# Lamellar Tearing Observations Regarding the Application of European Standards in the Field of Welded Steel Constructions

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*The problem of corrosion for old steel bridges in operation is often solved by direct replacement of elements or structure. Only a few studies have been done to determine the efforts influenced by corrosion in those elements. In general, it is considered that a corroded element has exceeded the bearing capacity and should be replaced, but if the corroded element is secondary it could be treated and kept. A factor in the rehabilitation of an old steel bridge in operation is the aspect of structure. If the structure is corroded, rehabilitation decision is taken is easier. Lamellar tearing describes the cracking that occurs beneath the weld and can be characterized as a brittle failure of steel, in the direction perpendicular to the plane of rolling. The paper presents a comprehensive study on lamellar tearing and summarizes some conclusions about the prevention of them. The conclusions will be exemplified in the case of a railway bridge, with a main truss girder. The paper presents also some observations regarding the stress analysis in fillet welds, resulting from the engineering practice.*

*Keywords: historical steel bridge, corrosion, rehabilitation, fatigue, Lamellar tearing, welded beam*

## Observations on the phenomenon of lamellar tearing

Laminar tearing is a defect resulting in the welding process and poses a danger to joints with. The phenomenon occurs in cross joints and in T with corner weldings (fig.1).

The lamellar tearing takes place in a number of stages. Corrosion of the samples is prevented by a detailed examination of the lamellar tears but the sequence of tearing can be followed on slice bend test micro sections:

- Numerous elongated inclusions make steel susceptible to lamellar tearing.

- Tears at inclusions on the same plane linked by ductile tearing accompanied by plastic deformation

- Inclusions on different planes linked by shear fracture and the formation of shear walls.

The degree of through-thickness strain needed to initiate lamellar tearing depends on the through-thickness ductility which in turn depends on the inclusion type, shape, and distribution, as well as the properties of the metal matrix [1].

The phenomenon of lamellar disintegration occurs at a temperature of 400 ... 500 ° C. The phenomenon may even occur at a lower temperature in the case of very sensitive materials [11].

In order to avoid it, some technological measures (eg 100°C preheating, which have positive effects) and constructive measures will be taken. Figure 1 presents some sensitive details of lamellar tearing and solutions for their improvement by engaging all layers on the thickness of the element. This problem can occur when the welding residual stresses act on the thickness of the smallest of the joining elements (s) [9]. Cracking occurs when the ductility in the thickness of the plate is very low, It appears under the welding cord to the thick elements (s) [2].

Cracking normally occurs in the base metal, almost at the outer boundary of the ZIT (Thermal Influenced Area). The cracks have a characteristic appearance in stages as well as *yarns*, being parallel to the direction of rolling of the steel plate. Unlike hydrogen cracking, lamellar breakage is not necessarily limited to the ZIT area. In some cases, cracking may occur at the middle of the thickness of a plate if it is blocked by welding on both sides [3,4].

It is generally advisable to avoid stressing on the element's thickness. The sensitivity of the material to lamellar tearing is expressed quantitatively by the Z index. [10]

Lamellar tearing may be neglected if the condition:

$$Z_{Ed} < Z_{Rd}$$

where: $Z_{ED}$ - is a sum of Z coefficients expressing the effect of bridging the deformations of the welded joints.

$Z_{RD}$- Calculation value of material capacity to avoid lamellar tearing;

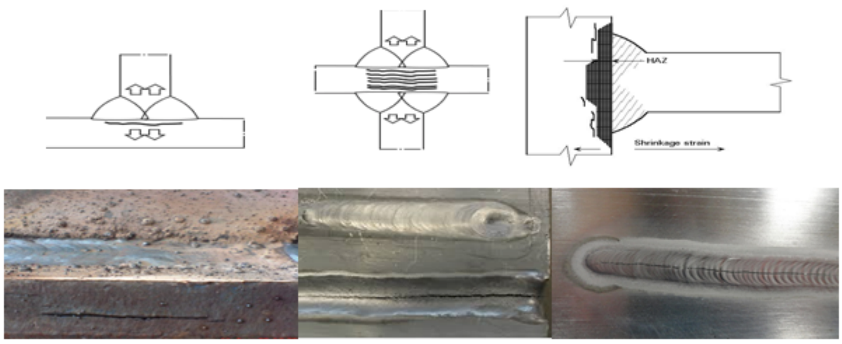


Fig.1 The phenomenon of lamellar tearing and improvement of behavior at lamellar tearing; examples. Examples of lamellar tearing

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**Table 1**
COEFFICIENTS Z ACCORDING TO EUROPEAN STANDARD [1]

| The Value $Z_{Ed}$ (SR EN 1993-1-10) | Calculation value required $Z_{Rd}$ SR EN 10164 |
|---|---|
| $Z_{Ed} \leq 10$ | - |
| $10 \leq Z_{Ed} \leq 20$ | Z 15 |
| $20 \leq Z_{Ed} \leq 30$ | Z 25 |
| $Z_{Ed} > 30$ | Z 35 |

The choice of height for determining the index is illustrated by figure 2.

