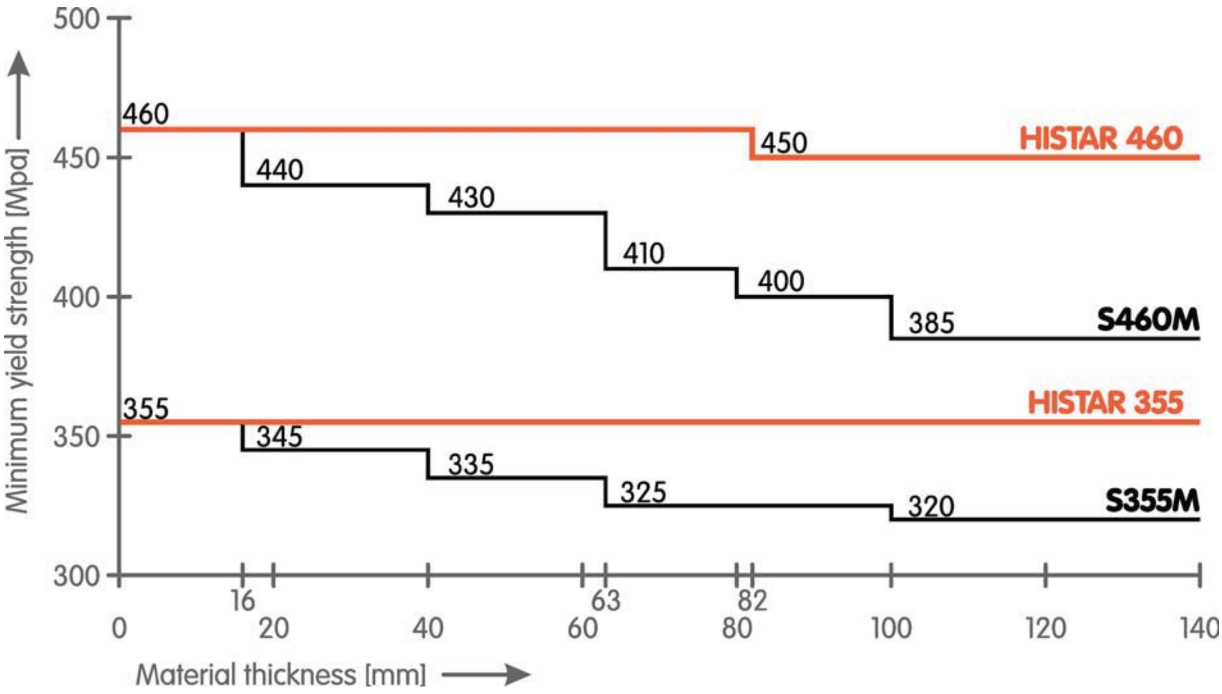


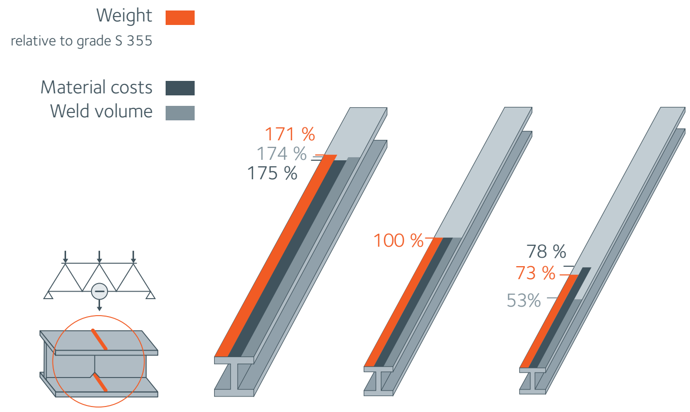
Figure 11:Minimum yield strength of HISTAR steels and EN10025-4 steels according to the material thickness

Figure 12: Use of HD-sections in the power plant in Datteln

These potential savings are shown on Figure 13 for tensile-stressed chords used in truss constructions. And it is even possible to choose the various section members required for truss constructions from a single section series (e.g. HD400), as the truss joints can be greatly simplified.

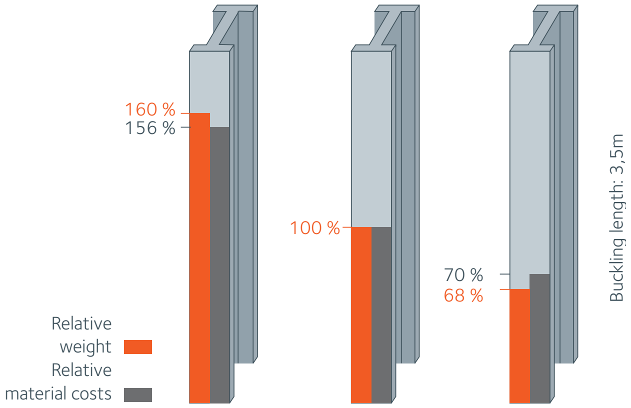
Indeed, since the sections of a same serie all have the same inner-distance between 2 flanges, they can be directly welded together without the need of elaborate joining techniques in the connection area, see Figure 16.

