Experimental Investigation on One Most Used Steel Joint with Intumescent Paint

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Abstract. The modern steel structures use mostly the intumescent paint-protection against the fire. One of the main problems of these protective paints consists of the layer's thickness in order to optimize both the fire protection's problem and the costs of this protection's procedure. The authors offer some preliminary experimental results on intumescent paints layer's thickness optimization in order to assure as soon as possible the same heat transfer-gradient and also the same strength of the joint's members material.

Keywords: fire protection, steel joint, intumescent paint layer optimization, experimental investigation.

1 Introduction

In comparison with the concretes, the steel structures present the disadvantage of their additional fire protection requirements; otherwise over approximately $550 \ldots 600^0\,C$, their bearing capacity became unacceptable low, respectively the unprotected steel members present an inherent fire resistance of some 15 to 30 minutes. Between several fire protection methods, the intumescent paints are widely applied. By means of intumescent fire protection, which depends also on the so-called *Shape-Factor* (*massivity*), this fire resistance can be improved substantially. By definition, *Shape-Factor* (*massivity*) $\chi = \dfrac{A_m [m^2/m]}{V[m^3/m]}$ represents the ratio between A_m - the exposed surface area of the member per unit length and V - the volume of the member per unit length. For a member having unit length, this means in fact $\chi = \dfrac{L[m]}{S[m^2]}$ the ratio between the L - the exposed steel perimeter and S - the steel cross section. In reference Twilt, L. et al. (1996), there are presented several useful values and graphs regarding on the *Shape-Factor*, depending on the steel members shape and size, respectively the fire evolution (the corresponding temperature). It is a well-known fact, that *the hollow sections* present several structural advantages, particularly in case of compression and torsion loading. *The rectangular hollow sections* allow supplementary an easy connection to the flat surfaces and consequently they are widely applied for columns and trusses. From fire protection point of view, how is stated in Packel JA et al (1992), these rectangular hollow sections present several advantages; between others one can mention: their surface area (e.g. in particular case of the square hollow sections) is about 2/3 of the same size ***I***-section shape; the hollow sections trusses may have smaller members as a result of their higher structural efficiency; the absence of some re-entrant corners makes the intumescent paint application, respectively the fire protection itself more easier, sure and durable; in comparison with the ***I***-sections, the rectangular hollow sections present less surfaces (only four) for painting and consequently, taking into the consideration all above-presented arguments, one requires less material and less labour in this last case (of the rectangular hollow sections). In the other hand, in order to assure a higher stiffness of the joints between these rectangular hollow sections column and horizontal ***I***-profile members, the below-presented and analyzed solution is widely applied.

2 The Analyzed Connection

In the article of Jármai K, Farkas J, Kurobane Y (2006), based on the previously -with meticulous care prepared– research results of Kurobane and Shinde, the authors deeply analyzed several widely applied beam-to-column connections improved from seismic behaviours point of view.

The cheapest one was analyzed in the following from fire-resistance point of view, at a reduced scale model (approximately at 1:5), presented in Fig. 1.

One of the main problems of these protective intumescent paints consists of the layer's thickness in order to optimize both the fire protection's problem and the costs of this protection's procedure. If for the long structural elements there are quite clear recommendations regarding on the layer's thickness, in the case of the joints' area (surrounding/vicinity) only a few number of information one can find in literature. In the vicinity of the steel joints, there are usually different shape and cross-sectional areas of the connection elements, and consequently, their heat-transfer is very different. Based on this fact, their heating gradient (and of course, their strength) became very different if one applies the same intumescent layer's thickness. Twilt L et al (1996) stated the fact that the connection of both protected and unprotected steel structures normally present lower local Shape-Factor than the adjacent members and will therefore attain lower steel temperatures. So, it was useful to determine/monitory these temperatures.

In this sense, the authors of the present contribution foreseen thermo resistors: #***1*** - in column; #***3*** **-** in adjacent (here: horizontal) member, respectively in #***2*** - the connection zone, presented in the same Fig 1. One other one: #***0*** - was positioned in the electric furnace near the steel specimen.

