Smart plates for cost savings in bridge construction - The longitudinally profiled plates

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SUMMARY

After being extensively used in railway bridges until the mid 20th century, steel products suffered a decline in Europe until the late seventies. This decline was associated to the development of the prestressed concrete technique.
Nowadays, this trend has been reversed, thanks to the productivity improvements made by the fabricators and by the availability of new steel products such as longitudinally profiled plates. These plates whose thickness varies lengthwise and enable the fabrication of welded girder flanges to closely match the stress distribution and therefore to reduce weight and save costs. The paper presents this high tech product - LP-plates - and shows how they can reduce the fabrication cost and improve the safety of steel bridges. Several examples for constructions are illustrated..

LONGITUDINALLY PROFILED PLATES

LP plates have been manufactured for the first time in 1983 in the heavy plate mills of GTS Industries in France and Dillinger Hüttenwerke in Germany. The manufacture of LP plates requires a fast and powerful roll setting equipment as well as a sophisticated thickness control device allowing a continuous and in real time adjustment of the roll gap during the rolling pass.

LP plates are available in all types of structural steel grades delivered in normalized condition according to the European standards:

EN 10 025
(for general structural steels with a minimum YS up to 355 N/mm²)

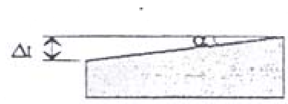
EN 10 113
(weldable fine grain structural steels with a minimum YS up to 460 N/mm²)

EN 10 155
(weathering steels)

Various plates profiles can be produced, among which the simplest types are shown in fig.2. Combinations of these different types are also possible.

Type		Max. Thickness variation in mm	Max. slope in mm/m
1		55	8
2		55	8
3		55	8
4		55	8
5		55	8
6		55	8
7		35	8
8		35	8
9		35	8

Figure 1:Types of Longitudinally Profiled Plates



DIMENSIONS :	
- length :	as per Dillinger Hütte GTS delivery program (≤28 m)
- width :	≤ 4300 mm
- thickness :	20 mm ≤ th. ≤300 mm
- slope α :	≤8 mm/m (≤ 5 mm/m)
- max. thickness variation :	≤55 mm
- maximal weight :	≤63 t
Delivery conditions :	as rolled, normalized
Mechanical properties :	in accordance with EN 10 025 EN 10 113-2 EN 10 155
French standard :	NF A 36270

Figure 2: Delivery Program

Dimensions (see figure2)

The maximum values shown in figure 1 and 2 reflect the maximum feasibility. In the majority of the cases, these values depend from each others and therefore cannot be freely combined. Nevertheless the LP plate feasibility can be checked thanks to our LP software "WINDOWS PC LP delivery program" (Fig. 3a, 3b, 3c,).