In the case of compression loaded members, advantages relating to the buckling stress curve “a” or “$a_0$” arise that go beyond the high yield strength due to the better classification of sections in S460. By using HISTAR 460 in building structures where buckling lengths play a role, between 50% and 55% of material can be saved compared to S235, see Figure 15.



| Steel grade | S 235 JR | S 355 JR | HISTAR 460 |
|---|---|---|---|
| Section | HD 400 x 1086 | HD 400 x 634 | HD 400 x 463 |
| Ultimate load (kN) | 27027 | 26260 | 27117 |

Figure 13 : Economical use of HISTAR beams in truss applications



| Steel grade | S 235 JR | S 355 JR | HISTAR 460 |
|---|---|---|---|
| Section | HD 400 x 1086 | HD 400 x 677 | HD 400 x 463 |
| Ultimate load (kN) | 25254 | 24580 | 25156 |

Figure 14 : Economical use of HISTAR steel in heavy columns

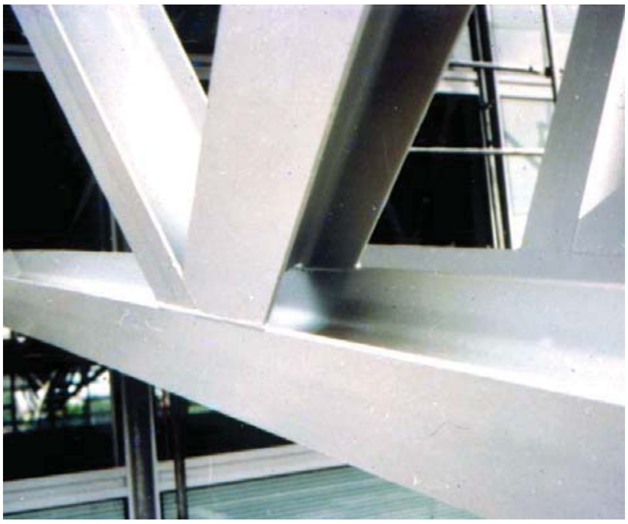
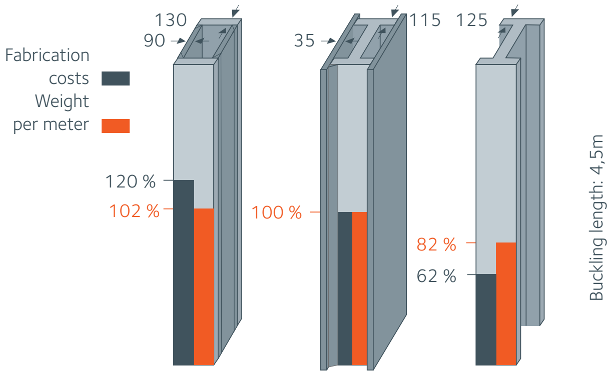


Figure 16: Optimised truss joint with sections from one series



| Steel grade | S 355 | S 355 JR | HISTAR 460 |
|---|---|---|---|
| Section | Box column | HD 400 x 990<br>+ plates | HD 400 x 1086 |
| Ultimate load (kN) | 47463 | 46568 | 50544 |
| Weight (kg/m) | 1342 | 1320 | 1086 |

Figure 15: Economical use of HISTAR columns compared to built-up sections

Figure 16: Example – power plant in Diandong, Yunnan province (China)

The resistance of a beam in relation to the buckling length for a selection of steel grades is presented in Figure 17. In addition, the advantages of HISTAR beams are explained with an exemplary calculation in Annex A1.

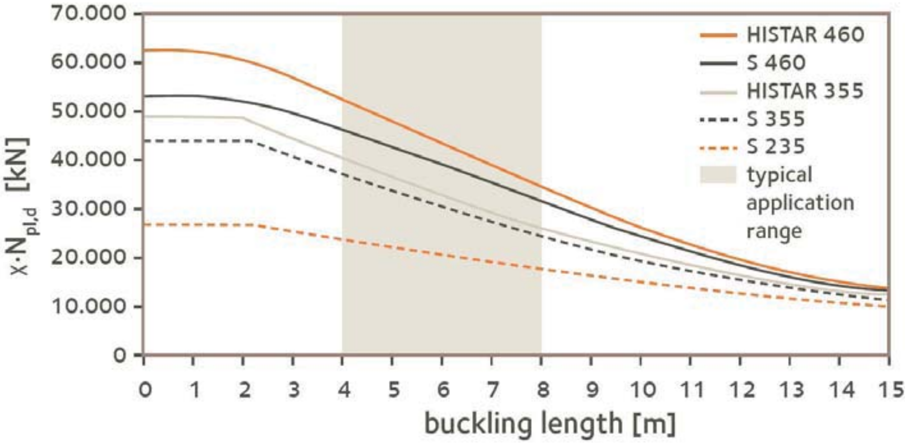


Figure 17: Resistance in relation to buckling length

In the example shown in Figure 16, the efficient use of rolled sections is shown. By using HISTAR 460 and HD-sections for high-load beams, there was no need for welded sections. As for the truss construction, large HL-sections were used for both the chord members and diagonals, thus allowing for an overall cost-effective solution.

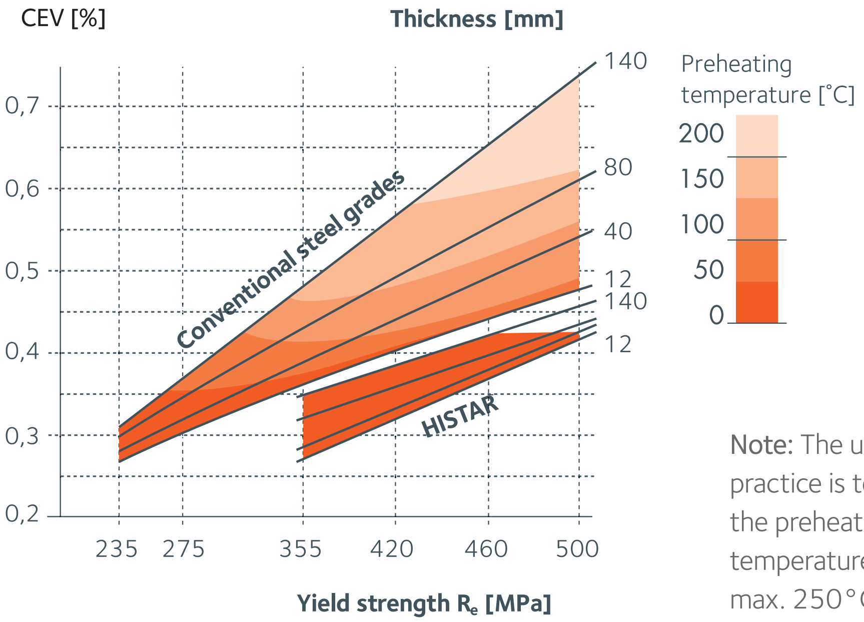
Figure 18: Boiler house of the power plant Wilhelmshaven, Germany

