How to design an economical standard set of welded built-up I-shaped cross sections for the use of mass production

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Objekttyp: **Article**

Zeitschrift: **IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen**

Band (Jahr): **10 (1971)**

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-11172

How to Design an Economical Standard Set of Welded Built-up I-Shaped Cross Sections for the Use of Mass Production

Comment construire une série normalisée de sections à I soudées et économiques pour les besoins de la production en série

Entwurf einer normierten Reihe von wirtschaftlichen, geschweissten I-Profilen für den Massenfertigungsbedarf

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We can say that any standard product is a junior partner of the mass production. In our report let it be a built-up welded I-shaped cross section with two axis of symetry as usually applied to an I-beam shown in Fig. 1.

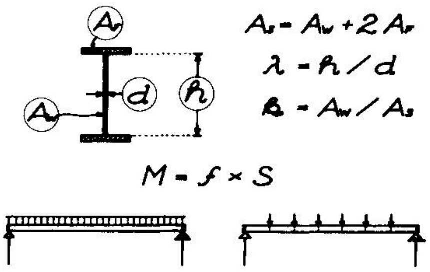

Fig. 1.

The question of weight economy is how to shape an I-cross section to get out of it the most effective bending moment. The traditional idea is this is given by massive flanges and a slender web. The web slenderness is defined by three parameters : the depth h , the thickness d , and their ratio λ equal to h devided by d .

Their influence on the weight economy of an I-cross section is different, as shows Fig. 2. There we see 3 lines indicating the relationship of the section modulus to the web area to total section area ratio k .

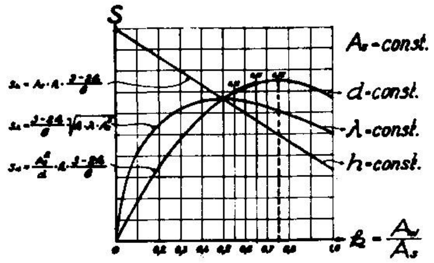

Fig. 2.

The total cross section area remains always constant.

The depth h being constant too, the maximum section modulus requires the whole 100 % of the material in both flanges. Nothing of it remains for the web area. This is not our case, but one of lettice girder.

The web thickness d being constant, the maximum section modulus requires 75 % of material in the web area and 25 % in both flanges, only.

Lastly, the slenderness ratio being constant, 50 % of material are to be put in both the web and the flanges.

The condition of a constant slenderness ratio λ can be fullilled when the I-beam is hot rolled in the mill.

The condition of a constant web thickness d is fulfilled when the I-beam is built up. Really, that is our case. But for the welding technology purposes 75 % in the web area and 25 % in both flanges only are unsuitable because of neglecting the required cross section rigidity. Therefore, the ratio k varying within 65 % down to 55 % is practically quite well acceptable for both the welding technology as well as the weight economy.

Now, the minimum weight to maximum bending moment diagram can be drown, to be seen in Fig. 3. The lower zone I of it is parabolic. Here, the allowable bending stress is the only working condition of economy. At a point where the web slenderness ratio must be respected, too, the weight economy diagram changes in the tangent of the parabolic zone I . Thus, the diagram is divided in two zones.

In the lower parabolic zone I the section modulus can be increased by increasing the web depth, but in the higher linear zone II by increasing the area of flanges, only. The web depth increasing is already impossible the upper limit of the web slenderness ratio λ being just reached.

This conclusions are applied to one size of the web thickness, only. But they can be extended to several sizes, in our example 6 , 8 , 10 , 12 mm .

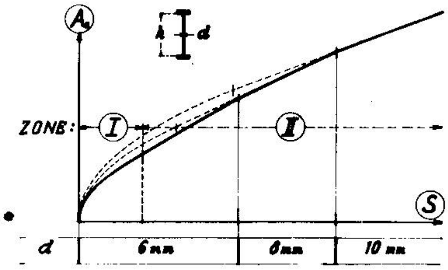

Fig. 3.

Thus, a bundle of different diagrams of that sort is layed down, as shows Fig. 4. A curved line inscribed into it represents a complex weight economy diagram characterising the optimalized relationship of the minimum total section area to the maximum section modulus.

Now, we can afford the further step towards the standardisation. For this purpose, we can use the following rule : the weight difference between two adjacent members of a standard I-section set may be up to 10 % maximum. According to this rule the graduation of the web depth is done in a scale of 25 mm up to 500 mm, of 50 mm up to 1.000 mm and of 100 mm above the depth size of 1.000 mm. As we can notice the parabolical zone I refers to the minimum web thickness as permitted by the welding technology. All greater web thickness sizes correspond to the tangent zone II . As we already know the upper limit of the web depth size is defined by the web slenderness ratio λ . This depends either on the web buckling resistence or on the possibilities of the welding technology. From this point of view the web slenderness ratio λ is to be graduated in a set of 5 members as follows : 100 , 120 , 145 , 170 and 200 . This graduating must not exceed the supposed 10 % weight difference.

