ArcelorMittal Europe - Long products
Sections and Merchant Bars

ACB® and Angelina™ beams

A new generation of castellated beams

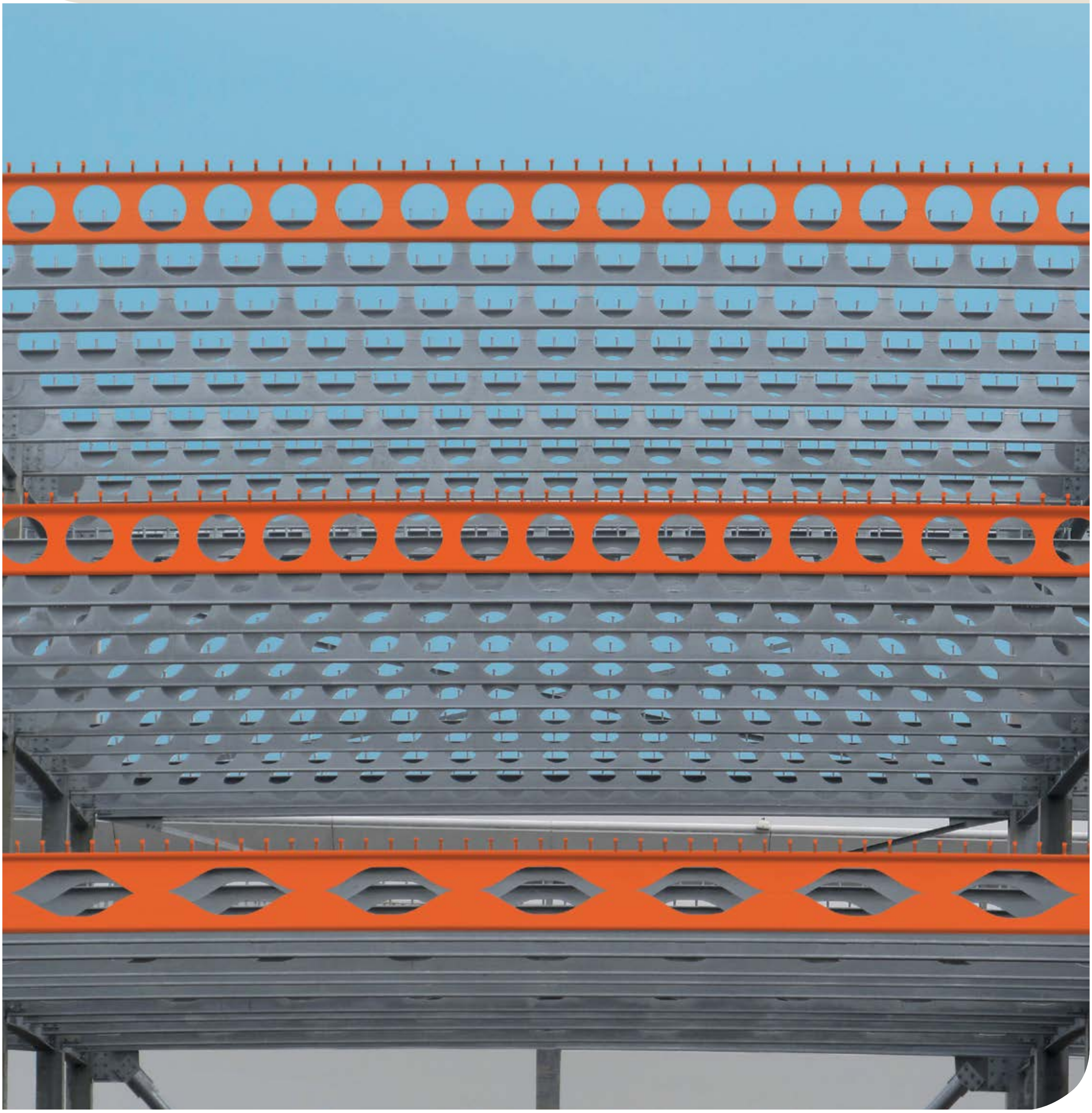

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Table of contents

Géric, Thionville; Architecte: Architectes Ertim/Design-Team

1. Introduction

The castellated ACB® and Angelina™ beams, with their circular and sinusoidal web openings, elegantly combine function with flexibility. Alternatives to trusses and open-web joist systems, castellated beams are lightweight, long-spanning, structural elements that enable the design of vast column-free spaces. They can be used in composite or non-composite systems.

Their web openings permit installation of mechanical, electrical and plumbing (MEP) pipes and ducts within the depth of the beam, thereby allowing for compact ceiling systems and maximized floor-to-ceiling heights. In addition, the repetition of the perforations ensures that variations, during construction or throughout the life of the structure, in the layout of the MEP system can easily be accommodated.

Architecturally striking, castellated ACB® and Angelina™ beams are every year seeing increased use in the built environment. Today, with improvements that have been implemented in design standards, analysis tools, and manufacturing, it is easier than ever to incorporate them into a framing system.

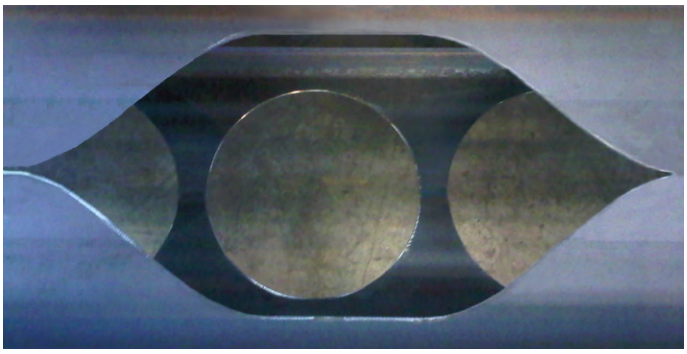
- **Manufacturing**

Optimized manufacturing methods, including flame cutting and bending, enable cost-effective production of ACB® and Angelina™ beams, even as they are customized to meet individual project needs. In addition, efficiency of production leads to quick release of the sections for final fabrication.

- **Design standards**

Eurocode 3 for steel structures and Eurocode 4 for composite structures provide guidance with respect to the design of castellated beams. Information includes analysis recommendations for use of these elements in traditional applications, such as the support system for floors and roofs; assumptions to employ when considering how the sections will behave in response to fire events; and information about using castellated beams fabricated from S460 high-strength steel.

Figure 1: Comparison of web opening of ACB® and Angelina™ beams



- **Composite construction**

The development of the various aspects of composite steel and concrete construction – connections, use of steel sheet decking, large floor areas without expansion joints (up to 80m and even more), fire resistance, user comfort and durability – has greatly contributed to the ACB® and Angelina™ beams solution in floors.

- **Analysis tools**

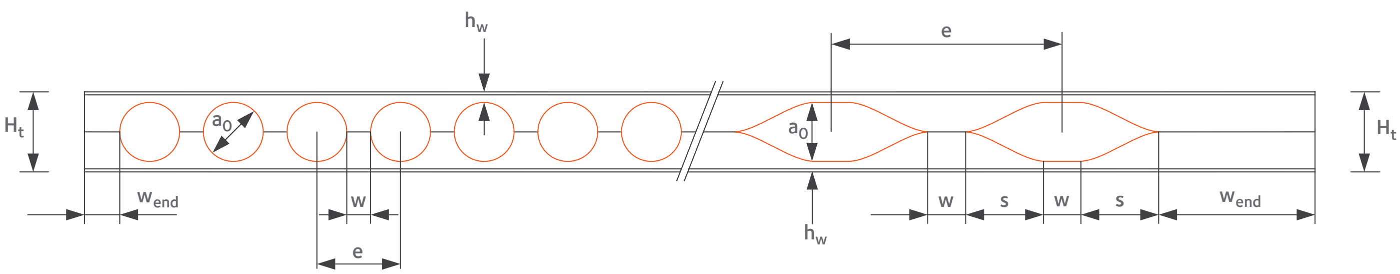
To facilitate easy analysis of castellated beams, two software systems have been developed and made available to engineering offices and architects: ACB+ and ANGELINA. These tools take into account Eurocode design principles as well as results of full-scale tests and numerical simulations. With ACB+ and ANGELINA, users can determine optimal system weights, based on section size, opening depth, width and distance and determine the impact that varying steel grade will have on the solution. These systems are designed to assist engineers and architects in finding the most efficient, economical castellated beam solutions.

- **Fabrication technique**

Castellated ACB® and Angelina™ beams are created from a standard hot-rolled steel section. The length of the beam is established based on the framing layout in the structure. Dimensions that define the shape and layout of the openings – i.e. a_0 (diameter or height of opening), s (length of sinusoidal curve), and w (length of the intermediate web post) – are governed by strength and serviceability requirements and are verified by the designer.

ACB® - Castellated beam with circular openings

Angelina™ - Castellated beam with sinusoidal openings



H_t:	total beam height
h_w:	T-section height at opening
a_0:	diameter or height of the opening
w_{end}:	length of the end web post
s:	length of the sinusoid
w:	length of the intermediate web post
e:	spacing of openings

2. Typical applications

2.1. Roof support systems

ACB® and Angelina™ beams are an attractive solution in roof support as they provide the functionality of trusses with one simple, prefabricated element. When used as roofing elements castellated beams can span up to 40 meters, and they can be used as simply supported members, cantilever elements or as part of moment or portal frames of the structure.

By employing ACB® and Angelina™ beams, designers can achieve light, airy spaces that are attractive to building owners. The height of the openings can reach 80 % of the total beam depth and as a result of efficient fabrication methods, it is possible to minimize the distance between openings. These characteristics of castellated beams result in seemingly transparent design solutions that blend elegantly into their built environment.

2.2. Floor support systems

Modern construction increasingly demands accommodation of building systems (heating, ventilation, air conditioning, etc.) as well as structural support within minimal ceiling spaces (Fig. 3). Castellated beams provide efficient solutions to these demands allowing pipes and ducts to pass through their openings while having the capacity to span up to 20 meters thereby providing large, column-free floor areas.

With ACB® and Angelina™ beams, floor thickness can be reduced by 25 to 40 cm, when compared to conventional solutions. For typical buildings, with height limit of 35 to 40 meters, a gain of 20 cm per floor enables the addition of one floor within the same construction height. For buildings with a limit on number of floors, minimizing the floor-to-floor height results in efficiencies with respect to façade elements, columns, stabilizing structures, separating walls and vertical access walls.

Figure 2: ACB® roof beams

Figure 3: Angelina™ floor beam

Figure 4: Renovation using ACB® beams at headquarters of Crédit Lyonnais, Paris

2.3. Specialty applications

2.3.1. Building renovations and adaptive reuse

ACB® and Angelina™ beams are often employed in the renovation and adaptive reuse of existing structures (Fig. 4). With their perforations, they fit in beautifully to such buildings and help to preserve architecture, openness and flexibility of the spaces.

2.3.2. Parking structures

Castellated beams bring lightweight, adaptable solutions to car parks and serve as an economical alternative to precast concrete tees (Fig. 5). Easily spanning the 15 to 16 meters required by typical parking structures, the open webs of ACB® and Angelina™ beams allow natural light to flood these often dark spaces. In addition, the openings facilitate smoke evacuation and improved air circulation between sections.

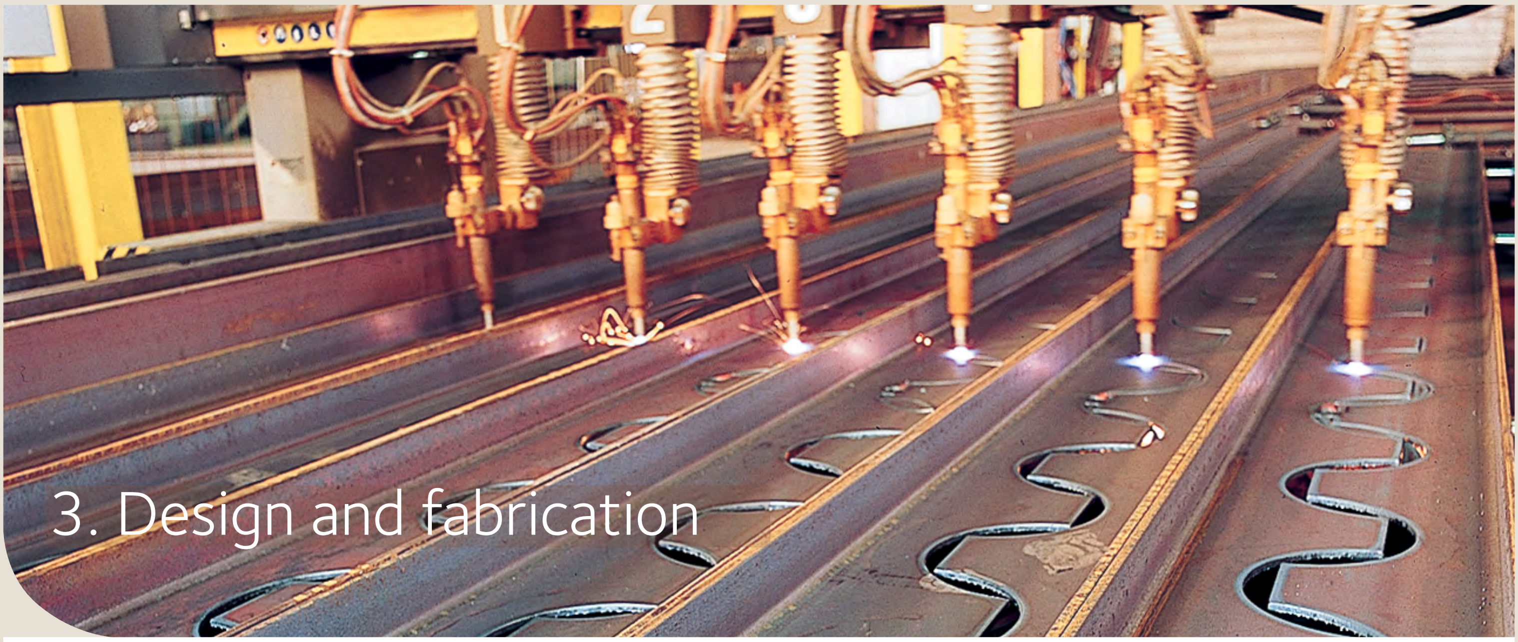
Similar to solid web sections, castellated beams can be cambered to enable drainage of runoff from rain, snow and ice accumulation.

2.3.3 Corrosive environments

ArcelorMittal structural steels are typically delivered with a silicon content ranging between 0.14% and 0.25%, and, as such, are capable of forming a zinc layer during hot-dip galvanization. With phosphorus contents typically lower than 0.035%, the element has little, if any, influence on final thickness of the coating within a particular silicon range. Tests have been performed to understand the effect of the welding procedure between the two T-sections and results have shown that welding has no significant impact on the hot-dip galvanization process.

Figure 5: Castellated beams used in parking structures

3. Design and fabrication



Flame cutting of hot rolled sections

ACB® and Angelina™ beams are fabricated by a method that uses exclusivelly hot-rolled structural sections. The fabrication shop where these profiles are created is located within close proximity of the ArcelorMittal Differdange (Luxembourg) heavy section rolling mill. The nearness of these two sites limits transport, maximizes responsiveness and contributes to the competitiveness of the manufacturing costs.

Fabrication of ACB® and Angelina™ beams, is described as follows (see also Fig. 6):

A double (ABC®) or single (Angelina™) cut following a specified path is made in the web through flame cutting.

The two resulting T-sections are realigned and welded together. The final product has a greater depth than the original section and also features an increased ratio of moment of inertia to weight.

The flame cutting process can be customized in order to meet project needs. It can also be adjusted to account for deformations of the holes when pre-cambering is required.

Cuts are performed in such a way that waste material is limited and weld areas are as efficient as possible. Welds are visually inspected or, on request, can be inspected according to the project owner's or customer's specifications.

Figure 6: Fabrication process for castellated beams

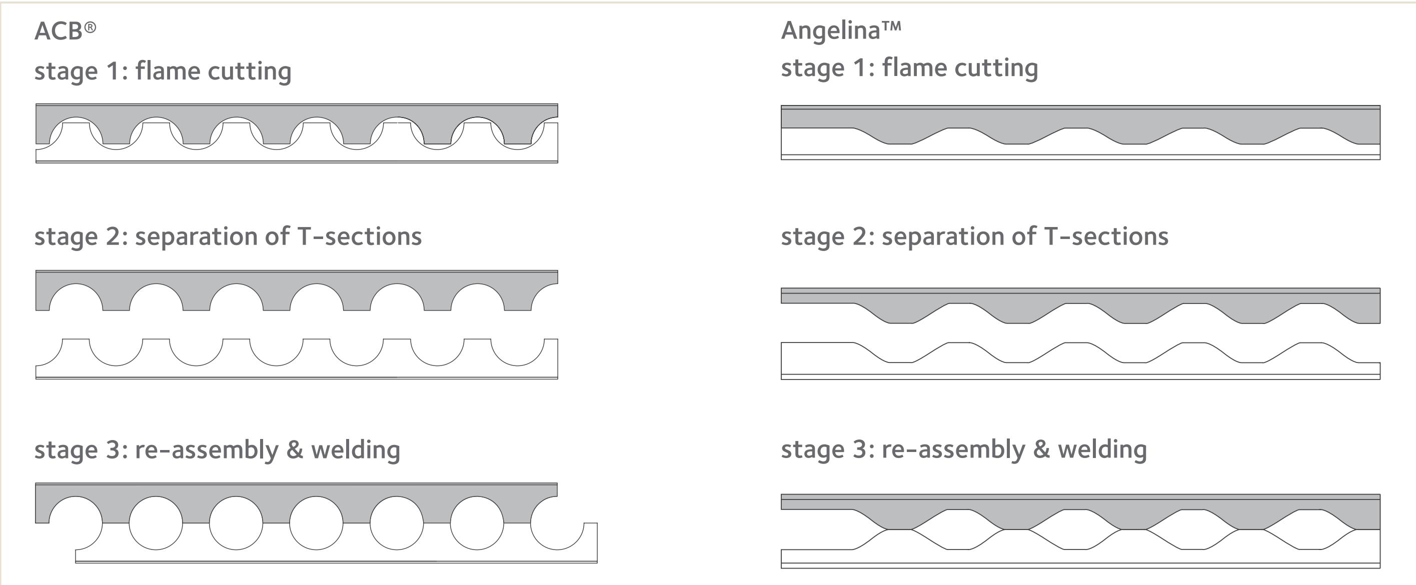


Figure 7: Fabrication of Angelina™ beams

3.1. Determination of size and spacing of openings

For a given section, there are endless combinations of opening sizes and spacing that can be implemented. Items that are typically considered when determining the appropriate layout for a project follow:

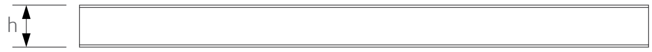
- To maintain aesthetic proportions, the ratio between the opening height (a_0), spacing (e) and final height (H_t) should be kept in a specific range. The range is generally governed by the application in which the system will be used (Fig. 8). In some cases, opening height (a_0) is governed by the size of components of the MEP or other building systems.
- To ensure structural integrity and efficiency, customization of the upper and lower T-sections can and should be considered.
- To simplify fabrication, wherever possible, the designer should consider adjusting the geometry of openings such that welding of the first and the last web posts can occur without infills.

Figure 8: Size and spacing of openings

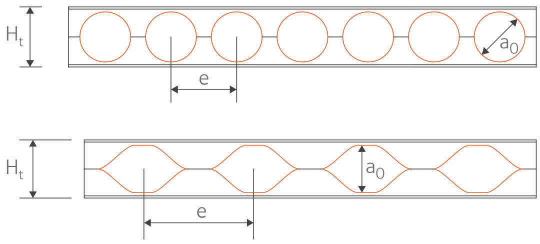
Applications:
Roofing
Footbridges
Wide-span purlins

Objective: Optimization of the height/weight ratio

Starting section (height h)



Design type 1 (ACB® and Angelina™)

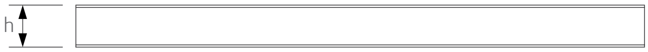


Diameter or height a_0 = 1,0 to 1,3 h
Spacing e = 1,1 to 1,3 a_0
Final height H_t = 1,4 to 1,6 h
Common steel grades: S355

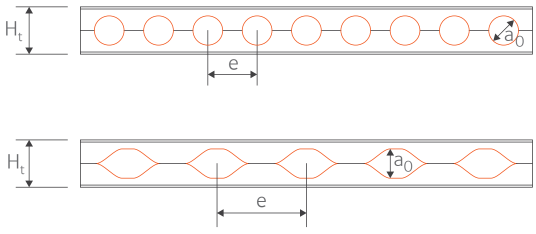
Applications:
Floors
Parking structures
Offshore structures

Objective: Optimization of load/weight ratio

Starting section (height h)



Design type 2 (ACB® and Angelina™)



Diameter or height a_0 = 0,8 to 1,1 h
Spacing e = 1,2 to 1,7 a_0
Final height H_t = 1,3 to 1,4 h
Common steel grades: S355, S460, HISTAR® 460

Castellated beams spanning 25 meters and featuring important camber

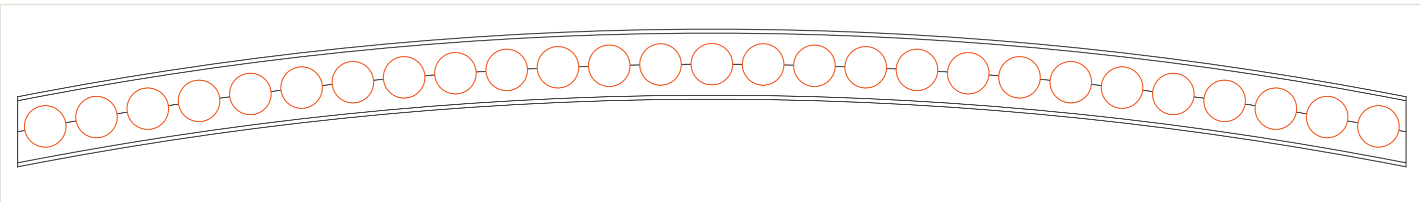
3.2. Customization of castellated beams

3.2.1. Curving or cambering

Where required to accommodate architectural or serviceability issues (i.e. to meet requirements of unique roof slopes or to accommodate deflection of the section under self-weight and dead load from the floor slab), castellated beams can be curved and cambered. Achieved during fabrication, curved or cambered ACB® sections are produced by modifying the T-sections before welding in the final state (Fig. 9).

For cambering of castellated beams, a minimum deformation of 15 mm is required, and in order to avoid any risk of inverted installation, camber will be clearly marked on the beam before it leaves the fabrication facility.

Figure 9: Example of a curved ACB® beam



3.2.2. Tapered profiles

Tapered sections can easily be produced by inclining the cut path and reversing one of the T-sections before welding (Fig. 10). The unique configuration of these sections make them particularly efficient solutions for long cantilevers, such as stadium stands; continuous beams, such as footbridges or frame rafters .

Figure 10: Tapered ACB® beams

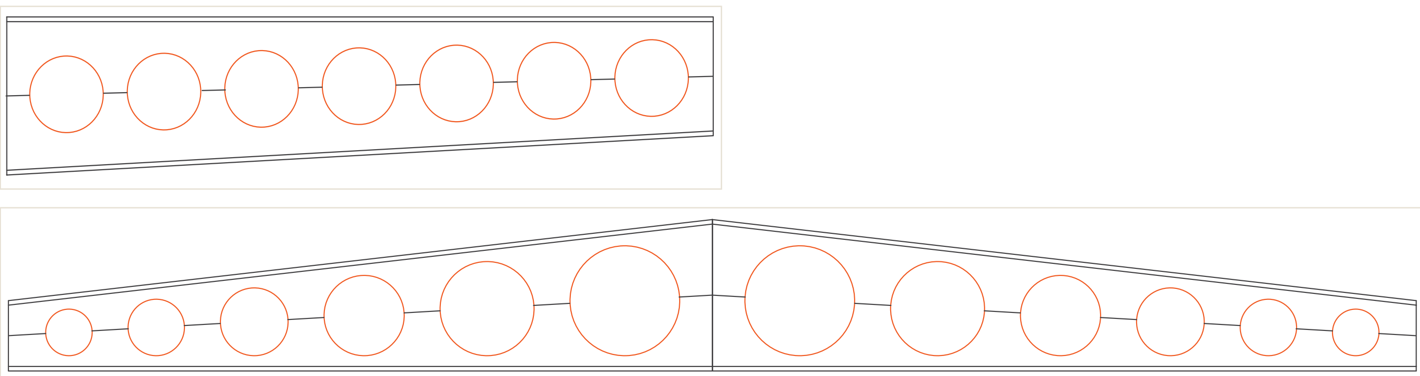
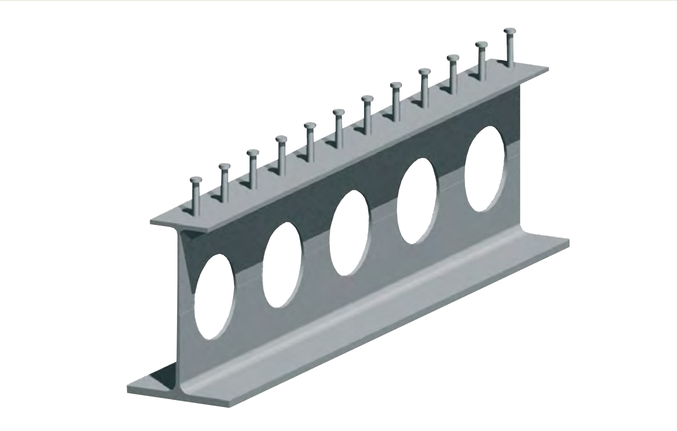


Figure 11: Asymmetrical ACB® beam



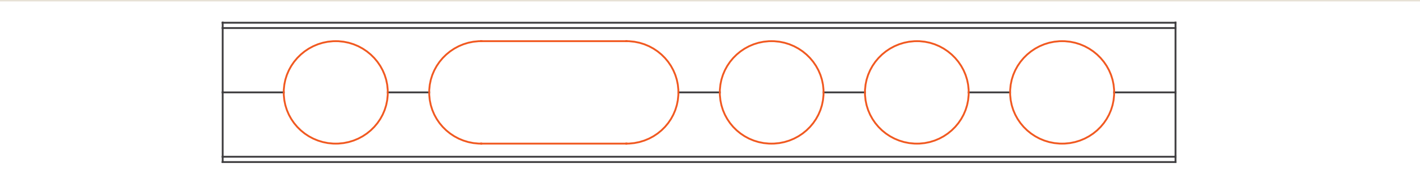
3.2.3. Asymmetrical sections

Top and bottom T-sections from differing profiles, or even steel grades, can be welded together to produce asymmetrical profiles (Fig. 11).
Configurations of this type are particularly suited for use composite design (i.e. when the steel section engages the floor slab to provide increased structural capacity) as they enable to most efficient use of steel in the beam.
For such systems, it is common to have a heavier T-section on the bottom of the beam, as it is exposed to tension in bending. The top T-section can generally be lighter weight because it is braced by the slab above.

3.2.4. Elongated openings

It is sometimes necessary to open up the space between two openings. Whenever possible, the larger openings should be positioned near the center of the beam (Fig. 12), where shear forces are typically lowest. In cases where an elongated opening must be located near the supports, it is may be necessary to reinforce it at the perimeter (Fig. 13b).

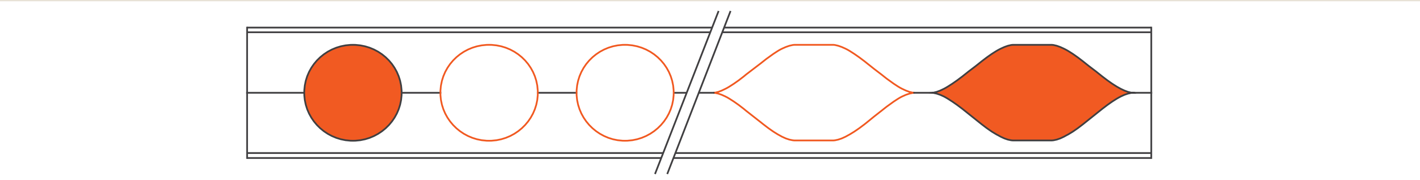
Figure 12: Elongated opening



3.2.5. Infill of openings

In order to support high shear forces (i.e. in close proximity of supports or point loads) or for fire safety reasons, it can be necessary to infill certain openings (Fig. 13a). This is done by inserting a custom-cut steel plate into the opening and welding it from both sides of the web. The thickness of the plate and its fillet weld, generally limited to 4mm, are optimized according to local stresses.

