Strengthening of a node of connection of floor slabs with racks in structural systems with and without a crossbar framework

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Abstract. The article deals with different options for strengthening node of connection of floor slabs with racks in systems with and without a crossbar framework. Modeling of the strengthened nodes in the environment of SCAD has been made, the analysis and comparison of numerical calculation data to select the most rational option of strengthening is carried out.

1 Introduction

As a result of natural tests of the constructive cell of the beamless floor which is built in the system of a framework KUB-1, mal distribution of deflections and violation of regularity of fields of tension in material of floor slabs in zones of their interface to framework columns, and, respectively, insufficient and different rigidity of these knots was revealed [1, 2, 3].

The identified problems indirectly demonstrate a violation of the production technology of the joints at a building site as in a framework of KUB-1 system all interfaces of structural elements must to have the same rigidity [4].

Respectively, there was a need to develop new technical solutions to strengthening the nodes of connection of floor slabs with framework racks for the safety of constructive systems with and without a crossbar framework.
According to the project documentation for construction of buildings and constructions for the KUB series without small caps joint of floor slabs with columns (figure 1) it is carried out by welding of special metal elements with the subsequent monolithic assembly nodes. The opening in a plate of overlapping is framed with a rolling corner.

Several options of the modified node of connection floor slabs with a column (figure 2) were developed. In 1 option (figure 2, a) the device of a metal holder from a rolling corner on top and bottom of the joint is supposed (I will perhaps embrace to arrange only on top – option 1 *). Corners are fastened with welding to embedded parts of a plate, and to a column anchor bolts or pins. In the 2nd option (figure 2, b) strengthening of the existing node is carried out by adding rods of horizontal fittings laid in mutually perpendicular directions on top of a plate and passing through a column. In the 3rd option (figure 2, c) strengthenings the device of the top holder consisting of the rolling corners having anchoring from a column on a plate is meant.
Figure 1. A node of connection of floor slabs with racks without crossbar framework: 1 – embedded part connecting a column rod to an embedded part of floor slabs; 2 – concrete monolithic seal

Figure 2. Modeling of nodes of connection floor slabs with a column in without a crossbar framework

2 Materials and methods

To compare of the efficiency of the presented strengthening options in terms of unloading of node by decrease in the perceived efforts computer modeling
and calculation for durability and for deformations of nodes of connection of floor slabs with a column by means of the SCAD computer system on the constant and live evenly distributed load were made.

3 Results

Isofields of tension arising in overlapping plate material taking into account strengthening by 1 option and without it are in fig. 3, 4. The received values of deflections of a plate in over columned and a console part, the normal and tangent tension arising in connection node on top and low without trabeation are given in table 1.

![Isofields of tension of Nx (t/sq.m) in material over a column of a part of floor slabs of serial node (without strengthening)](image)

Figure 3. Isofields of tension of Nx (t/sq.m) in material over a column of a part of floor slabs of serial node (without strengthening)
Figure 4. Isofields of tension of Nx (t/sq.m) in material over columned part of a plate of the node strengthened by option 1

Table 1. Comparison of ways of strengthening of node of connection of a floor slabs with a column in without a crossbar framework.

| Parameter, units of measure | Option of execution of knot |
|----------------------------|-----------------------------|
|                            | without strengthenings | 1 | 1* | 2 | 3 |
| $Z^{\text{in}}$, ММ        | -0,28                     | -0,17 | -0,21 | -0,23 | -0,19 |
| $Z^{\text{out}}$, ММ       | -0,74                     | -0,51 | -0,59 | -0,64 | -0,61 |
| $N_{x}^{\text{even, even}}$, t/M$^2$ | 137±161                | 135±15 | 137±160 | 116±13 | 133±156 |
|                            | 9                         | 170 | 160 | 155 |
| $N_{x}^{\text{even, odd}}$, t/M$^2$ | -144±-168              | -147±- | -137±- | -134±- | -137±-160 |
|                            | -170/3                   | 147±17 | 169±200 | 187±22 | 218±254 |
| $N_{y}^{\text{even, even}}$, t/M$^2$ | 225±264                | 184 | 228 | 245 | -210±-245 |
| $N_{y}^{\text{even, odd}}$, t/M$^2$ | -237±-276              | -158±- | -197±- | -212±- | -210±-245 |
| $N_{z}^{\text{even, even}}$, t/M$^2$ | 67                      | 44 | 62 | 57 | 48 |
| $N_{z}^{\text{even, odd}}$, t/M$^2$ | -67                     | -49 | -44 | -56 | -44 |
| $T_{xy}^{\text{even}}$, t/M$^2$ | ±(85±100)               | ±(14±17) | ±(28±37) | ±(70±8) | ±(74±87) |
| $N_{x}^{\text{arm}}, $т   | -1,05                     | -0,79 | -0,86 | -0,91 | -0,86 |
| $Q_{z}^{\text{arm}}, $т   | +0,43                     | +0,26 | +0,34 | -0,35 | -0,27 |
Notes:
- $Z^v, Z^w$ – vertical shift of a plate in over columned and a console part;
- efforts are taken at a loading "a body weight a live load";
- for steel C245 $R=240$ MPa $=24465$ t/m$^2$;
- $N^{vI}$ – tension in material in over columned part of a plate (– plate top stretching; – plate bottom compression);
- $N_x^{vI}$ – longitudinal effort in working fittings of a column;
- $Q_z^{vI}$ the cutting effort operating on working fittings of a column;
- $N^I$ – the effort in the entered embedded part is obese overlapping plates;
- in nodes 1 и 1* the corner of strengthening is simulated by a plate, i.e. only one shelf of a corner.

