Falko Schröter[1]

Heavy steel plates for efficient constructional steelwork

Summary

There are traditionally two important fields of application for heavy plates in civil engineering: heavy steel buildings made of welded constructions (for example multistory buildings, shipbuilding halls or power plant buildings) and bridges with spans between 4 and 1000 m. Nowadays, a wide range of heavy plates is available for these fields of application. These heavy plates offer to technical designers a nearly unlimited range of dimensions, strength and toughness levels. In particular the thermomecanically rolled steel plates and the longitudinally profiled plates will be presented in detail. Due to optimised properties heavy plates enable very economical and durable constructions.

1. Development of heavy plates

At present heavy plates are widely used in constructional steelwork. Among these in particular the steel grades between S235 and S355 (that means a yield stress of 235 and 355 MPa respectively) are very popular. The development of heavy plates for steel structures during the past decades firstly aimed at increasing the strength level with at the same time keeping an acceptable weldability. Thus, the volume of steel used in the construction could be reduced. At the beginning of the 70th, the development reached the high-strength steel levels S460 and S690 (yield stress of 460 and 690 MPa respectively) which, however, required a relatively difficult welding procedure coming along with higher fabrication costs and, therefore, limiting the wider use of these steel grades.

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[1] Dr.-Ing. Falko Schröter, Marketing Manager, AG der Dillinger Hüttenwerke, D-66748 Dillingen, Germany

The demand to reduce weight, i.e. the reduction of the dead weight of the structure and the reduction of the total volume of steel required, was the starting point for the development of the longitudinally profiled plates (LP-plates) [1]. By a special control of the rolling gaps during the rolling process a longitudinal profile with a continuously varying thickness along the length of the plate can be given to a heavy plate. Thus, various types of LP-plates with different shapes can be produced (Fig. 1). Such plates allow an optimised adaption of the plate thickness to the actual stress in the structure.

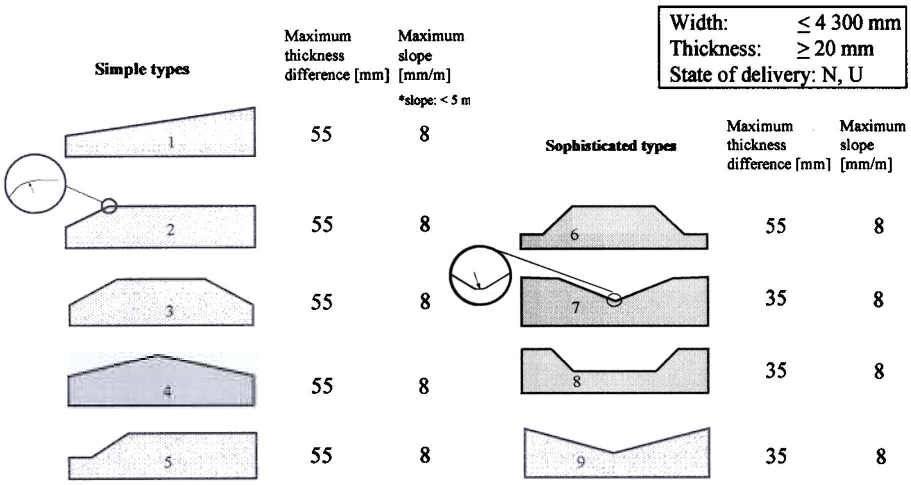

Fig.1 Various shapes of LP-plates

Fig. 2 LP-plates (wedge-shaped) in the upper flange of the bridge Schengen

An example for the application of these plates is presented in the Fig. 2. In the Schengen-Viaduct, border bridge linking Germany with Luxembourg across the river Mosel, more than one third of the total steel amount used were LP-plates, in particular for the upper flanges of the open box girder construction.

Today, LP-plates are applied in bridgebuilding all over Europe. Besides reducing the weight, the application of LP-plates saves also fabrication costs and time due to the possibility of avoiding complicated weldings. Moreover, the structural fatigue behaviour in particular for steel and composite bridges is optimised by avoiding fatigue-sensitive weldings.