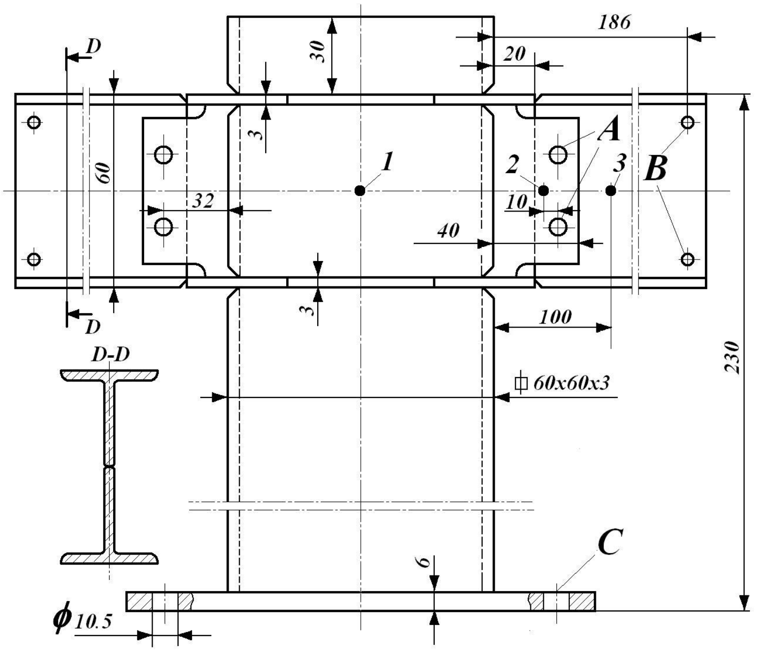

Fig. 1. The tested beam-to-column connection (at 1:5 ratio reduced scale model)

3 The Experiment Preparation

The authors conceived and realized an original electric furnace which allows, by means of its electronic control system, to reproducing the ISO-curve (the so-called “standard fire-curve”), defined in ISO 834. How one can observe in the Fig 1, the column is realized from a square hollow section 60*60*3 mm and for the horizontal members, instead of normal ***I***-60 profile, were welded two ***T***-30 profiles, having a global stiffness more near the column’s one (see Section ***D-D***).

Two different cases of intumescent paint-protections were applied:

I. with uniform (*three layers*) paint, respectively
II. with different layers (*two,* respectively *three ones*) of paint.

For this second case the Shape-Factors have been calculated, based on the above-mentioned relation:

- for the column $\chi = \frac{L[mm]}{S[mm^2]} = \frac{240}{684} = 0.350$;
- for the horizontal members $\chi = \frac{L[mm]}{S[mm^2]} = \frac{2\bullet 116}{2\bullet 226} = 0.513$.

One can conclude that these Shape-Factors present the ratios $\approx 1/3 = 2/6$, respectively $\approx 1/2 = 3/6$.

Consequently, the authors decided to apply, in this second case, two equal thickness layers on the column, respectively three ones on the horizontal members.

4 The Obtained Results

Fig. 2 shows the temperature variation in cases of two (***2R***), and three layers (***3R***) at point ***#3***. In Fig 3 the theoretical displacement is presented at level ***B*** due to change of the Young modulus (depending on temperature), for a nominal total load F=10 *kN*, applied in these two points ***B***, when uniform number of layers are applied. One can obtain better bearing capacity of the system. by applying different number of layers on different members.