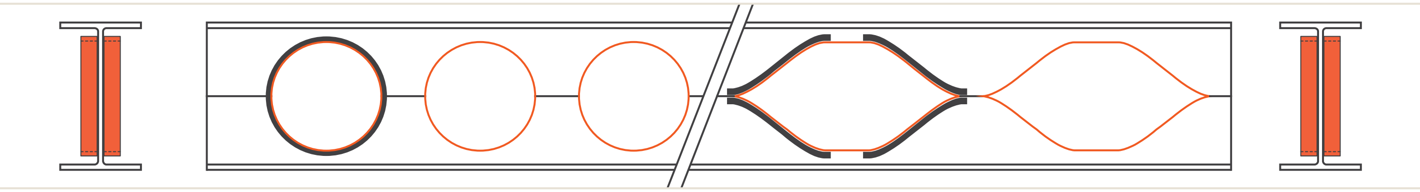
Figure 13a: Filled openings

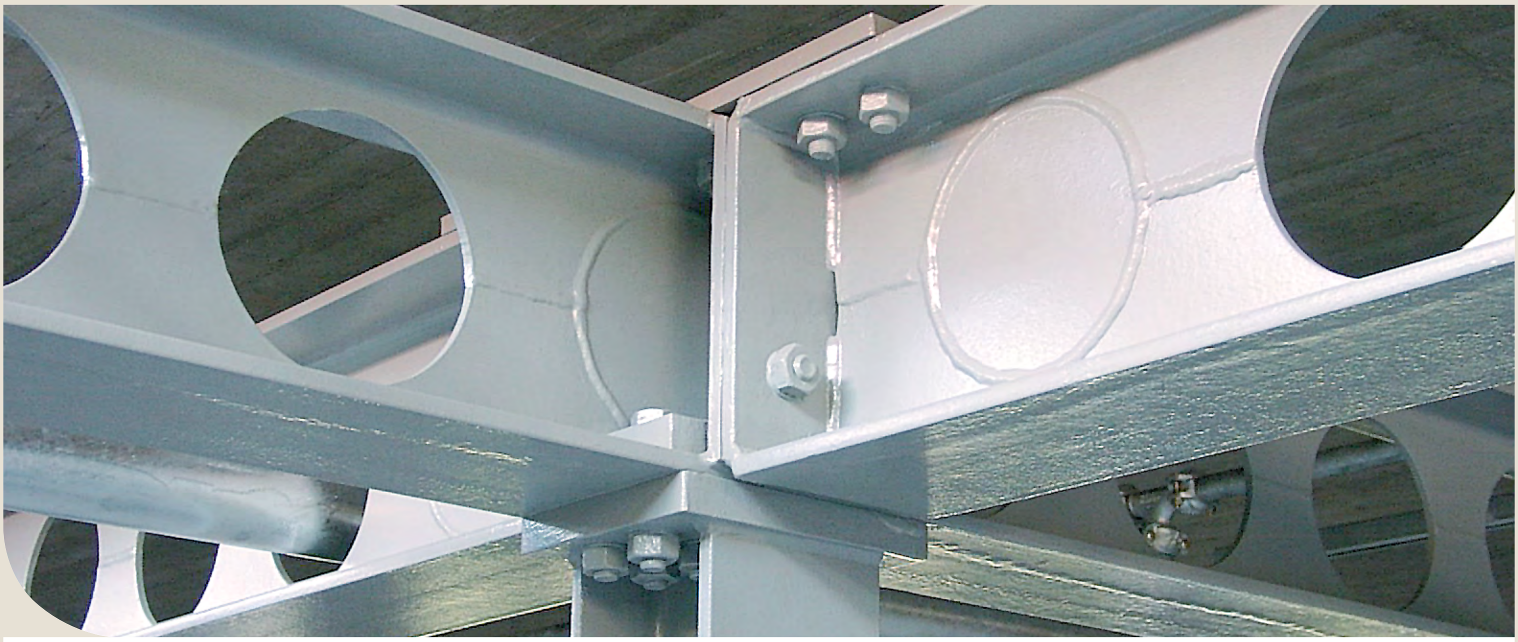


3.2.6. Reinforced openings

In cases where infilling is not permitted for architectural reasons or when elongated openings are necessary close to supports, a hoop or stiffener welded around the opening can be used to increase rigidity of the opening (Fig. 13b).

Figure 13b: Reinforced opening





ACB® beam featuring filled openings at support

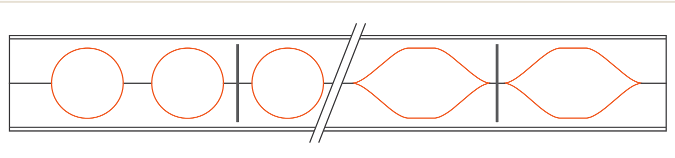
3.2.7. Web reinforcement

Serviceability limit states require sufficient stiffness to reduce deflection and minimize vibrations. Castellated beams can efficiently meet these needs by optimizing the distribution of steel throughout the profile.

At times, optimization may result in a risk of buckling at one or two web posts near the supports. In order to fortify the section, the following options can be considered:

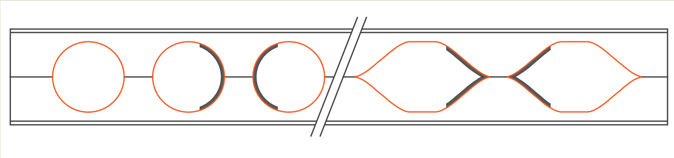
- selection of a heavier section
- use of a higher steel grade, which would increase the load bearing capacity of the web posts
- infilling of openings, though this can result less flexibility for accommodating building systems
- stiffening of openings, which would maintain flexibly for accommodating building systems.

Figure 14: Stiffened of web post



Alternately, testing has shown that a rigid plate, welded to the web post (Fig. 14), is an effective solution to reinforcing the beam web. Two part hoops can also be used (Fig. 15).

Figure 15: Stiffener welded around the opening



3.2.8. Supporting concentrated loads

In order to avoid plastic deformation of elements within the cross-section, which can occur when concentrated loads are applied to the beam, stiffeners or infills should be considered wherever concentrated loads are expected.

3.3. Welding standards

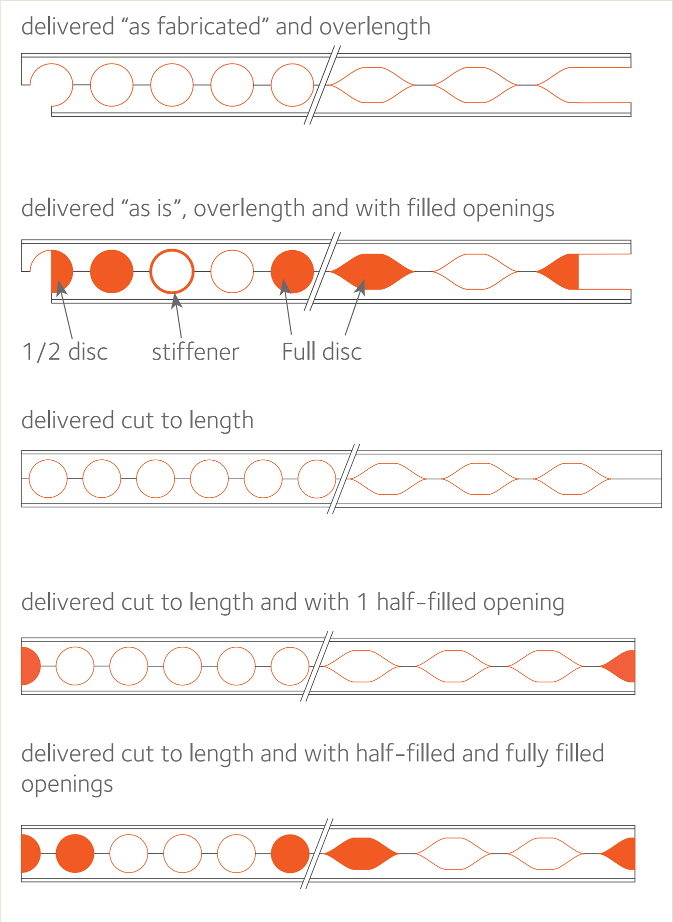
At ArcelorMittal's fabrication facility, welders are qualified in accordance with the European standard EN 287-1 for MAG 135 and MAG 136 processes. Typically, butt welding is used for castellated beams. The fillet weld thickness generally does not require full penetration welding.

A series of tests has been carried out to validate the model used in the software ACB+ and ANGELINA. This model can be used to calculate the required fillet weld thickness to resist the defined stresses.

3.4. Fabrication options

Select examples of fabrication options are shown in Figure 16.

Figure 16: Fabrication options

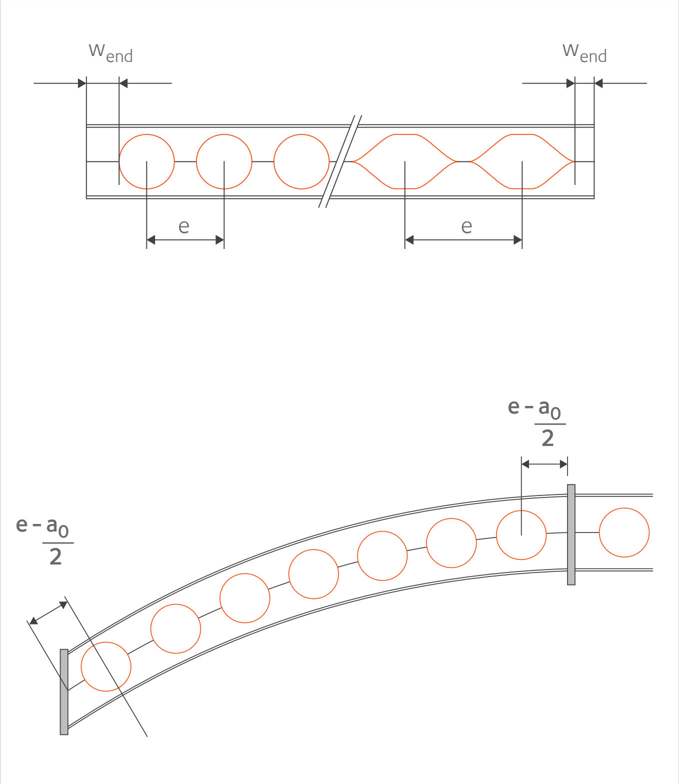


3.5. Optimization of the openings

When designing the framework, special care should be given to the positions of the openings in order to avoid unnecessary filling (Fig. 17).

- The first step is to optimize the beam from a structural point of view.
- The second step is to adjust the spacing between openings so as to have a complete web post at the ends of the beam.

Figure 17: Optimization of openings layout



3.6. Splicing of castellated beams

As with standard beam sections, it will sometimes be required to splice castellated beams. In such cases, the designer should take splice locations into account when laying out the openings. If necessary to maintain load path within the system, it is possible to infill or partially infill one or two openings. Partial filling is an easy and economical solution (Fig. 18).

3.7. Curving of beams

The curving of castellated beams can be included in the beam fabrication process without problem.
It can be required for the following reasons:

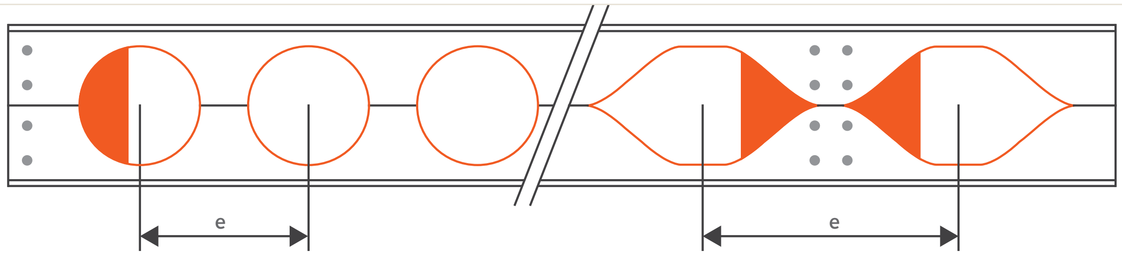
- architectural requirements for the roofing system
- compensation of the deflection resulting from the self-weight of the floor.

Other forms of curving or cambering can be offered on request, the minimum camber being 15mm.

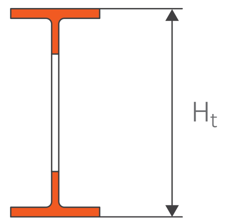
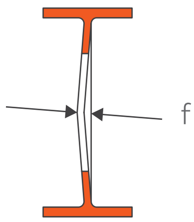
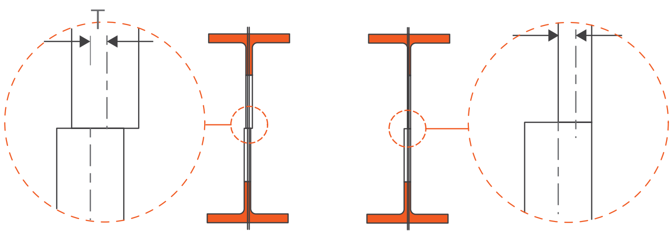
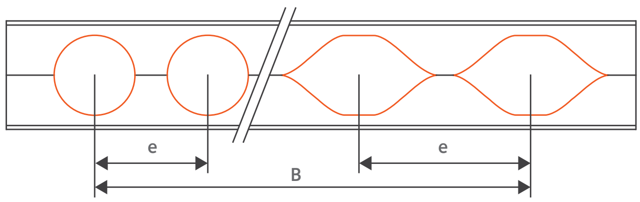
3.8. Coordinating fabrication considerations with design requirements

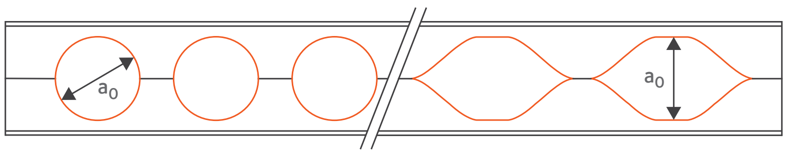
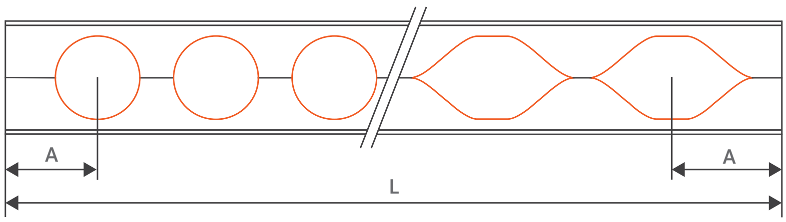
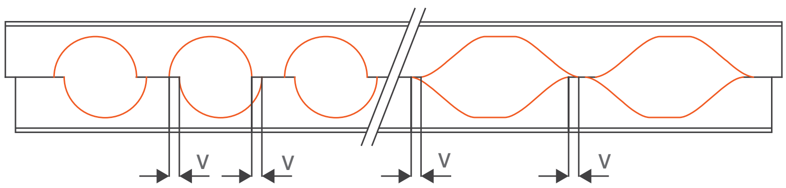
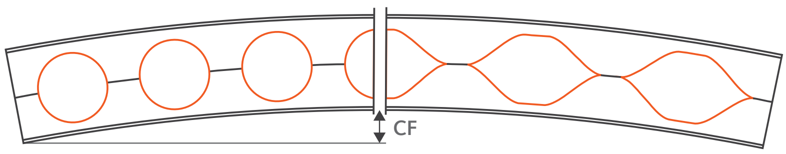
In order to achieve the most economical fabrication of castellated beams, requirements of the cutting process, such as minimum distance between web/flange root and the edge of the openings or minimum radius of curved beams, are included in the ACB+ and ANGELINA software (see section 9. Predesign software).

Figure 18: Partially filled openings at splice locations



4. Tolerances of ACB® and Angelina™ sections

Final height: H_t $H_t < 600$ $600 \leq H_t < 800$ $H_t \geq 800$	 + 3 / - 5 mm + 4 / - 6 mm + 5 / - 7 mm	
Bending of web: f $H_t < 600$ $H_t \geq 600$	 $f \leq 4$ mm $f \leq 0{,}01\ H_t$	
Misalignment of T-sections: T (between axis of upper section and axis of lower section)	$T \leq 2$ mm	 Symmetrical section Hybrid section
Spacing: e Distance from first to last opening: B	+/- 0,01 e +/- 0,02 e	

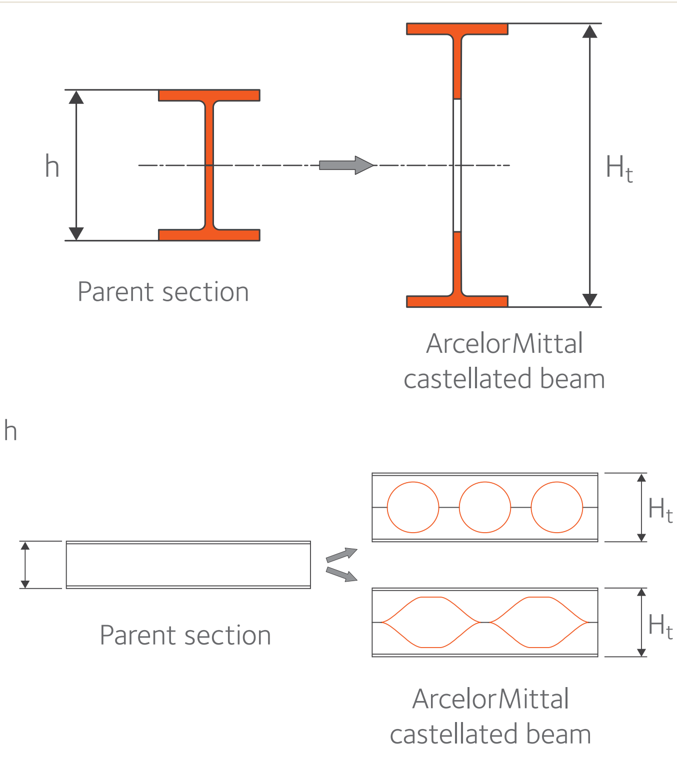
Diameter/height: a_0	+ 5 / - 2 mm	
Length: L Distance of 1[st] opening from end: A	+/- 2mm +/- 0,02 e	
Offset of web posts: V Example:	V ≤ 0,03 % L if L = 10 000 mm V ≤ 3mm	
Camber: CF	+/- 0,05 CF CF min. 5mm	

Industrial site BOBST in Mex (CH) MP INGENIEURS CONSEILS SA – Crissier (CH); Architectes: RICHTER & DAHL ROCHA – Lausanne (CH); Engineers: MP INGENIEURS CONSEILS SA – Crissier

5. Castellated beams in roofing and metal decking applications

When used in roof support systems, ACB® and Angelina™ beams are typically symmetrical sections; composed of an upper and lower T-section cut from the same hot-rolled parent shape (Fig. 19). Determination of the appropriate parent section and final height is typically based on opening size and spacing requirements. Alternately, when final height and opening size are known, the necessary spacing and appropriate parent shape can be selected.

Figure 19: Configuration of a castellated beam



Architects and engineers have a large choice of possible opening size and spacing. From these values, the starting section can be determined and the final height of the castellated beam can be deduced.

The process can also be reversed: from a required final height and opening dimensions, the designer can easily determine the starting section required to satisfy this configuration.

5.1. Design recommendations

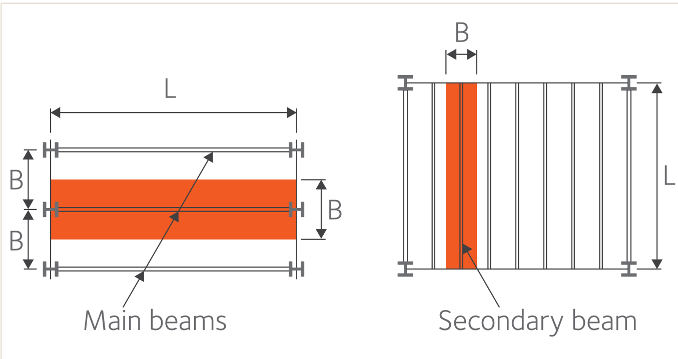
As for the rolled sections, it is essential to base the design of a project in castellated beams on criteria and limits that make the best use of the performance offered by this type of element.

5.1.1. Establishing the overall height of the castellated beam

The overall height, H_t, of the castellated beam is determined as a function of the following (Fig. 20):

- beam span (L)
- beam spacing (B)
- strength requirements, i.e. dead load and live load demands
- serviceability requirements, i.e. deformation and vibration limits.

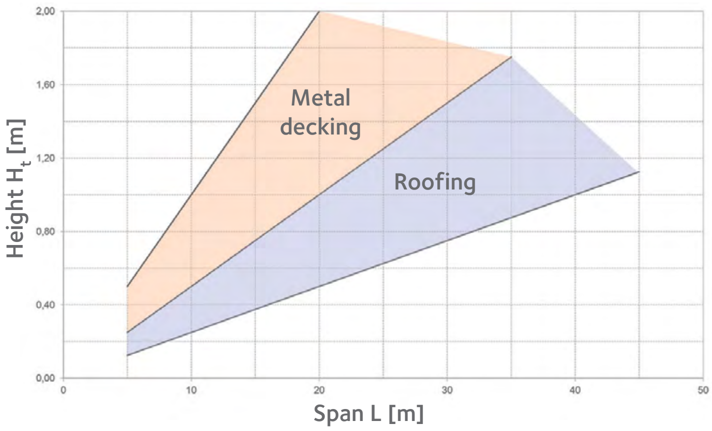
Figure 20: Use of beams in structure



When used in standard roof support systems, castellated beams can typically have slenderness, or unbraced length to height, ratios ranging from 20 to 40 depending on support conditions (Fig. 21). For initial design assumptions, a value of 30 is generally used to determine the section properties of secondary beams and fixed beams of frames. Through iteration, a more efficient solution can be determined.

For non-composite floor beams of buildings, the slenderness varies between 10 and 20. For normal service loads, an intermediate value of 15 can be used as a starting point for design.

Figure 21: Height of castellated beam as a function of the span



5.1.2. Determining layout of web openings

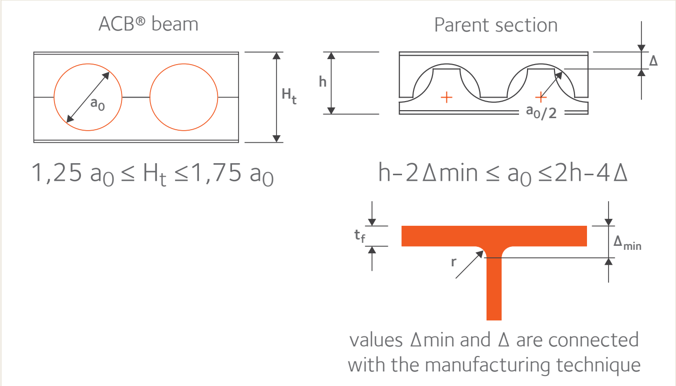
Layout of web openings is typically governed by architectural desires (transparency and light dispersion) and functional requirements (distribution of building system elements through the penetrations).

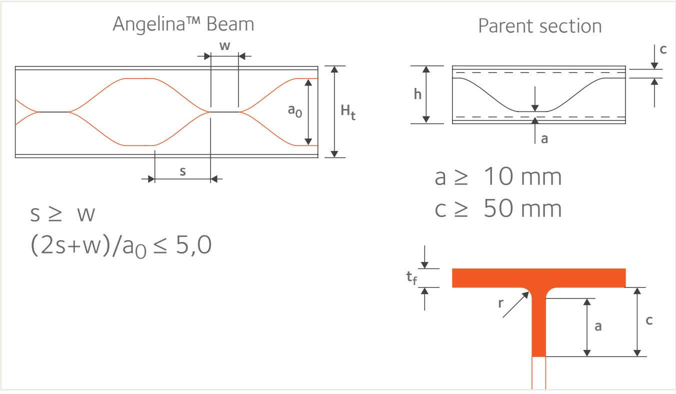
However, there are geometric limits to be respected for good mechanical behavior of the castellated beam.
These limits apply to:

1) Opening size (Fig. 22):

- with a_0, s and w values in function of the finished beam
- with a_0, a and c values in function of the parent section.

Figure 22: Geometric limits on openings in ACB® and Angelina™ beams

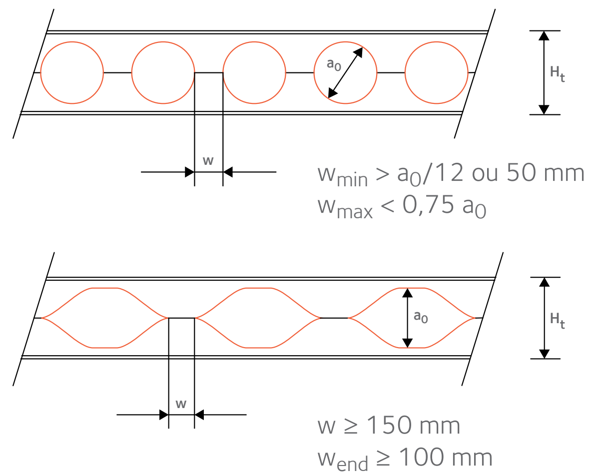




P. de Coubertin gymnasium (Bourges, France ; Arches Études)

2) Spacing of the openings (Fig. 23):
When determining spacing between web openings, both strength and fabrication requirements should be taken into account. From a strength perspective, a minimum spacing is established to avoid localized failure from insufficient bearing at the web posts between openings. Similarly, this minimum ensures that enough material is present to provide the welded connection between the upper and lower T-sections at the fabrication facility. A maximum spacing is established to achieve the most efficient fabrication of the castellated beam by minimizing the length of weld required. This maximum also guarantees that the beam depth will increase when the openings are cut and the section is shifted for welding. If the distance between web penetrations is large and the opening size is small, for example, the final beam would not gain much, if any height, or improved efficiency in design.

Figure 23: Geometric limits for spacing between openings



5.2. Design checks

Similar to the design of any structural element, castellated beams must meet Ultimate Limit States criteria (strength or resistance needs) as well as Serviceability Limit States requirements (deflection and vibration demands) when looking at the overall design of the section. It is important to recognize, as well, that the removal of material in the web of the section can result in stress concentrations that could affect local behavior within the beam.

To assess potential local instabilities within the section, the following should be considered:

- capacity of the section at the web posts, taking into account demand from:
  - vertical shear forces
  - moment forces
  - shear-moment interaction
  - horizontal shear forces
- shear buckling resistance
- capacity of the section at the web openings, taking into account demand from:
  - shear force resistance
  - moment and axial force interaction
  - moment, shear and axial force interaction
- resistance to Lateral Torsional Buckling

When assessing the behavior of the overall section, the following should be considered:

- vertical deflection
  For the calculation of the overall deflection of a beam, the beam is divided in elementary panels of two types: “Plain” and “Opening” panels, for which calculation method differs. The contribution of the “Plain” zones to the deflection of the beam is derived from classical calculation under bending moment. The calculation method for the deflection of the “Opening” zone is a sum of values of elementary effects due to axial, shear and bending deflection. The deflection of the beam is obtained as the sum of the contributions of each elementary zone.
- eigen frequency.

ACB+ and ANGELINA software (see section 9. Presdesign software) enable users to verify castellated beam configurations based on the previously discussed design considerations. In addition, using the predesign tables in section 10. Predesign charts of castellated beams, designers can make an determine castellated beam section properties to consider for a given loading criteria.

Géric Thionville; Architectes Ertim/Design-Team; ©geric-oh-dancy

6. Castellated beams in composite floor systems

The use of ACB® and Angelina™ beams in composite floors (Fig. 24) maximizes both floor.
Spans achievable with castellated beams can reach 30 meters, thus making them a great solution for floor support systems in office buildings, where typical floor spans are 18 meters.
In addition, typical spacing of castellated composite beams are 2.5 to 3 meters with a metal deck, 3 to 9 meters with precast slabs such as Cofradal 200/230/260, or cast-in-place slabs such as Cofraplus 220, are used.
As such, ACB® and Angelina™ beams enable engineers to optimize the use of steel not only within the beam itself but also in the layout of the floor framing.

6.1. Design recommendations

6.1.1. Establishing the overall height of the castellated beam

In addition to the criteria defined in section 5. Castellated beams in roofing and metal decking applications, when using castellated beams in composite design the following considerations should be made:
The overall height, H_t, of the castellated beam is determined as a function of the following:

1) beam span
Beam span (L) will typically vary between 8 and 30 meters depending on application. When the design assumes there exist single, simply supp single spans, the concrete slab is assumed to be in compression throughout the span.

Figure 24a: Angelina™ beams in composite floor systems

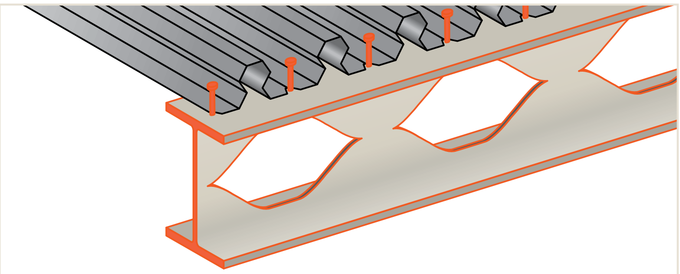
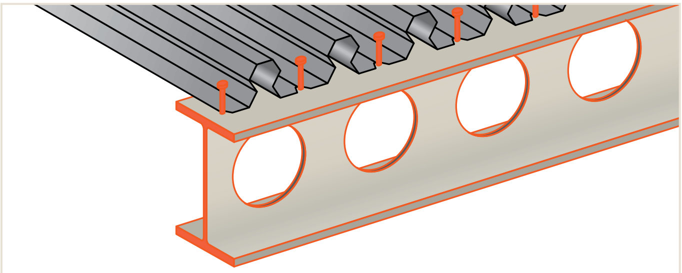


Figure 24b: ACB® beams in composite floor systems



In situations where the beam is continuous of over intermediate supports, the concrete is assumed to experience tensile forces and cracking at the supports.

2) beam spacing
Beam spacing (B) of the framing depends on floor type:

- For steel decking
  - B = 2.5 to 3 meters without shoring during construction
  - B = 3 to 5 meters with shoring during construction

  When spans of 5 to 7 meters need to be achieved without shoring during construction, ArcelorMittal Cofradal 200/230/260 is an ideal solution.
- For cast-in-place slabs, such as ArcelorMittal Cofraplus 220
  - B = 3 to 6 meters without shoring during construction
  - B = 6 to 9 meters with shoring during construction
- For precast concrete slabs
  - B = 2.7 to 7 meters with shoring during construction

  When spans of 5 to 7 meters need to be achieved without shoring during construction, ArcelorMittal Cofradal 200/230/260 is an ideal solution.
- Allowed structural thickness of floor, H_t corresponding to the height of the composite section (height H_t of the beam plus the slab thickness).