Aspects of fabrication and manufacturing costs savings gained more and more importance during the 80th and led to the development of the modern generation of thermomecanically (TM or TMCP) rolled heavy plates [2, 3]. TM-rolled heavy plates in steel grades S355M, S420M and S460M, which can be delivered since the end of the 80s, offer not only a high strength but also an excellent weldability. Basically, the material influences the weldability by its carbon equivalent, a summary of the effects of the alloying contents on cracking tendency. TMCP-rolled steel enables much lower carbon equivalents than corresponding normalised steel grades of the same yield stress. Thus, the possibility of designing even more economical steel constructions is established.

2. Building construction

As far as building construction is concerned, two different fields of application may be distinguished; on the one hand the simple and standardised multi-story and hall buildings and on the other hand the heavy welded constructions for industrial halls, power plants and special tall multi-story buildings. Regarding the standardised constructions, which hold the biggest share of the total steel consumption in the construction market, heavy plates are only used for head plates or stiffeners for framework constructions predominantly composed of rolled beams. Mostly the steel grades S235 and S275 are applied here.

In cases in which high loads or large spans have to be designed, columns, piles and girders are normally welded and made from heavy plates. This design and construction method shows an economical advantage up from a girder height of about 600 mm because the cross sections of the supporting structure can be adapted individually to the constructional task by only using a minimum of steel. The steel grade S355 is predominantly applied for these applications, but sometimes even heavy plates of the higher steel grade S460 are used.

Common dimensions for heavy plates in the heavy building construction area are: thickness from 8 to 100 mm, width up to 1.5 m and length up to 18 m.

The following examples give an impression of the typical application range of heavy plates:

- Power plant buildings, e.g. the thermal power station Schwarze Pumpe, Germany, (Fig. 3) with an overall height of 161 m. The columns and beams were mainly fabricated with TM-rolled heavy plates S355M/ML and the standard structural steel S255J2G3 mod. in plate thicknesses up to 65 mm. Additionally, S690QL was used in some high tension loaded areas.

Fig. 3 Building construction with heavy plates: Power Station Schwarze Pumpe

- Commerzbank Tower, Frankfurt, Germany (Fig. 4): Due to the very high requirements of architects on the aesthetics of multi-story buildings, heavy steel skeleton constructions have been more and more used during the past 10 years. A typical example for this is the Commerzbank Tower in Frankfurt with a height of more than 298 m [4]. Its steel framed structure contains about 18000 t of heavy plates. Thereby, the S355M steel was used for plate thicknesses exceeding 30 mm, whereas in highly loaded girders and columns S460M has been applied. Thus, fabrication costs could be reduced by this optimal selection of heavy plates.
- Sony Center Berlin, Building F, Germany: Also in this example the architectural requirements were decisive for the application of high-strength heavy plates. The supporting structure consists of 3 heavy columns on which 2 welded truss girders made of

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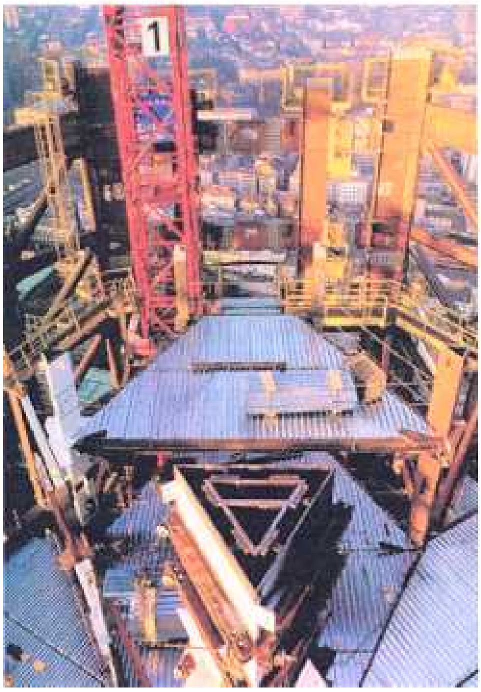

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Bridges

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S275NL or S355NL lying side by side. The dimensions used in these plate bridges are: thicknesses between 160 mm and 220 mm, widths of about 2300 mm and a length of about 4400 mm. The main advantage of this bridge type is the small traffic interruption period during erecting the bridge. So, the whole process of erecting the bridge from pulling down the old bridge structure up to the passage of the first train does not take more than 8 hours. Moreover these small-span bridges show an outstanding fatigue behaviour because weldings can be totally avoided.