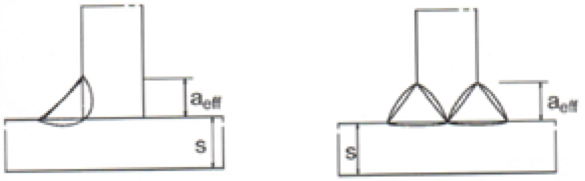

Fig.2 Choosing the height of welding

The main factors influencing lamellar tearing are the following:

- Weld size: Laminar tearing is more likely to occur on long welds, usually when welding length at T-head joints is greater than 20 mm [8].

-The welding process: the material and the choice of the welding process are the primary causes of lamellar tearing, the choice of the welding process has only a relatively small influence on the risk of occurrence of the phenomenon [5,7]. However, processes that introduce a large amount of heat into the joint, generate lower voltages in a larger ZIT area and thus penetration of deeper welding may be beneficial. In the case of hydrogen sulphide, welding will increase the risk of lamellar tearing; In practice, a low percentage of hydrogen is recommended, especially when welding sensitive steels [6].

**Example 1:**

Under the rail, the upper flange - welded section of the cheson section - the material used: S355 K2

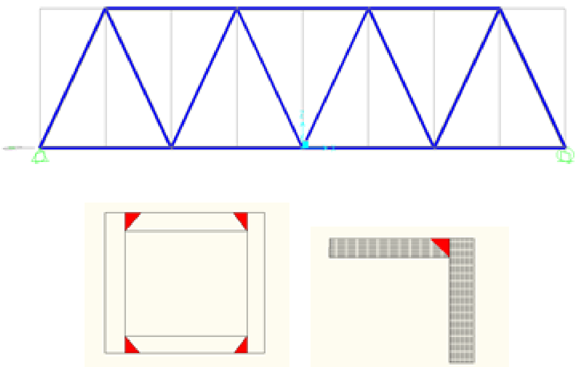

Fig.3 Railway bridge in welded beam welded beam solution; Welding details.

To determine the values of Z (Tab.of SR EN 10164).
Za = 9 (aeff = 30 mm)
Za = 8 (shape and position of the weld)
Za = 6 (s = 30; Zc = 0.2 s)
Za = 3 (narrow shrinkage)
Za = 0 (without preheat)
- Result ZEd = 26 -> S355 K2 + Z25

Conclusion: Detail A is sensitive to lamellar tearing and needs to be improved (fig. 4)

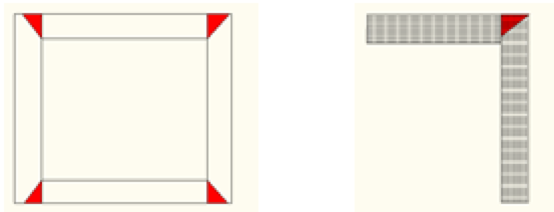

Fig.4 Improved welding detail

The Z values are reconsidered:
Za = 9
Za = -25
Za = 6
Za = 3
Za = 0
- Resulting ZEd = -7 -> consequently for S355K2 steel does not need to impose Z quality).

**Example 2**

Structure description. In Oradea, the construction of a road bridge over the Crisul Repede River was started. Although the total length of the bridge does not exceed Ltot = 85.0m and the site conditions do not impose any limitations on the height of the main beams, the designer (an engineering office in Italy) chose a continuous treble with varying height on three openings with the following dimensions : Large central opening (L = 49.70m) and small marginal openings (L = 15.875m) (fig. 5). On the site construction, at the bottom of the main beams, lamellas.

The elements were corrected and non-destructive - NDT (Non Destructive Testing), after which they were put into operation.

**Recommendations on the use of certain types of welds to avoid lamellar tearing.**

Below are four recommendations to avoid - in engineering practice - lamellar tearing:

- Instead of having two overlapped welds, we can choose two less permeable cords (case a);

- In the case of b, instead of a cord in the thinner element that can modify its fibers, we can choose two penetrating welds;

-In the case of c, instead of a larger welding, two smaller weldings are preferred;

And in the case of d, the second solution is preferred because the largest surface cord will not be disposed in the rolling direction.