  The beams should be spaced according to the following ratios:
  - $L/H_t > 20$: B = 2.5 to 3 meters
  - $L/H_t < 15$: B = 3 to 5 meters

Figure 26: Composite floor beam

3) serviceability requirements

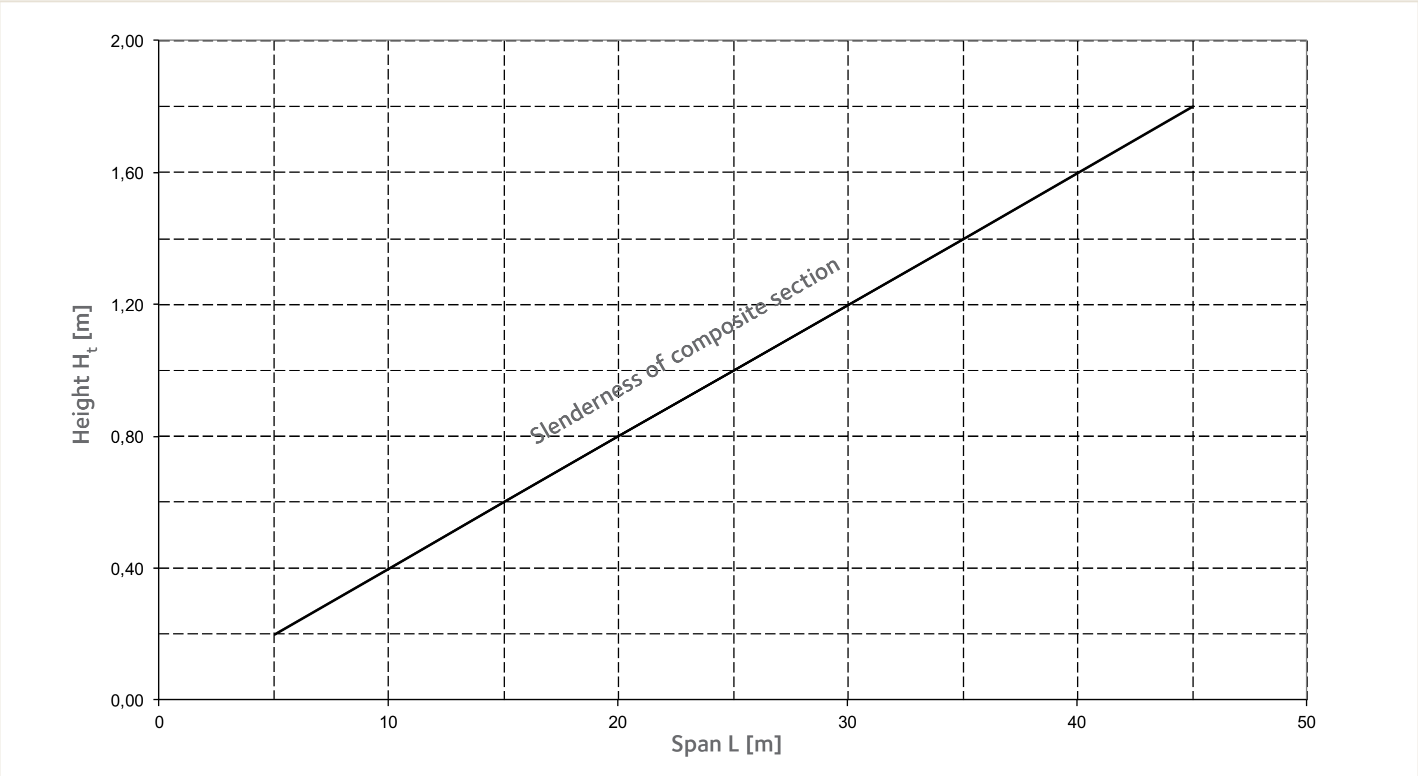
For floor structures, Serviceability Limit States often govern the design. Vibration tolerances are generally specified by acceptance classes [A to E] and compared to the predicted response that the floor system will have due to vibrations induced from loading (i.e. human traffic) expected from the intended use of the building.

For more information on considering serviceability requirements in your design, please refer to the document titled "Design Guide for Floor Vibrations", which is available in the Library section of **sections.arcelormittal.com**.

6.1.2. Determining layout of web openings

Layout of web openings is typically governed by architectural desires (transparency and light dispersion) and functional requirements (distribution of building system elements through the penetrations). In office buildings, for example, a height between 250 and 350 mm is adequate in most cases. Minimum and maximum height and spacing values, as they relate to the hot-rolled parent section, are governed by the same the rules given in section 5. Castellated beams in roofing and metal decking applications.

Figure 25: Height, H_t, of floor beam as a function of span



6.2. Design checks

In addition to the design checks defined in section 5. Castellated beams in roofing and metal decking applications, castellated beams used in composite construction would require verification of the following:

- section capacity during construction (i.e. without contribution of the concrete slab and dependent on shoring conditions)
- capacity of shear studs, ensuring that they can help achieve the desired composite action
- bending moment capacity of the composite section
- vertical deflection within tolerable serviceability limits, even when taking into account shrinkage of concrete.

ACB+ and ANGELINA software (see section 9. Presdesign software) enable users to verify castellated beam configurations based on the previously discussed design considerations.

In addition, the predesign tables in section 10. Castellated beams predesign charts offer a quick answer based on predefined solutions for composite floor applications.

Géric Thionville; Architectes Ertim/Design-Team; ©gilles-martin

7. Stability in fire and fire safety

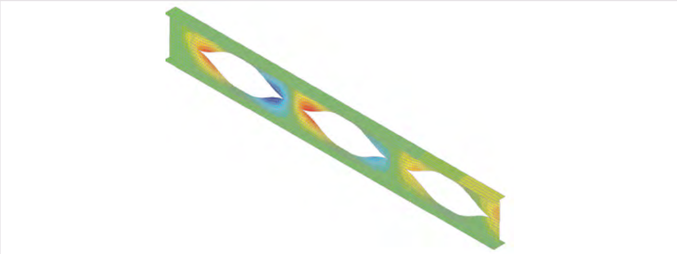
As with other steel beams, the integrity of a structural system using castellated framing can be easily maintained in the event of fire. In addition to protecting the structure with active elements, such as sprinklers and other fire suppression systems, it is common to employ passive protection methods, including spray-applied fireproofing or intumescent paint.
In some cases, passive protection can be reduced or even avoided by reinforcement of the structural support framing or when analysis based on the natural fire safety concept in accordance with EN1991-1-2 is performed.

Fireproofing material, of any type, can be applied to castellated beams using the same techniques that would be employed for basic hot-rolled steel sections. The thickness to be applied is generally established taking into account fireproofing manufacturer recommendations, as well as the expected behavior of the section under loading during a fire event. The thickness must be sufficient to maintain structural integrity at the critical temperature for components of the castellated beam. ACB+ software can be used to calculate those critical temperatures.

Figure 27: Protection by spraying on ACB® beam

For castellated beams, the surface area to be protected against fire is essentially equivalent to the surface area of the hot-rolled parent structural shape. Values of painting surface per unit length (A_L, m^2/m) and painting surface per unit mass (A_G, m^2/t) are indicated for individual sections in the tables of the ArcelorMittal Europe Sales Programme Sections and Mechant bars, which is available in the Products & Services section of **sections.arcelormittal.com.**
Furthermore, ArcelorMittal's Technical Advisory Department uses the SAFIR software with a module especially developed for the design by numerical simulation of castellated beams. Colors in the different areas in Figure 28 reflect the steel temperatures after the considered fire duration.

Figure 28: Analysis of the hot beam using the SAFIR finite element software.



7.1. Spray-applied fireproofing

In office buildings, where regulations typically require fire resistance of one hour, the most suitable fire safety solution is spray-applied fireproofing if the beams are not visible.
For Angelina™ beams, it may be necessary to increase the Corresponding thickness of the coating by 2 to 3 cm around the opening to ensure sound protection of the sharp contour.

To accommodate ductwork, a 3 to 5 cm difference between opening dimensions and duct size is recommended. This tolerance can help prevent damage of the fire protection around the openings during installation of the services.
In some cases, no additional anti-corrosion treatment is necessary if the product is sprayed onto the raw steel surface.

7.2. Intumescent paint

In the case of visible floor or roof beams intumescent paint provides fire resistance without influencing the aesthetic of the structure.

8. Castellated ACB® and Angelina™ beams: a solution for sustainable structures

Preservation of natural resources has become a major priority in the built environment.

As a result, it is necessary for construction concepts to comply with a shift in the desires of building owners and focus on new concepts in the realm of sustainability, including incorporation of life cycle analyses into designs and use of innovative building systems to achieve sustainability goals.

With buildings and other structures, sustainability goals take into account environmental, economic, and social, as well as efficiencies in construction. These factors are interdependent and in sometimes conflicting. Responding to these correctly ensures that future generations will be left with a pleasant environment. Sustainable construction using ACB® and Angelina™ beams is fully consistent with the various aspects of the sustainability goals.

Environmental aspects of sustainability
When considering the environmental aspects of sustainability, areas of focus tend to be use of building materials that won't harm people or the environment, reduction of building waste during construction and at the end of a structure's useful life, and use of construction materials that have low embodied carbon levels.

For several years, World Steel Association has collected information related to steel production throughout the world. Recently a significant update has been completed to its database that helps to better identify the environmental impact of steel production and recycling. Life Cycle Assessments (LCA) of steel sections, such as Environmental Product Declarations (EPD) based on the World Steel Association database, are now based on the most appropriate "End-of-Life recycling rate" methodology, which takes into account the environmental benefits of recycling and reusing the material. As stated in ISO 14025, EPD's are independently verified to confirm that all calculations conform with the EN15804 standard. ArcelorMittal's EPD's for structural sections are available at **sections.arcelormittal.com**.

ACB® and Angelina™ beams achieve the highest levels of environmental responsibility in various ways:

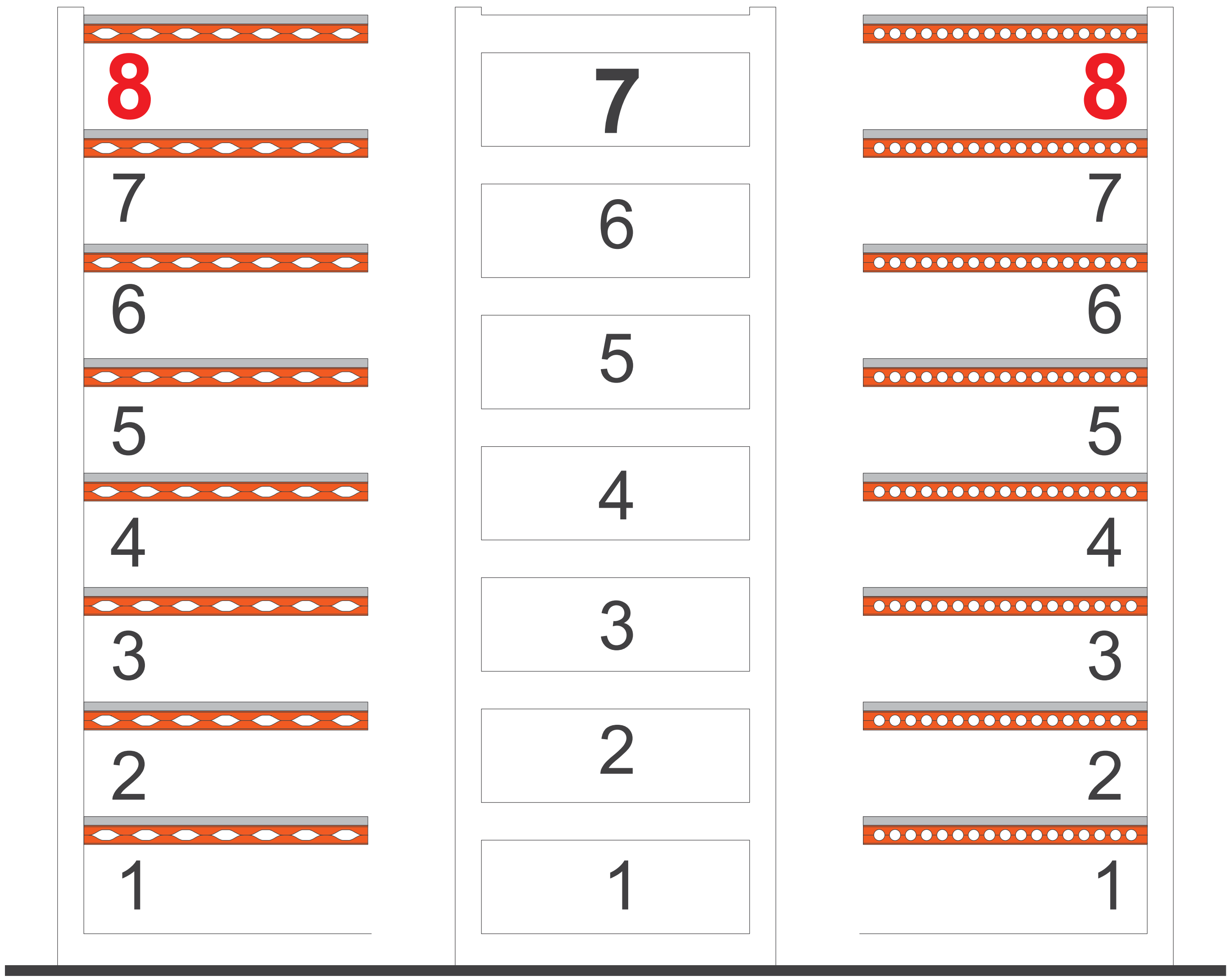
1. Composition: Castellated beams are fabricated from structural steel shapes. Steel is not only one of the most recycled materials in the world, but it is also a material that can be indefinitely recycled with minimal impact to its quality, meaning it is being upcycled more and more frequently. The structural shapes that are rolled by ArcelorMittal and used in the fabrication of castellated beams are produced from 100% scrap material, with 85% of that being recycled steel.

2. Manufacturing process: ArcelorMittal produces hot-rolled structural sections using electric arc furnace (EAF) technology, which enables significant reductions of noise, particle and CO_2 emissions as well as water and primary energy consumption when compared to other steel manufacturing technologies. In addition, when fabricating castellated beams, ArcelorMittal uses automated technologies that enable precise, versatile cutting. This ensures that waste is minimized even as the sections are customized for each project.

3. Flexibility in use: Employing castellated beams enables the integration of building systems and structural support within the same elevation. In addition, the web openings allow for flexibility when renovating or refurbishing existing buildings. Beyond that, if a building reached the end of its useful life, it would be possible, after dismantling of the structure, to use the castellated beams, or any structural shapes, as construction elements in new projects. Structural systems that use ACB® and Angelina™ beams are easy to maintain or to dismantle and may avoid resource up to 99%.

4. Embodied carbon levels: Castellated beams are optimized for each project ensuring that steel is used most efficiently. As such, simple castellated beams (i.e. those not curved or tapered), can have embodied carbon levels up to 25% lower than standard hot-rolled sections, thereby making them an environmentally attractive solution when strength demands enable their use.

Figure 30: Additional level through ACB® and Angelina™ beams



Economical aspects of sustainability
In addition to being interested in the reducing investment costs, building owners are also concerned about optimization of operational costs and achievement of the longest possible service life of their structures. This means that the building must be designed and constructed in the most flexible and efficient manner.

Using ACB® and Angelina™ beams in their designs enable architects, engineers and builders to easily fulfill investors' desires by combining high-quality sections and materials with functionality, elegance and easy construction.

With castellated beams, bottom-of-ceiling to top-of-floor heights can be reduced, which can be advantageous in adding additional floors to a building of fixed height (on average, reductions in floor system height resulting from the use of castellated beams can lead to the addition of one floor level for every eight storeys in a building, see Fig. 30) or reducing overall height of a building. Castellated beams can also assist in reducing the number of columns in a building and the size of the foundation elements.

Socio-cultural aspects of sustainability
This aspect allows the architect to reconcile his own aesthetic demands for a building with the social expectations of its surrounding environment. Again, thanks to the prefabrication construction system, castellated beams 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.

Steel and its contribution to efficiencies in construction
Using steel in construction projects offers numerous advantages , as it offers flexibility, structural efficiency and cost effectiveness. Castellated beams are high quality, readily available design solutions that are offered in a range of sizes and material grades, including high-strength ArcelorMittal HISTAR® steels. Fabricated in specialized workshops the end product is delivered to site ready for erection, with even quality control performed at the production facility.

This means that construction is simplified by requiring smaller sites and less equipment than other construction products, which can help reduce costs for traffic control measures and reduce accident potential on site. In addition, noise and dust disturbance are kept to minimum levels, and as with all steel erection projects, cleanliness of construction and low water consumption will be inherent to the project.

9. Predesign software

ACB+ software enables the configuration of a variety of ACB® beam solutions:

- single span beams
  - straight composite beam
  - straight steel beam
- tapered steel beam with single slope or double slopes
- curved steel beam
- cantilever steel beams
  - straight steel beam
  - tapered steel beam.

The software is available in English, French, German, Italian and Spanish languages.

ANGELINA software enables the configuration of a variety of Angelina™ beam solutions:

- single span beams
  - straight composite beam
  - straight steel beam.

The software is available in English, French, German and Spanish languages.

Both software packages perform the capacity checks based on Ultimate Limit State – verifying cross section capacity, local buckling, and lateral torsional buckling – according to Eurocode 3 and Eurocode 4 (EN 1993 and EN 1994) design requirements. In addition, the software calculates deflections and natural frequencies based on Serviceability Limit State requirements.

The software includes the full list of hot-rolled sections from the ArcelorMittal catalogue.
This free software can be downloaded from **sections.arcelormittal.com**.

10. Predesign charts of castellated beams

ArcelorMittal has developed predesign charts to enable engineers to quickly determine initial section sizes and web opening layouts based on the loading conditions of their projects. To refine and customize their solutions to more specifically meet project needs, ACB+ and ANGELINA software provide an opportunity to explore an unlimited selection of design options, including varying the number and size of openings and changing span lengths.
Adding partial or complete infills and exploring the use of web stiffeners is also recommended to increase capacity.

The predesign charts have been developed for non-composite and composite beams in steel grades S355, S460 and HISTAR® 460. Using these charts helps to quickly identify the maximum span length for 5 different categories of castellated beam solutions.The charts assume a partial safety factor, γ_{M1}, of 1.0 according to EN 1993-1-1.

ACB® for roofing (charts 1 to 3)
This chart has been developed for steel grade S355 with starting sections considered to be IPE for light loads, HEA for medium loads, HEB for heavy loads.

Chart notes:
- An approximate spacing, e, of 1.25 * a_0 is assumed
- Design assumes a limit is set on final height
- Deflection limit is set at L/180.

ACB® for metal decking (charts 4 to 9)
This chart has been developed for steel grades S355 and S460 with starting sections considered to be IPE for light loads, HEB for medium loads, HEM for heavy loads.

Chart notes:
- An approximate spacing, e, of 1.5 * a_0 is assumed
- Design assumes a limit is set on final height
- Deflection limit is set at L/180.

Composite ACB® (charts 10 to 15)
This chart has been developed for steel grades S355 and S460 and normal concrete class C30/37.
The starting sections considered to be IPE for light loads, HEA for medium loads, HEB for heavy loads.

Chart notes:
- An approximate spacing, e, of 1.5 * a_0 is assumed
- Design assumes a limit is set on final height
- Composite slab assumes to be 120 mm thick with trapezoidal steel deck own weight of 2,12 kN/m² (212 kg/m²)
- Slab span set to 3 m perpendicular to the beam
- A full shear connection between the slab and the section is assumed
- The beam is assumed to be propped and laterally braced during construction
- Deflection limit is set at L/180.

Angelina™ for roofing and for metal decking (charts 16 to 18)
This chart has been developed for steel grades S355 and S460 with starting sections considered to be IPE for light loads and HEA for medium loads.

Chart notes:
- Web post length, w, is set to 200 mm or 250 mm
- Deflection limit is set at L/200.

Composite Angelina™ (charts 19 to 27)
This chart has been developed for steel grades S355 and HISTAR® 460 and normal concrete class C30/37.

Figure 29: Design load

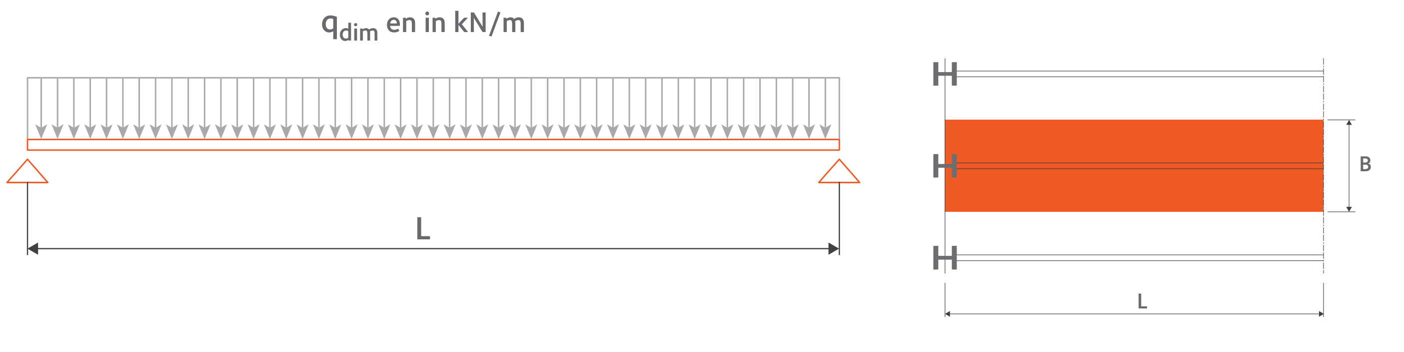


Chart notes:

- The openings proportions are fixed such that a_0=s
- Web post length w is set to 200 mm or 250 mm
- For charts with cast-in-place concrete, composite slab assumed to be 120 mm thick with trapezoidal steel deck own weight of 2,12 kN/m² (212 kg/m²), and slab span set to 3 m perpendicular to the beam
- For charts with prefabricated slab element, Cofradal 200, slab assumed to have an own weight of 2,00 kN/m², and slab span set to 6 m perpendicular to the beam
- When Cofradal 200 is used, the effective width is assumed to be 1 m and the available height for shear resistance is assumed to be 20 cm
- A full shear connection between the slab and the section is assumed
- The beam is assumed to be shored and laterally braced during construction
- Deflection limit is set to L/200 and vertical deflection of the composite section takes into account shrinkage of the concrete.

Design load

The design load, q_{dim}, is in kN/m, is project specific and should be compared with the ultimate load, q_u, given in the charts.

This ultimate load takes into account all criteria required for Ultimate Limit States (ULS) and deflection at Serviceability Limit States (SLS). To compare design load directly with the ultimate load, the following ULS load combination should be used:

$$q_{dim} = (1{,}35\ G + 1{,}5\ Q)\ B$$

where :

B = beam spacing [m],
G = permanent load per square meter [kN/m²],
Q = variable load per square meter [kN/m²].

Using the predesign charts

There are three possible procedures:

Case 1, where design load, q_{dim}, and the span length, L, are known:
Design load, q_{dim}, is taken equal to ultimate load, q_u, and the intersection of the line representing q_u and L can be located on the chart. The design section that will have adequate capacity to meet project needs can be identified by the curve located to the right of the point of intersection. Using the curve name (i.e. A, B, C, etc.), the user can enter the table below the chart and determine the corresponding section size that was used in creating the curve. The table also indicates the properties of the web openings that were used in creating the curve. Once the section is identified, the web opening size and layout should be checked against any functional requirements specific to the project.

Case 2, where the section size is known along with the span length, L:
Using the table corresponding to the chart in question, the appropriate design curve (A, B, C, etc.) can be identified. By following this curve to its intersection with the necessary span length, the section capacity can be found. The capacity, q_u, should be compared to the design load to verify that $q_{dim} \leq q_u$.

Case 3, where the section size is known along with the design load, q_{dim}:
In this case, q_{dim} is taken equal to q_u and the design curve is determined from the section size and the table corresponding with the appropriate predesign chart. The intersection of the line representing q_u and the design curve can be located on the chart. This intersection corresponds to the permissible span length that will ensure desired capacity of the section is achieved.

Example of Angelina™ predesign

Beam A to be designed as Angelina™ beam for a composite floor with a span length of L =16 m and a spacing of B =3 m.

For architectural reasons, the final height of the floor is limited to 700 mm (this allows the maximum height of the Angelina™ section to be H_t = 580 mm) with a 120 mm slab.

Design parameters :
- Slab thickness = 12 cm
- Concrete class; C30/37
- Steel deck with 60 mm rib height.

Loading criteria:

$$q_{dim} = (1.35\ G + 1.5\ Q)\ B$$

with

$G = g_{Angelina} + g_{slab} + g_2$

The weight of the Angelina™ beam is initially assumed to be 1kN/m, equivalent to $g_{Angelina} = 0.33 kN/m^2$.

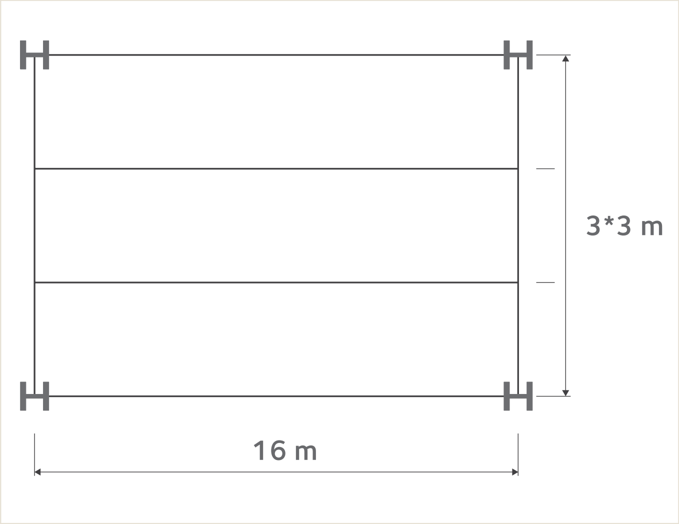
For a 12 cm thick slab on steel decking, the weight g_{slab} = 2,12 kN/m^2

g_2= additional permanent load = 1.0 kN/m^2

Q = variable load, value chosen for this example: 6 kN/m^2

The design load, q_{dim}, is:

$q_{dim} = (1.35x(2.12 + 0.33 + 1) + 1.5\ x\ 6)x\ 3 = 41$ kN/m



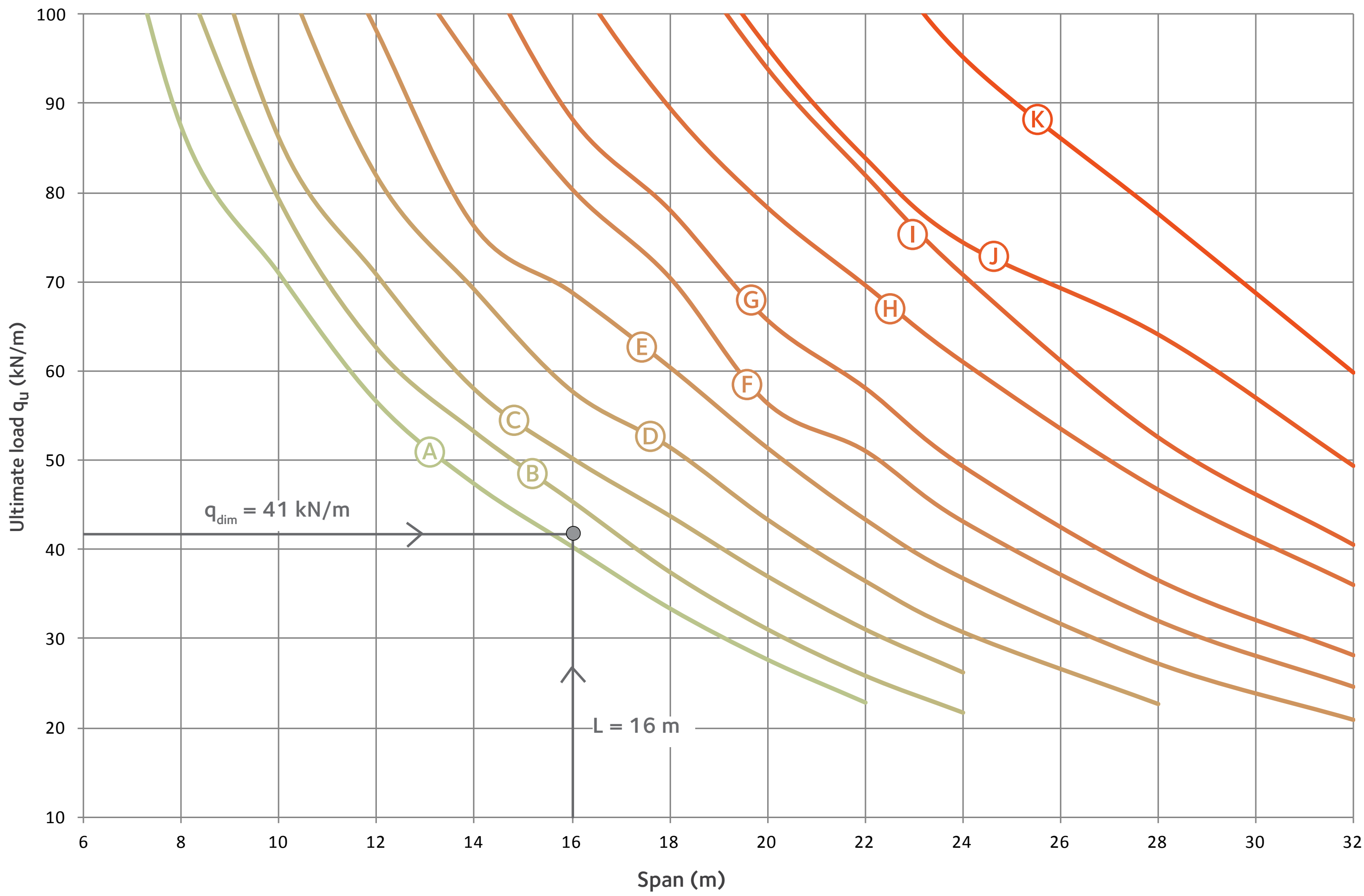
Using the predesign charts for sizing as a function of load and span, the required section can be determined (case 1). Given that a maximum height of the beam is imposed at 580mm, the solution should come from wide flange section range. The choice of chart falls on the HEB range in S355.

Using q_{dim} = qu and length to enter the predesign charts and table identifies curve B as a potential solution.

The required section is HE 320 B with H_t=487,5 mm and a_0=335 mm.

With the section is known, one can enter the values in the ANGELINA software in order to refine the results and carry out the various ULS and SLS checks.