In accordance with the general rules of welding technology (EN 1011), HISTAR® grades offer optimum weldability for all manual and automatic welding processes.

Due to the low carbon equivalent, pre-heating is not required for welding energies of 10-60 kJ/cm and processing temperatures > 0 °C, provided welding consumables with low hydrogen content are used.
Under these conditions, HISTAR® 355 steels, for example, can be welded in any thickness without the need for pre-heating, see Figure 19.

As for conventional construction steels, drying before welding is recommended for ambiant temperatures below 5 °C and when the surface is wet.

This reduces energy costs in steel processing and increases productivity, since time can be saved due to the omission of pre-heating. The greater material throughput in the workshop area increases its capacity and efficiency, which in turn is reflected in the costs.



**Note:** The usual practice is to limit the preheating temperature at max. 250 °C.

No pre-heating of HISTAR steels under the following conditions:

- for $R_e < 460$: $H_2$ 10 ml/100 g
- for $R_e > 460$: $H_2$ 5 ml/100 g
- $E > 10$ kJ/cm

$$CEV\ (\%) = C + \frac{Mn}{6} + \frac{(Cr+Mo+V)}{5} + \frac{(Cu+Ni)}{15}$$

Figure 19 :Preheating temperatures for conventional structural steel gtrades and HISTAR grades (acc. to EN 1011 - 2:2001/method A)

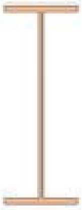
This advantage can be exemplified with a welded joint of an HD 400x1086 support section (see Figure 20). For an S355 section, the pre-heating process takes approx. 4 hours before one can begin welding, which in turn will take another 8 hours. By using HISTAR steels, pre-heating can be eliminated. This saves time and energy and thus generates a significant economic advantage.

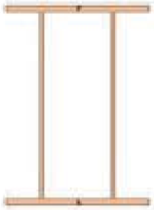
As for the dimensioning of fillet welds, HISTAR 460 has the additional advantage over conventional S460 that the welding coefficient for fillet welds for the dimensioning of HISTAR 460 is $\beta_w = 0.80$ compared to $\beta_w = 1.00$ for S460.

HISTAR® steels meet all the requirements of conventional structural steels. Under normal conditions, stress relief heat treatment, thermal cutting and mechanical processing can be performed in the same way as with comparable thermomechanical rolled structural steels in the respective tensile strength range.

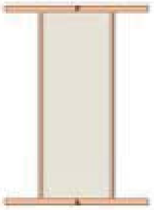
Figure 20: Welding of an HD 400 x1086 section made of HISTAR 460

## Sections based on HL- and large HE- profile range

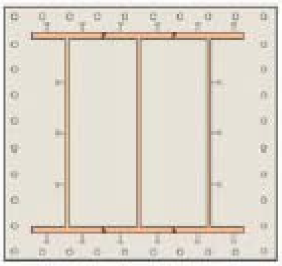




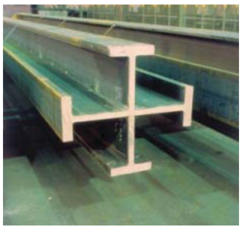
Box section welded from two sections

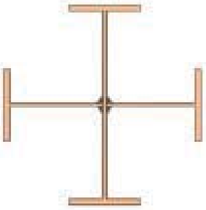


Composite column: box section with concrete reinforcement welded from two sections

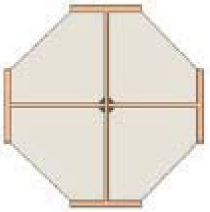


Composite column: box section welded from three sections encased in concrete



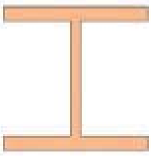


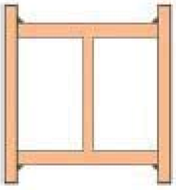
Cruciform section made out of one rolled sections and two T-sections



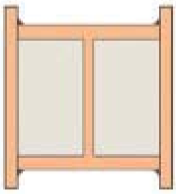
Composite beam: cruciform beam with concrete filling

## Sections based on HD- and medium HE- profile range

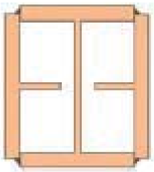




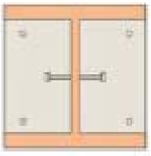
Wide flange beam boxed with two plates



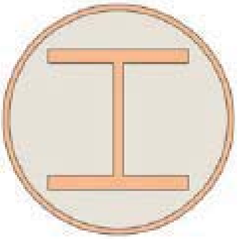
Composite column: wide flange beam boxed in two plate and filled with concrete



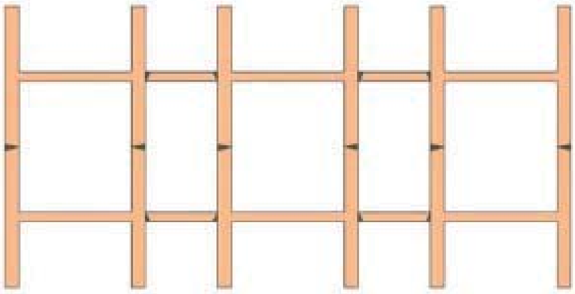
Box section made out of one rolled section and two T-sections



