The Strength of the Reference Node of the Beams, Taking into Account the Temperature Effects

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Abstract. The features of the resistance of the support nodes of flexible reinforced concrete crossbars are considered taking into account the temperature effects. As the main area of work, a theoretical study of the influence of temperature effects on the strength and configuration of embedded metal parts and welds of the support nodes of prefabricated crossbars of various types is presented, which is an expression of the result achieved. The documents of the regulatory framework governing the design and construction activities in the Russian Federation, the existing constructive solutions of the support nodes, as well as the works of domestic and foreign scientists corresponding to the studies in this area are used. Research methods are structural and analytical analysis. Regulatory and scientific-methodological materials were studied, which made it possible to establish the parameters and factors affecting the constructive solution of the support nodes of flexible concrete elements. On this basis, proposals for improving the calculation and design solutions of support nodes are substantiated. Proposals have been developed for the calculation and design of support nodes taking into account temperature effects. It was revealed that the influence of temperature deformations significantly affects the operation of the support unit. The boundary ranges of temperatures and element sizes are determined at which the consideration of temperature effects is necessary. The features of the stress-strain state of the support node are clarified. Design recommendations are provided that provide strength and durability of the structure.

1. Introduction

When designing the support nodes of the bent elements of ribbed plates, girders, rafters, trusses, arches, the node is made through metal embedded parts, connected at the construction site by bolts or welding (Figure 1). The quantity and quality of welds, as a rule, is not standardized [1-5]. The purpose of the connection is to ensure a fixed position of the structure during installation and operation.

Figure 1. Support nodes of beams.

However, in the process of installation and operation of the building, despite the structural simplicity, the connection is in a difficult stress state. This may affect the initial design of the element...
and the building as a whole. The welded assembly limits the horizontal movement of the element and the beam actually becomes statically indefinable. But in practical calculations, it is considered as an element with pivotally movable and fixed supports [1-5]. However, during the destruction of welds, the crossbar cannot play the role of a bond, but turns into a load element, which is realized in support reactions (Figure 2).

![Figure 2](image_url)

**Figure 2.** The stages of the crossbar during the destruction of the weld. 1 - the initial scheme, 2 - the destruction of the seams on one support, 3 - the destruction of the seams on two supports.

The paper considers the influence of temperature effects on the elements of the joint: embedded parts, anchor rods and welds, in order to clarify the stress-strain state and quantitative assessment of stresses in these parts.

Studies of the joints of beams (girders) and columns arranged using embedded parts have been the subject of many works by both Russian and foreign authors [6-13]. There are a sufficient number of patents for various types of joints of such structures [14-18]. Also, a number of articles [19-21] are devoted to studies of the work of beams subject to the influence of temperature differences or high temperatures. However, the effect of temperature on the elements of the junction of the crossbar with the column is not fully studied. The presented work is devoted to this area of research.

2. Methods
The main force factors affecting the assembly welds from bending of the element are: the vertical distributed force $p_v$ arising from bending from the rise of the free edge, the horizontal component $P_h$ and the support reaction of the element $R$ (Figure 3).

![Figure 3](image_url)

**Figure 3.** The scheme of the deformation of the node and the existing efforts.
From the temperature difference of the bolt in the welds arise stress $\sigma_t$. Their value depends on the size of the cross section of the element, its length and the magnitude of the difference (Figure 2). The length of the welds determines the dimensions of the supporting embedded parts of the support and the crossbar.

The standards allow the design and operation of reinforced concrete structures for various purposes with the systematic effect of temperatures not higher than 50 °C and not lower than 70 °C. The coefficient of linear temperature deformation $\alpha_{bt}$ for heavy concrete in the temperature range from -40 °C to +50 °C is assumed to be $1 \cdot 10^{-5}$ °C$^{-1}$ [1].

As an object of study, we consider the hinge unit supporting the crossbar on the column through metal embedded parts connected by welded flank seams. Crossbar length $l$, design span $l_0$, section width $b$, section height $h$.

Absolute beam elongation $\Delta l$ at maximum temperature difference $\Delta t$

$$\Delta l = \alpha_{bt} l_0 \Delta t.$$  

The relative elongation of the crossbar

$$e_{bt} = \Delta l / l_0 = \alpha_{bt} \Delta t.$$  

The force from the temperature effect on the welds and the embedded part of the support during the elastic work of concrete crossbar

$$P_b = A_b \sigma_b E_b = \alpha_{bt} \Delta t b h E_b.$$  

Here $E_b$ is the modulus of elasticity of concrete.