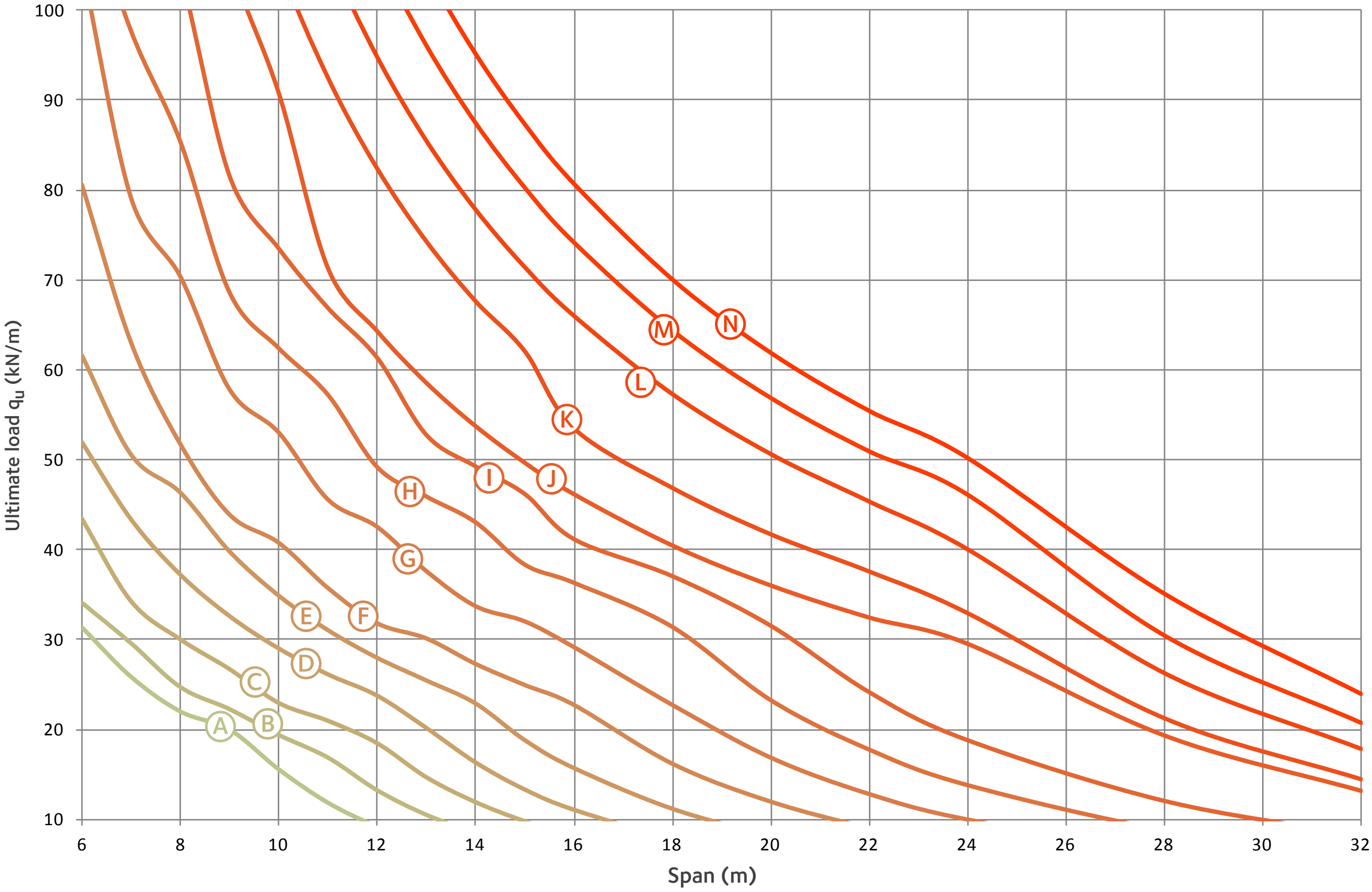
Abaque: Composite Angelina™ based on HEB, S355 with COFRAPLUS 60



Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
Ⓐ	HE 300 B	315	250	315	1130	457,5	129,3	87,5	71,0	56,6	47,4	40,4	33,5	27,7	22,9			
Ⓑ	HE 320 B	335	250	335	1170	487,5	138,5	105,6	79,3	62,6	53,3	45,4	37,5	31,1	25,9	21,7		
Ⓒ	HE 360 B	380	300	380	1360	550		120,6	86,2	70,8	58,0	50,3	43,8	37,0	31,0	26,2		
Ⓓ	HE 400 B	420	300	420	1440	610		137,9	106,4	81,9	69,1	57,7	51,4	43,3	36,4	30,7		
Ⓔ	HE 450 B	475	300	475	1550	687,5		151,5	120,9	98,1	76,2	68,8	60,4	51,3	43,3	36,7		
Ⓕ	HE 500 B	525	300	525	1650	762,5			132,4	111,1	94,3	80,4	70,5	56,4	51,1	43,2		
Ⓖ	HE 550 B	580	300	580	1760	840				130,6	107,7	88,4	78,1	65,7	58,1	49,4	12,6	
Ⓗ	HE 650 B	680	300	680	1960	990				153,2	125,4	104,8	89,5	78,3	69,6	61,0	16,2	11,0
Ⓘ	HE 700 B	730	300	730	2060	1065					154,9	130,7	109,8	94,0	82,0	70,9	20,2	13,7
Ⓙ	HE 800 B	780	300	780	2160	1190						136,3	112,6	96,3	83,9	74,4	25,2	17,1
Ⓚ	HE 900 B	830	350	830	2360	1315							155,9	128,6	109,9	95,2	31,9	21,8

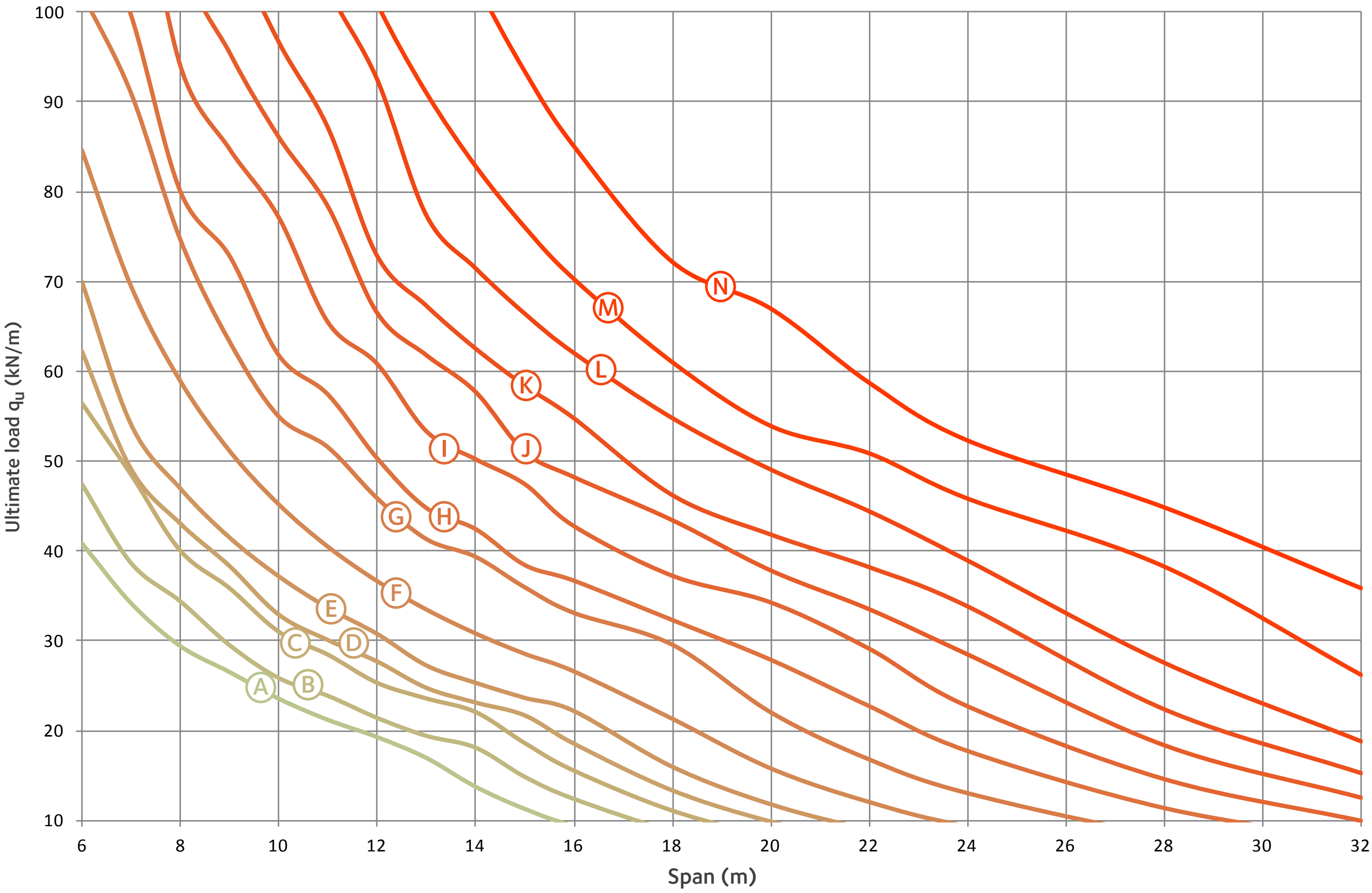
11. Predesign charts for ACB®

Chart 1: Non-composite ACB® based on IPE, S355, e=1.25 a_0



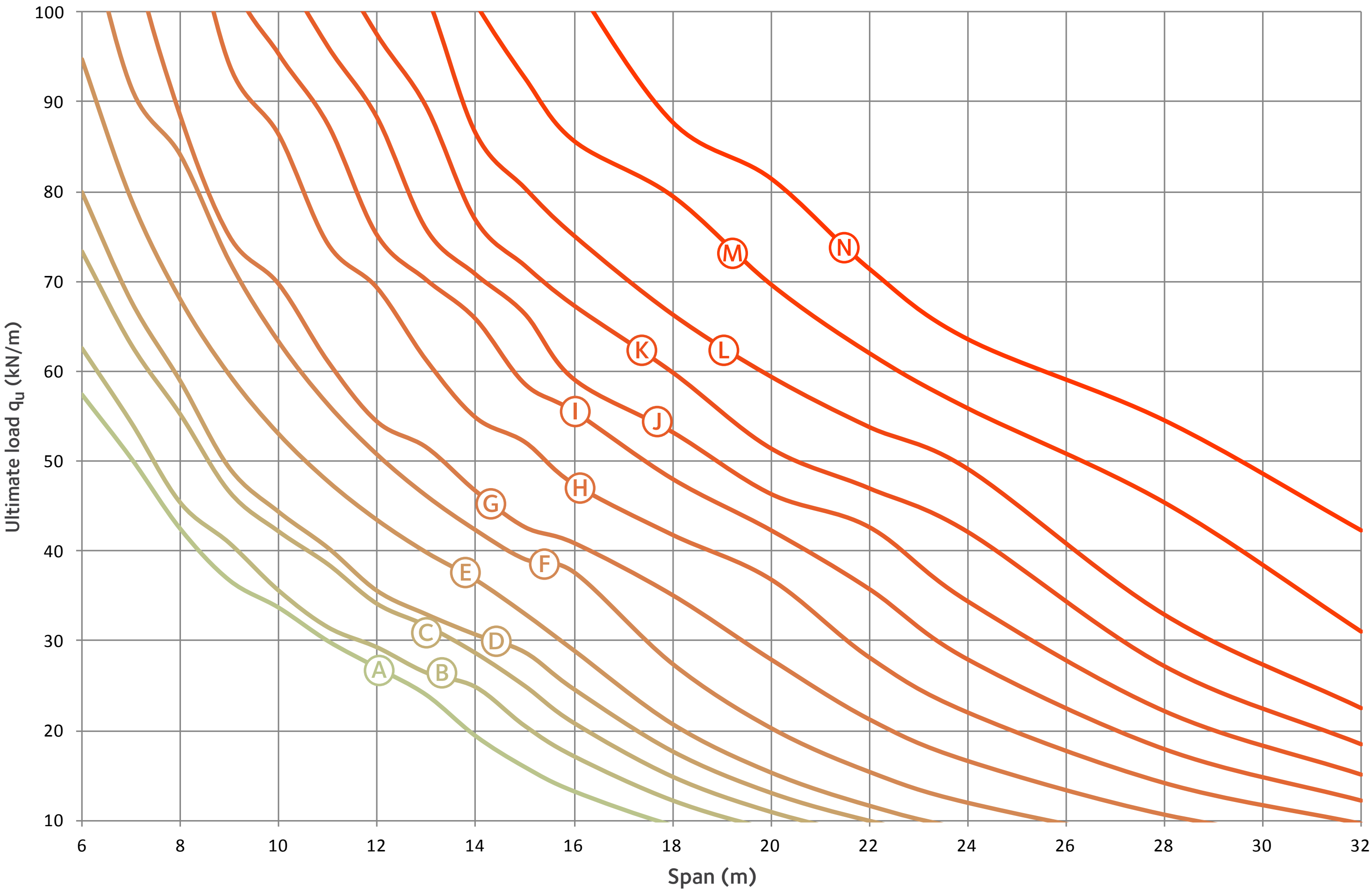
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	IPE 270	285	75	360	399	31,4	25,9	22,1	20,1	15,6	11,9											
B	IPE 300	315	75	390	445	34,2	29,6	24,8	22,3	19,4	16,9	13,2	10,5									
C	IPE 330	345	85	430	489	43,4	34,2	30,0	26,7	22,9	20,9	18,4	14,6	11,9								
D	IPE 360	380	100	480	535	52,0	43,4	37,3	32,7	29,1	26,2	23,8	20,2	16,4	13,4	11,1						
E	IPE 400	420	110	530	594	61,6	50,5	46,3	39,8	34,9	31,0	28,0	25,4	22,9	18,8	15,7	11,2	8,2				
F	IPE 450	475	115	590	672	80,6	63,0	51,7	43,9	40,8	35,7	31,8	30,1	27,3	24,9	22,7	16,2	12,0				
G	IPE 500	525	135	660	745		79,2	70,5	57,9	53,1	45,6	42,6	37,6	33,7	32,0	29,2	22,7	16,9	12,8			
H	IPE 550	580	150	730	822		97,7	85,4	68,6	62,4	57,2	49,2	45,9	43,1	38,4	36,3	31,4	23,3	17,8	13,8		
I	IPE 600	630	160	790	896				81,6	73,5	66,9	61,3	52,7	49,2	46,2	41,1	37,0	31,5	24,1	18,8	12,0	
J	IPE 750 x 134	785	196,2	981,2	1122					90,8	71,3	64,3	58,5	53,7	49,6	46,1	40,4	36,0	32,4	29,5	19,3	13,1
K	IPE 750 x 147	790	197,5	987,5	1127						92,5	82,4	74,3	67,6	62,1	53,5	46,9	41,7	37,6	32,9	21,2	14,4
L	IPE 750 x 173	795	198,7	993,7	1139							94,8	85,5	77,8	71,4	66,0	57,3	50,6	45,3	40,0	26,3	17,8
M	IPE 750 x 196	800	200	1000	1149								96,1	87,5	80,3	74,2	64,4	56,9	51,0	46,2	30,5	20,8
N	IPE 750 x 220	805	201,2	1006,2	1160									95,2	87,3	80,7	70,1	61,9	55,4	50,2	35,1	24,0

Chart 2: Non-composite ACB® based on HEA, S355, e=1.25 a_0



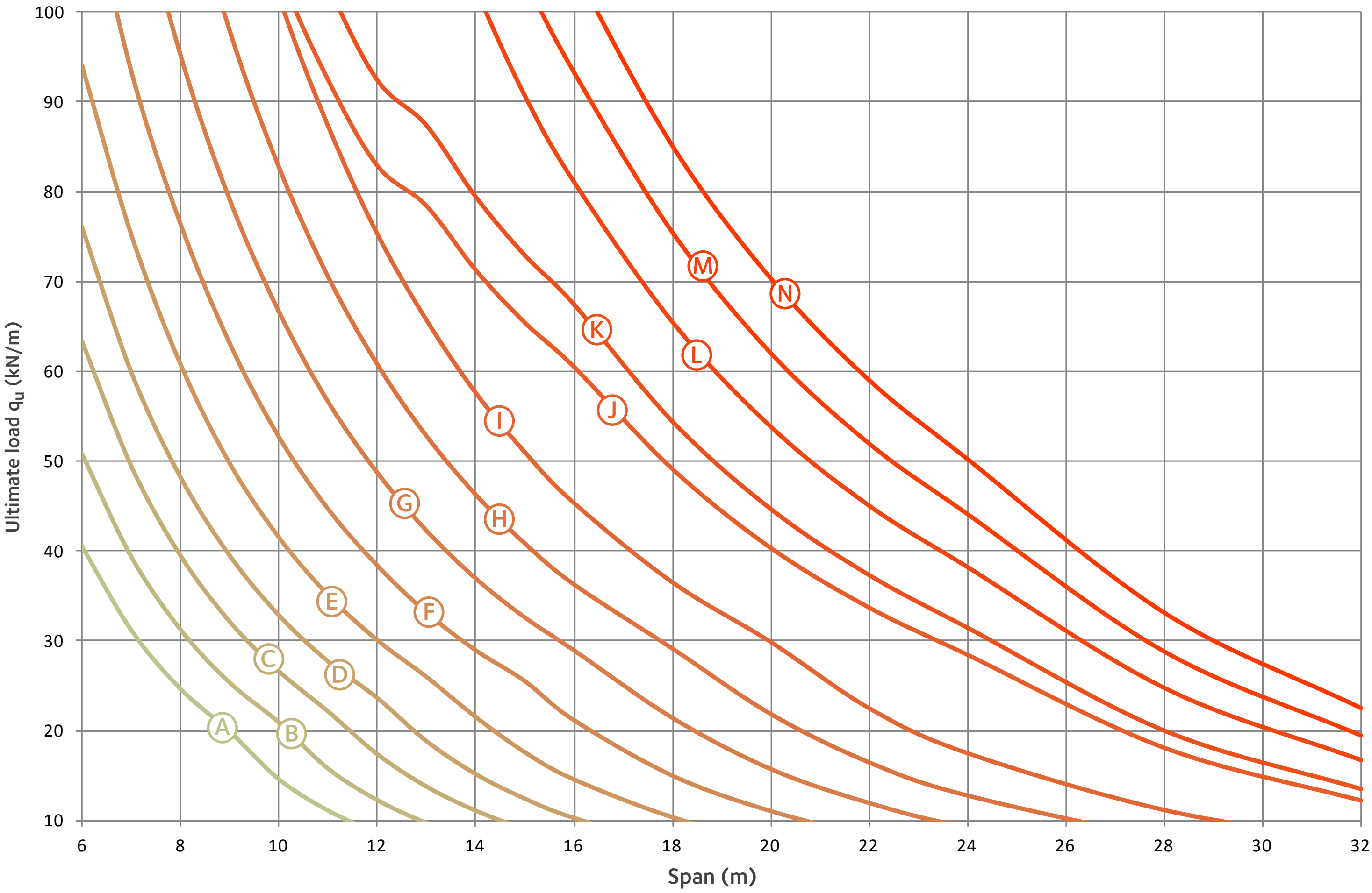
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	HE 280 A	285	75	360	399	40,9	34,2	29,4	26,6	23,6	21,2	19,3	17,0	13,8	11,3							
B	HE 300 A	305	75	380	430	47,4	38,7	34,4	29,5	25,9	23,9	21,4	19,5	18,1	14,9	12,4						
C	HE 320 A	325	85	410	459	56,4	48,4	40,0	35,8	31,0	28,4	25,3	23,6	22,0	18,6	15,5	11,1					
D	HE 340 A	345	85	430	489	62,3	49,1	43,1	38,3	32,9	30,1	27,7	24,7	23,1	21,7	18,5	13,3					
E	HE 360 A	370	90	460	521	70,0	54,1	46,9	41,5	37,2	33,6	30,7	27,2	25,3	23,6	22,2	15,9	11,8				
F	HE 400 A	410	100	510	581	84,6	69,5	58,9	51,2	45,2	40,5	36,7	33,5	30,9	28,6	26,6	21,4	15,8	12,1			
G	HE 450 A	460	120	580	654		91,0	74,7	63,4	55,0	51,6	45,9	41,4	39,4	36,0	33,2	29,6	22,1	16,9	13,1		
H	HE 500 A	515	125	640	732		99,6	80,1	72,9	61,8	57,5	50,4	44,8	42,5	38,5	36,7	32,4	27,9	22,8	17,8	11,4	
I	HE 550 A	565	145	710	805			94,0	84,7	77,1	65,4	60,8	53,3	50,2	47,4	42,7	37,2	34,2	29,1	22,7	14,6	
J	HE 600 A	620	160	780	881				95,5	86,1	78,4	66,5	61,8	57,7	51,0	48,2	43,4	37,8	33,5	28,4	18,3	12,5
K	HE 650 A	670	170	840	956					96,8	87,2	72,9	67,4	62,6	58,5	54,9	46,3	41,9	38,3	33,9	22,5	15,3
L	HE 700 A	725	185	910	1032							92,6	77,4	71,5	66,5	62,1	54,8	49,1	44,5	39,0	27,6	18,8
M	HE 800 A	830	210	1040	1183								91,0	82,9	76,1	70,3	61,0	53,9	50,9	45,8	38,3	26,2
N	HE 900 A	935	235	1170	1334										93,4	85,1	72,2	67,0	58,8	52,3	44,9	35,9

Chart 3: Non-composite ACB® based on HEB, S355, e=1.25 a_0



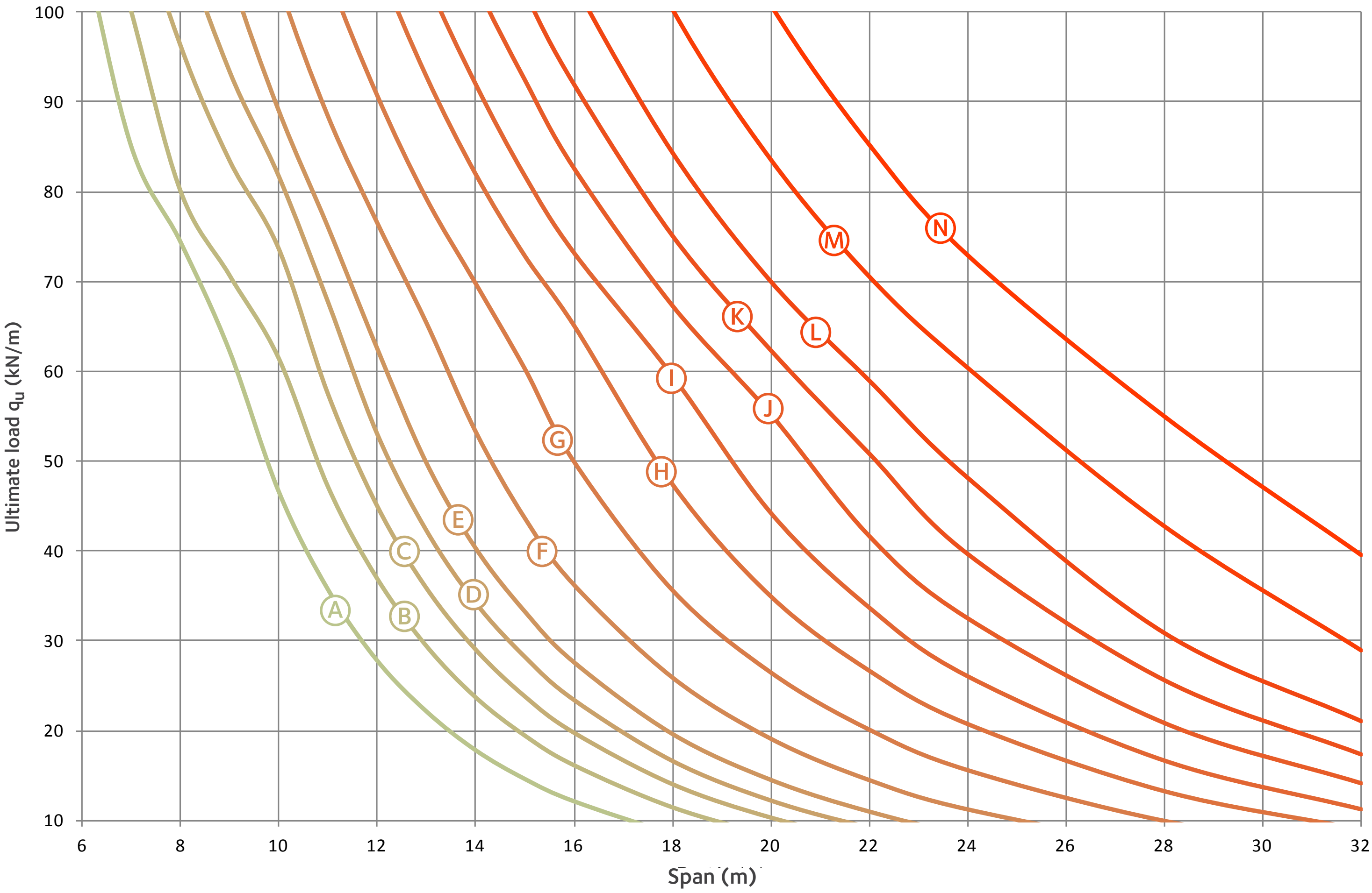
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	HE 280 B	295	75	370	414	57,5	50,4	42,5	36,8	33,7	30,0	27,0	24,0	19,4	16,0	13,3						
B	HE 300 B	315	75	390	445	62,6	54,4	45,4	40,9	35,6	31,6	29,3	26,5	24,9	20,6	17,2	12,3					
C	HE 320 B	335	85	420	474	73,4	63,1	55,3	46,7	42,2	38,6	34,2	31,8	28,7	25,1	20,9	15,0	11,0				
D	HE 340 B	355	85	440	504	80,0	67,9	58,9	49,2	44,3	40,4	35,6	32,9	30,7	28,7	24,6	17,7	13,1				
E	HE 360 B	380	100	480	535	94,8	79,2	68,1	59,6	53,1	47,8	43,5	39,9	36,9	33,1	29,0	20,8	15,4	11,7			
F	HE 400 B	420	110	530	594		91,8	84,2	72,3	63,4	56,4	50,8	46,3	42,4	39,2	37,7	27,5	20,4	15,5	12,1		
G	HE 450 B	475	115	590	672			88,5	75,1	69,8	61,1	54,4	51,6	46,7	42,7	40,9	35,1	28,0	21,3	16,6	10,6	
H	HE 500 B	525	135	660	745				94,1	86,4	74,2	69,3	61,2	54,9	52,1	47,4	41,8	36,8	28,1	22,0	14,1	
I	HE 550 B	580	150	730	822					95,3	87,5	75,1	70,2	65,8	58,6	55,5	48,0	42,3	35,8	27,9	17,9	12,2
J	HE 600 B	630	160	790	896						96,2	88,2	75,8	70,8	66,4	59,1	53,3	46,4	42,7	34,4	22,2	15,1
K	HE 650 B	685	175	860	973							97,5	89,5	76,9	71,8	67,4	59,9	51,5	47,0	42,2	27,2	18,5
L	HE 700 B	735	185	920	1047									86,5	80,4	75,1	66,3	59,4	53,8	49,1	32,9	22,5
M	HE 800 B	840	210	1050	1198										92,7	85,7	79,5	69,7	62,0	55,9	45,4	31,0
N	HE 900 B	945	235	1180	1349												87,8	81,5	71,5	63,6	54,6	42,3

Chart 4: Non-composite ACB® based on IPE, S355, e=1.5 a_0



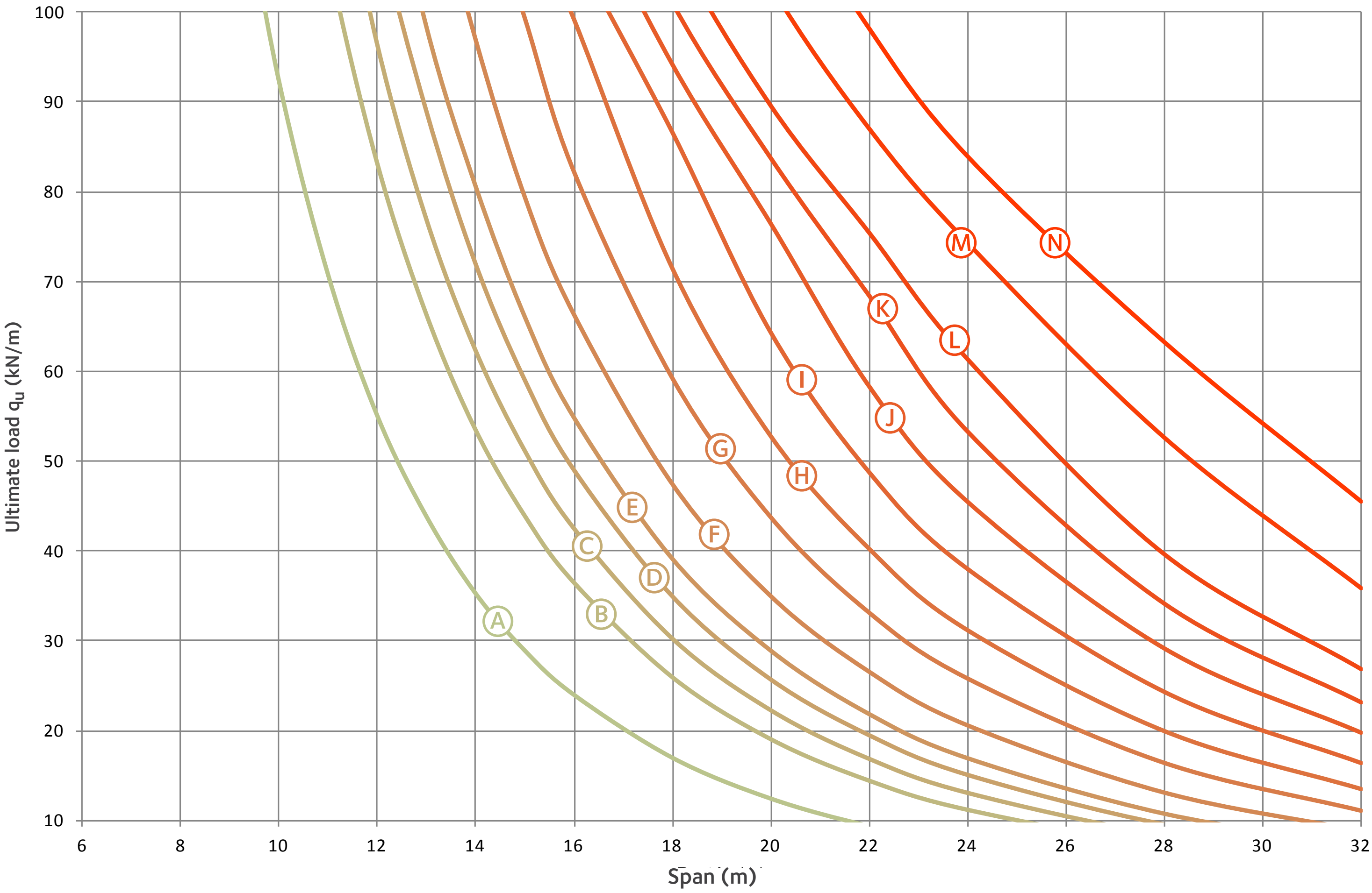
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	IPE 270	285	140	425	385	40,5	31,2	24,7	19,9	14,6	11,1											
B	IPE 300	315	155	470	428	50,9	39,5	31,4	25,4	21,0	15,9	12,3										
C	IPE 330	345	170	515	471	63,3	49,4	39,5	32,1	26,6	22,1	17,4	13,8	11,1								
D	IPE 360	380	190	570	515	76,1	60,0	48,3	39,5	32,9	27,8	23,7	18,9	15,2	12,5	10,3						
E	IPE 400	420	210	630	573	94,2	75,3	60,9	49,8	41,6	35,1	30,1	26,0	21,5	17,6	14,6	10,4					
F	IPE 450	475	235	710	647		93,5	76,5	63,2	52,8	44,7	38,4	33,2	29,0	25,6	21,2	15,0	11,1				
G	IPE 500	525	260	785	719			95,3	79,2	66,7	56,6	48,7	42,3	36,9	32,6	28,9	21,4	15,7	11,9			
H	IPE 550	580	285	865	793				98,1	82,9	70,6	60,9	52,9	46,4	40,9	36,4	29,2	21,9	16,5	12,8		
I	IPE 600	630	310	940	865						87,4	75,3	65,7	57,6	51,0	45,3	36,5	29,9	22,5	17,5	11,1	
J	IPE 750 x 134	755	392,5	1147,5	1081						92,5	83,0	78,5	71,3	65,5	60,6	49,2	40,4	33,8	28,5	18,1	12,3
K	IPE 750 x 147	755	395	1150	1086							92,5	87,5	79,5	73,0	67,5	54,5	44,7	37,4	31,5	20,1	13,6
L	IPE 750 x 173	765	397,5	1162,5	1097										90,7	81,1	65,5	53,9	45,1	38,2	24,8	16,7
M	IPE 750 x 196	770	400	1170	1107											93,4	75,5	62,1	52,0	44,2	28,9	19,5
N	IPE 750 x 220	780	402,5	1182,5	1118												85,2	70,4	59,1	50,3	33,2	22,6