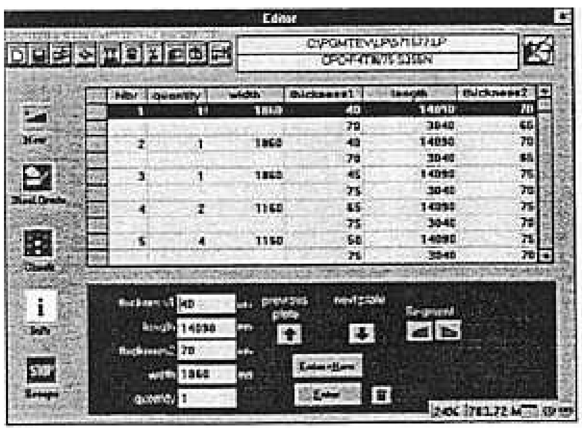


Fig. 3 a

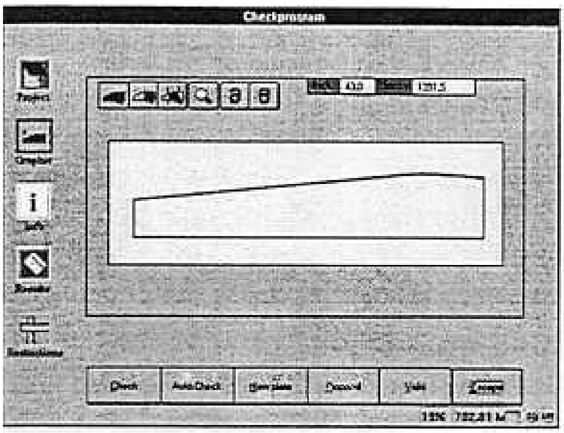


Fig. 3 b

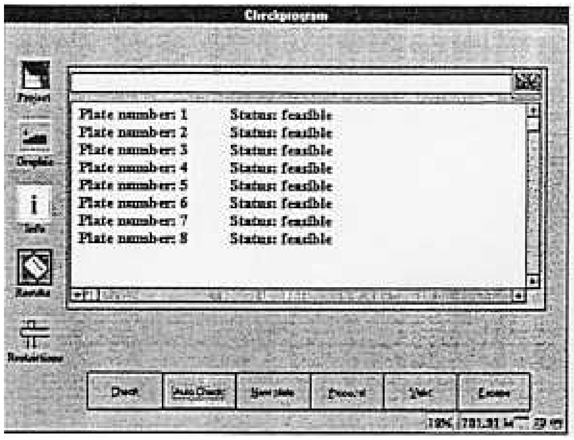


Fig. 3 c

The dimensions tolerances are :

- for thickness: the same as for normal plates with the thickest part of the plate as a reference value ;
- for flatness: the tolerance is that of EN 10 029 Standard class A or B.

BENEFITS DUE TO THE USE OF LP PLATES

A money saving product

Bending moments in steel structures and stresses in the girder flanges often vary along the structure.

A parabolic curve (see figure 4) is generally approximated by a staircaselike curve which is obtained in practice by welding conventional plates of increasing thickness.

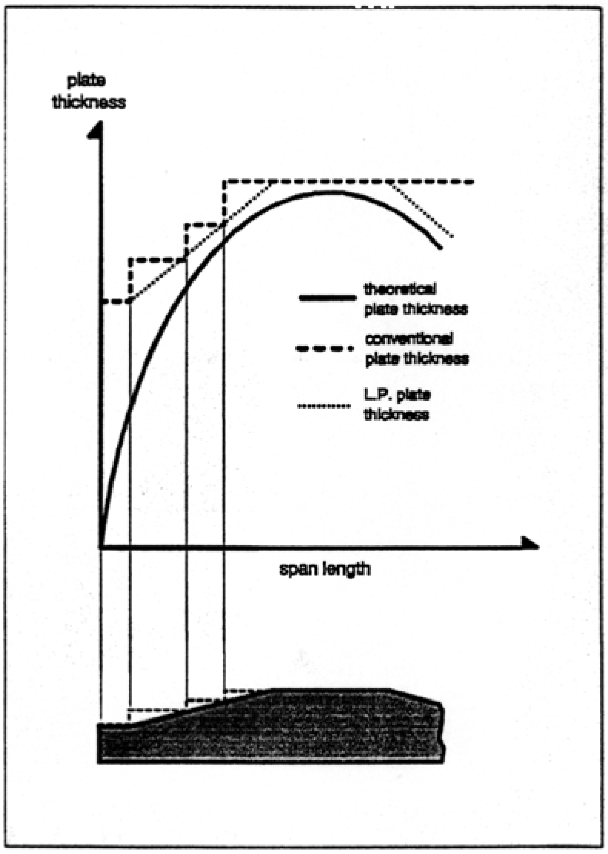


Figure 4: Solution using LP plates

An easier solution is to use plates with continuous thickness variation over their length in order to match as closely as possible the ideal profile (see also fig. 5).

The use of LP plates enable also to shift the welded joints in area less submitted to fatigue loading thus increasing the structure lifetime duration.

For the fabrication of a structure, a LP plate solution will always be lighter than a regular-plate solution. The variable-thickness-plate solution leads to a smaller purchasing cost than with regular plates, even if LP plates are more expansive on a price per ton basis. It has to be pointed out that the main part of the savings comes from the fabrication costs.

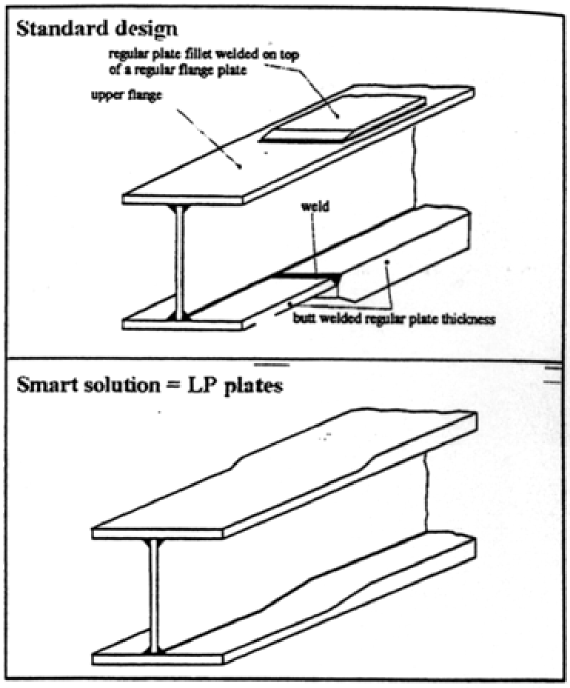


Figure 5: Welded girders design fabrication time and cost savings

Fabrication savings generated by LP plates.

