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CONSTRUCŢII. ARHITECTURĂ

MECHANICAL PROPERTIES OF STEEL AT HIGH TEMPERATURES

BY
ANA-DIANA ANCAŞ and D. GORBĂNESCU

The experimental test results obtained in the study of steel mechanical properties variation in case of high temperatures (fire) are presented. The properties. are referring to: Young's modulus, E, the elastic limit, σ_e, and the characteristic diagram of the material (the rotation stress-strain).

Theoretical laws that model the steel behavior at high temperature have been elaborated, based on the most significant studies presented in the literature.

1. Introduction

In case of rising the steel elements temperature, Young's modulus is decreasing, that involves the progressive diminution of element stiffness. At the same time, the elastic limit becomes lower, that induces the element carrying capacity decreasing.

In case of actual structures there is a complex interaction not only between the temperature evolution phenomena but also between the structural elements.

At high temperatures, the members undergo important thermal dilatations which are more or less restrained by the surrounding elements. This partial restraining of thermal dilatations produces additional stresses that are equivalent to a load increasing.

When the temperature of 450°C is exceeded, another important phenomenon should be taken into account: the creeping.

Now, the variation of steel mechanical properties caused by temperature is well-known, the most important studies being presented in [1].

2. Mechanical Properties of Materials

These mechanical properties, as the thermical-physical ones, are significantly modified by the temperature rising. They are generally diminished. In comparison with other materials, like concrete, the experimental results obtained for steel present a lower hashing. In case of steel, the most important mechanical properties are: the elastic limit (the same at tension and compression) and the characteristic diagram (the relation stress–strain), while the ultimate stress arises a secondary interest.

2.1. The Ultimate Stress

The design requirements involve the elastic limit of steel, not the ultimate stress, because that this characteristic has not a great importance in our study.

In Fig. 1 there is presented the variation of the ultimate stress dependence *vs.* temperature for two steel brands, ASTM A7 and A36, and the results hashing [2].

In the ordinate axis of the graph, the dimensionless ratio $\sigma_n(\theta)/\sigma_e(20)$ is considered, where $\sigma_n(\theta)$ is the ultimate stress at temperature θ and $\sigma_e(20)$ is the elastic limit at 20°C. These curves may be also adopted for brands of steel used in Europe.

The graph shows that the ultimate stress significantly increases around 200°C:

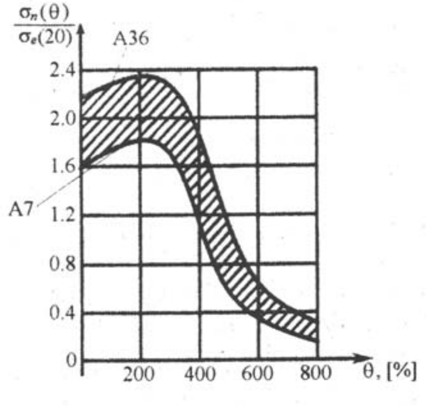

Fig. 1.- Dependence of ultimate stress *vs.* temperature.

2.2. The Elastic Limit

The considered limit corresponds to the yielding plateau when it exists, or to the conventional elastic limit ($\sigma_{0,2}$) when the characteristic diagram presents no yielding plateau.

The experimental results referring to the effect of temperature on this limit are presented in Fig. 2. In the graph, the dependence of the dimensionless ratio $\sigma_e(\theta)/\sigma_e(20)$ *vs.* temperature is represented and the obtained curves show no increasing of the elastic limit with the temperature rising.

At temperatures over 400°C, the results are obtained for great loading rates, in order to avoid the creep influence.

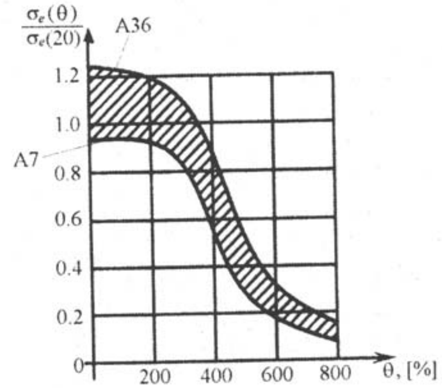

Fig. 2.– Dependence of elastic limit *vs.* temperature.

2.3. Longitudinal Modulus of Elasticity. Young's Modulus

The influence of temperature exerced on Young's modulus and the hashing of the experimental results are represented in Fig. 3 by considering the ratio $E(\theta)/E(20)$, where $E(\theta)$ is Young's modulus at temperature θ and $E(20)$ is its value at 20°C.

It can be noticed that Young's modulus decreases at a lower rate than the elastic limit, in case of temperature increasing.

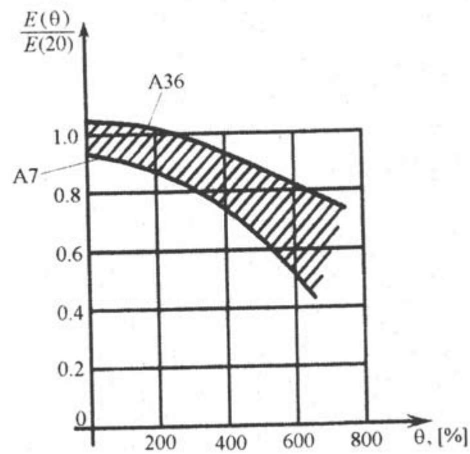

Fig. 3.– Dependence of Young modulus *vs.* temperature

2.4. The Characteristic Diagram of the Material. Stress–Strain Relation

In the literature there are only few studies referring to the temperature influence exerced on the characteristic diagram.

In Fig. 4 there are represented the experimental results obtained for tensile tests. Over 300°C, the diagram does not represents an elastic – perfect plastic behavior of the material, therefore, the adoption of such an idealized curve in structural design, no matter the temperature is, may be a source of great mistakes.

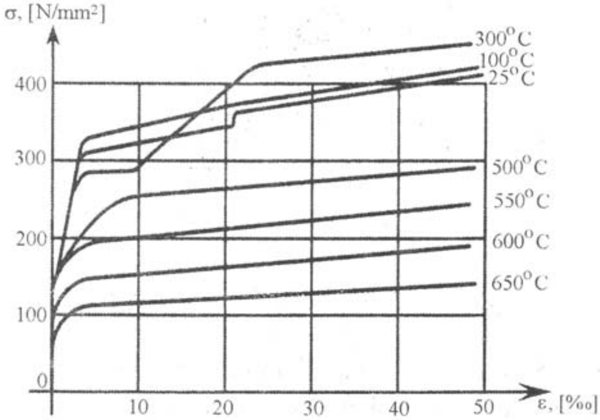

Fig. 4.– The temperature effect on σ–ε diagram.

3. Conclusions

From the previously presented tests results some important conclusions could be drawn namely:

1. The elongations corresponding to the rupture moment are significantly lower than those at 20°C.

2. The heating rate has a great influence upon the steel mechanical properties; the creep is a much more important phenomenon at high temperatures.

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"Gh.Asachi" Technical University, Jassy, Department of Structural Mechanics

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PROPRIETĂŢILE MECANICE ALE OŢELULUI LA TEMPERATURI ÎNALTE

(Rezumat)

Se prezintă rezultatele experimentale referitoare la studiul variaţiei proprietăţilor elastice şi mecanice ale oţelului la temperaturi înalte (incendiu): modulul Young, limita de elasticitate, diagrama caracteristică a materialului. Din multitudinea studiilor prezentate în literatură s-au reţinut cele mai reprezentative, utilizate apoi la elaborarea legilor teoretice de comportare a oţelului la temperaturi înalte.