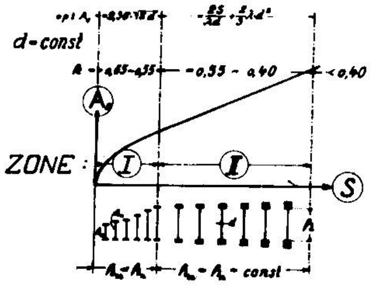

Fig. 4

Yet, we have to design a set of flange plate sizes. That can be done following the rule that the width of a flange plate is to be 20 times up to 25 times larger than its thickness. A survey of sizes of web plates as well as of flange plates is gathered in the tables on Fig. 5. The total number shown there is 21 shapes of flange sections and 71 shapes of web sections.

Now, we can make a final step to drow a matrix for designing an economical I-cross section standard set, seen in Fig. 6. The matrix consists of 5 main columns. Each of them covers the I - sections of the same limiting web slenderness ratio λ : 100, 120, 145, 170 and 200. It is devided into 4 subcolumns corresponding with the designed set of web thicknesses : 6, 8, 10 and 12 mm. Vertically, all columns are lined following the mentioned gradua-

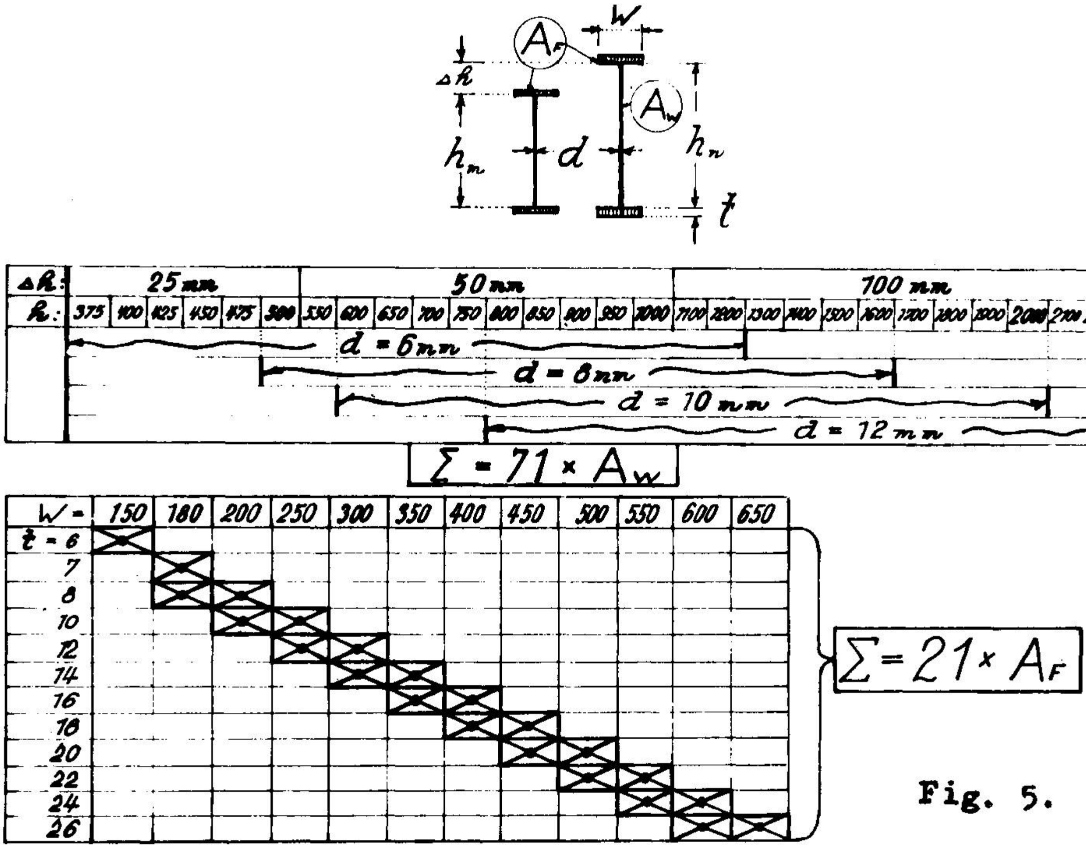

Fig. 5.

tion of web depths : from 375 mm up to 2.200 mm . Each column relates to one size of the web thickness and, vertically, is divided into two zones : I and II .