Data for comparison of ways of strengthening on the power factors arising in elements of strengthening (table 2) can be used for reasonable selection of the sizes of the strengthening elements, decreasing a materials capacity and costs for strengthening of node of connection of a plate of overlapping with a column.

**Table 2.** Comparisons of options on power factors in strengthening elements.

| Param | Nodet, strengthening element | 1, holder from a corner on top and low plates | 1*, holder from a corner on top plates | 2, re-bars | 3, holder from a corner with anchoring |
|-------|-------------------------------|---------------------------------------------|--------------------------------------|-----------------|-------------------------------------|
| $Z$, mm |                              | $-0,15$                                     | $-0,17$                             | –               | –                                   |
| $N_x$, t |                              | –                                         | –                                    | $1,14$          | $1,22$                             |
| $N_y$, t/sq.m | $1003 \div 1765$ | $1369 \div 2160$ | –                                   | –               |                                    |
| $N_y$, t/sq.m | $1007 \div 1772$ | $1373 \div 2167$ | –                                   | –               |                                    |
| $Q_z$, t |                              | –                                         | –                                    | $-0,17$         | $+0,39$                             |
| $M_y$, t |                              | –                                         | –                                    | $\pm 0,01$      | $\pm 0,02$                         |

4 Discussion
During the first decade of the 21st century many regulations and rules in the field of construction have been changed fundamentally in Russia in particular:
- when reissuing in 2000 Construction Norms and Regulations of II-7-81 * [5] and replacement of maps of the general seismic areas with new OSR-97 maps the seismicity of a number of territories was increased, the deficiency of seismic stability of urban development respectively increased;
- buildings with a beamless floor framework do not meet the requirements of the joint venture 31-114-2004 [6] which was put into operation in 2005 and containing a number of restrictions for construction of such frameworks in seismic countries and also the revised edition Construction Norms and Regulations of II-7-81 * [7], put into operation by the Ministry of Regional Development of the Russian Federation in 2011;
- in 2003 the requirements of construction standards Construction Norms and Regulations 2.01.07-85 * [8] by weight of snow cover increased.

As a result a large number both operated, and the unfinished buildings designed on former norms do not meet modern requirements.

The current situation require say assessment of bearing capacity and suitability for normal operation of structures of the existing buildings and also search for new options of strengthening the constructive systems applied in construction.

In Russia the constructive systems with without a crossbar framework which are characterized by quickness of construction, architectural expressiveness and free inner lay out with simultaneous ensuring durability, reliability and stability of the building were widespread.

There is a large number of scientific publications on the problems of using constructive systems with without a crossbar framework in construction practice, however information on pilot studies of work of such systems under load is very limited, there are no accurate recommendations about ensuring spatial rigidity of the building [4, 9, 10, 11, 12]. Besides, considerable shortcomings – complex technology and, respectively, labor of the joints between plates and plates with racks in the known constructive systems that often leads to reduction reliability of a system.

Therefore, it is very important to study deflected mode of girderless structures in order to find effective options to increase the reliability and seismic stability of buildings.

5 Conclusion
Analyzing the data of table 1 it is possible to note that:

– efforts \( (N^p_{ar} \text{ и } Q^p_{ar}) \) have the smallest absolute values for 1 option of strengthening. Respectively, its application will allow to raise degree of static indefinability of a design and will lead to redistribution of efforts at a loader without frame plate, to formation of plastic hinges [4] and decrease in a vertical load;

– the greatest decrease in deformations \( (Z_{nch}, Z_{kch}) \), and, therefore, reduction of tension in plate material \( (N_x, N_y, N_z, T_{xy}) \), is also observed for 1 option of strengthening.

By the results of comparison of options for reasons of efficiency of decreasing in force factors in an over a columned part of a floor slabs and labor coefficient of elements of strengthening 1 option is most preferable. Application of such method of strengthening will increase the rigidity of a horizontal disk of overlapping and increase seismic stability of a constructive system.

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