Chart 5: Non-composite ACB® based on HEB, S355, e=1.5 a_0



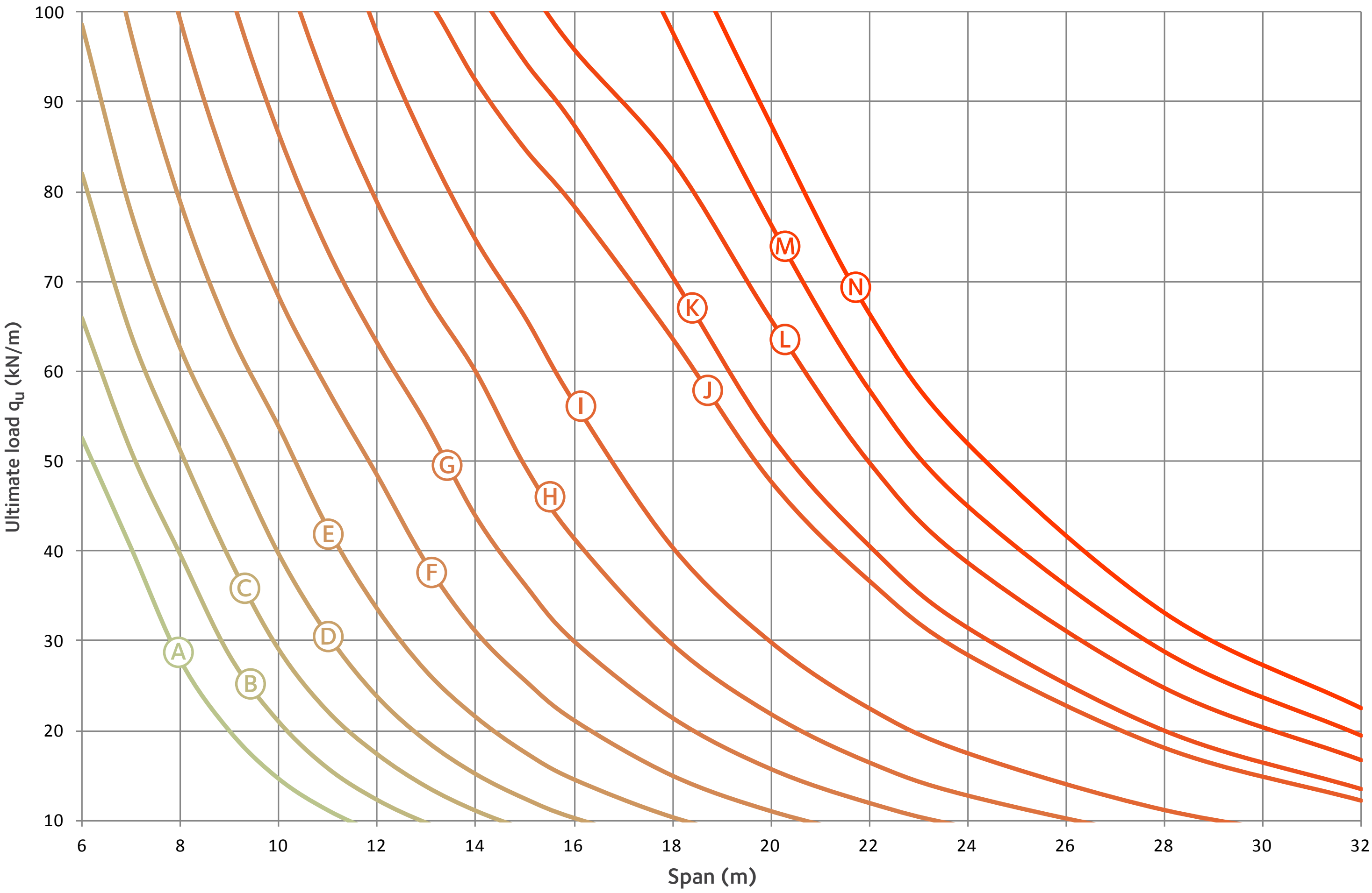
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
Ⓐ	HE 280 B	280	140	420	392		85,2	74,5	62,3	46,7	35,8	27,8	22,2	17,8	14,6	12,1						
Ⓑ	HE 300 B	310	150	460	426			80,2	70,7	61,5	47,2	37,0	29,5	23,8	19,5	16,2	11,5					
Ⓒ	HE 320 B	335	165	500	457			96,4	83,6	73,7	57,6	45,1	35,9	29,1	23,9	19,8	14,1	10,4				
Ⓓ	HE 340 B	355	175	530	485				93,5	81,8	67,8	53,1	42,3	34,3	28,3	23,5	16,7	12,3				
Ⓔ	HE 360 B	380	190	570	515					89,0	76,1	62,6	49,8	40,3	33,2	27,6	19,6	14,5	10,9			
Ⓕ	HE 400 B	420	210	630	573						88,5	76,6	65,5	53,4	43,7	36,3	25,9	19,1	14,5	11,2		
Ⓖ	HE 450 B	475	235	710	647							90,7	79,2	69,8	60,3	49,9	35,6	26,4	20,1	15,6		
Ⓗ	HE 500 B	525	260	785	719								92,8	82,0	72,8	65,1	47,4	34,9	26,6	20,7	13,2	
Ⓘ	HE 550 B	580	290	870	792									92,1	81,8	73,3	59,6	44,3	33,8	26,1	16,7	11,3
Ⓙ	HE 600 B	630	310	940	865										92,5	82,6	67,3	55,2	41,7	32,5	20,8	14,1
Ⓚ	HE 650 B	685	340	1025	938											92,0	75,1	62,3	50,8	39,6	25,6	17,3
Ⓛ	HE 700 B	735	365	1100	1010												84,3	70,0	58,9	48,1	30,8	21,0
Ⓜ	HE 800 B	840	420	1260	1154													83,5	70,5	60,4	42,7	28,9
Ⓝ	HE 900 B	945	470	1415	1301														85,2	72,9	54,9	39,5

Chart 6: Non-composite ACB® based on HEM, S355, e=1.5 a_0



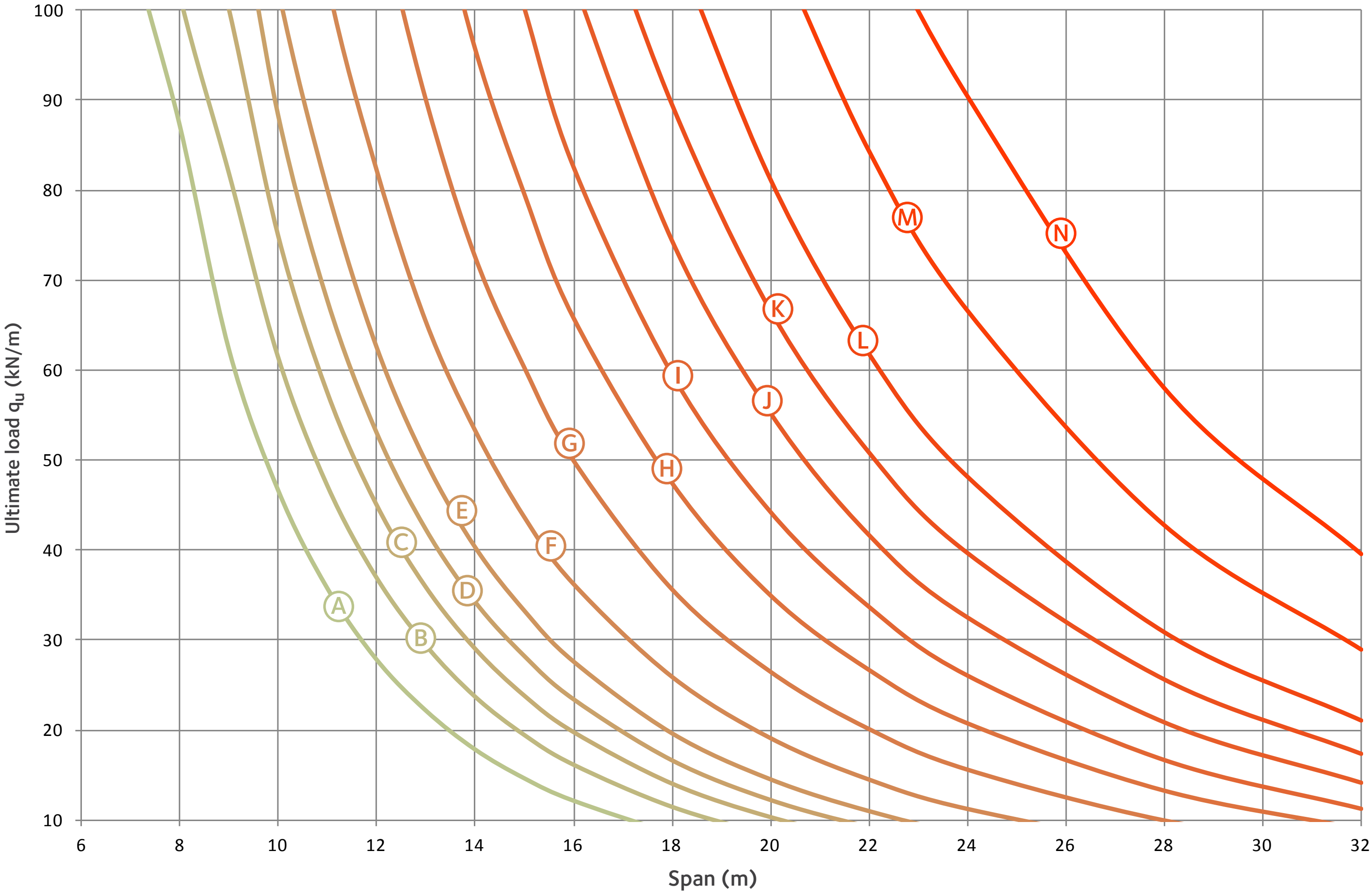
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	HE 280 M	280	140	420	422					92,5	70,9	55,1	43,9	35,3	29,0	24,1	17,0	12,5				
B	HE 300 M	310	150	460	466							83,2	66,3	53,4	43,9	36,4	25,9	19,0	14,4	11,1		
C	HE 320 M	340	165	505	498							96,4	76,9	62,3	51,1	42,5	30,2	22,2	16,8	13,0		
D	HE 340 M	380	180	560	535								89,1	72,1	59,1	49,1	35,0	25,8	19,6	15,1		
E	HE 360 M	410	195	605	566								98,4	80,7	66,2	54,9	39,2	29,0	21,9	17,0	10,8	
F	HE 400 M	450	220	670	619									97,0	79,5	66,4	47,5	35,0	26,6	20,6	13,1	
G	HE 450 M	500	245	745	687										99,4	82,3	59,3	43,8	33,2	25,8	16,5	11,1
H	HE 500 M	540	270	810	749											99,1	71,4	52,7	40,2	31,1	19,9	13,4
I	HE 550 M	600	300	900	823												86,7	64,4	48,8	38,1	24,4	16,4
J	HE 600 M	650	320	970	894												94,1	76,4	58,3	45,4	29,1	19,7
K	HE 650 M	700	350	1050	962													83,7	68,4	53,3	34,1	23,1
L	HE 700 M	750	375	1125	1031													89,6	75,4	61,4	39,6	26,8
M	HE 800 M	855	425	1280	1176														87,1	74,3	52,7	35,9
N	HE 900 M	955	475	1430	1315														98,2	84,0	63,3	45,6

Chart 7: Non-composite ACB® based on IPE, S460, e=1.5 a_0



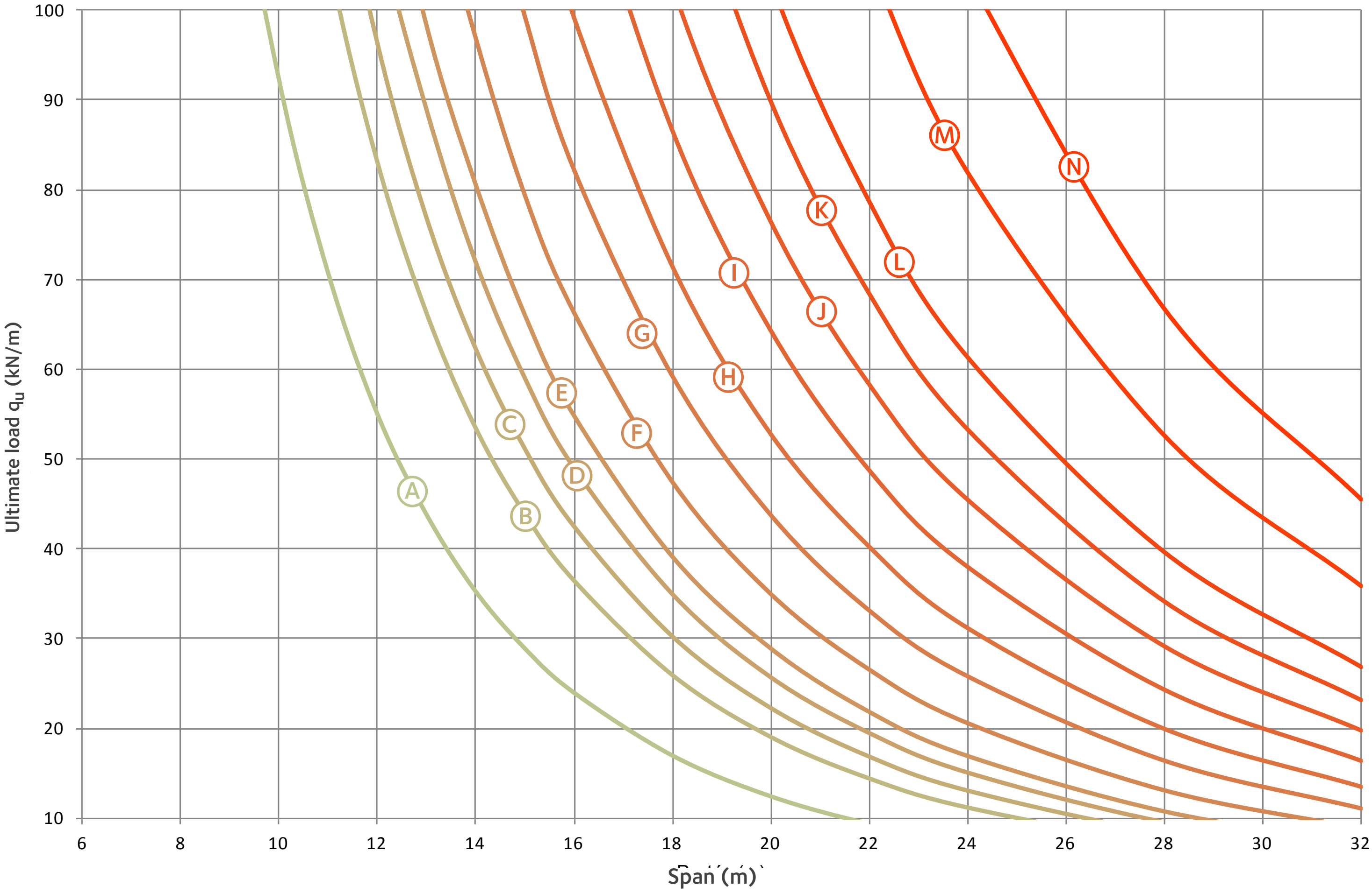
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	IPE 270	285	140	425	385	52,5	40,3	27,8	19,9	14,6	11,1											
B	IPE 300	315	155	470	428	66,0	51,1	39,6	28,4	21,0	15,9	12,3										
C	IPE 330	345	170	515	471	82,0	64,1	51,2	39,1	29,1	22,1	17,4	13,8	11,1								
D	IPE 360	380	190	570	515	98,6	77,7	62,6	51,2	39,7	30,7	23,8	18,9	15,2	12,5	10,3						
E	IPE 400	420	210	630	573		97,6	78,9	64,6	53,9	42,5	33,6	26,6	21,5	17,6	14,6	10,4					
F	IPE 450	475	235	710	647			99,1	81,9	68,4	58,0	48,5	38,7	31,1	25,7	21,2	15,0	11,1				
G	IPE 500	525	260	785	719				102,6	86,4	73,4	63,1	54,1	43,9	36,2	29,9	21,4	15,7	11,9			
H	IPE 550	580	285	865	793					107,4	91,5	78,9	68,5	60,1	49,6	41,5	29,7	21,9	16,5	12,8		
I	IPE 600	630	310	940	865						113,2	97,6	85,2	74,7	66,1	56,6	40,4	29,9	22,5	17,5	11,1	
J	IPE 750 x 134	755	392,5	1147,5	1081						119,9	107,5	101,7	92,5	84,8	78,5	63,7	47,8	36,7	28,5	18,1	12,3
K	IPE 750 x 147	755	395	1150	1086							119,9	113,3	103,1	94,6	87,5	70,6	52,9	40,7	31,5	20,1	13,6
L	IPE 750 x 173	765	397,5	1162,5	1097									113,2	103,8	95,9	83,5	65,8	49,9	38,7	24,8	16,7
M	IPE 750 x 196	770	400	1170	1107												97,9	76,5	58,0	45,1	28,9	19,5
N	IPE 750 x 220	780	402,5	1182,5	1118												110,4	87,6	66,5	52,1	33,2	22,6

Chart 8: Non-composite ACB® based on HEB, S460, e=1.5 a_0



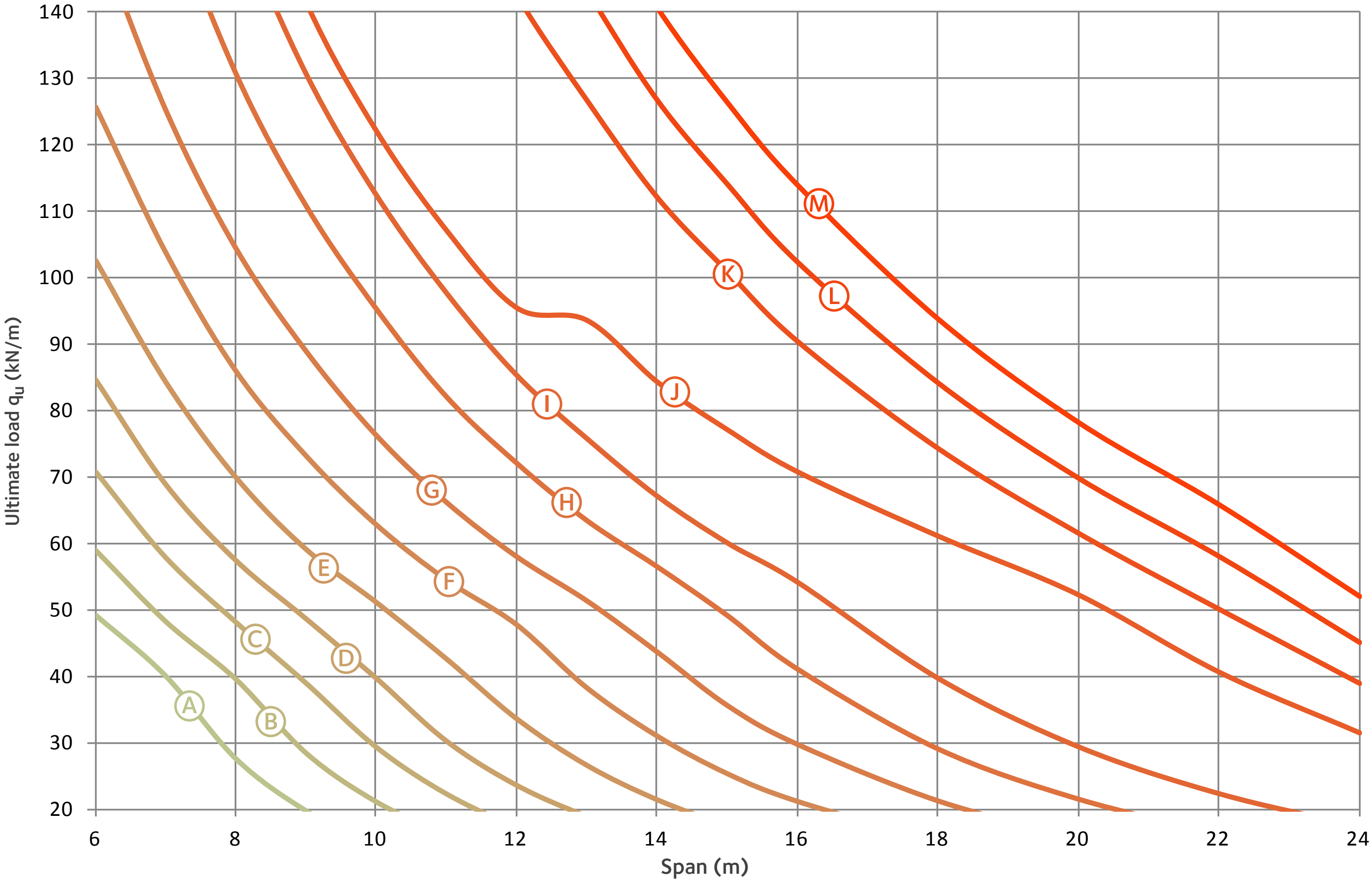
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
Ⓐ	HE 280 B	280	140	420	392		108,3	87,3	62,3	46,7	35,8	27,8	22,2	17,8	14,6	12,1						
Ⓑ	HE 300 B	310	150	460	426			101,8	82,0	61,5	47,2	37,0	29,5	23,8	19,5	16,2	11,5					
Ⓒ	HE 320 B	335	165	500	457				100,2	75,1	57,6	45,1	35,9	29,1	23,9	19,8	14,1	10,4				
Ⓓ	HE 340 B	355	175	530	485				118,2	88,4	67,8	53,1	42,3	34,3	28,3	23,5	16,7	12,3				
Ⓔ	HE 360 B	380	190	570	515					102,4	80,1	62,6	49,8	40,3	33,2	27,6	19,6	14,5	10,9			
Ⓕ	HE 400 B	420	210	630	573						103,3	82,3	65,5	53,4	43,7	36,3	25,9	19,1	14,5	11,2		
Ⓖ	HE 450 B	475	235	710	647							111,9	90,1	72,6	60,3	49,9	35,6	26,4	20,1	15,6		
Ⓗ	HE 500 B	525	260	785	719								117,1	95,7	79,5	65,8	47,4	34,9	26,6	20,7	13,2	
Ⓘ	HE 550 B	580	290	870	792									119,3	100,3	82,7	59,6	44,3	33,8	26,1	16,7	11,3
Ⓙ	HE 600 B	630	310	940	865										119,8	103,4	74,4	55,2	41,7	32,5	20,8	14,1
Ⓚ	HE 650 B	685	340	1025	938											119,2	89,5	66,6	50,8	39,6	25,6	17,3
Ⓛ	HE 700 B	735	365	1100	1010												108,0	81,1	61,8	48,1	30,8	21,0
Ⓜ	HE 800 B	840	420	1260	1154													108,3	84,3	66,6	42,7	28,9
Ⓝ	HE 900 B	945	470	1415	1301														110,4	90,4	57,9	39,5

Chart 9: Non-composite ACB® based on HEM, S460, e=1.5 a_0



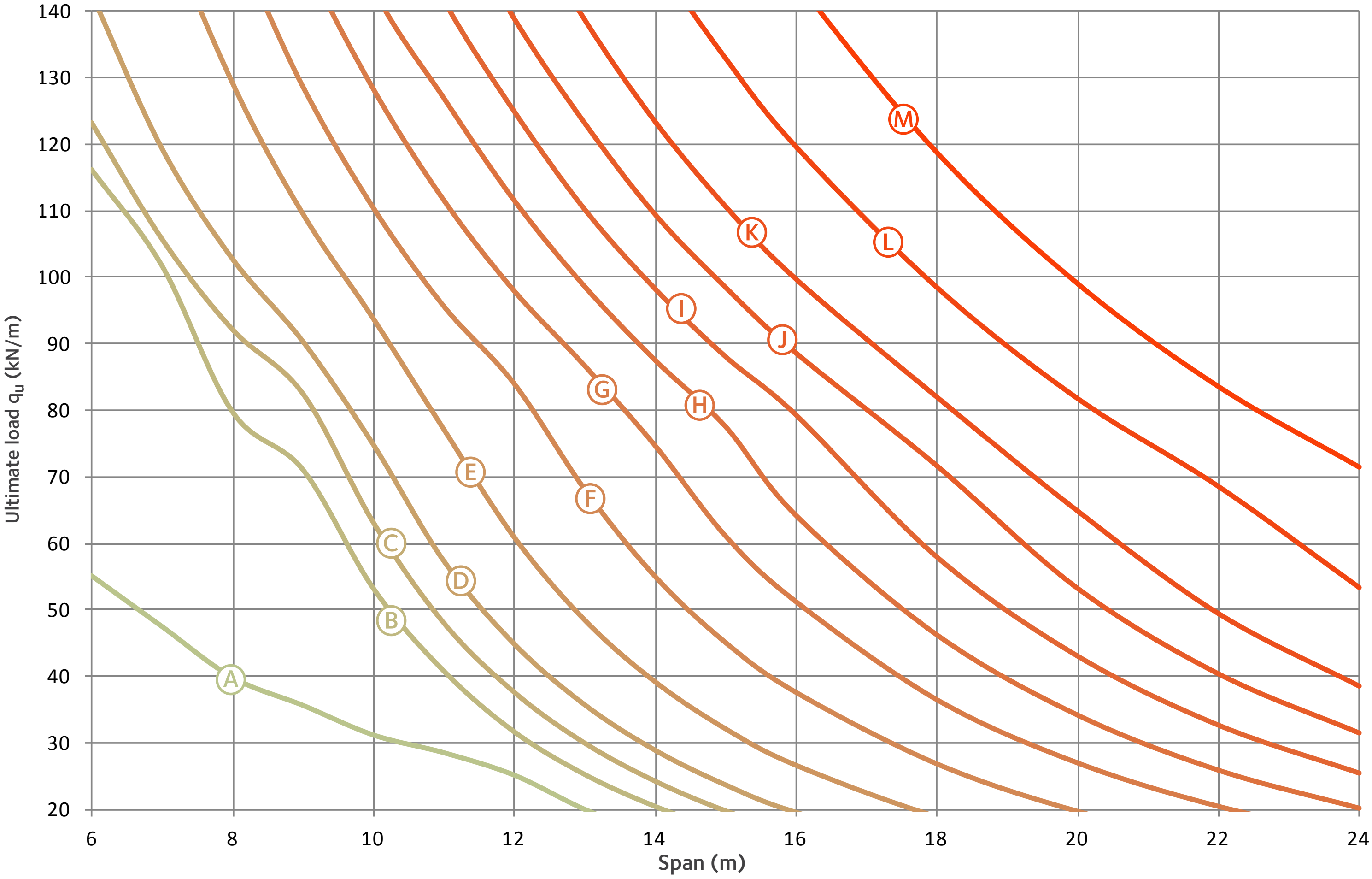
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)																
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	28	32
A	HE 280 M	280	140	420	422					92,5	70,9	55,1	43,9	35,3	29,0	24,1	17,0	12,5				
B	HE 300 M	310	150	460	466						106,1	83,2	66,3	53,4	43,9	36,4	25,9	19,0	14,4	11,1		
C	HE 320 M	340	165	505	498							96,4	76,9	62,3	51,1	42,5	30,2	22,2	16,8	13,0		
D	HE 340 M	380	180	560	535							110,2	89,1	72,1	59,1	49,1	35,0	25,8	19,6	15,1		
E	HE 360 M	410	195	605	566								98,4	80,7	66,2	54,9	39,2	29,0	21,9	17,0	10,8	
F	HE 400 M	450	220	670	619								118,1	97,0	79,5	66,4	47,5	35,0	26,6	20,6	13,1	
G	HE 450 M	500	245	745	687										99,4	82,3	59,3	43,8	33,2	25,8	16,5	11,1
H	HE 500 M	540	270	810	749										118,7	99,1	71,4	52,7	40,2	31,1	19,9	13,4
I	HE 550 M	600	300	900	823												86,7	64,4	48,8	38,1	24,4	16,4
J	HE 600 M	650	320	970	894												102,7	76,4	58,3	45,4	29,1	19,7
K	HE 650 M	700	350	1050	962													89,8	68,4	53,3	34,1	23,1
L	HE 700 M	750	375	1125	1031													103,3	78,7	61,4	39,6	26,8
M	HE 800 M	855	425	1280	1176														105,6	82,0	52,7	35,9
N	HE 900 M	955	475	1430	1315															104,1	66,8	45,6