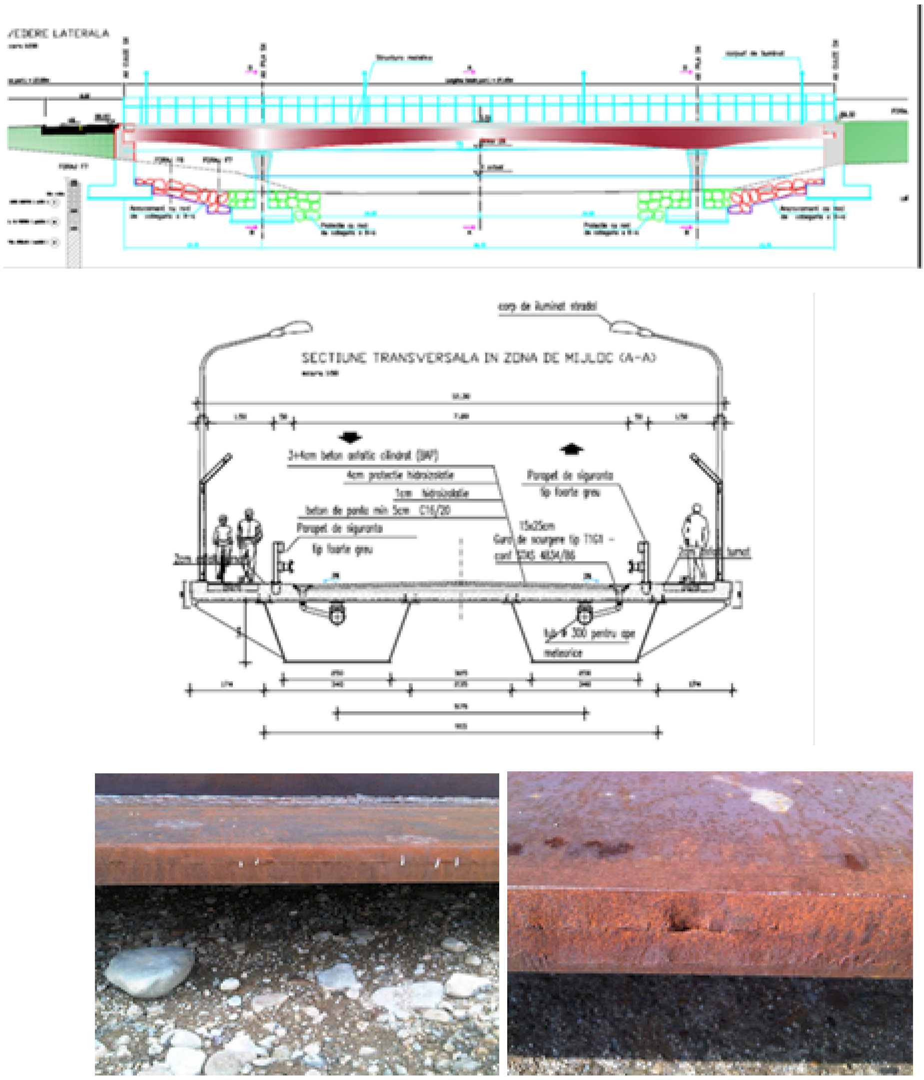


Fig 5. General layout of the Oradea bridge; details - lamellar tearing

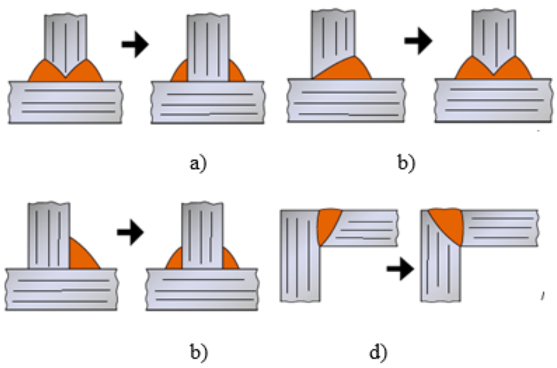


Fig. 6. Recommendations to avoid - lamellar tearing

## Conclusions

Historical steel bridges can have a big problem with corrosion because once corrosion affects elements the section of the beam element decreases, so that we can no longer consider in design the whole element section. Globally and usually in the design it can be taken only 90% of the initial section.

Consequently, lamellar tearing is a serious defect to the structures required for repeated and dynamic loads (bridges, running beams, cranes, offshore structures, etc.), this may lead to the failure of the element. Choosing the type of welding, the jointing method and the welding process are essential elements.

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