Due to construction technique, bridges with big spans (more than 150 m) belong to the field of pure steel structures. Constructions made of welded heavy plates are almost generally applied for such types of bridges.

Mainly heavy plates of the steel grade S355 are used in the European bridgebuilding. However, high strength plates of S420 and S460 are more and more employed for big-span bridges. Sometimes even the higher-strength steel grade S690, e.g. in the water-quenched and tempered condition, is used. Normally the plate thicknesses are less than 50 mm, but exceptionally even plates of thicknesses up to 150 mm can be found in the load bearing sections.

Typical examples for modern bridgebuilding are given in the following:

- Erasmus-bridge Rotterdam, The Netherlands: The Erasmus-bridge connects the inner city of Rotterdam with the North bank of the Nieuwe Maas, Kop Van Zuid. The steel bridge has an overall length of 499 m with a 410 m-long cable-stayed bridge composed of a 139 m-tall pylon and a 89 m-long flap bridge. Totally, 6000 t heavy plates of the steel grades S355M (thickness less than 100 mm, 4200 t), S460L (thickness less than 80 mm, 2000t) and S460QL (thickness less than 125) were used for this bridge.
- Øresund-bridge, Danmark-Sweden: The Øresund fixed link consists of a 7500 m-long framework composite bridge, a 4000 m-long artificial island and a 3500 m-long tunnel. The approach bridges and the cable-stayed main bridge were built as a truss bridge with a upper concrete deck and a lower steel deck (railroad deck). Heavy plates of the steel grades S460M/ML in thicknesses up to 80 mm (60000 t) were used for the shore spans, whereas the main bridge was constructed of S420M/ML in thicknesses up to 50 mm 16000 t).
- Nesenbachtal-bridge, Germany: This bridge located near the city Stuttgart was constructed as a composite bridge with a welded box girder and a concreted deck (Fig. 5). In order to retain the very low construction height of 3,00 m the highest-strength steel S690QL has been used in the areas of high stresses in a total amount of 200 t. Finished in 1999 it was

the first bridge in Germany using this material. Another recent example for the usage of this special steel grade is the road bridge in the GVZ Ingolstadt in which especially graceful and thin pile heads could be designed.

Fig. 5 The Nesenbachtal-bridge

4. Perspectives

Today, the designers of constructional steelwork can choose from a nearly unlimited program of heavy plates with regard to dimensions and steel grades.

By this program nearly unlimited opportunities are offered to designers in order to combine optimal dimensioning and design of the building as well as efficient fabrication properties with regard to an economical and competitive construction. The current delivery programs of the plate products accomplish the demands and the desires for the next coming decades.

The future developments of heavy plate technology for steelwork are characterised by the user's desire of facilitating further reductions of fabrication costs using further improved heavy plates. Additional higher requirements on the homogeneity of the mechanical and chemical characteristics and on the dimensional tolerances and flatness signify a great challenge for the processing and rolling technologies of the heavy plates.

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Summary

The application of modern high-strength steels offers to designers working in the fields heavy buildings and steel bridges the opportunity to realise structures not only fulfilling the highest demands on elegance and aesthetics but also considering the necessity of an economical and environment-friendly construction. By using heavy plates made of thermomechanically rolled steel grades the total weight of the structure can be reduced and fabrication costs can be saved due to the outstanding strength, toughness and also fabrication properties. For instance, these materials show an excellent weldability in spite of their high strength. Furthermore, these heavy plates can be delivered in a nearly unlimited range of dimensions facilitating an individual solution of the designing problem. Therefore, heavy plates of the steel grades S355M/L, S420M/L and S460M/L in thicknesses up to 120 mm have been widely used in the construction of bridges and multi-story buildings in all over Europe. Furthermore longitudinal profiles plates showing a profile along the length according to various shapes are available. By using these LP-plates weldings can be avoided and thus fabrication costs be reduced as well as the structural safety be increased. These modern steels represent the right answer to the increasing requirements on modern constructional materials.