Chart 10: Composite ACB® based on IPE, S355, e=1.5 a_0



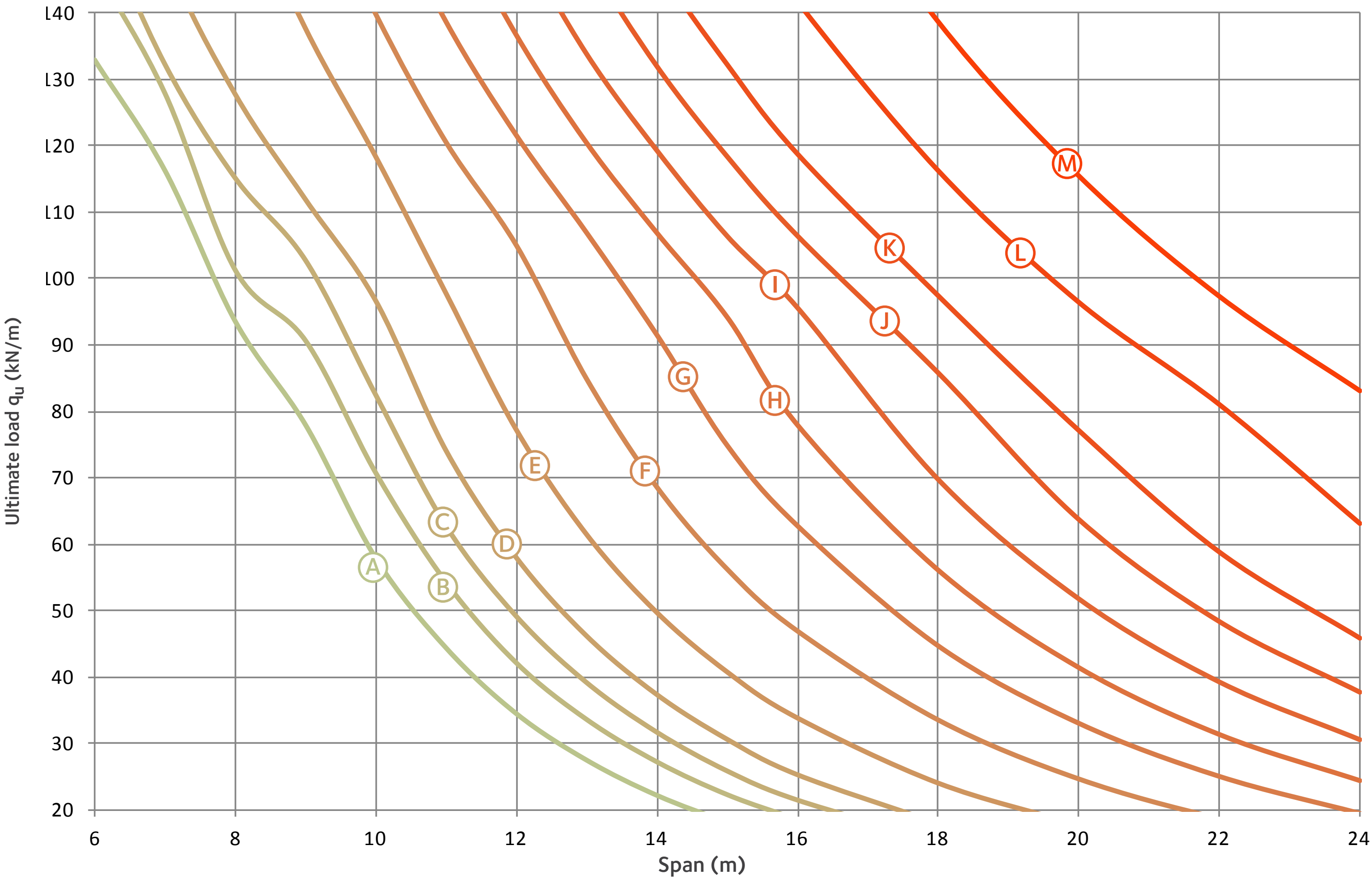
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
Ⓐ	IPE 270	285	142,5	427,5	384	49,2	40,1	27,7												
Ⓑ	IPE 300	315	157,5	472,5	427	58,9	48,1	39,4	28,3	20,9										
Ⓒ	IPE 330	345	172,5	517,5	470	70,8	57,9	48,1	39,0	29,3	22,3									
Ⓓ	IPE 360	375	187,5	562,5	513	84,7	68,9	57,4	48,6	39,7	30,2	23,5								
Ⓔ	IPE 400	415	207,5	622,5	570	102,4	84,1	69,8	59,0	51,0	42,5	33,5	26,5	21,4						
Ⓕ	IPE 450	465	232,5	697,5	642	125,5	103,6	85,8	73,0	62,7	54,4	47,6	38,1	30,9	25,2	21,0				
Ⓖ	IPE 500	515	257,5	772,5	714		125,2	104,4	88,9	76,2	66,2	58,0	51,3	43,6	35,6	29,7	21,2			
Ⓗ	IPE 550	555	277,5	832,5	781			130,7	110,8	95,3	82,0	72,0	63,4	56,4	49,1	41,0	29,0	21,4		
Ⓘ	IPE 600	615	307,5	922,5	857				130,6	112,4	97,6	85,2	75,7	67,0	60,0	54,1	39,6	29,3	22,2	
Ⓙ	IPE 750 x 147	755	395	1150	1086					122,1	107,1	95,5	93,6	84,3	77,1	70,8	61,1	52,3	40,7	31,5
Ⓚ	IPE 750 x 173	765	397,5	1162,5	1097								126,5	111,9	100,7	90,2	74,1	61,3	49,9	38,7
Ⓛ	IPE 750 x 196	770	400	1170	1107									126,7	114,0	102,3	84,1	69,8	58,0	45,1
Ⓜ	IPE 750 x 220	780	402,5	1182,5	1118										126,3	113,9	93,8	78,2	65,8	52,1

Chart 11: Composite ACB® based on HEA, S355, e=1.5 a_0



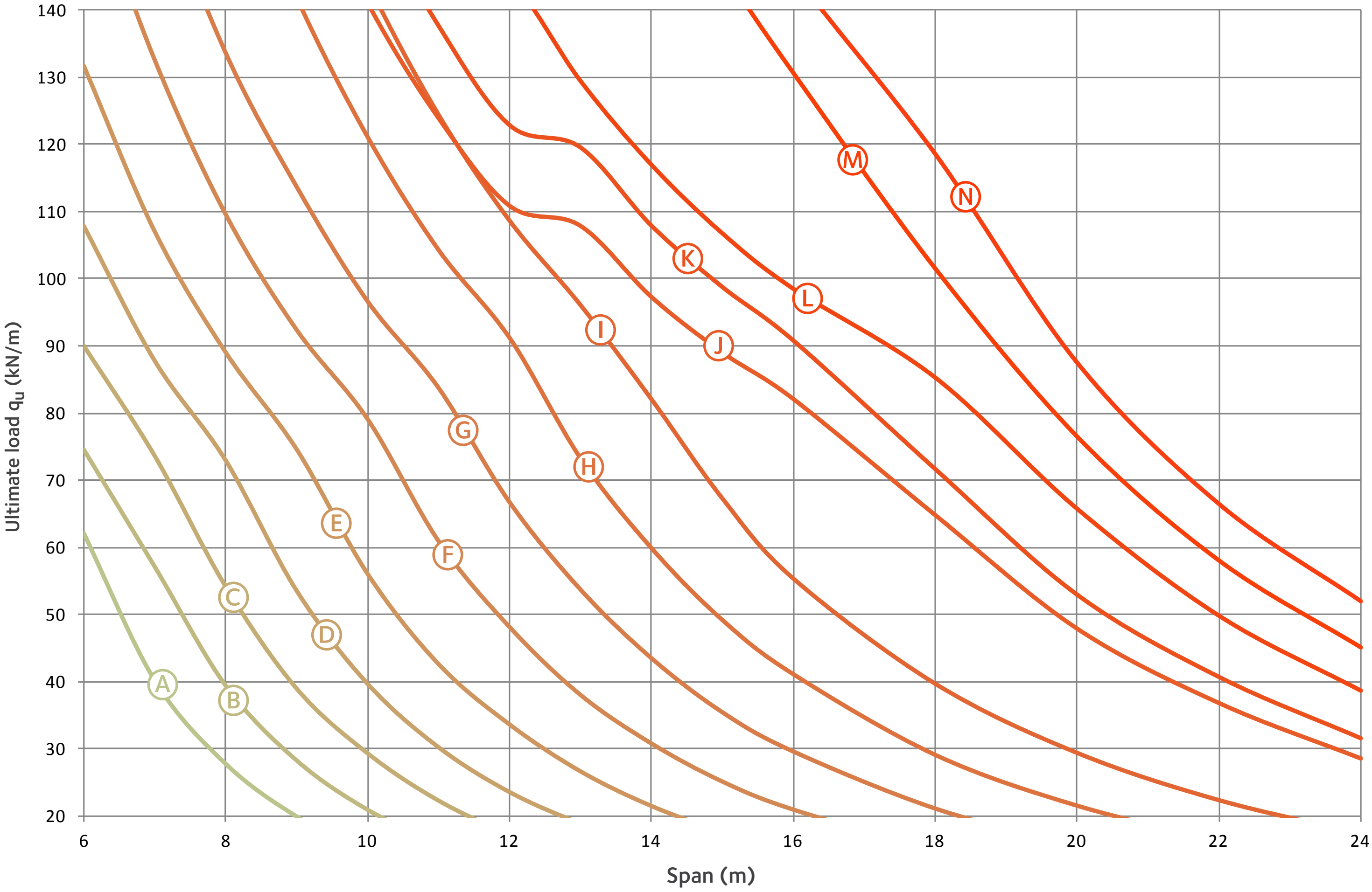
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
A	HE 300 A	270	135	405	398	55,1	47,5	39,9	35,7	31,3	28,6	25,2	20,1							
B	HE 320 A	290	145	435	426	116,2	101,7	79,7	71,0	53,1	40,7	31,6	25,2	20,4						
C	HE 340 A	300	150	450	451	123,1	105,7	92,1	82,4	63,1	48,0	37,6	29,9	24,2						
D	HE 360 A	320	160	480	479		119,3	102,8	90,4	74,9	57,4	44,9	35,8	28,9	23,7					
E	HE 400 A	360	180	540	537			129,3	109,6	93,8	77,2	61,0	48,5	39,2	32,2	26,7				
F	HE 450 A	410	205	615	608				128,7	110,5	95,7	84,0	68,2	55,1	45,1	37,6	26,9			
G	HE 500 A	460	230	690	680					128,3	111,6	98,0	86,7	74,7	61,1	51,2	36,5	26,9	20,4	
H	HE 550 A	500	250	750	747						127,0	111,6	98,7	87,6	77,6	64,2	46,3	34,2	25,9	20,1
I	HE 600 A	550	275	825	819							125,0	110,2	98,3	88,1	79,3	58,0	43,0	32,6	25,4
J	HE 650 A	600	300	900	891							138,9	123,1	109,4	98,4	88,6	71,6	53,2	40,3	31,4
K	HE 700 A	650	325	975	962								138,8	123,4	110,7	99,7	82,0	64,8	49,4	38,5
L	HE 800 A	740	370	1110	1101										133,1	119,8	98,6	81,9	68,7	53,4
M	HE 900 A	840	420	1260	1244												118,7	98,9	83,5	71,3

Chart 12: Composite ACB® based on HEB, S355, e=1.5 a_0



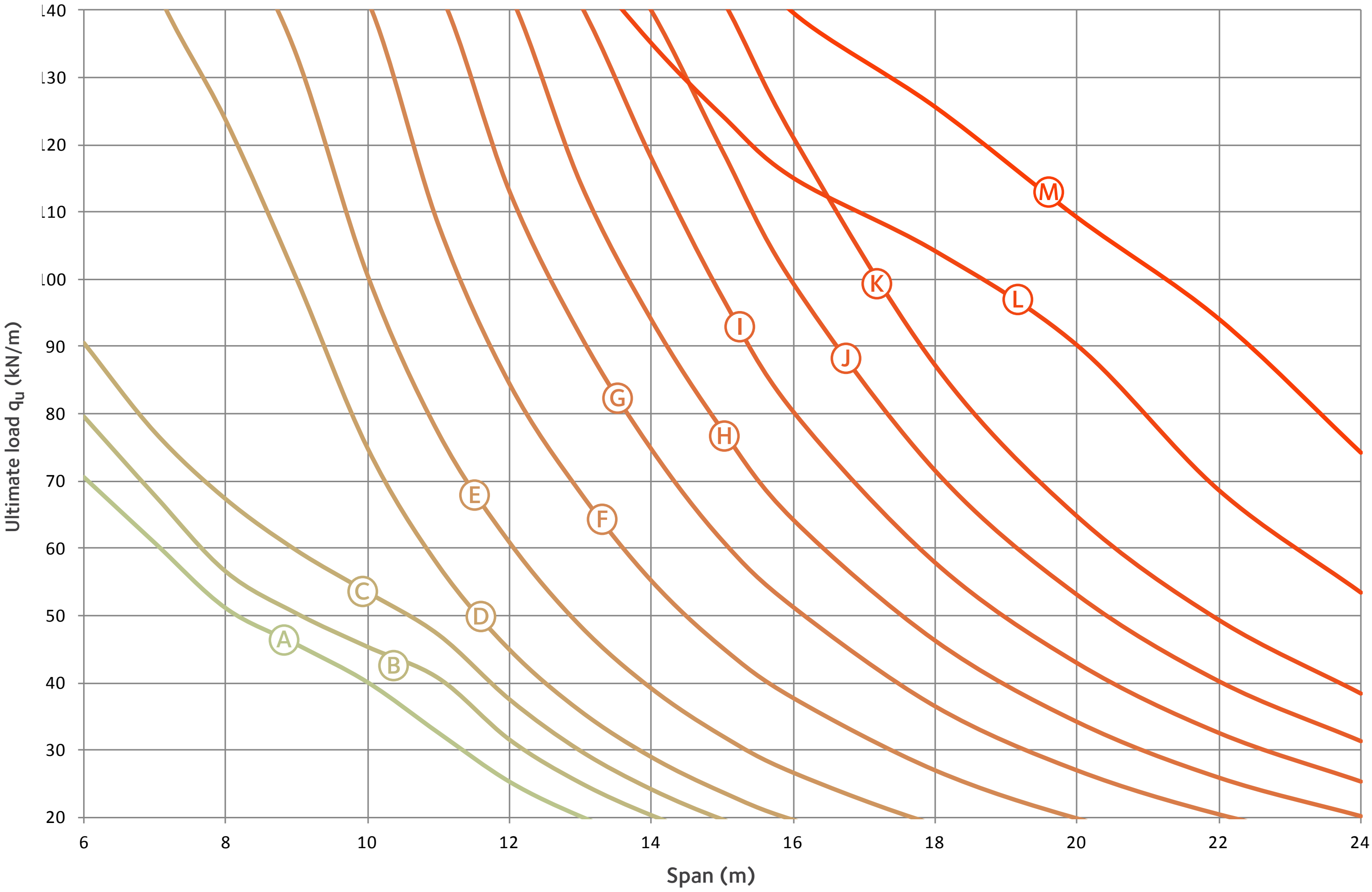
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
Ⓐ	HE 300 B	270	135	405	408	132,8	116,1	93,4	77,8	57,7	44,2	34,3	27,3	22,1						
Ⓑ	HE 320 B	290	145	435	436		127,9	101,3	90,6	70,6	54,1	42,0	33,5	27,1	22,1					
Ⓒ	HE 340 B	300	150	450	461		132,3	115,2	102,8	82,6	62,8	49,2	39,2	31,7	25,9	21,5				
Ⓓ	HE 360 B	320	160	480	489			127,8	112,0	96,7	74,2	58,1	46,2	37,4	30,7	25,3				
Ⓔ	HE 400 B	360	180	540	547				137,8	118,4	97,9	77,3	61,5	49,8	40,8	33,9	24,1			
Ⓕ	HE 450 B	410	205	615	618					139,8	120,5	105,0	84,8	68,5	56,2	46,9	33,5	24,6		
Ⓖ	HE 500 B	460	230	690	690						138,7	121,6	106,9	91,5	74,8	62,7	44,7	33,0	25,0	
Ⓗ	HE 550 B	500	250	750	757							136,7	120,5	106,9	94,2	78,0	56,2	41,5	31,4	24,5
Ⓘ	HE 600 B	550	275	825	829								133,9	119,4	106,5	95,7	69,9	51,9	39,3	30,6
Ⓙ	HE 650 B	600	300	900	901									131,9	118,3	106,3	85,7	63,6	48,2	37,6
Ⓚ	HE 700 B	650	325	975	972										132,1	118,7	97,3	77,0	58,7	45,7
Ⓛ	HE 800 B	740	370	1110	1111												116,2	96,4	80,9	63,0
Ⓜ	HE 900 B	840	420	1260	1254												138,6	115,4	97,3	83,0

Chart 13: Composite ACB® based on IPE, S460, e=1.5 a_0



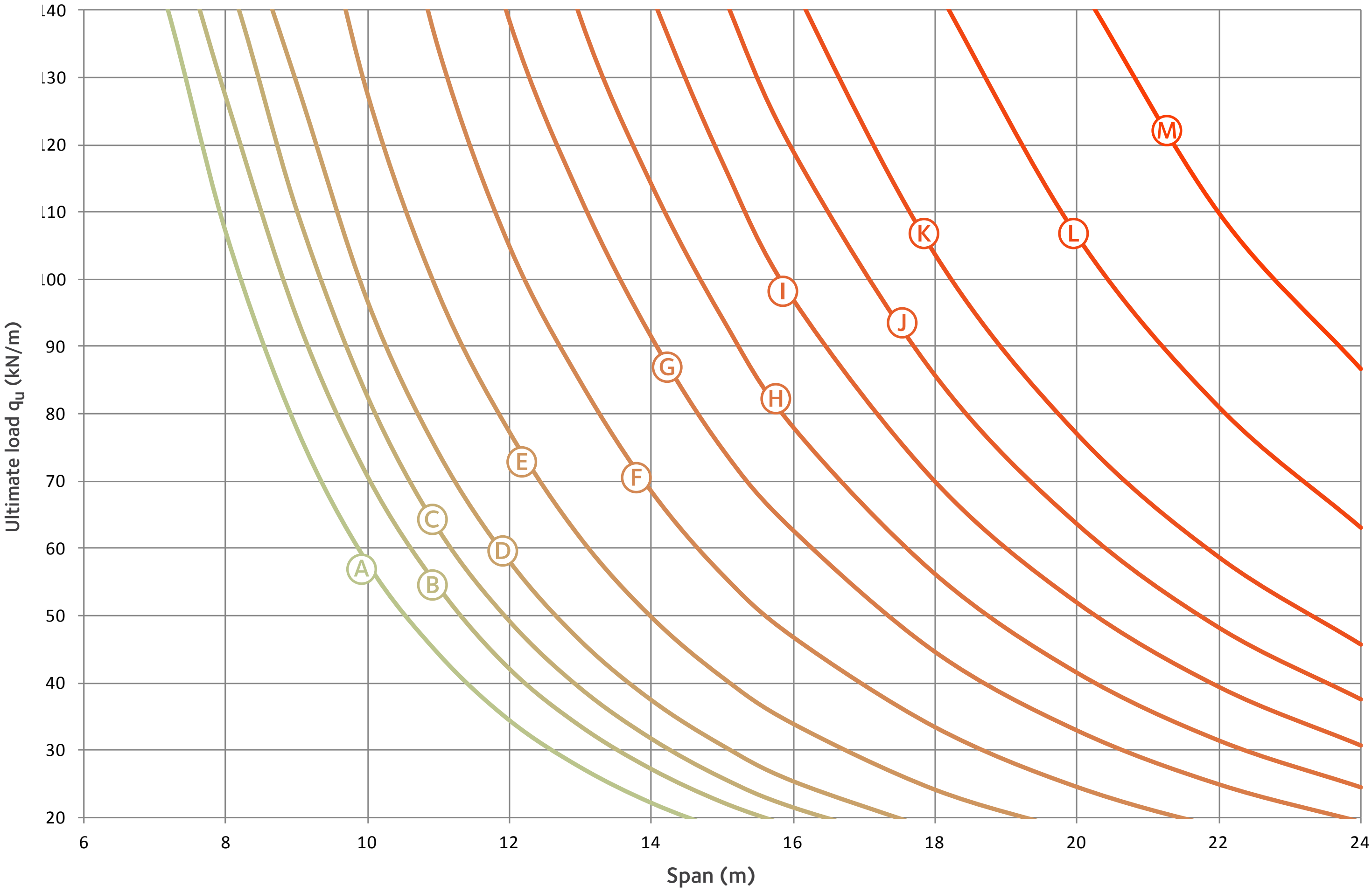
Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
A	IPE 270	285	142,5	427,5	384	62,0	40,1	27,7												
B	IPE 300	315	157,5	472,5	427	74,6	57,1	39,4	28,3	20,9										
C	IPE 330	345	172,5	517,5	470	90,0	73,6	54,1	39,0	29,3	22,3									
D	IPE 360	375	187,5	562,5	513	107,8	87,7	72,9	53,5	39,7	30,2	23,5								
E	IPE 400	415	207,5	622,5	570	131,7	107,0	89,0	74,5	56,0	42,5	33,5	26,5	21,4						
F	IPE 450	465	232,5	697,5	642		132,7	109,7	92,5	79,2	61,1	48,3	38,1	30,9	25,2	21,0				
G	IPE 500	515	257,5	772,5	714			133,8	113,8	96,8	83,9	66,9	53,9	43,6	35,6	29,7	21,2			
H	IPE 550	555	277,5	832,5	781					121,1	104,3	91,2	73,2	59,8	49,1	41,0	29,0	21,4		
I	IPE 600	615	307,5	922,5	857						124,4	108,6	96,0	82,0	67,2	55,3	39,6	29,3	22,2	
J	IPE 750 x 134	755	392,5	1147,5	1081						123,9	110,8	107,8	97,2	89,0	82,0	64,8	47,8	36,7	28,5
K	IPE 750 x 147	755	395	1150	1086						137,7	122,9	119,6	107,9	98,8	90,8	71,6	52,9	40,7	31,5
L	IPE 750 x 173	765	397,5	1162,5	1097								129,6	117,1	106,9	98,6	85,4	65,8	49,9	38,7
M	IPE 750 x 196	770	400	1170	1107											130,6	101,5	76,5	58,0	45,1
N	IPE 750 x 220	780	402,5	1182,5	1118												118,7	87,6	66,5	52,1

Chart 14: Composite ACB® based on HEA, S460, e=1.5 a_0



Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
Ⓐ	HE 300 A	270	135	405	398	70,6	60,8	51,1	45,7	40,0	32,5	25,2	20,1							
Ⓑ	HE 320 A	290	145	435	426	79,6	67,9	56,6	50,4	45,4	40,7	31,6	25,2	20,4						
Ⓒ	HE 340 A	300	150	450	451	90,6	77,3	67,3	59,7	53,5	47,2	37,6	29,9	24,2						
Ⓓ	HE 360 A	320	160	480	479			123,7	100,0	74,9	57,4	44,9	35,8	28,9	23,7					
Ⓔ	HE 400 A	360	180	540	537				133,3	100,6	77,2	61,0	48,5	39,2	32,2	26,7				
Ⓕ	HE 450 A	410	205	615	608						107,9	84,4	68,2	55,1	45,1	37,6	26,9			
Ⓖ	HE 500 A	460	230	690	680							113,0	91,6	74,7	61,1	51,2	36,5	26,9	20,4	
Ⓗ	HE 550 A	500	250	750	747								114,3	94,0	77,6	64,2	46,3	34,2	25,9	20,1
Ⓘ	HE 600 A	550	275	825	819									118,1	97,4	80,4	58,0	43,0	32,6	25,4
Ⓙ	HE 650 A	600	300	900	891										119,2	99,4	71,6	53,2	40,3	31,4
Ⓚ	HE 700 A	650	325	975	962											121,2	87,3	64,8	49,4	38,5
Ⓛ	HE 800 A	740	370	1110	1101									135,1	124,4	115,1	104,2	90,2	68,7	53,4
Ⓜ	HE 900 A	840	420	1260	1244											139,7	125,7	109,2	94,1	74,3

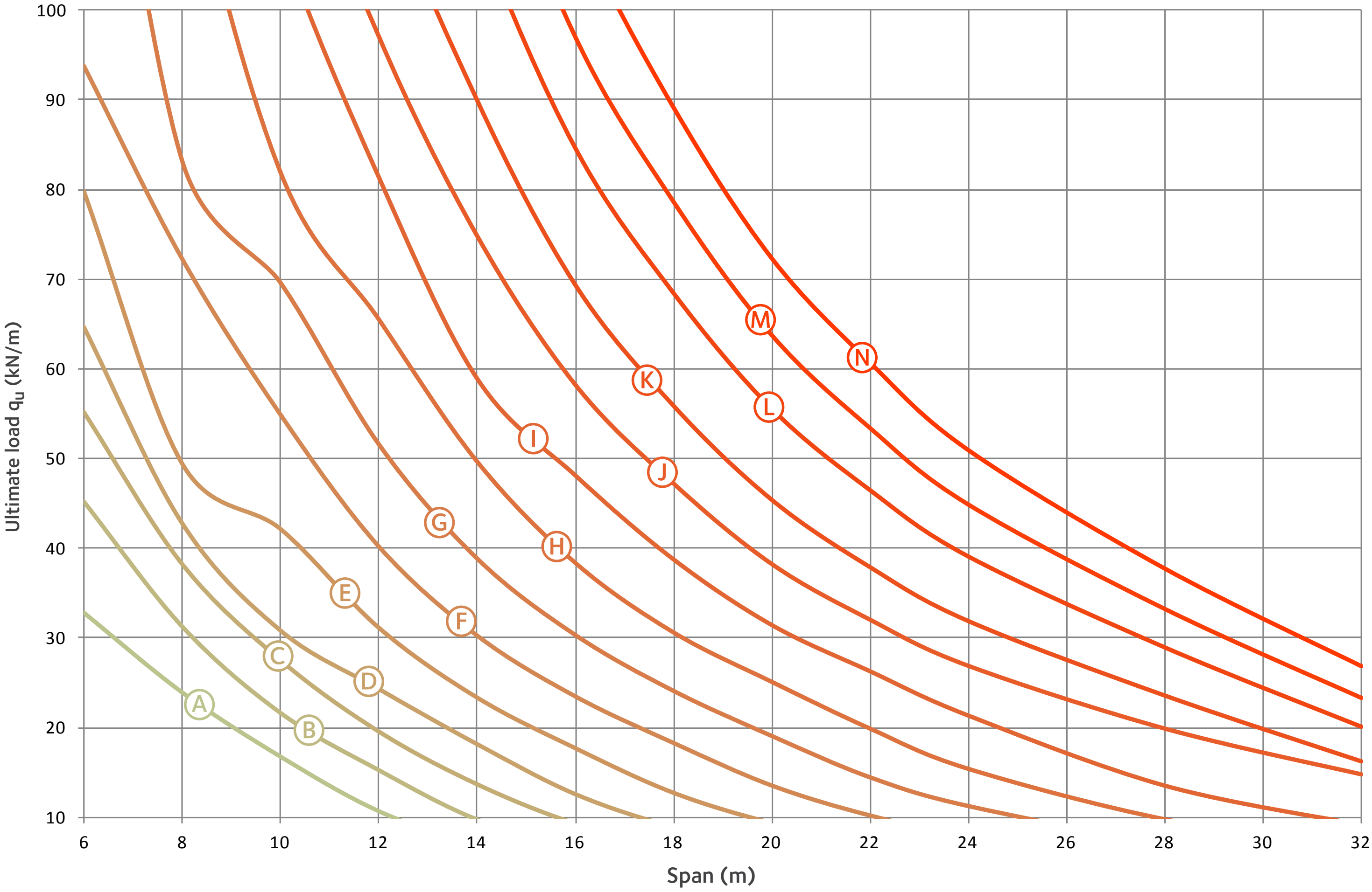
Chart 15: Composite ACB® based on HEB, S460, e=1.5 a_0



Sections		Dimensions (mm)				Ultimate load q_u (kN/m) according to the span (m)														
		a_0	w	e	H_t	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
A	HE 300 B	270	135	405	408			107,0	77,8	57,7	44,2	34,3	27,3	22,1						
B	HE 320 B	290	145	435	436			127,1	94,3	70,6	54,1	42,0	33,5	27,1	22,1					
C	HE 340 B	300	150	450	461				110,3	82,6	62,8	49,2	39,2	31,7	25,9	21,5				
D	HE 360 B	320	160	480	489				129,2	96,7	74,2	58,1	46,2	37,4	30,7	25,3				
E	HE 400 B	360	180	540	547					127,6	97,9	77,3	61,5	49,8	40,8	33,9	24,1			
F	HE 450 B	410	205	615	618						134,3	105,0	84,8	68,5	56,2	46,9	33,5	24,6		
G	HE 500 B	460	230	690	690							138,4	112,2	91,5	74,8	62,7	44,7	33,0	25,0	
H	HE 550 B	500	250	750	757								138,9	114,1	94,2	78,0	56,2	41,5	31,4	24,5
I	HE 600 B	550	275	825	829										117,4	96,9	69,9	51,9	39,3	30,6
J	HE 650 B	600	300	900	901											119,0	85,7	63,6	48,2	37,6
K	HE 700 B	650	325	975	972												103,7	77,0	58,7	45,7
L	HE 800 B	740	370	1110	1111													106,4	80,9	63,0
M	HE 900 B	840	420	1260	1254														109,8	86,7