To give an example of the savings generated by the use of LP plates, we have chosen the case of the fabrication of a girder flange with a length of 24 m and a width of 0.8 m.

We assume that the static calculations have shown that the optimal shape has a thickness decreasing from 120 mm at one end to 40 mm at the other end. This profile can be obtained in different ways using regular or LP plates:

two tapered plates : one 12 m long plate with thickness decreasing from 120 mm to 80 mm welded to another 12 m long plate with thickness decreasing from 80 mm to 40 mm (not only one plate because of the too high thickness difference),

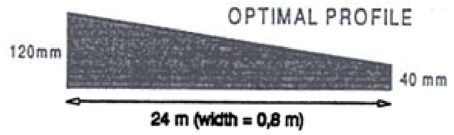
one 120 mm thick regular plate with a length of 24 m,

two conventional plates with 12 m length, one 120mm thick and the order 80 mm thick,

three 8 m long regular plates with thicknesses of 120, 93 and 67 mm

Figure 6 shows the different solutions and a comparison of their respective weight, number of welds and total cost. The one plate solution is very expensive because of the weight of useless steel. Solutions with 2 or 3 regular plates are equally costly, the extra weight of steel of the two plates solution being balanced by the additional weld in the three plates solution. The LP plate solution is cheaper than the last two solutions by 10%.

This example shows that LP plates generate large fabrication savings. Another advantage in using these plates lies in the possibility of transferring welds, and therefore fatigue notches, to less critical areas thus improving the fatigue behaviour of the structure



ALTERNATIVE SOLUTIONS	WEIGHT (TONS)	NUMBER OF WELDS	COSTS RELATIVE
120 80 40	12	1	100
120	18	0	130
120 80	15	1	110
120 93 67	14	2	115

Figure 6: Economics for the fabrication of a girder plate flange

USES OF LP PLATES

An increasing use in France.

The yearly cumulative production of LP plates is shown on figure 7. The consumption which had been of 2,700 tons only between 1983 and 1988 has reached 32,000 tons at the end of 1997.
LP plates have been used so far in road, highway and railway bridges in France, Germany, United Kingdom, Belgium and Congo.

It should be underlined that LP plates have been used in other types of structures such as overhead crane track girders, overhead cranes, steel car park structures, steel mill structures.

They have been used up to now in 106 bridges covering a wide range of structures types (fig. 8):

- small composite bridges (30 to 40 tons of LP plates),

- box girder steel bridges with orthotropic slabs such as the Sauertal bridge (length = 1,195 m, max. span length = 150 m) built in 1987 at the border between Germany and Luxembourg.

- long composite bridges such as the Somme viaduct (length 760 m) or the Haute Colme viaduct (length 1,830 m) longest high speed train (TGV) bridge in France, described below.

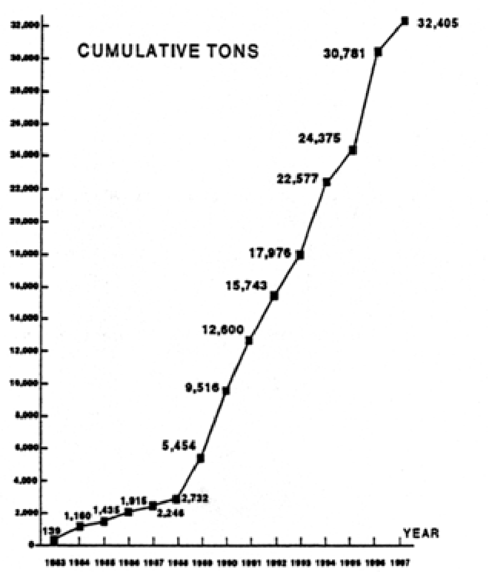


Figure 7: DH-GTS deliveries of LP plates

EXAMPLES FOR THE USE OF LP PLATES

An outstanding example is the Haute Colme viaduct, which is today the longest European railway bridge.