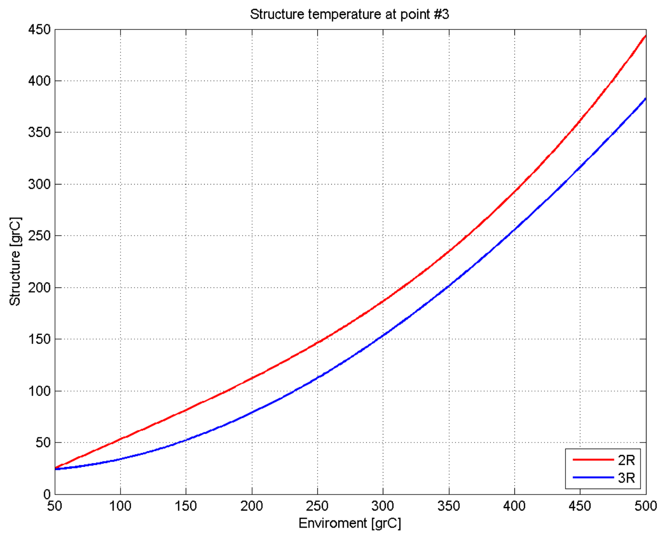

Fig. 2. The temperature variation in cases of two (2R), and three layers (3R) at point #3

In this sense, the authors used a well-known formula from literature (applicable for temperatures in range of $0\ldots.600^0 C$):

$$E(T)[GPa] = e_0 + e_1 T + e_2 T^2 + e_3 T^3 , \tag{1}$$

where $e_0 = 206.0$; $e_1 = -0.044326$; $e_2 = -3.502 \cdot 10^{-5}$; $e_3 = -6.592 \cdot 10^{-8}$.

The code "***0R***" was applied for the unprotected structure.

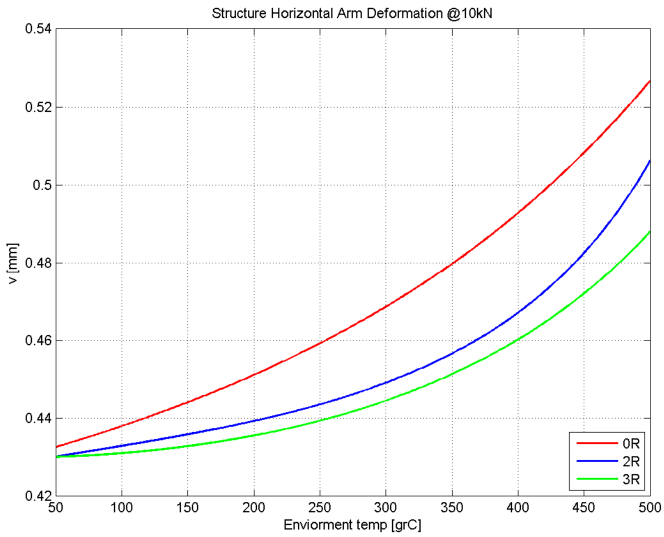

Fig. 3. The theoretical displacement at level *B* due to the Young moduli changes

5 Conclusions

In this first stage the authors investigated one of the joint types most applied in seismic design. Based on the presented curves (only a few numbers of them), as preliminary results on intumescent paints layer's thickness optimization, on can conclude that by choosing carefully the paint-thickness became possible to growing up the bearing capacity of different structural members.

One has to mention the fact that the authors applied these layers only by simply painting procedure (with paintbrush), where the thickness-monitoring/control wasn't the best.

It is well-known, that in the industrial conditions they are applied by spraying technology, where became possible a higher-accuracy thickness-controlling.

By analyzing the curves from Fig. 2, one can observe an approximately $70\,^{0}C$ reducing over the heat transfer to this horizontal member (at point ***#3***) for different layer-thicknesses (which were applied on the vicinity zones); how was mentioned, the horizontal member was always covered with three layers of paint.

Drawing up similarly heat transfer curves, became possible to select adequate paint-layer's thicknesses in order to assure as soon as possible the same heat transfer-gradient and also the same strength of the joint's members.

From Fig. 3 on can observe a relatively substantial influence of the layers thickness (instead of three, of two ones) starting from approximately $450\,^{0}C$; of course, the unprotected steel structure presents much greater displacements at point ***B*** as the covered ones.

Finally, the presented experimental results represent only a first step in the authors' further investigations.

In the next period the authors intend to analyzing carefully other widely used steel joints and to putting in evidence several useful aspects of the intumescent paints' application on steel structures connection areas.

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