We elect the area of flange plates of such a size that the web area ratio k decreases from 65 % down to 55 % relating to any web depth size in the zone I , and from 55 % to 40 %

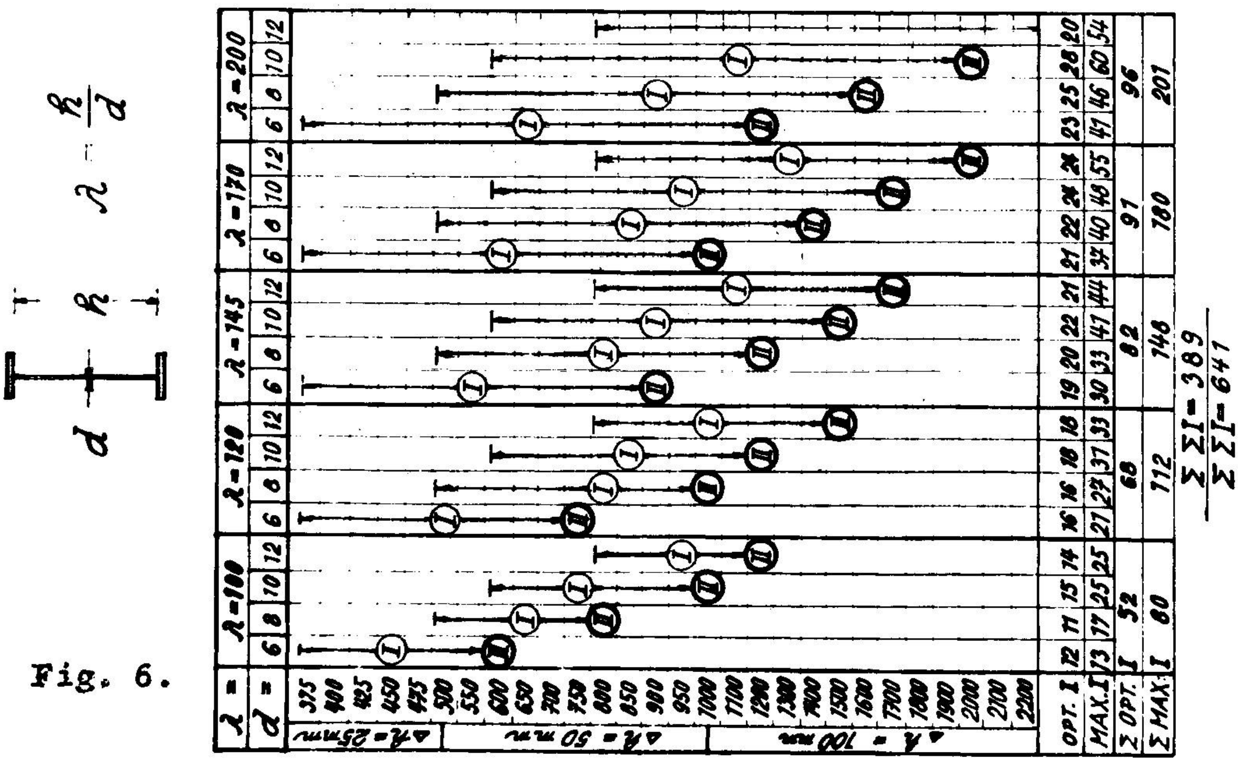

Fig. 6.

relating to each limiting slenderness ratio in the zone II. An I-section shaped with a ratio K bellow 40 % is considered as statically as well as economically unfavorable.

Under the lower edge of the table there are noted the reduced sum figures of recommended most economical I-shaped sections related to their total sums.

In that way the table in Fig. 6 shows final results of solving the discussed problem how to design an economical standard set of welded built-up I-shaped cross sections.

The just described method especially the idea of arranging the standard sets in 5 groups according to 5 recommended slenderness ratios involves some remarkable advantages :

1) : any sort either of a mild steel or of a high strength steel can be used;

2) : different standard specification of the web buckling resistence can be applied;

3) : weight savings up to 5 % can be reached in comparision with a usual design method;

4) : the designed standard sets can be put into practice as specifications for the mass fabrication on a specialized welding production line.

Furthemore, an idea might arrise to design a european standard of this kind based on the just mentionned method.

I hope this short report may be successful in giving some informations to you about our research aims on that field in our country.

SUMMARY

The mass production can only be developed when the product is standardized. This report deals first with the conditions of weight economy of an I-cross section and, having defined them, describes a method how to design an economical standard set of welded built-up I-shaped cross sections (Fig. 6) for the use of mass production.

RESUME

La fabrication en séries peut seulement être développée si le produit est standardisé. La présente contribution à la discussion traite d'abord des conditions d'économie en poids d'un profil en I. Sur cette base une méthode est développée qui permet de projeter une série standardisée de profils en I soudés et économiques, (fig. 6) en vue de la fabrication en séries.

ZUSAMMENFASSUNG

Die Massenfertigung kann nur entwickelt werden, falls das Erzeugnis normiert ist. Dieser Diskussionsbeitrag behandelt zuerst die Bedingungen der Gewichtswirtschaftlichkeit eines I-Profils. Aufgrund derselben wird dann eine Methode entwickelt, die es ermöglicht, eine normierte Reihe von wirtschaftlichen, geschweissten I-Profilen (Bild 6) für den Massenfertigungsbedarf zu entwerfen.