Composite beam or column; wide flange beam partially encased



Composite column: wide flange sections encased in concrete-filled steel tube



Mega column built from 6 wide flange beams and 4 connection plates

Figure 21: Optimised beam cross sections on the basis of rolled beams

# 5. Optimised construction elements in power plant construction

## Sections for supporting high loads

In addition to the conventional use of I-sections as bending beams or columns, they are also suitable for building up optimised construction elements. This allows two hot rolled I-sections to be welded together as a cross-shaped section or box section This compensates for the reduction in the buckling load around the weak axis, which is typical for I-sections. While cross-shaped sections are more favourable for connections to beams and truss girders, they have a considerably larger coating area compared to box sections. Corrosion protection does not have priority in power plant construction since the entire building is surrounded by the façade. Only during the construction phase, which can indeed take several months, sufficient protection against corrosion must be provided.

After the assembly, concrete can only be filled with the help of formwork. In this respect, box sections, in particular round pipes including rolled sections, offer significant constructional advantages. If these construction elements must meet fire protection requirements, a thin-walled, low-strength round pipe in conjunction with a heavy HISTAR 460 I-section can offer a solution.

In Figure 21, various optimisation options are shown: from assembled rolled sections to various composite members.

Figure 22: cross-shaped column filled with concrete

Figure 23: concrete-filled pipe with an embedded rolled section

# Use of cellular beams

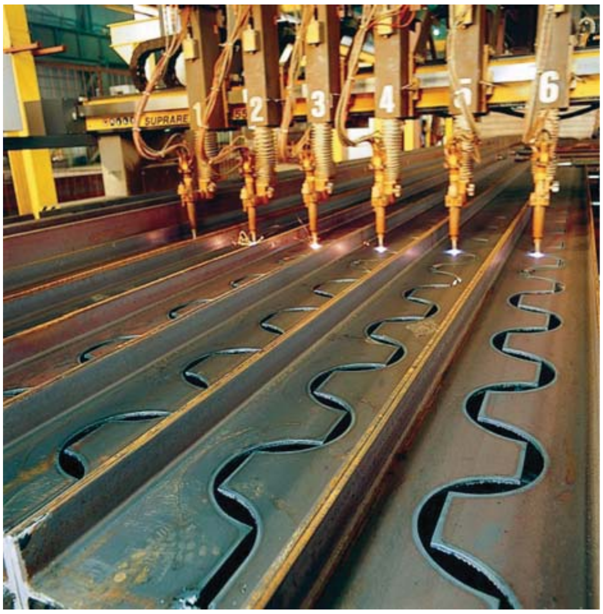
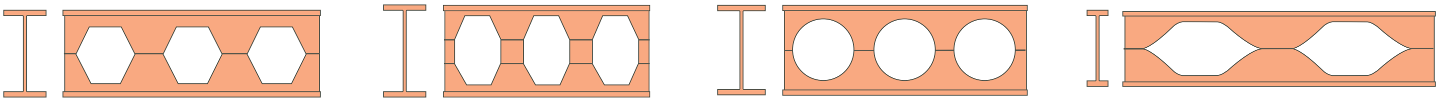


Figure 24: Cutting rolled sections for the manufacturing of ACB beams

Figure 25: ease of installation of ACB beams



Cellular beams
with hexagonal openings

Cellular beams
with octagonal openings

ACB cellular beams
with circular opening

ANGELINA® cellular beams with
sinusoidal openings

Figure 26: Types of cellular beams

In addition to the complex architectural design possibilities, the use of cellular beams (ACB beams) in plant construction offers the advantage of great ease of installation. Cellular beams are manufactured from standard rolled sections with a defined cutting sequence and subsequent rotation and welding. ArcelorMittal offers three different cutting variations which can be used to create four types of cellular beams.

Due to the rotation, the created beams are deeper than the initial section. The bending resistance is thus increased. In addition, it is possible to combine different sections or different steel grades into one hybrid section. Thanks to flexible cutting, it is possible—within the technical limits—to create a large number of different cellular beams from the same initial section and thus define the cross section and/or final depth of the beam.

Constructions can thus be optimised in terms of height, weight or e.g. a minimum cell size.

The final depth of an IPE600 section, for example, can range between approx. 640 mm and 980 mm. The cell diameters lie between 160 and 780 mm. The optimum cell size for single beams is generally about 5% larger than the depth of the initial section

### 1. Use of ACB beams in power plant construction

The possibility to change the arrangement of the holes according to customer requirements allows optimum solutions to be found for every situation. In cooperation with the customer it is thus possible by using cellular beams to perfectly harmonise the areas of ductwork and cabling with the load capacity and hence benefit from the weight reduction. Thanks to the higher load capacity, constructions are less heavy and larger spans can be achieved. With ACB beams, a maximum beam depth of over 1,800 mm can be achieved with rolled sections.

### 2. Installation ease

In this respect it is especially worth noting that when using ACB beams there is no need to create holes for ducts and cables. An important parameter for determining the right ACB beam is the maximum diameter of ducts to be led through the beam. The diameter of the opening should be at least 3-5 cm larger than the ducts in order to facilitate the installation of the cables and prevent damage to any corrosion inhibitor or fireproofing paint that may have been applied to the beam.