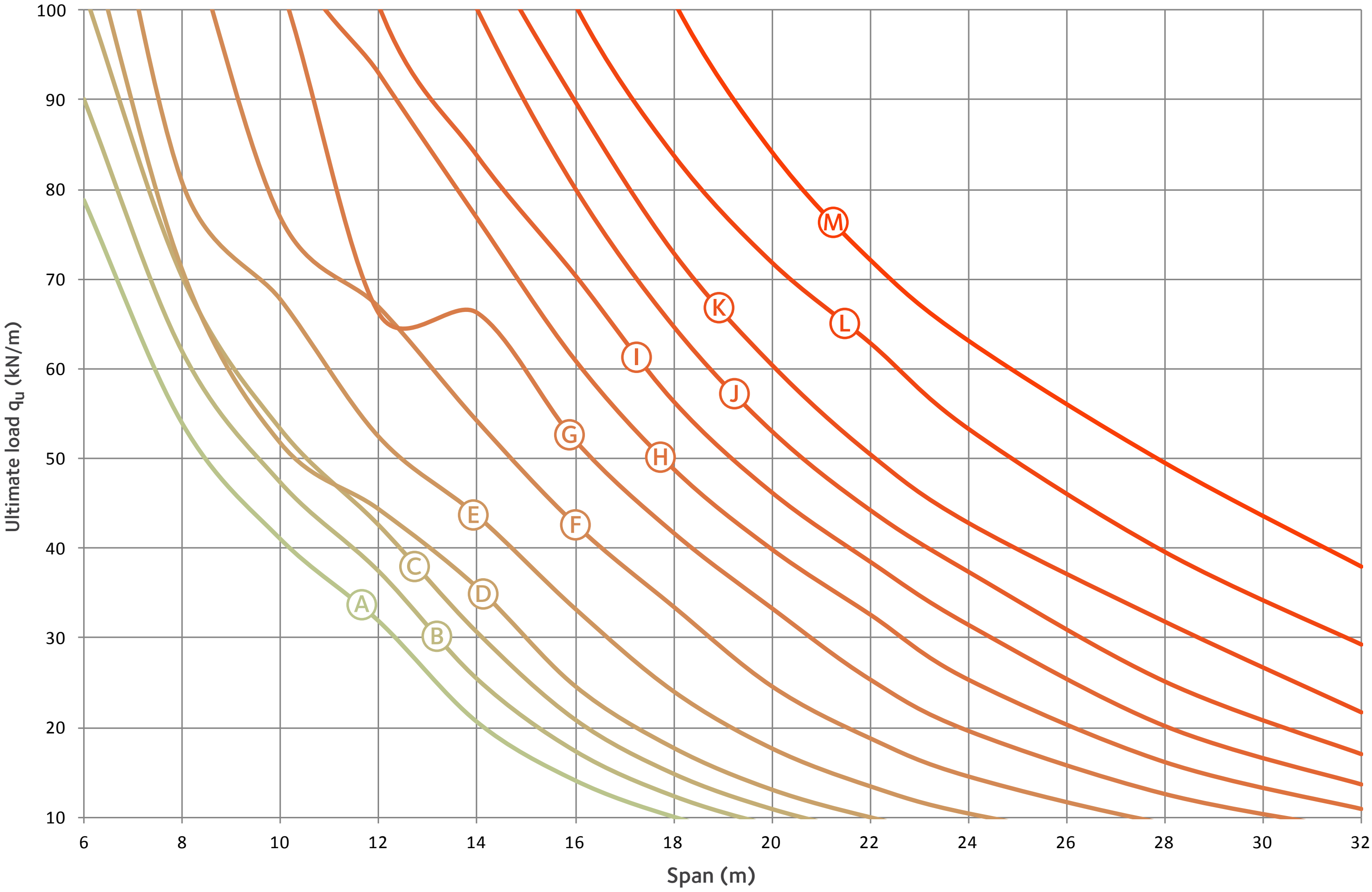
12. Predesign charts for Angelina™ beams

Chart 16: Non-composite Angelina™ based on IPE, S355



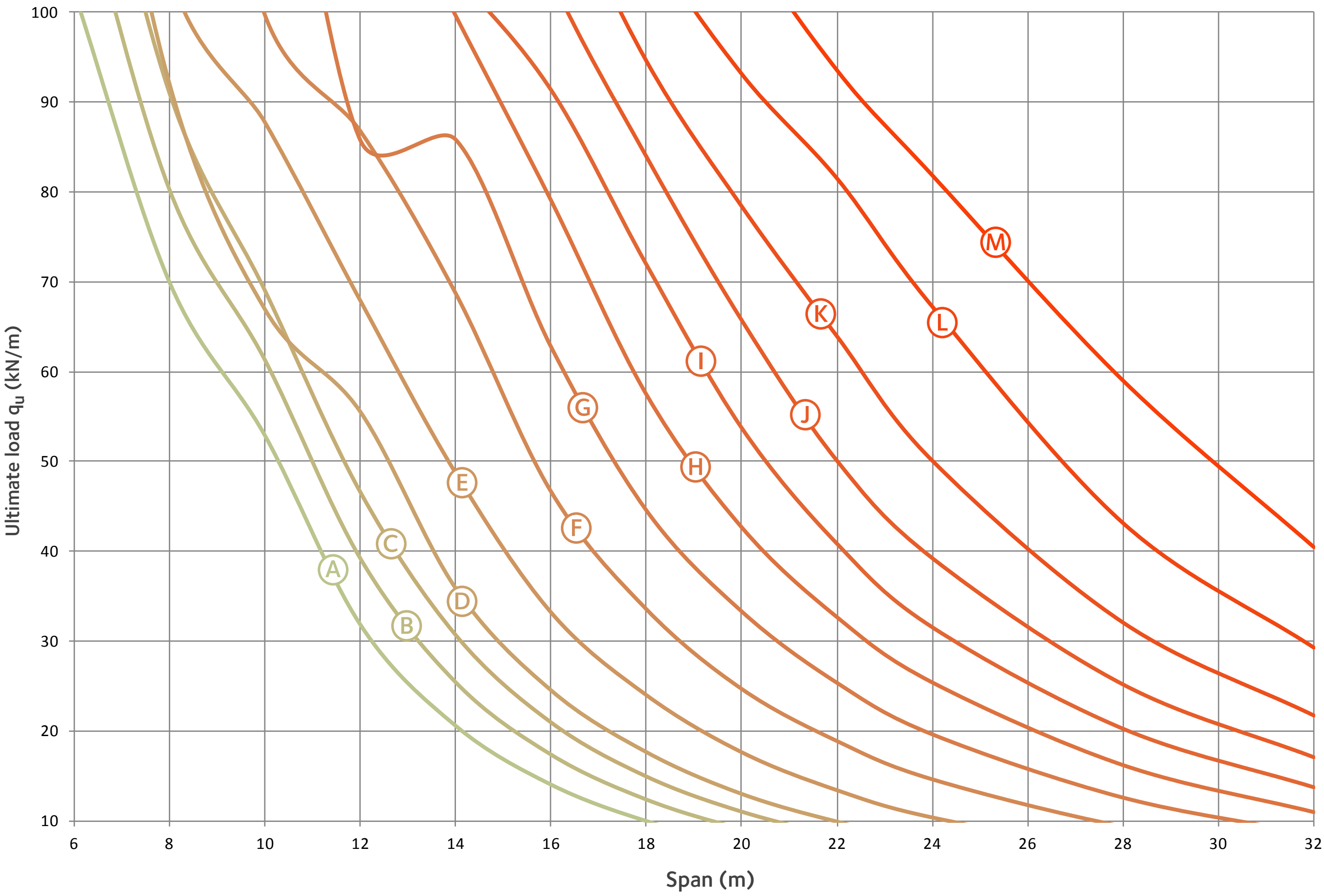
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
A	IPE 270	285	200	285	970	412,5	32,7	23,9	16,7	10,6								
B	IPE 300	315	200	315	1030	457,5	45,1	31,2	21,6	15,3								
C	IPE 330	345	200	345	1090	502,5	55,2	38,3	27,5	19,5	13,6							
D	IPE 360	375	250	375	1250	547,5	64,7	42,8	30,9	24,3	18,2	12,6						
E	IPE 400	415	250	415	1330	607,5	79,8	49,4	42,1	31,1	23,3	17,7	12,7					
F	IPE 450	465	250	465	1430	682,5	93,7	72,2	54,9	40,2	30,3	23,5	18,3	13,6	10,2			
G	IPE 500	515	250	515	1530	757,5		83,2	69,6	51,6	38,9	30,3	24,1	19,1	14,5	11,3		
H	IPE 550	555	250	555	1610	827,5			82,0	65,6	49,7	38,4	30,7	25,1	19,9	15,4		
I	IPE 600	615	250	615	1730	907,5				81,4	58,9	48,1	38,7	31,4	26,3	21,3	13,5	
J	IPE 750 x 134	755	250	755	2010	1130,5				97,1	74,9	58,3	47,3	38,3	32,1	26,9	19,9	14,8
K	IPE 750 x 147	755	250	755	2010	1130,5					90,0	69,4	55,9	45,4	37,9	31,9	23,6	16,2
L	IPE 750 x 173	765	250	765	2030	1144,5						84,6	68,4	55,5	46,4	39,0	28,9	20,0
M	IPE 750 x 196	770	250	770	2040	1155						97,0	78,6	63,7	53,4	44,8	33,2	23,3
N	IPE 750 x 220	780	250	780	2060	1169							89,2	72,4	60,7	51,0	37,8	26,9

Chart 17: Non-composite Angelina™ based on HEA, S355



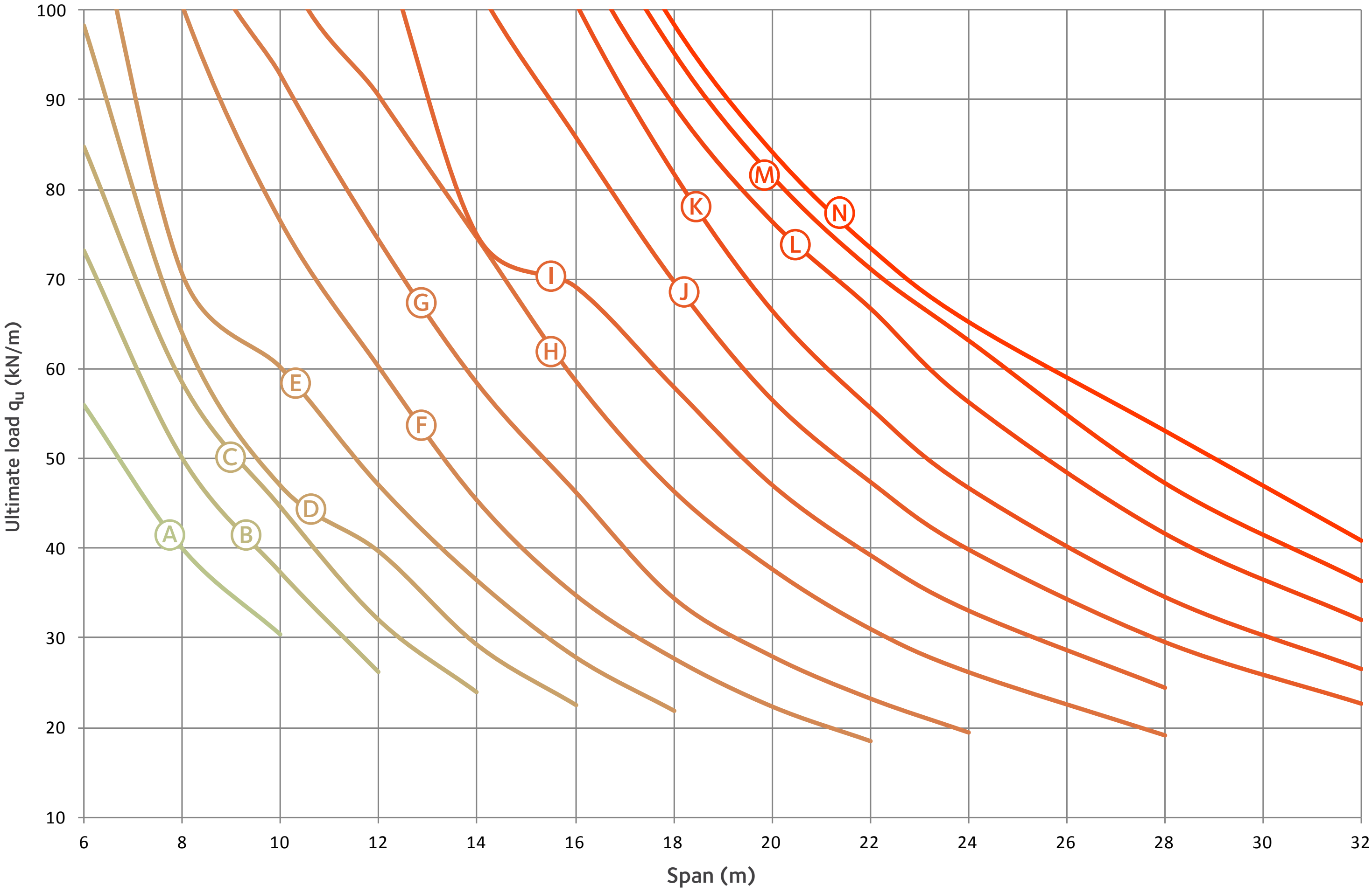
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
Ⓐ	HE 300 A	305	200	305	1010	442,5	78,9	53,9	41,0	31,8	20,6	14,1	10,0					
Ⓑ	HE 320 A	325	200	325	1050	472,5	90,1	62,0	47,4	37,5	25,5	17,4	12,4					
Ⓒ	HE 340 A	340	200	340	1080	500		70,2	53,3	42,6	30,7	20,9	14,9	11,0				
Ⓓ	HE 360 A	365	250	365	1230	532,5		71,0	51,7	44,3	35,6	24,6	17,7	13,0	10,0			
Ⓔ	HE 400 A	405	250	405	1310	592,5		80,8	67,8	52,5	43,7	33,3	24,1	17,7	13,5	10,4		
Ⓕ	HE 450 A	455	250	455	1410	667,5			77,0	67,0	54,3	42,7	33,6	24,7	18,9	14,6		
Ⓖ	HE 500 A	500	250	500	1500	740				66,2	66,3	52,0	41,7	33,3	25,4	19,6	12,6	
Ⓗ	HE 550 A	555	250	555	1610	817,5				93,1	76,9	61,0	48,9	40,0	32,7	25,4	16,2	11,0
Ⓘ	HE 600 A	600	250	600	1700	890					83,9	70,5	56,5	46,3	38,6	31,5	20,2	13,7
Ⓙ	HE 650 A	655	250	655	1810	967,5						80,2	64,8	53,1	44,3	37,4	25,2	17,1
Ⓚ	HE 700 A	755	250	755	2010	1067,5						89,9	73,0	60,5	50,6	42,9	31,9	21,8
Ⓛ	HE 800 A	805	250	805	2110	1192,5							83,8	71,8	62,9	53,3	39,5	29,2
Ⓜ	HE 900 A	900	250	900	2300	1340								84,3	72,2	63,2	49,6	38,0

Chart 18: Non-composite Angelina™ based on HEA, S460



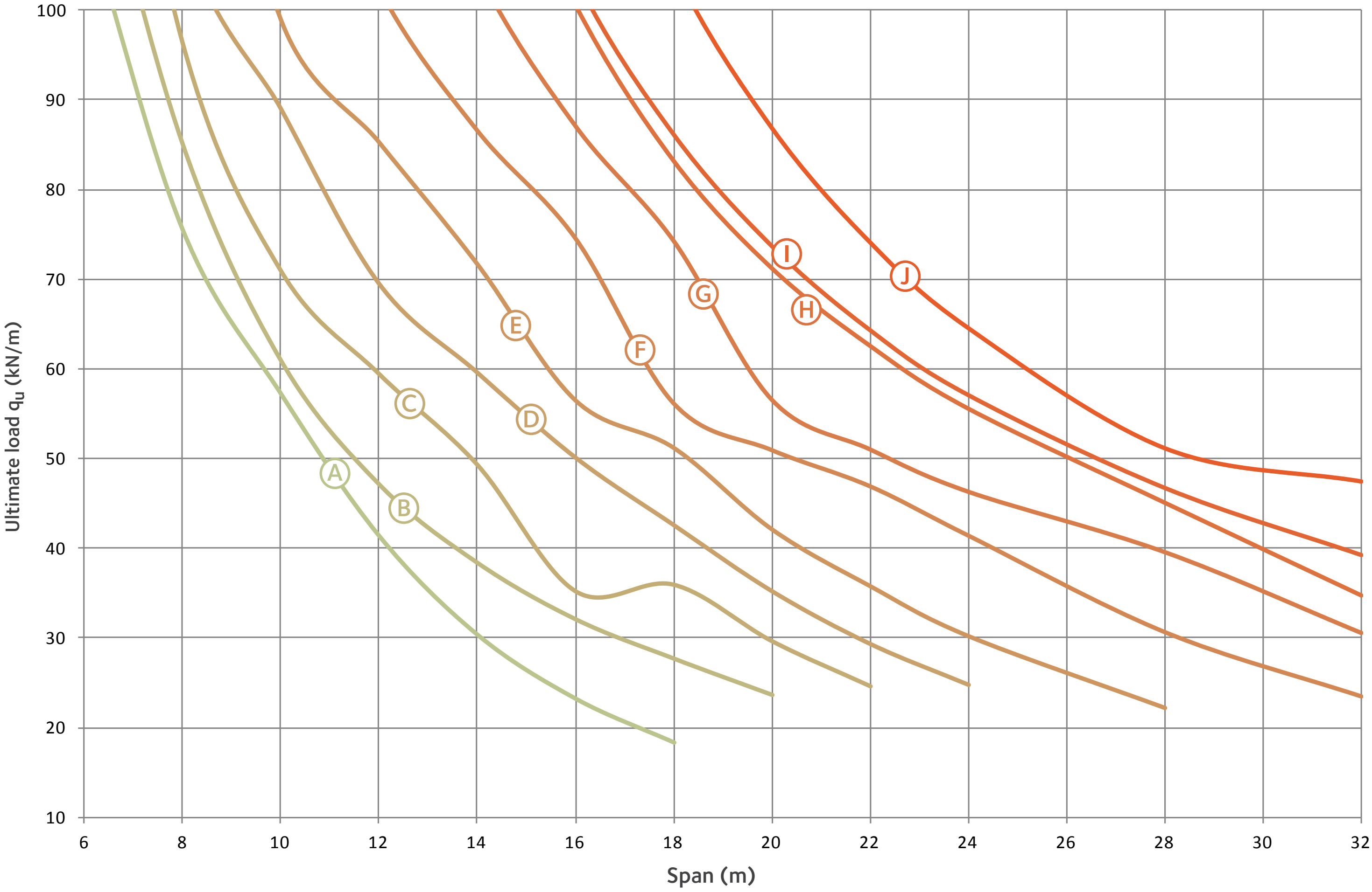
	Sections	Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
A	HE 300 A	305	200	305	1010	442,5		69,9	52,9	31,8	20,6	14,1	10,0					
B	HE 320 A	325	200	325	1050	472,5		80,3	61,4	39,3	25,5	17,4	12,4					
C	HE 340 A	340	200	340	1080	500		91,0	69,0	46,6	30,7	20,9	14,9	11,0				
D	HE 360 A	365	250	365	1230	532,5		92,1	67,0	55,6	35,9	24,6	17,7	13,0	10,0			
E	HE 400 A	405	250	405	1310	592,5			87,8	68,0	48,8	33,3	24,1	17,7	13,5	10,4		
F	HE 450 A	455	250	455	1410	667,5			99,7	86,8	68,7	46,7	33,6	24,7	18,9	14,6		
G	HE 500 A	500	250	500	1500	740				85,8	85,9	62,8	44,6	33,3	25,4	19,6	12,6	
H	HE 550 A	555	250	555	1610	817,5					99,7	79,1	57,5	42,7	32,7	25,4	16,2	11,0
I	HE 600 A	600	250	600	1700	890						91,4	71,9	53,7	40,8	31,5	20,2	13,7
J	HE 650 A	655	250	655	1810	967,5							83,9	65,7	50,1	39,2	25,2	17,1
K	HE 700 A	755	250	755	2010	1067,5							94,6	78,4	64,0	50,1	32,1	21,8
L	HE 800 A	805	250	805	2110	1192,5								93,1	81,5	67,2	43,1	29,2
M	HE 900 A	900	250	900	2300	1340									93,6	81,9	59,1	40,5

Chart 19: Composite Angelina™ based on IPE, S355 with COFRAPLUS 60



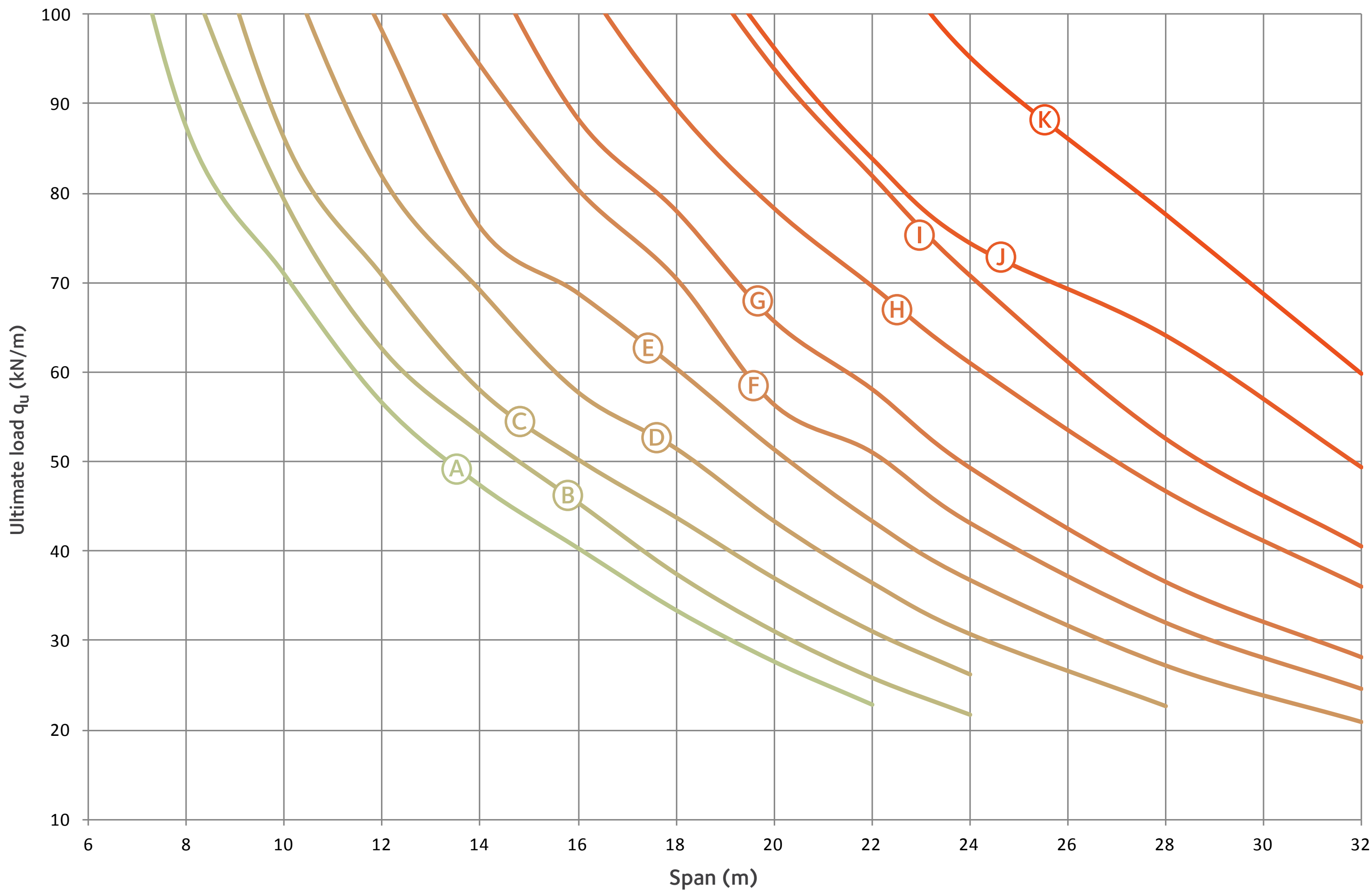
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
A	IPE 270	285	200	285	970	412,5	56,0	40,0	30,3									
B	IPE 300	315	200	315	1030	457,5	73,1	50,0	37,3	26,2								
C	IPE 330	345	200	345	1090	502,5	84,7	58,5	44,6	32,0	23,9							
D	IPE 360	375	250	375	1250	547,5	98,2	63,9	46,9	39,6	29,1	22,5						
E	IPE 400	415	250	415	1330	607,5	116,9	70,6	60,2	47,0	36,4	27,9	21,9					
F	IPE 450	465	250	465	1430	682,5	136,3	100,6	76,4	60,2	45,3	34,8	27,7	22,3	18,5			
G	IPE 500	515	250	515	1530	757,5		114,1	92,8	74,3	58,4	46,3	34,4	27,9	23,2	19,4	12,6	
H	IPE 550	555	250	555	1610	827,5		159,8	106,9	90,5	74,7	58,8	46,5	37,8	31,1	26,3	16,2	11,0
I	IPE 600	615	250	615	1730	907,5			137,8	108,6	75,0	69,2	58,1	47,1	39,3	33,1	20,2	13,7
J	IPE 750 x 134	755	250	755	2010	1130,5				125,8	102,8	86,0	69,8	56,6	47,4	39,9	25,2	17,1
K	IPE 750 x 147	755	250	755	2010	1130,5				152,8	125,1	101,0	81,8	66,6	55,7	46,7	31,9	21,8
L	IPE 750 x 173	765	250	765	2030	1144,5					135,3	107,7	89,5	76,5	66,8	56,3	39,5	29,2
M	IPE 750 x 196	770	250	770	2040	1155					144,1	114,8	95,3	81,5	71,2	63,2	49,6	38,0
N	IPE 750 x 220	780	250	780	2060	1169					148,8	118,5	98,5	84,2	73,5	65,2	49,6	38,0

Chart 20: Composite Angelina™ based on HEA, S355 with COFRAPLUS 60



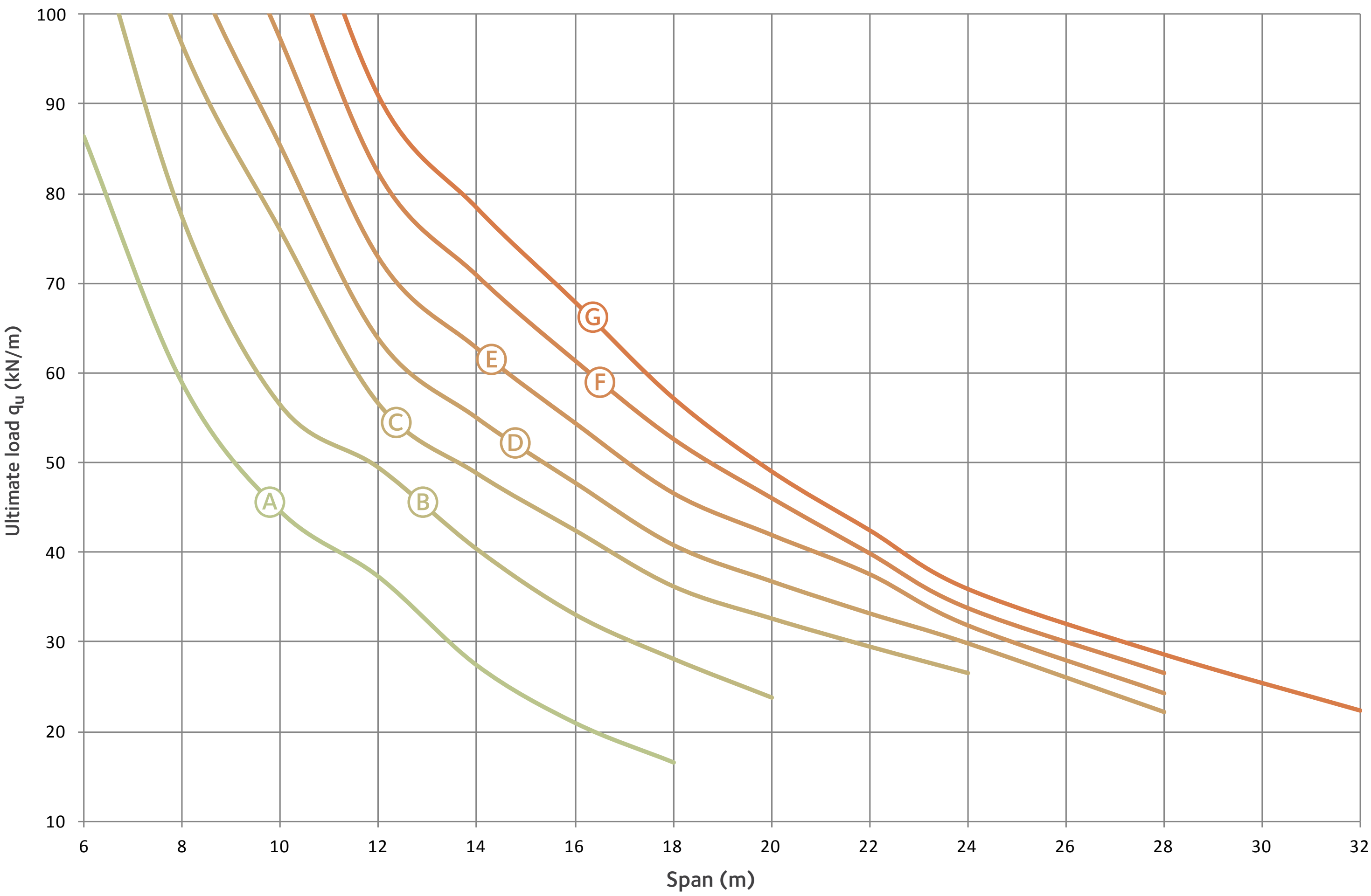
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	30	32
Ⓐ	HE 300 A	305	200	305	1010	442,5	111,6	75,7	57,3	41,4	30,4	23,2	18,3					
Ⓑ	HE 320 A	325	200	325	1050	472,5	124,9	85,3	61,0	47,2	38,4	32,1	27,7	23,6				
Ⓒ	HE 360 A	365	250	365	1230	532,5	150,9	96,5	71,0	59,4	49,3	35,2	35,9	29,6	24,6			
Ⓓ	HE 400 A	405	250	405	1310	592,5		109,8	89,1	69,6	59,7	50,2	42,7	35,3	29,4	24,8		
Ⓔ	HE 450 A	455	250	455	1410	667,5		143,7	99,1	85,4	71,8	56,5	51,2	42,1	35,8	30,2	22,2	0,0
Ⓕ	HE 550 A	555	250	555	1610	817,5			128,1	102,5	86,7	74,6	56,2	51,0	47,0	41,5	30,7	23,5
Ⓖ	HE 650 A	655	250	655	1810	967,5				130,5	104,5	87,1	74,3	56,6	51,0	46,3	39,6	30,6
Ⓗ	HE 700 A	755	250	755	2010	1067,5					125,4	100,6	83,2	71,2	62,6	55,6	45,1	34,7
Ⓘ	HE 800 A	805	250	805	2110	1192,5					130,2	103,7	86,1	73,7	64,3	57,0	46,7	39,2
Ⓙ	HE 900 A	900	250	900	2300	1340					128,2	131,8	104,8	86,9	74,1	64,5	51,1	47,4