Completed in 1991, it was built by Baudin-Chateauneuf in the North of France, on the TGV link between Lille and the arrival point of the Channel tunnel, near Calais. It is a two tracks railway bridge with a total length of 1,830 m, over crossing three roads, the Haute Colme canal and the river Aa. The bridge has 48 spans with lengths ranging from 25 to 65 m, most of the spans having a 40 m length (Fig.9).

The structure is a composite one, with two steel girders (2.5 m high) and a concrete deck, the total width being 12.660 mm (Fig. 11), 5,200 tons of steel plates, among which 1,270 tons of LP plates, were used for the construction.

In the numerous intermediate 40 m length spans (fig. 12), where for example in the bottom flange regular plates of different thicknesses (75/90/75 mm) were originally forecasted, a LP plate double wedge type has been substituted (60/90/60). Thas leading to a reduction of 2 weld joints as well as a weight reduction.

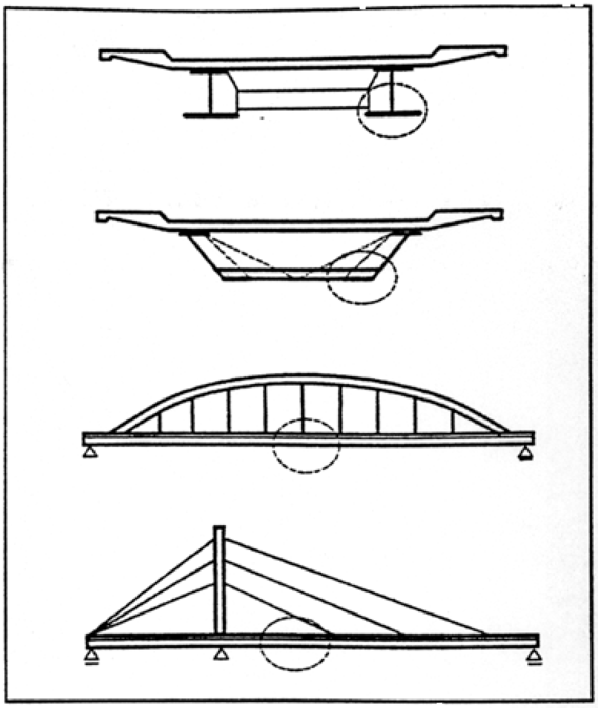


Figure 8: Possibilities to use LP plates in bridge construction

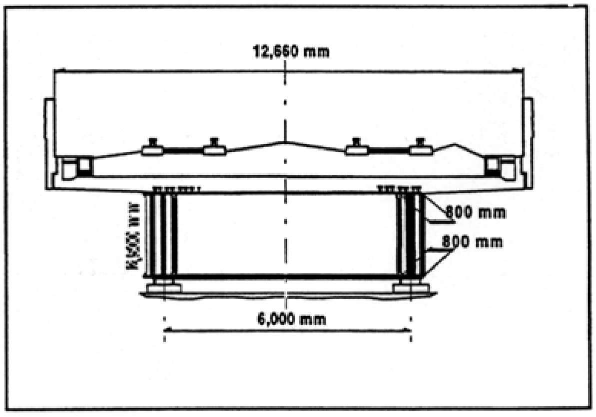


Figure 9: Haute Colme viaduct - Cross section

The same exercise was also carried out on the main span (fig.10). In the upper flange of the longest central span (65 m) for example, where four conventional plates of different thicknesses 70/95/80/60 mm were replaced by one 55/95/81 mm thick double wedge plate and one 81/55 mm thick tapered plate.