Another aspect is the adaptability of buildings and equipment over a long period. While the number of ducts and their location are clearly defined when constructing a new building, it is not unusual that duct layouts change over the years. Should ducts have to be re-routed or if new ducts are added, the ACB beams with their even distribution of web openings have the advantage that this can be achieved easily without having to create new openings. Thus, additional costs are greatly reduced in this context.

### 3. Large spans possible

In power plant construction there is a particular demand on large areas of column-free spaces. In lignite-fired power stations up to 40,000 m$^2$ of areas are required, most of which do not have to take heavy loads. Here, the use of ACB beams can be beneficial. By first cutting the rolled section apart and then welding it back together again, the overall depth and thus also the load capacity are increased while the weight is reduced. This allows for greater spans or, conversely, lower weights. Considering the large tonnage of rolled sections required in power plant construction, the use of ACB beams can have an economic advantage. This is also reflected in the rising trend of material and transport costs.

### 4. Use as platform supports

As mentioned above, large column-free areas and platforms are required in power plant construction.

Annex A2 shows the advantages that can be gained by using ACB beams as platform supports. The ACB beam used weighs approx. 60% less than the plain beam section and is approx. 10% cheaper.

### 5. Use as boiler stiffeners

Another way of using cellular beams is as boiler stiffeners. These are construction elements that are used to reinforce the boiler and are subject to permanent bending stress. Depending on the size of the boiler, rolled sections with an overall depth between approx. 600 mm and 1,100 mm are used. Larger sections are generally made by welding sections.

In this respect, the use of large ACB beams is to be considered, since deformation is the decisive factor for the use of boiler bandages – and the great bending stiffness of these beams is clearly a major advantage. In its product range, ArcelorMittal offers ACB beams with round, hexagonal and sinusoidal openings with overall depths exceeding 1,800 mm.

The advantage of the weight reduction, already explained in the previous chapter, becomes even more important in this respect. Since the complete boiler, including attachments and boiler frame structure, is attached to the boiler frame structure, all loads must be transferred upwards to the boiler beams and then down again via the boiler frame structure. The weight reduction achieved with the boiler stiffeners thus also reduces stress on the boiler frame structure.

In addition, the evenly distributed web openings for the ducts and the hoisting method (strand jack) generally used are also very favourable. The stiffeners, which are subject to very high temperatures, are also manufactured in grade 16 Mo 3

### 6.Additional advantages of ACB beams

ACB beams can be manufactured with variable depth along the length. This is particularly useful when using the beams as cantilever arms or frames, since the beam resistance can be adjusted to the loading.

In addition, defined cambers can be created during the manufacturing process so that deflections caused by permanent loads can be compensated for.

Additional advantages and applications can be found in the brochure “ACB Cellular Beams”.

# 6. Foundations for high loads

For decades, bearing piles made of steel have been used as a cost efficient solution for deep foundations, especially when high vertical loads need to be transferred into the foundation soil. All wide-flange beams are suitable for this. The HP steel piles are optimised for this type of application. Compared to normal beams, the radii of gyration of these special, wide-flange beams with identical flange and web thicknesses are distributed more evenly around the two main axes. Thanks to the large range of standard sections and HP piles, the design engineer is able to find the ideal solution in terms of bearing capacity and pile driving properties. In addition, high-strength steel grades such as HISTAR can be used to reduce the required amount of steel but maintain the bearing capacity and optimise costs.

The specific shape of the pile and the properties of the steel mean that HP piles can be used in various soil conditions. Since it is a prefabricated product, the quality can be tested in advance. In addition, the piles can be subjected to loads immediately after their installation.

Worldwide, there are various methods for predicting the bearing capacity of the piles. For large projects, static tests or PDA tests (Pile Driving Analyzer) can be carried out on-site to determine the possible bearing capacity more accurately and define the safety factor more favourably than when empirical calculation methods are used.

Steel piles obtain their bearing capacity through skin friction. In suitable soils, the point bearing pressure can also be defined in addition to the bearing capacity. In addition, there are various ways to further increase the skin friction and point-bearing pressure, cased piles with specially designed tips, to name one.

After previous agreement with the plant, rolled sections can be supplied in lengths up to 40 m or more. If required, even longer sections can be achieved by means of special fasteners or by welding. This is particularly beneficial if during installation it turns out that the required application depth is lower than the calculated depth. Since during the first phase of the project the soil conditions can only be estimated by means of geotechnical examinations, it is a great advantage to be able to flexibly respond to soil layers and conditions.

Figure 27: Use of HEB 800 with lengths ranging between 33.80 and 38.80 m as driven piles for water intake at the power plant Wilhelmshaven. During the construction phase they serve as tension piles to prevent lift, in their final function they transfer loads.

The subsequent connection of the pile head to the steel or concrete foundation can be achieved relatively easily by means of various connection methods.

The piles are normally installed using pile hammers which are so strong and flexible that they can drive piles into extremely compact soils without negatively affecting the surrounding area. Vibrations and noise can be controlled via various control systems.

The piles can be used in almost all types of soil. Even if soft layers of soil lie above the compacted, load-bearing soil, the piles are still reliable and economical since the soft layers have neither a negative effect on the installation nor on the bearing capacity of the piles. If displacement piles are used, an additional advantage may be that no soil material (possibly contaminated) is excavated that would need to be disposed of.

Examinations of steel piles that have been removed from the soil after 50 to 80 years have shown that the total reduction in steel thickness due to corrosion is so minimal that no impairment of their bearing capacity is to be expected. Further guidance in this respect can be found in EC3, part 5.