From the design experience for rectangular crossbars, without prestressing the reinforcement, the optimal section height is assigned $h = l_0 / n$, and the section width $b = h / m$ at $n = 10 \div 15$, $m = 2 \div 4$.

$$A_b = l_0^2 / n^2 m.$$  

Then, the force from the temperature effect can be represented in the form (5)

$$P_b = \alpha_{bt} \Delta t E_b (l_0^2 / n^2 m).$$  

The force due to the temperature effect is reduced due to the frictional forces $P_{fr}$, depending on the magnitude of the support reaction $R = q l_0^2 / 2$ and the coefficient of friction of sliding materials of the base plates $k_{fr}$.

$$P_b = k_{fr} R = k_{fr} q l_0^2 / 2,$$

where $q$ is the full load on the bolt.

Effort from temperature influence taking into account friction forces

$$P_b = \alpha_{bt} \Delta t E_b (l_0^2 / n^2 m) - q k_{fr} l_0 / 2$$  

or

$$P_b = \alpha_{bt} \Delta t E_b l_0 (l_0 / n^2 m - q k_{fr} / 2).$$

Crossbars without prestressing reinforcement, of rectangular cross section, made of heavy concrete of class B20, $E_b = 27.5 \cdot 10^3$ MPa ($27.5 \cdot 10^3$ kN/m$^2$) were considered as experimental samples. Temporary and constant load was taken 10 kN/m$^2$, with a cargo strip width of 6 m, the linear load $v = 60$ kN/m. The constant load of the crossbar weight $g$ was calculated separately, $g = \gamma A_b$, where $A_b$ was determined in accordance with formula (4), $\gamma = 2500$ kG/m$^3$ (25 kN/m$^3$).

Variable parameters were: the calculated span of the crossbar $l_0$, the temperature difference $\Delta t$, the total linear load on the crossbar $q = g + v$.

3. Results and discussion

The following values were calculated: the relative deformation of the crossbar due to the influence of temperature in the range (20-80) °C, the magnitude of the horizontal reaction of the supports (rebuff) and the friction forces that reduce the rebuff force.

The horizontal reaction was under the assumption of elastic work of concrete. The modulus of elasticity was set in accordance with a given class of concrete.

The dependence of the resistance value was established as a function of two variables - the span of the element and the temperature difference at a fixed load $v$.

Accounting for the self-weight of an element was taken into account automatically depending on the span $l_0$ and the coefficients $n$ and $m$. 

3
Based on the calculation results, the graphs of figure 4 and figure 5.

**Figure 4.** Dependence of the pressure force on the span and temperature difference at \( n=12, \ m=4 \).

**Figure 5.** The effect of friction forces on the longitudinal force of the thrust, \( \% \).

The analysis of the results shows that the friction forces significantly affect the strength of the resistance from temperature effects during spans of 5-6 m and a temperature difference of 20-40 \( ^\circ \text{C} \). At large temperature differences and an increase in spans, the effect of friction forces decreases. Under accepted conditions, the effect of friction forces is (1-3.5) \( \% \).
In practical calculations, the effect of friction is neglected, which leads to a margin of safety. The horizontal force increases in proportion to the increase in span, which is associated with an increase in the size of the cross section and an increase in temperature difference.

The obtained values of the force $P_h$ are the initial data for calculating the length of the welds and the dimensions of the support plates.

Figure 6 presents the minimum lengths of the welds, ensuring the preservation of the originally adopted design scheme and serving as initial data for establishing the dimensions of the support plates.

![Figure 6. Length of welds, mm (leg 10 mm).](image)

When welds are located on the lateral surfaces of the crossbar, the length of the support plate is equal to half the length of the weld, and the width is determined by the width of the section.

4. Conclusions

Table 2 and the graph in Figure 7 show the minimum lengths of the support plates from the conditions for the placement of two flank welds while ensuring the strength of the welded joint on the weld metal without taking into account the increase in the length of the welds in case of lack of welding.

| Span | 20 °C | 40 °C | 60 °C | 80 °C |
|------|-------|-------|-------|-------|
| 5 m  | 95    | 189   | 284   | 379   |
| 6 m  | 136   | 273   | 409   | 546   |
| 7 m  | 186   | 371   | 557   | 743   |
| 8 m  | 243   | 485   | 728   | 970   |
| 9 m  | 307   | 614   | 921   | 1228  |

Table 1. Estimated base plate length, mm.
A check of the strength of the welded joint along the fusion boundary showed that the calculation of the strength of the weld metal is critical for establishing the length of the joints. The results of the study clarify the work of welded joints of the supporting plates of columns and beams under temperature effects and allow improving the design schemes of buildings taking into account the real work of the nodes.

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**Figure 7.** Estimated base plate length.
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