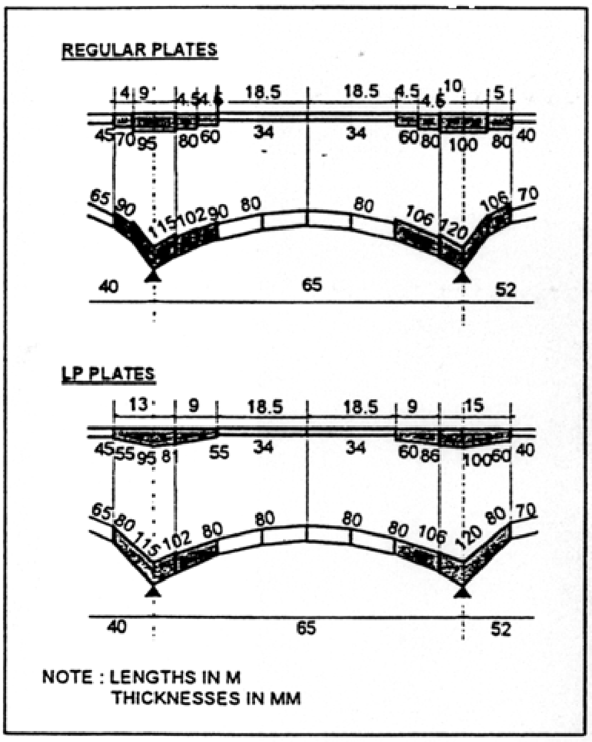


Figure 10: Haute Colme viaduct : 65 meter span

Such solutions led to a saving in steel weight of 108 tons, which is equivalent to 8.2 % of the weight of the parts where LP plates have been used and 2.1 % of the weight of the total steel structure. They also allowed to reduce by 160 the total number of welds, thus decreasing by 6 % the total structure welding costs.

A typical example of a road bridge designed with LP-plates is the Vohburg bridge in Germany,built by DSD. The bridge was completed in 1995 and crosses the river Danube near the city of Vohburg.

The composite steel construction exists of 2 main girdes with a concrete deck. The side spans reach a length of 31,5 m whereas the main span reaches 60 m. The bridge has a width of 11,9 m. The web height is 3,15 m at the bearing points and decreases to 1,25 m in the mid span area.

Due to extended use of LP-plates for the girder plates the weight savings reached 11 % compared with the classic approach. At the same time several weld seams could be saved and some welds could be shifted to low stress and low fatigue areas.

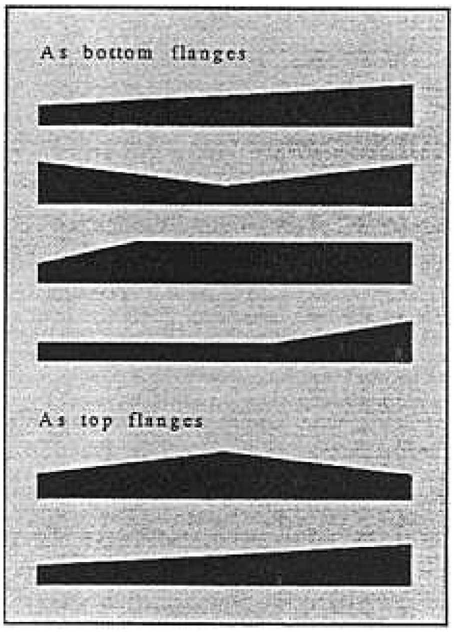
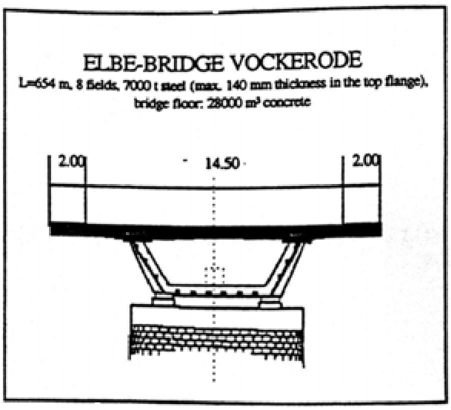


Figure 11: Types of LP plates used in the Vohburg bridge

Fabrication cost savings and saving ultra sonic testing time leads to another reduction of 5-10 % in fabrication costs.



The Elbebrücke Vockerode is another example for the extended use of LP-Plates. The A9 highway bridge crosses the Elbe river roughly 20 km east of Dessau.

The old bridge of the 30ies had to be replaced as a part of the large infrastructual programme for eastern Germany. The new composite bridge has a length of 654 m with 7 side span of 55 to 90 m length and a central span of 125 m. The width is 18,5 and 21 m, the height varies from 3,5 to 6 m. For each of the 2 lane bridge sides 3.500 t of steel S355 J2G3 have been used. The open box girder has been built with LP-plates in the upper girder plates

The thicknesses varied between 40 and 90 mm so that weight savings of up to 15 % have been calculated. The savings of fabrication costs were up to 10 %. The first lane (direction to Berlin) has recently been opened and the second lane is under construction.

CONCLUSION

The use of LP-plates in more than 100 bridges around Europe demonstrate the economical advantage of these plates. They result from:

- reduction of the quantity of welded joints,
- weight savings,
- fabrication savings (bevelling, welding, welds inspection time),
- smoother aspect of the flanges (fatigue behaviour improvement, architecture).

They have opened a new aera for steel constructions. Steel fabricators nicknamed them "smart plates".