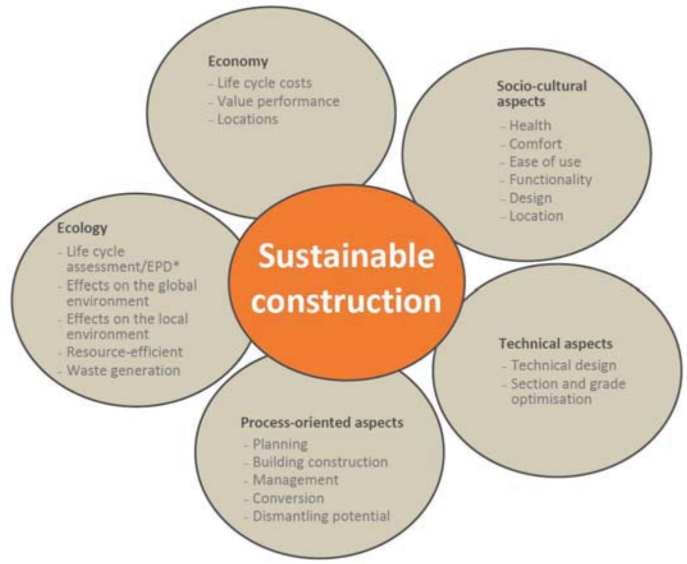
Finally, it should be mentioned that because of the inherent properties of steel, the piles can be subjected to both compressive and tensile loads. In particular this ability makes them interesting for constructions that, depending on the level of the ground water, require the piles to absorb both compressive and tensile loads. Used as tension piles, they often present a more optimised and cost-efficient solution than injection or bored piles. Ultimately, even high tensions that occur, e.g. during pile driving, especially in compact soils, pose no threat to the stability of the piles.

Bending stress caused by e.g. the lateral pressure of soft layers of soil or horizontal loads above the foundation plate, can be transferred by the bending capacity of the steel sections. The same is true for horizontal movements caused by earthquakes.

In summary it can be said that the steel piles can be used for a large number of foundation applications and are ideally suited for high vertical loads in most soil conditions.

Figure 28: Driven piles with reinforcement at the base to increase the cone friction resistance and thus provide support for high loads

# 7. Hot rolled sections in sustainable construction



The preservation of natural resources in our industrialized societies has become a priority in the creation of the built environment. Consequently, the industrialized building concepts have to comply with changing economical parameters like the incorporation of life cycle analyses in the design of buildings, as well as with technological changes for considering at an equal level sustainability goals with respect to the environment and society

These sustainability goals are in nature:

- in ecological aspects
- in economical aspects
- in socio-cultural aspects
- in technical aspects
- in process aspects

They are interdependent as well as ambivalent, providing a coherent response to complex questions and ensuring the future generations a pleasant built environment. Sustainable construction using hot rolled steel sections is fully consistent with the various aspects of the sustainability goals.

- Ecological aspects of sustainability

The main ecological goals aim at using construction materials that are safe from health and environmental points of view, at reducing structures waste when dismantling buildings at the end of their service life, and at preserving as best possible the energy content in the construction materials, thus maintaining their ideal efficiency, Here, structural steels offer high material efficiency and rolled sections constitute the most recycled construction material in the world. In the modern electric arc furnace (EAF) route, steel is produced using 100% scrap as a raw material (upcycling). Also, used steel elements can be deployed for further use in renovation and refurbishment of existing buildings. In addition, the EAF technology of steel allows for significant reductions of noise, particle- and $CO_2$- emissions as well as water and primary energy consumption in the production mills.

- Economic aspects of sustainability

Beside being interested in the reduction of investment costs, investors are also concerned about the optimization of operational costs and the achievement the longest possible service life in combination with high flexibility in use of the building. Rolled sections in structural steel allow architects and designers to easily fulfill the requirements of investors by combining high quality, functionality, aesthetics, low weight and short construction time. Slender superstructures can be designed which decrease construction height and foundation works leading to a further decrease of material, fabrication, transport and construction costs. Short construction times and therefore reduced traffic disturbance save user costs during construction. Tenders including the lifecycle costs prove the competitiveness and sustainability of steel and composite structures. Recovered steel can be recycled indefinitely. Assuming an appropriate design, whole structures or their individual steel elements can be re-used after dismantling of the original building and offer so significant economical life-cycle potential.

- Socio-cultural aspects of sustainability

This aspect allows the architect toreconcile his own aesthetic demands for a building with the social expectations of its surrounding environment. Again, thanks to the prefabrication construction system, rolled steel sections provide the user with transparent and lean structures combined with robustness and safety. Local inhabitants and their social environment remain clean in uncontaminated surroundings as steel in structures does not release any harmful substances into the environment.

- Technical aspects of sustainability

Structures made of rolled beams have the advantage of being able to resist high level utilization and are adaptable to changes in use. These robust construction solutions are capable of coping well with variations in use during service life without damage or loss of functionality.

- Process aspects of sustainability

Steel constructions offer many advantages through their flexibility, lightness and cost effectiveness. Rolled beams are used as primary bearing elements. They are industrially produced to a high quality, offer good availability in a full range of sizes and steel grades, including HISTAR.
Fabricated in specialized workshops the end product is delivered to site ready for erection. Quality control has already been carried out at the production. Smaller construction sites and plant equipment are therefore needed whilst minimal noise and dust disturbance on site are characteristics for steel construction. Structures using hot rolled sections reduce erection times. Hence, transportation cost as well as accident potential is reduced.

For years, WorldSteel association is collecting information on the steel production, All impact value of environmental impact of steel production and steel recycling are peer reviewed by an independent organism (PE International) to confirm that all theses calculations are in line with the standard ISO 14040-44. High strength HISTAR grades allow, in comparison with conventional structural steels, to cut down the weight and material costs of steel structures, -reducing processing time and energy.

To document in a standardized way the environmentally relevant information, an EPD (Environmental Product Declaration) in accordance with ISO 14025 is available for structural steel at sections.arcelormittal.com
.

