Comparative analysis of typical and reinforced support parts’ design parameters for reinforced concrete roof beams

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Abstract. Reinforced concrete roof beams are the structural elements of industrial buildings that are most susceptible to destruction in emergency situations and abnormal operation are observed; the schemes for strengthening beams are proposed and the parameters’ analysis in comparison with a typical solution is given.

Introduction

The covering beam outcome into the emergency category, occurs mainly due to the loss of the support part bearing capacity [1, 2, 3, 4].

Currently, the issue of strengthening the support parts of reinforced concrete roof beams is mainly solved by means of a device containing a tension device and unloading brackets installed on the support part of the beam on both sides and connected to each other; made of two rod elements forming an acute angle, when the end of one rod element is connected to the top of the beam, and the end of the other element is connected to the bottom [5, 6]. The opposite ends of the rods are joined by the support plates located on both sides of the beam and connected by the strips installed at the end of the beam. The connection of the bar elements with the upper and lower parts of the beam is made by means of strips forming a box filled with concrete. The tensioning device is made in the form of a screw pair of a coupling and a stop pin. The sleeve is attached to each support plate, and the pin-stop is installed on the supporting structure on which the beam leans [7, 8]. Shaft elements of relief brackets, support plates and strips are located with a gap from the beam [9, 10].

However, this device does not effectively use the capabilities of the unloading brackets due to the lack of connection between them and the impossibility of transferring forces to each other [11, 12]. Because of this drawback, it is necessary to assign the dimensions of the brackets according to the maximum load on each element, and this is the additional weight of the device and the load on the beam.

It is proposed to strengthen the support parts of reinforced concrete beams of the covering, on both sides of the beam to install the unloading brackets in the form of a rod elements’ pair forming an acute angle, each end of rod elements located horizontally to connect to the bottom of the beam, and each end of rod elements located at an acute angle - with the upper part of the beam, the opposite ends of the bar elements are connected with the support plates located on both sides of the beam and connected by the strips [13]. Between the rod elements, mirrored on both sides additional tensioning devices connected to the rod elements, rigidly - with the upper element and flexibly, through a threaded connection, with the lower element, and the rod elements are rigidly connected to the upper and lower parts reinforced concrete girder, made in the form of anchors, are installed, as shown in Figure 1 for a duo-pitch roof.
beam. It is precisely due to the creation of adjustable forces in additional tensioning devices that an
increase in the bearing capacity and reliability of the supporting parts of reinforced concrete beams is
achieved, with the provision of the loads redistribution possibility not only between the rods of the
unloading brackets, but also between the reinforcing structure and the reinforced concrete beam.

Figure 1. Device for strengthening the supporting parts of reinforced concrete roof beams.

Materials and technique
In order to analyze the effect of unloading brackets, in the form of rod elements’ pairs made of steel
channels, installed on a beam with parallel chords of a square cross section, on its supporting parts
operation, numerical modeling was carried out in the software package Etabs 2019 [14]. Figure 2 shows
the sections of a reinforced concrete beam with a length \( L = 6 \) m, and Figure 3 shows the dimensions of
elements and parts.

As a result of numerical modeling, realized with a stepwise increase in concentrated loads \( F_1 \) and
\( F_2 \), acting at a distance of a quarter span from each support, the values of bending moments were
obtained, presented for the experiment No. 10 on Figure 4.

Figure 2. Cross sections taken into account for a reinforced concrete beam.
Figure 3. Dimensions of elements and parts in mm

Figure 5 shows a diagram of shear forces in a beam collapse situation. [15].

| Experiment (10) | Moment Scheme (kN.m) |
|----------------|----------------------|
|                |                      |

Figure 4. Bending moments plot in a beam

Figure 5. Plot of transverse forces during beam collapse

To illustrate the involvement of the reinforcing brackets in the work of the beam, Table 1 shows the values of the resulting transverse forces and moments, before and after reinforcing the beam with the brackets.

As it can be seen from Table 1, the concentrated loads on the beam are in some cases applied from both sides the same, and in other cases they are different. The influence degree of the reinforcing
brackets on the maximum moments in the beam, expressed as a percentage, of the applied loads’ values and the method of their application, is characterized as follows, presented in Table 2.

**Table 1.** Transverse forces and moments in beam sections from concentrated loads.

| Experiment number | Applied loads (T), on distance L/4 (m) | Moment (max) in unpowered nom field (kNxm) | Moment (max) in enhanced field (kNxm) | Transverse force (max) in unreinforced field (kN) | Transverse power (max) in enhanced field (kN) | Beam collapse (yes / no) |
|-------------------|--------------------------------------|------------------------------------------|---------------------------------------|---------------------------------------------|---------------------------------------------|------------------------|
| 1                 | 6                                    | 105.01                                   | 100.85                                | 64.5                                        | 73.89                                       | no                     |
| 2                 | 6                                    | 112.98                                   | 104.3                                 | 66.94                                       | 81.25                                       | no                     |
| 3                 | 7                                    | 119.36                                   | 115.12                                | 74.3                                        | 83.7                                        | no                     |
| 4                 | 7                                    | 127.2                                    | 118.57                                | 76.75                                       | 91.1                                        | no                     |
| 5                 | 8                                    | 133.6                                    | 129.38                                | 84.1                                        | 93.51                                       | no                     |
| 6                 | 8                                    | 141.5                                    | 132.84                                | 86.55                                       | 100.86                                      | no                     |
| 7                 | 9                                    | 147.89                                   | 143.65                                | 93.9                                        | 103.3                                       | no                     |
| 8                 | 9                                    | 155.77                                   | 147.1                                 | 96.36                                       | 110.67                                      | no                     |
| 9                 | 10                                   | 162.15                                   | 157.9                                 | 103.7                                       | 113.1                                       | no                     |
| 10                | 10                                   | 170.04                                   | 161.14                                | 106.17                                      | 120.5                                       | yes                    |

**Table 2.** Assessment of the influence degree of reinforcing brackets on the maximum moments in the beam.

| Experiment number | 1 | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-------------------|---|----|----|----|----|----|----|----|----|----|
| The difference of moments in enhanced field and in non-enhanced field, % | 3.96 | 7.7 | 3.55 | 6.78 | 3.15 | 6.12 | 2.86 | 5.56 | 2.62 | 5.23 |

**Summary**

Reinforcement of the supporting part of the reinforced concrete beam with unloading brackets, in the form of a bar elements’ pair, increases the bearing capacity of the reinforced concrete beam, and with the same loads on both sides of the supporting parts of the beam, the bending moment is increased by 4%, at the minimum values and by 2.62% at the maximum load values. Whereas under unequal loads, the influence of the unloading brackets increases and reaches, at the minimum values, up to 7.7%, and at the maximum loads - up to 5.23%.

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