Chart 21: Composite Angelina™ based on HEB, S355 with COFRAPLUS 60



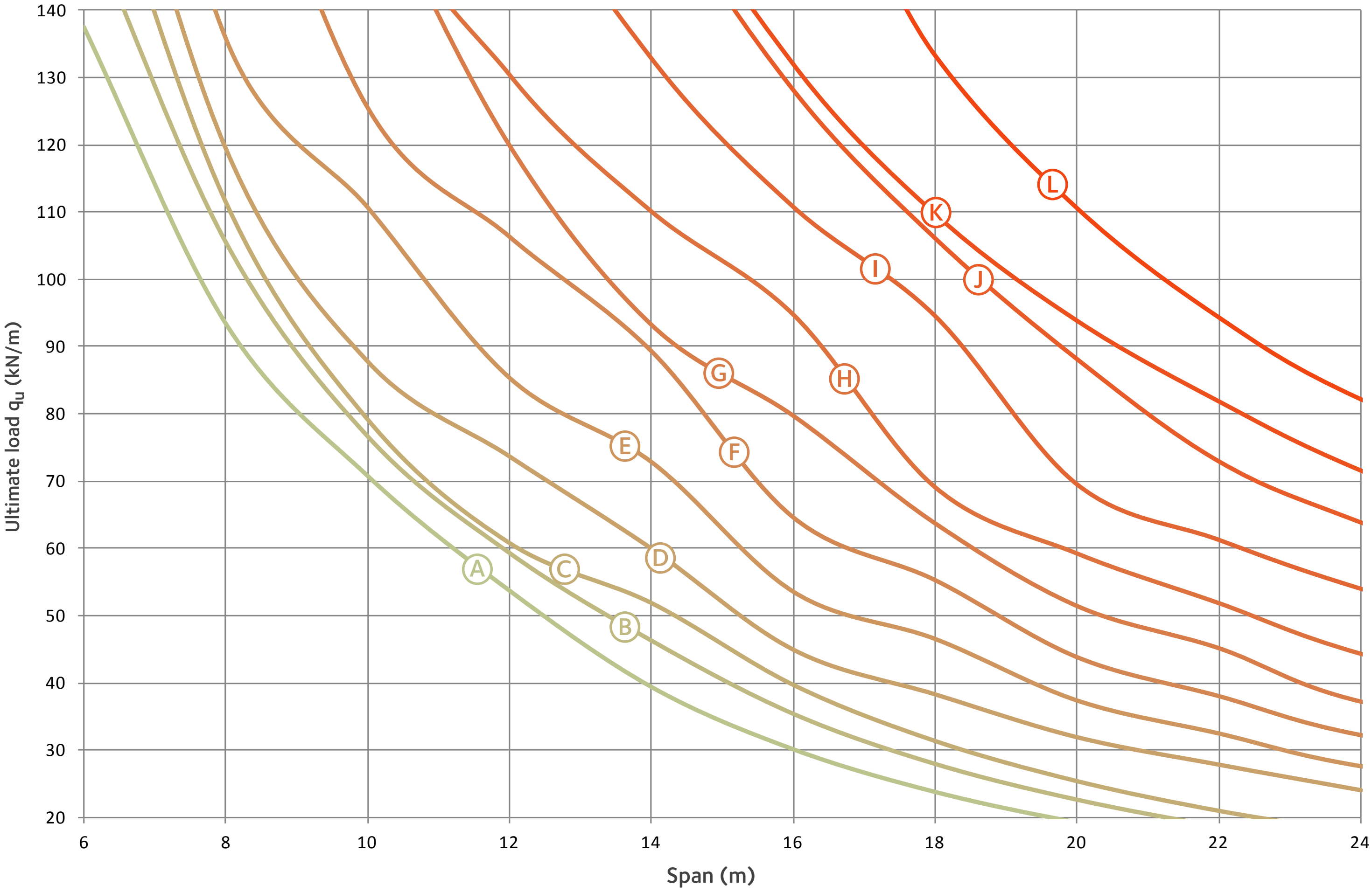
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	28	32
Ⓐ	HE 300 B	315	250	315	1130	457,5	129,3	87,5	71,0	56,6	47,4	40,4	33,5	27,7	22,9			
Ⓑ	HE 320 B	335	250	335	1170	487,5	138,5	105,6	79,3	62,6	53,3	45,4	37,5	31,1	25,9	21,7		
Ⓒ	HE 360 B	380	300	380	1360	550		120,6	86,2	70,8	58,0	50,3	43,8	37,0	31,0	26,2		
Ⓓ	HE 400 B	420	300	420	1440	610		137,9	106,4	81,9	69,1	57,7	51,4	43,3	36,4	30,7		
Ⓔ	HE 450 B	475	300	475	1550	687,5		151,5	120,9	98,1	76,2	68,8	60,4	51,3	43,3	36,7		
Ⓕ	HE 500 B	525	300	525	1650	762,5			132,4	111,1	94,3	80,4	70,5	56,4	51,1	43,2		
Ⓖ	HE 550 B	580	300	580	1760	840				130,6	107,7	88,4	78,1	65,7	58,1	49,4	12,6	
Ⓗ	HE 650 B	680	300	680	1960	990				153,2	125,4	104,8	89,5	78,3	69,6	61,0	16,2	11,0
Ⓘ	HE 700 B	730	300	730	2060	1065					154,9	130,7	109,8	94,0	82,0	70,9	20,2	13,7
Ⓙ	HE 800 B	780	300	780	2160	1190						136,3	112,6	96,3	83,9	74,4	25,2	17,1
Ⓚ	HE 900 B	830	350	830	2360	1315							155,9	128,6	109,9	95,2	31,9	21,8

Chart 22: Composite Angelina™ based on HD, S355 with COFRAPLUS 60



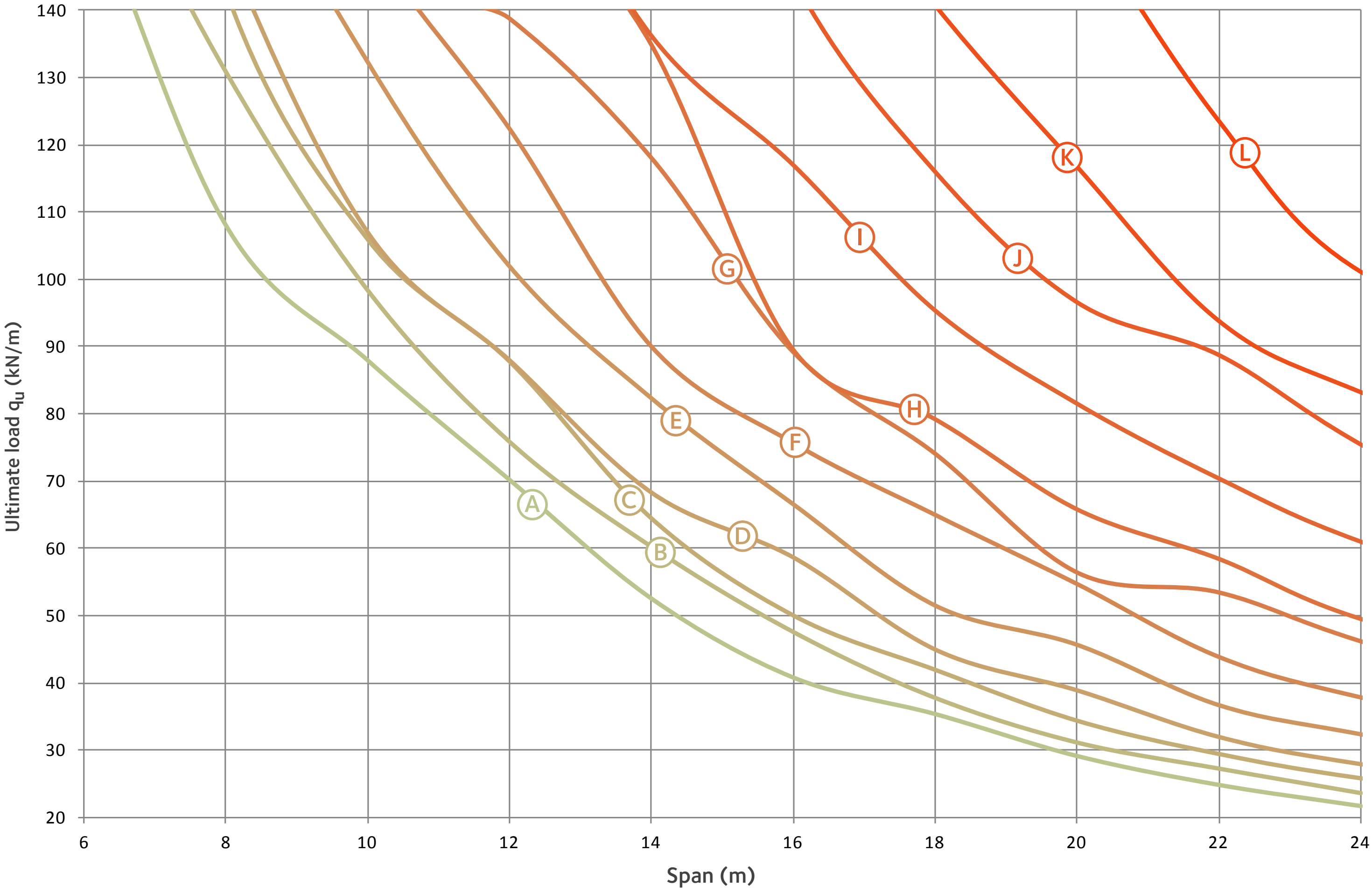
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)											
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24	30	32
A	HD 320 x 74.2	350	200	350	1100	476	86,4	58,9	44,6	37,3	27,4	21,0	16,6					
B	HD 320 x 97.6	350	200	350	1100	485	113,6	77,4	56,5	49,5	40,4	33,1	28,2	23,9				
C	HD 360 x 147	440	300	440	1480	580	128,4	96,6	75,9	56,6	48,8	42,4	36,2	32,6	29,5	26,5		
D	HD 360 x 162	440	300	440	1480	584	144,4	108,8	85,4	63,8	55,0	47,8	40,8	36,8	33,2	29,8	22,2	
E	HD 360 x 179	440	300	440	1480	588		124,2	97,3	72,9	62,8	54,5	46,7	42,0	37,6	31,9	24,3	
F	HD 360 x 196	440	300	440	1480	592		140,1	109,6	82,3	70,9	61,4	52,7	46,1	39,9	33,8	26,6	
G	HD 400 x 216	440	300	440	1480	595		155,0	121,2	90,9	78,4	67,9	57,2	49,0	42,4	35,9	28,6	22,3

Chart 23: Composite Angelina™ based on HEA, HISTAR® 460 with COFRAPLUS 60



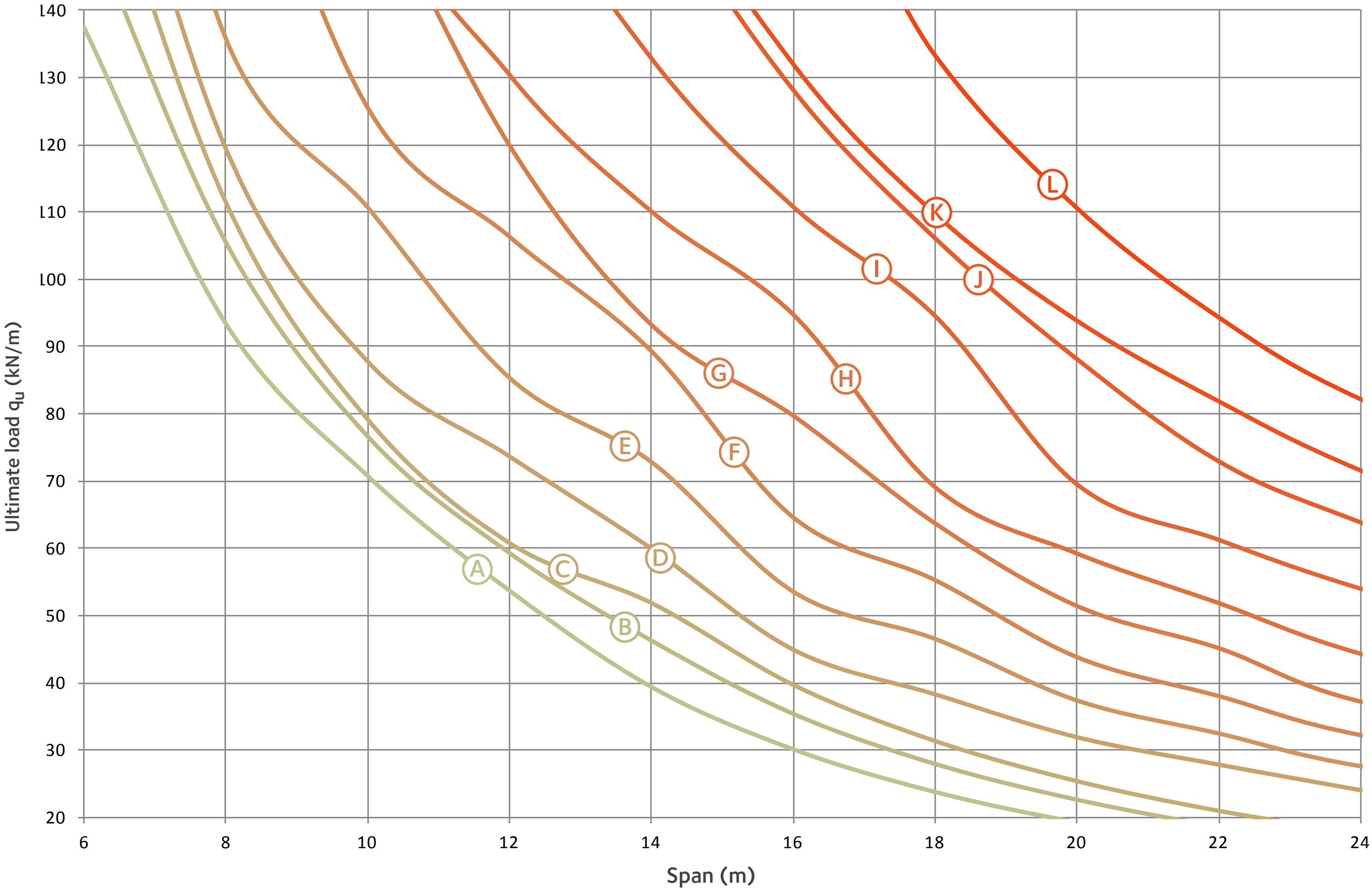
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)									
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24
Ⓐ	HE 300 A	305	200	305	1010	442,5	137,5	93,4	70,7	53,7	39,4	30,1	23,8	19,2	15,9	
Ⓑ	HE 320 A	325	200	325	1050	472,5		105,6	76,7	59,3	46,3	35,4	27,9	22,6	18,6	15,7
Ⓒ	HE 340 A	340	200	340	1080	500		111,6	79,3	60,9	52,0	39,8	31,4	25,5	21,0	17,7
Ⓓ	HE 360 A	365	250	365	1230	532,5		119,5	87,8	73,7	60,0	44,9	38,3	31,9	27,8	24,0
Ⓔ	HE 400 A	405	250	405	1310	592,5		135,9	110,7	85,4	72,9	53,6	46,5	37,4	32,5	27,6
Ⓕ	HE 450 A	455	250	455	1410	667,5			125,6	106,4	89,4	64,7	55,4	43,9	38,1	32,3
Ⓖ	HE 500 A	500	250	500	1500	740				120,0	93,3	79,8	63,8	51,4	45,2	37,2
Ⓗ	HE 550 A	555	250	555	1610	890				130,4	110,1	94,7	69,0	59,2	51,8	44,3
Ⓘ	HE 650 A	655	250	655	1810	967,5					132,9	110,8	94,6	69,6	61,3	54,0
Ⓙ	HE 700 A	755	250	755	2010	1067,5						128,1	106,1	88,1	72,9	63,8
Ⓚ	HE 800 A	805	250	805	2110	1192,5						132,1	109,8	93,9	81,9	71,6
Ⓛ	HE 900 A	900	250	900	2300	1340							133,4	110,6	94,4	82,2

Chart 24: Composite Angelina™ based on HEB, HISTAR® 460 with COFRAPLUS 60



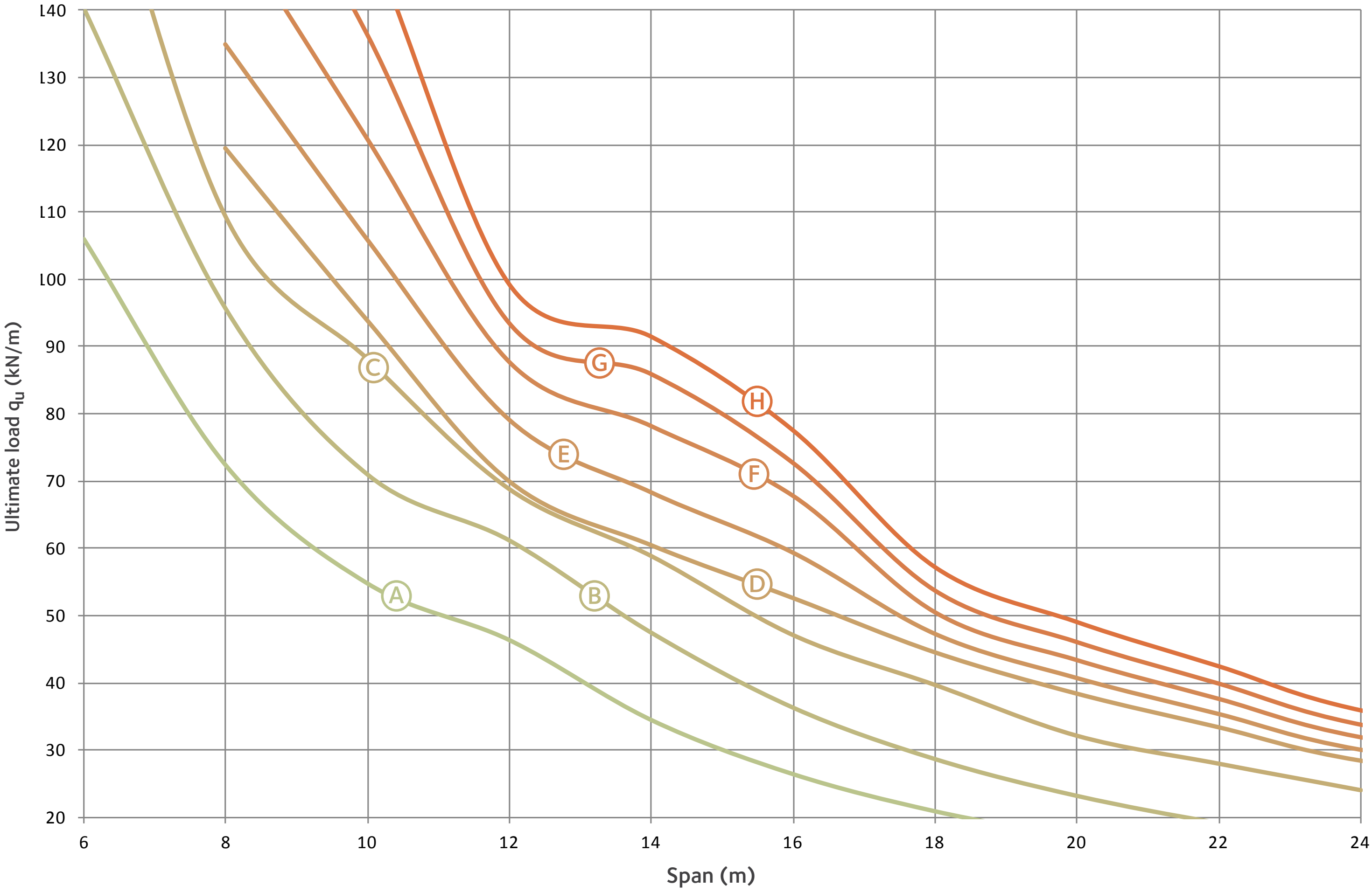
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)									
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24
A	HE 300 B	315	250	315	1130	457,5		108,2	88,0	70,2	52,6	40,8	35,4	29,1	24,8	21,7
B	HE 320 B	335	250	335	1170	487,5		131,0	98,5	76,0	60,3	47,7	37,8	31,2	27,3	23,7
C	HE 340 B	355	250	355	1210	517,5			106,0	87,8	64,5	50,0	41,9	34,3	29,4	25,8
D	HE 360 B	380	300	380	1360	550			107,1	88,0	68,4	58,7	45,0	38,9	32,0	28,0
E	HE 400 B	420	300	420	1440	610			132,4	102,0	82,4	66,6	51,5	45,7	36,7	32,4
F	HE 450 B	475	300	475	1550	687,5				122,5	90,1	75,7	65,0	54,8	43,9	37,9
G	HE 500 B	525	300	525	1650	762,5				138,8	118,1	89,2	74,1	56,4	53,4	46,2
H	HE 550 B	580	300	580	1760	840					134,8	89,5	79,1	65,7	58,4	49,5
I	HE 650 B	680	300	680	1960	990					136,3	117,0	95,4	81,5	70,4	61,0
J	HE 700 B	730	300	730	2060	1065							116,1	96,7	88,8	75,5
K	HE 800 B	780	300	780	2160	1190								116,7	93,8	83,2
L	HE 900 B	830	350	830	2360	1315									123,6	101,1

Chart 25: Composite Angelina™ based on HD, HISTAR® 460 with COFRAPLUS 60



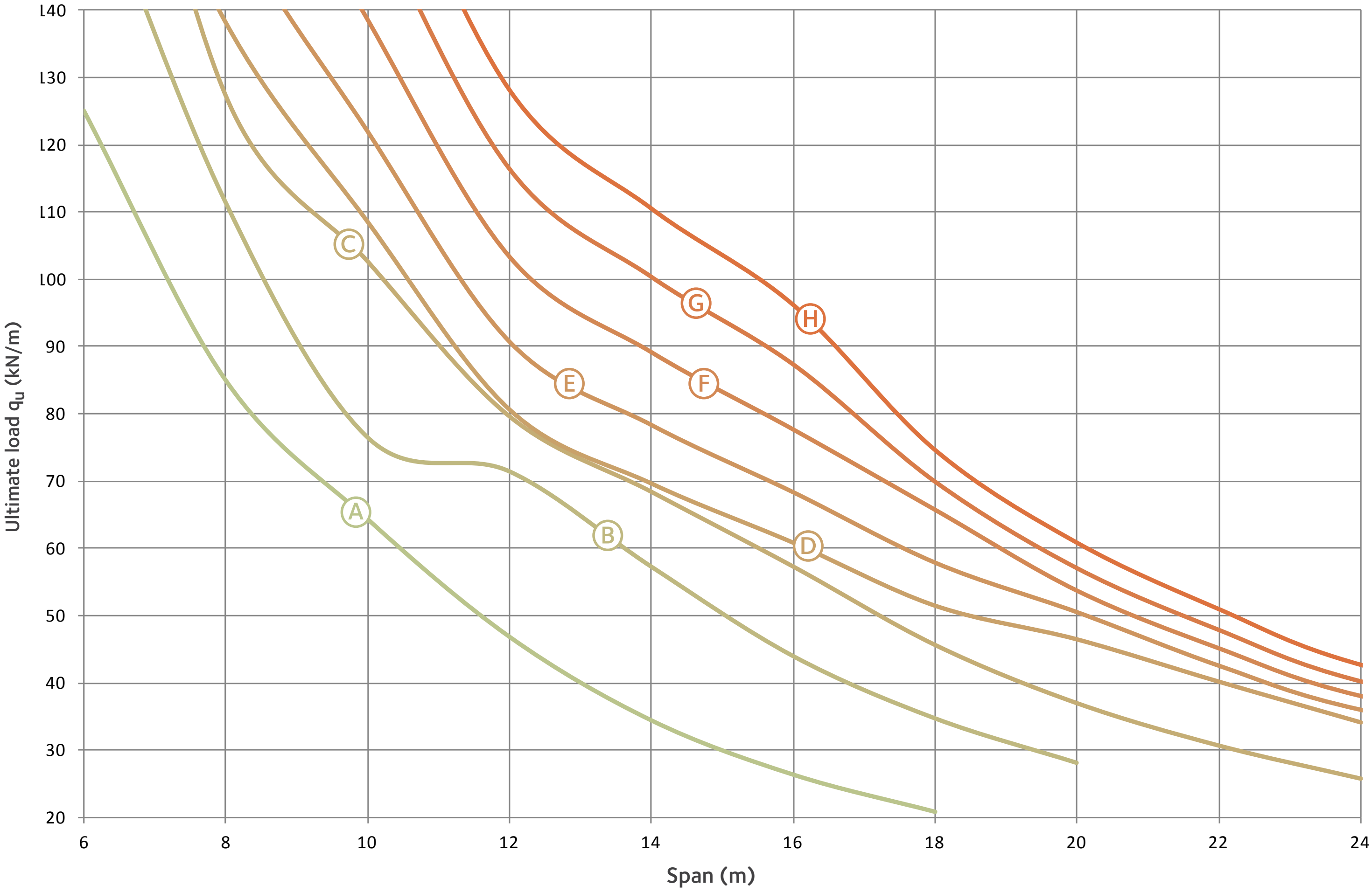
Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)									
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24
Ⓐ	HE 300 A	305	200	305	1010	442,5	137,5	93,4	70,7	53,7	39,4	30,1	23,8	19,2	15,9	
Ⓑ	HE 320 A	325	200	325	1050	472,5		105,6	76,7	59,3	46,3	35,4	27,9	22,6	18,6	15,7
Ⓒ	HE 340 A	340	200	340	1080	500		111,6	79,3	60,9	52,0	39,8	31,4	25,5	21,0	17,7
Ⓓ	HE 360 A	365	250	365	1230	532,5		119,5	87,8	73,7	60,0	44,9	38,3	31,9	27,8	24,0
Ⓔ	HE 400 A	405	250	405	1310	592,5		135,9	110,7	85,4	72,9	53,6	46,5	37,4	32,5	27,6
Ⓕ	HE 450 A	455	250	455	1410	667,5			125,6	106,4	89,4	64,7	55,4	43,9	38,1	32,3
Ⓖ	HE 500 A	500	250	500	1500	740				120,0	93,3	79,8	63,8	51,4	45,2	37,2
Ⓗ	HE 550 A	555	250	555	1610	890				130,4	110,1	94,7	69,0	59,2	51,8	44,3
Ⓘ	HE 650 A	655	250	655	1810	967,5					132,9	110,8	94,6	69,6	61,3	54,0
Ⓙ	HE 700 A	755	250	755	2010	1067,5						128,1	106,1	88,1	72,9	63,8
Ⓚ	HE 800 A	805	250	805	2110	1192,5						132,1	109,8	93,9	81,9	71,6
Ⓛ	HE 900 A	900	250	900	2300	1340							133,4	110,6	94,4	82,2

Chart 26: Composite Angelina™ based on HD, S355 with Cofradal 200



Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)										
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24
A	HD 320 x 74.2	350	200	350	1100	476	106,1	72,4	54,8	46,3	34,4	26,4	20,8	16,9		
B	HD 320 x 97.6	350	200	350	1100	485		95,6	71,0	61,2	47,5	36,4	28,7	23,3	19,2	16,2
C	HD 320 x 127	350	300	350	1300	495		109,3	88,2	68,8	58,8	47,1	39,7	32,1	28,0	24,0
D	HD 360 x 147	440	300	440	1480	580		119,5	93,9	70,0	60,5	52,6	44,5	38,4	33,4	28,4
E	HD 360 x 162	440	300	440	1480	584		134,8	105,9	79,1	68,3	59,3	47,3	40,7	35,4	30,1
F	HD 360 x 179	440	300	440	1480	588			120,9	87,7	78,2	67,8	50,5	43,4	37,6	31,9
G	HD 360 x 196	440	300	440	1480	592			136,5	93,6	86,0	72,8	53,8	46,1	39,9	33,8
H	HD 400 x 216	440	300	440	1480	595				99,3	91,5	77,6	57,2	49,0	42,4	35,9

Chart 27: Composite Angelina™ based on HD, HISTAR® 460 with Cofradal 200



Sections		Dimensions (mm)					Ultimate load q_u (kN/m) according to the span (m)										
		a_0	w	s	e	H_t	6	8	10	12	14	16	18	20	22	24
A	HD 320 x 74.2	350	200	350	1100	476	125,1	85,0	64,4	46,9	34,4	26,4	20,8			
B	HD 320 x 97.6	350	200	350	1100	485		111,4	76,5	71,5	57,3	44,1	34,8	28,2		
C	HD 320 x 127	350	300	350	1300	495		127,3	102,7	79,7	68,4	57,3	45,7	37,0	30,7	25,8
D	HD 360 x 147	440	300	440	1480	580		138,2	108,6	80,6	69,6	60,8	51,4	46,4	40,1	34,0
E	HD 360 x 162	440	300	440	1480	584			122,0	90,7	78,3	68,3	57,8	50,5	42,5	36,0
F	HD 360 x 179	440	300	440	1480	588			138,7	103,4	89,2	77,7	65,8	53,8	45,2	38,1
G	HD 360 x 196	440	300	440	1480	592				116,5	100,4	87,4	70,0	57,1	47,9	40,3
H	HD 400 x 216	440	300	440	1480	595				128,2	110,6	96,3	74,7	60,9	51,0	42,8

13. Technical advisory and beam finishing

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- T cut-outs
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- curving
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- welding and fitting of studs
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Eurostructures Beam Finishing Centre
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Version 2015 - 1