# Annex A1

## Comparison of rolled section S235 with HISTAR 460

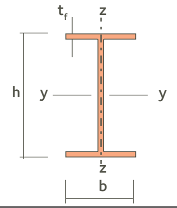
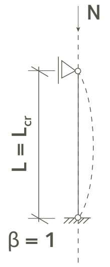
| Cross Section | | Limits | | Buckling about axis | buckling curve | |
|---|---|---|---|---|---|---|
| | | | | | S 235<br>S 275<br>S 355<br>S 420 | S 460 |
| Rolled sections |  | h/b > 1,2 | $t_f \leq 40$ mm | y – y<br>z – z | a<br>b | $a_0$<br>$a_0$ |
| | | | 40 mm < $t_f \leq 100$ | y – y<br>z – z | b<br>c | a<br>a |
| | | h/b ≤ 1,2 | $t_f \leq 100$ mm | y – y<br>z – z | b<br>c | a<br>a |
| | | | $t_f > 100$ mm | y – y<br>z – z | d<br>d | c<br>c |

Figure 30: Table from EN 1993-1-1: 2005

This table shows that for all rolled S460 sections, a more favourable buckling curve can be selected. Thus, slimmer sections can be used and proven.

The example below of a compression member illustrates the advantage of HISTAR 460.

Member subject to normal compression.
Design compression force:



$N_{Ed}$ = 6.600 kN
System length = buckling length
L = 325 cm
Buckling resistance verification according to EN 1993-1-1: 2005 (D)

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$N_{b,Rd}$ is the buckling resistance of the member compression

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$

For a member made of **S235**, a rolled section **HEM 400** is required.

The proof looks like this :

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} = \sqrt{\frac{325{,}8 \cdot 22{,}5}{37950}} = 0{,}440$$

It follows :

$$\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right] = 0{,}637$$

The imperfection factor $\alpha$ included therein results from the buckling curves. For a rolled section HEM 400 made of S235, the buckling curve b must be chosen. The imperfection factor corresponding to buckling curve b is :

$\alpha$ = 0,34
This results in the stress reduction factor $\chi$

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \leq 1$$

$$\chi = 0{,}91$$

$$N_{b,Rd} = \frac{0{,}91 \cdot 325{,}8 \cdot 22{,}5}{1{,}0} = 6.671\,\text{kN}$$

$$\frac{6.600}{6.671} = 0{,}99 \leq 1 \quad \text{Verified!}$$

For a member made of **HISTAR 460**, a rolled section **HEA 400** is required. Verification :

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} = \sqrt{\frac{159 \cdot 46{,}0}{16804}} = 0{,}660$$

It follows :

$$\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right] = 0{,}748$$

The imperfection factor $\alpha$ included therein results from the buckling curves. For a rolled section HEA 400 made of HISTAR 460, the buckling curve $a_0$ must be chosen with.

$\alpha$ = 13
This results in the stress reduction factor $\chi$

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \leq 1$$

$$\chi = 0{,}91$$

$$N_{b,Rd} = \frac{0{,}91 \cdot 159 \cdot 46{,}0}{1{,}0} = 6.655\,\text{kN}$$

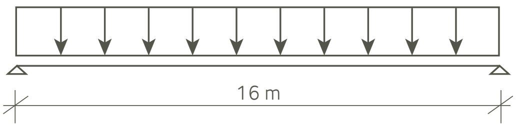
$$\frac{6.600}{6.655} = 0{,}99 \leq 1 \quad \text{Verified!}$$

In this example, the advantages of HISTAR 460 become very clear. The beam made of S235 weighs 256 kg/m while the beam made of HISTAR 460 only weighs 125 kg/m.
**This results in a weight reduction of roughly 50%.**

# Annex A2

## Comparison of rolled section with ACB beam

Single beam subject to uniformly distributed load
Span : 16,00 m
Assumption: Beam laterally restrained



**Rolled section IPE 550**

LF1 permanent loads
$g_{Section}$ = 1,06 kN/m
$g_{Grid}$ = 0,38 kN/m
$g_{Total}$ = 1,44 kN/m

LF 2 Loads suspended from platform ceiling (2.00 kN/m², beam distance 1.25 m)
$q_1$ = 2,50 kN/m

LF 3 Platform area load (2.50 kN/m², beam distance 1.25 m)
$q_2$ = 3,125 kN/m

Load combination
1,35 • LF1 + 0,7 • 1,5 • LF2 + 1,5 • LF3
= 9,25 kN/m
$M_{max}$ = 296,0 kNm

Proof of bearing capacity:
12,13 kN/cm² $\leq$ 22,5 kN/cm² Verified !

SLS verification:
Maximum deflection at midspan : l/250
56,0 mm $\leq$ 64 mm Verified !

**ACB sections from IPE 400**
($a_0$ = 460 mm, S = 580 mm, H = 630 mm)

LF1 permanent loads
$g_{Section}$ = 0,66 kN/m
$g_{Grid}$ = 0,38 kN/m
$g_{Total}$ = 1,04 kN/m

LF 2 Loads suspended from platform ceiling (2.00 kN/m², beam distance 1.25 m)
$q_1$ = 2,50 kN/m

LF 3 Platform area load (2.50 kN/m², beam distance 1.25 m)
$q_2$ = 3,125 kN/m

Load combination
1,35 • LF1 + 0,7 • 1,5 • LF2 + 1,5 • LF3
= 8,65 kN/m
$M_{max}$ = 276,8 kN/m

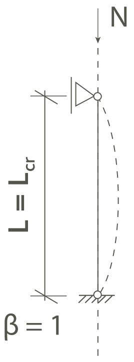
Proof of bearing capacity:
15,06 kN/cm² $\leq$ 23,5 kN/cm² Verified !

