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Fire Resistance of Metal Compressed Structures

SHUKUROVA K.K.

Senior lecture at Tashkent Architecture and civil engineering institute

ABSTRACT: The article describes the method to determine the fire resistance of the compressed metal columns.

KEYWORDS: Fire resistance, metal structures, flexibility, thermal creep of steel, strength, centrally compressed rods.

I.INTRODUCTION

The fire resistance of bearing metal structures is lost due to a decrease in the strength and elasticity of the metal when heated, as well as due to the development of its plastic and temperature deformations.
By the concept of fire resistance of a structure is meant the time after which the structure loses its bearing and enclosing ability.
The temperature at which deformations from the load in the supporting structures go beyond the elastic limits and the strength sharply decreases is considered critical.
The fire resistance limits of metal structures are established empirically or determined by calculation. In the calculation, the critical heating temperature is determined by the static calculation and the heating time of the structure to the critical temperature, the thermotechnical calculation.

II.METHOD OF RESEARCH

When heated to high temperatures, centrally compressed rods (columns, frames, racks and braces of trusses) lose their bearing capacity or stability (as a result, loss of strength).
The loss of strength occurs due to a decrease in the resistance of the metal of the heated rod to stresses from operational loads in its cross section. Usually this case occurs in rods with low and medium flexibility.
Rods with great flexibility during heating, due to the presence of small eccentricities caused by axis curvature, eccentric loading, etc., can lose their bearing capacity due to loss of stability due to a decrease in the elastic modulus and an increase in the thermal creep deformations of the metal at high temperatures.
In both cases, the critical temperature of the rod is determined by the critical creep strains of the metal εп (in total with the strains resulting from a decrease in the elastic modulus).
The critical deformation (elastic or elastoplastic) of a metal for the case of loss of stability of a centrally compressed rod is found

$$\varepsilon_{\kappa p} = \frac{\sigma_{\kappa p}}{E} \qquad (1)$$

where is $\sigma_{\kappa p}$ the critical stress found by the Euler formula

$$\sigma_{\kappa p} = \frac{N_{\kappa p}}{A} = \frac{\pi^2 \cdot I_x E}{l_{ef}^2 A} = \frac{\pi^2 \cdot E}{\lambda^2}$$

$\lambda = \frac{l_{cfx}}{i_x}$ - rod flexibility;

$i_x = \sqrt{\frac{I_x}{A}}$ Section inertia radius

l_{cfx} - Estimated bar length.

E –modulus of elasticity of the metal.

Substituting (2) in (1) we obtain

$$\varepsilon_{\kappa p} = \frac{\pi^2 E}{E \lambda^2} = \frac{\pi^2}{\lambda^2} \qquad (3)$$

Formula (3) shows that the critical deformations of a metal depend only on the flexibility of the rod.

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Under the action of fire, when the rod is under a constant working load, it loses stability due to the development of creep deformations of the heated metal. In this case, the loss of stability of the rod is characterized by a sharp increase in deformations at small increments of temperature.

The critical temperature (ε_n) and the degree of loading of the rod ($\gamma_a = \frac{\sigma_o}{\sigma_T}$) determine the critical temperature of the compressed rod.

The calculated critical deformation of its creep of steel is found by the formula:

$$\varepsilon_{\kappa p} = \frac{\sigma_{c з}}{\sigma_o\left[\frac{\Delta\sigma_e}{\Delta\sigma}\cdot(1-K)+K\right]}\left(\frac{\pi^2}{\lambda^2}-\frac{\sigma_o}{E}\right)$$

Where

$\sigma_{cp} = \frac{(\sigma_1+\sigma_2)}{2}$ - medium voltage;

$\sigma_o = \frac{N}{A}$ - operating voltage in the center of the section,

$\Delta\sigma_e = \frac{(2N\cdot e)}{W} - \frac{(2\sigma_o A\cdot e)}{W}$ -stress difference from the presence of initial eccentricity

$$l = \frac{M}{N}$$

K - is the coefficient of the level of stresses arising due to the deflection ft.

The coefficient k takes into account the effect of a change in the temperature deflection from 0 to a final value on the temperature creep strain of steel. Based on this consideration, the coefficient k should vary from 0 to 1.

For calculations, it can be taken equal to:

K=0,5 at $\lambda \leq 125$; K=0,75 at $125 < \lambda \leq 150$; K=1,0 at $\lambda > 150$

Thus, formula (4) is a generalized expression for calculating the critical deformation ε_m when the bearing capacity of a compressed rod is lost.

The heating of metal structures in a fire depends on many factors, among which the main ones are the intensity of the fire and methods of protecting metal structures.

The choice of options for constructive solutions is recommended to be made on the basis of a comparison of technology - economic indicators. To ensure comparability of design options, they should have the same purpose, be designed for the same loads, designed in accordance with current standards and for the same climatic, seismic, soil and operating conditions.

The emergence and continuous improvement of computer technology has allowed us to put forward the idea of an automated search for a low-cost design. Such problems are called optimal design problems or optimization problems. Using the methods of mathematical programming, it is possible to solve the problems of a purposeful search for a structure, the costs of creating which are minimized by some quality criterion, for example, by minimizing material costs or by cost, and finally, by reduced costs. The selected quality criterion is called the objective function, the minimum of which must be found. Often the minimum of the objective function is found while satisfying a number of restrictions on the conditions of stiffness, strength, stability, and some design limitations. The objective function and its limitations are written in a certain mathematical form. After compiling such a mathematical model, they begin to solve it by one or another method of mathematical programming. The result is optimal, i.e. the most profitable, technical solution.

The existing structure of the cost of building structures, the practice of construction and operation revealed that for large spans of 80 ... 100m, altitudes, loads and difficult soil conditions, where the dead weight of the structures makes up most of all existing loads, steel and wooden structures are beneficial, and for small and middle spans, where massiveness is required, high protective qualities, reinforced concrete structures are more profitable.

For construction in the North, steel supporting and lightweight building envelopes are more effective. For the northern regions of the country, the cost of transportation costs is very high and reaches 40 ... 50% of the total cost of construction. Thus, the task of increasing the efficiency of construction in the North should be solved by reducing weight, increasing the degree of factory readiness, and assembly. Delivery of structures should be carried out by the most efficient modes of transport, up to aviation.

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An increase in the seismicity of the construction area from 6 to 9 points increases (ceteris paribus) the efficiency of using steel frames and profiled steel flooring. This is due to the fact that with a decrease in mass, the load from the seismic effect also decreases.

III. CONCLUSION

The correct choice of structures and materials is influenced by temperature and humidity conditions, the presence of chemically aggressive effects in the production process. In conditions of high humidity without chemical aggression, the advantages of reinforced concrete structures compared with steel or wooden in terms of service life and repair costs are undeniable.

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