SLS verification:
Maximum deflection at midspan : l/250
60,7 mm $\leq$ 64 mm Verified !

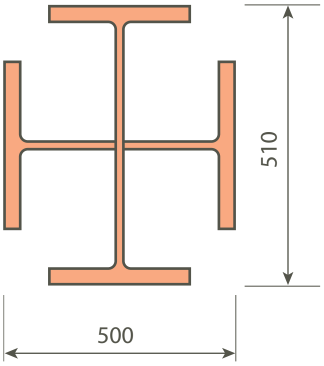
The initial section IPE400 for the ACB beam only weighs 66,3 kg/m compared to 106 kg/m of the plain beam IPE550. By using the ACB beam, 38% of the weight and 10% of the component costs can be saved. In addition to this, there are more advantages and saving potentials, because ducts can be led through the beams.

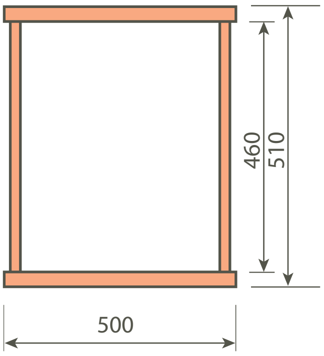
# Annex A3

## Comparison of box section with cross-shaped section



The given system has the following length:
Buckling length
$L_{cr}$ = 1000 cm
The cross sections have been chosen to ensure that the outer dimensions are comparable and that the weight per meter is roughly the same.





Box section:

Designed as a welded box section made of S460 sheet plates with a thickness of 25 mm.

$A$ = 480 cm$^2$
$I_y$ = 187,703 cm$^4$
$I_z$ = 181,938 cm$^4$

The slightly lower moment of inertia of area is decisive.
$L_{cr}$ = 1,0.1000 = 1000 cm

Buckling curve c

$$N_{cr}=\frac{\pi^2\cdot EI}{L_{cr}^2}=\frac{\pi^2\cdot 21000\cdot 181938}{1000^2}=37709\,\text{kN}$$

$$\bar{\lambda}=\sqrt{\frac{A\cdot f_y}{N_{cr}}}=\sqrt{\frac{480\cdot 44}{37.709}}=0{,}748$$

$$\Phi=0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]=0{,}5\left[1+0{,}49\left(0{,}748-0{,}2\right)+0{,}748^2\right]=0{,}914$$

This results in the stress reduction factor κ:

$$\kappa=\frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}=\frac{1}{0{,}914+\sqrt{0{,}514^2-0{,}748^2}}=0{,}695$$

The compressive resistance is thus calculated as:

$$N_d=\kappa\cdot A\cdot\frac{f_y}{\gamma_{M1}}=0{,}695\cdot 480\cdot\frac{44}{1{,}0}=14669\text{ kN}$$

The required box section has a weight of 377 kg/m

**Cross-shaped section:**

The cross-shaped beam consists of two HEB 500 sections made of HISTAR 460. This eliminates the disadvantage of the distinct weak axis.

It follows: : $I_{y'cross} = I_{z'cross} = I_{y'HEB500} + I_{z'HEB500}$

This also applies to other axes at any angle to the y and z axis. However, in the case of cross-shaped sections it must be ensured that the torsional buckling load $N_{cr,\vartheta}$ is also determined and compared with the flexural buckling load $N_{cr}$.
A = 478 cm²
$I_{cross}$= 119,820 cm²

Despite being welded, the same buckling curves apply to the cross-shaped sections as to the used rolled sections for buckling around their strong axis.

In this case, this results in the buckling curve $a_0$.

The critical load for the flexural buckling is calculated as:

$$N_{cr} = \frac{\pi^2 \cdot EI}{L_{cr}^2} = \frac{\pi^2 \cdot 21000 \cdot 119.820}{1000^2} = 24.834\ \text{kN}$$

The critical load for the torsional buckling is calculated as:

$$N_{cr,\vartheta} = \frac{1}{i_p^2} \cdot \left[ E_\omega \left( \frac{\pi^2}{L_{cr}^2} \right) + GI_T \right] = \frac{1}{22{,}4^2} \cdot \left[ 21000 \cdot 2 \cdot 7{,}018 \cdot 10^6 \left( \frac{\pi^2}{1000^2} \right) + 8100 \cdot 2 \cdot 538 \right] = 23.187\ \text{kN}$$

Buckling is decisive :

$$\bar{\lambda} = \sqrt{\frac{A \cdot f_y}{N_{cr}}} = \sqrt{\frac{478 \cdot 46}{23.187}} = 0{,}974$$

$$\Phi = 0{,}5 \left[ 1 + \alpha \left( \bar{\lambda} - 0{,}2 \right) + \bar{\lambda}^2 \right] = 0{,}5 \left[ 1 + 0{,}13 \left( 0{,}974 - 0{,}2 \right) + 0{,}974^2 \right] = 1{,}024$$

This result in the stress reduction factor $\kappa$ :

$$\kappa = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} = \frac{1}{1{,}024 + \sqrt{1{,}024^2 - 0{,}974^2}} = 0{,}745$$

The compression resistance is calculated as follow :

$$N_d = \kappa \cdot A \cdot \frac{f_y}{\gamma_{M1}} = 0{,}745 \cdot 478 \cdot \frac{4\ 6}{1{,}0} = 16.378\ \text{kN}$$

Although the required box section is considerably cheaper to manufacture, its weight of 377 kg/m is identical and can also support the same loads. The decisive benefit is that connecting beams or bracings to the rolled sections is cheaper than to a box section.

# Technical Advisory & Finishing

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