Comparison of experimental and theoretical data for steel fiber reinforced concrete slabs on ground under a point load according to design codes of the Republic of Belarus and the Russian Federation

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Comparison of experimental and theoretical data for steel fiber reinforced concrete slabs on ground under a point load according to design codes of the Republic of Belarus and the Russian Federation

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Abstract. Fiber reinforced concrete is a perspective construction material. But there is still a lack of calculation methods for that material. Some calculation methods for steel fiber reinforced concrete structures are offered in the Republic of Belarus and the Russian Federation design codes. The comparison has been made for experimental and theoretical data concerning steel fiber reinforced concrete slabs on ground under a point load. Mean value correction factors and coefficients of variation of the error terms have been determined. Determination of those values is a first step to further reliability index determination.

1. Introduction
Fiber reinforced concrete is one of the perspective construction materials. Such a concrete belongs to a vast class of composite materials which are widely used in different industries. In fiber reinforced concrete fibers are uniformly distributed inside the concrete matrix. Fibers themselves can be either metallic or nonmetallic, either mineral or organic. The name of the material depends on the fibers origin — steel fiber reinforced concrete, glass fiber reinforced concrete and so on.

Steel fibers inside the concrete matrix are randomly distributed. In plain concrete microcracks unite into macrocracks which leads to failure or loss of important qualities, such as water permeability, freeze-thaw resistance, resistance to aggressive substances and so on. In case of steel fiber reinforced concrete the opening of microcracks is restricted with steel fibers. Random fiber distribution makes it possible to control cracks in various directions.

2. Research objectives
The main research objective is to estimate the reliability of current calculation methods for steel fiber reinforced concrete (SFRC) slabs on ground (industrial floors).

In order to achieve the objective it is necessary to fulfill the following tasks:
1. To collect information concerning current calculation methods for SFRC slabs on ground and analyze them.
2. To collect information concerning experimental data for SFRC slabs on ground.
3. To perform analysis of bearing capacity of SFRC slabs on ground according to the chosen calculation methods.
4. To make a comparison between theoretical and experimental bearing capacity values.

3. Calculation methods

In this paper SFRC slabs on ground are analyzed according to methods offered in the following codes:
— TCP 45-5.03-300-2015 “Steel fiber concrete products and structures. Design rules” (Republic of Belarus) [1];
— SP 29.13330.2011 “Floors” (Russian Federation) [2].

3.1. TCP 45-5.03-300-2015 “Steel fiber concrete products and structures. Design rules” calculation method

The code is used for SFRC cross section design. The sequence of calculations needed to determine the ultimate bending moment is described hereafter.

In order to determine the SFRC tensile strength $f_{\text{ftd}}$ it is essential to define the failure variant.

Fiber anchorage length:

$$l_{f,an} = \frac{\eta d_f f_{fk}}{f_{ck}},$$

where $d_f$ – fiber diameter, $f_{fk}$ – characteristic fiber tensile strength, $f_{ck}$ – characteristic concrete compressive strength.

The $\eta$ coefficient has a tabulated value.

If $l_{f,an} < \frac{l_f}{2}$ then failure occurs due to fibers being torn apart (failure variant 1). In that case the SFRC tensile strength is calculated according to 7.2.6 [1]:

$$f_{\text{ftd}} = 1.1 f_{cd} \left[ K_T k_{or} \rho_{fv} \cdot \frac{f_{fd}}{f_{cd}} \left(1 - \frac{l_{f,an}}{l_f}\right) + 0.08 - 0.1 \cdot \sqrt{2 \rho_{fv} - 0.005}\right],$$

where $f_{cd}$ – concrete compressive strength, $K_T$ – tabulated coefficient, $k_{or}$ – fiber orientation coefficient for cross sections in tension, $\rho_{fv}$ – fiber volume percentage, $f_{fd}$ – fiber tensile strength, $l_f$ – fiber length.

If $l_{f,an} \geq \frac{l_f}{2}$ then failure occurs due to fibers being pulled out (failure variant 2). In that case the SFRC tensile strength is calculated according to 7.2.7 [1]:

$$f_{\text{ftd}} = 1.1 f_{cd} \left[ K_T \cdot \frac{k_{or} \rho_{fv} l_f}{8\rho_{fv}} + 0.08 - 0.5 \rho_{fv}\right].$$

The SFRC compressive strength is defined as follows:

$$f_{\text{fcd}} = f_{cd} + k_n \varphi_f \rho_{fv} f_{fd},$$

where $k_n$ – fiber orientation coefficient for cross sections in compression, $\varphi_f$ – fiber confinement reinforcement efficiency coefficient.

Coefficients $k_{or}$ and $k_n$ have tabulated values.

The fiber confinement reinforcement efficiency coefficient:

$$\varphi_f = \frac{5 + L}{1 + 4.5 L},$$

where

$$L = \frac{k_n^2 \rho_{fv} f_{fd}}{f_{cd}}.$$ 

According to 7.2.12 [1] the SFRC compressed zone characteristics:

$$\omega = 0.8 - 0.008 f_{\text{fcd}}.$$
The relative compressed zone height limit:

\[ \bar{\xi}_{\text{lim}} = \frac{\omega}{1 + \frac{\sigma_{sR}}{\sigma_{sc,u}} \left( 1 - \frac{\omega}{1.1} \right)} \]  (8)

Compressed zone height:

\[ x = \frac{f_{fcu}h}{f_{cd} + f_{fcd}} \]  (9)

\[ \bar{\xi} = \frac{x}{h} \leq \bar{\xi}_{\text{lim}}, \]  (10)

where \( h \) – cross section height.

The ultimate bending moment:

\[ M_{kd} = 0.5f_{cd}bhx. \]  (11)

3.2. SP 29.13330.2011 “Floors” calculation method

The code offers the theory to determine forces acting in the floor slab under loads of different configurations and also the bearing capacity of the slab.

Hereafter is the calculation method for a floor slab under a point load.

The ultimate bending moment:

\[ M_{ult} = f_{fcd} \frac{h^2}{3.5}, \]  (12)

where \( f_{fcd} \) is SFRC tensile strength.

The ultimate point load:

\[ P_{ult} = \frac{M_{ult}}{K_1}. \]  (13)

The \( K_1 \) coefficient has a tabulated value and depends on the load area dimensions and the radius of relative stiffness.

4. Experimental data

The database contains 11 specimens. The data used is presented in table 1.

| No. | Reference | Authors         | Slab dimensions (mm) | Fiber dosage (kg/m³) | Modulus of subgrade reaction (N/mm³) | Failure load (kN) |
|-----|-----------|----------------|----------------------|----------------------|--------------------------------------|-------------------|
| 1   |           | Meda, Plizzari | 3000x3000x150        | 30                   | 0.0785                               | 265               |
| 2   |           |                | 3000x3000x150        | 30                   | 0.0785                               | 238.6             |
| 3   | [3]       | Meda, Plizzari |                      | 30                   | 0.0785                               | 252.3             |
| 4   |           |                | 3000x3000x150        | 30                   | 0.0785                               | 246.2             |
| 5   |           |                | 3000x3000x150        | 45                   | 0.0785                               | 231.9             |
| 6   |           | Beckett        | 3000x3000x150        | 20                   | 0.035                                | 350               |
| 7   | [4]       | Beckett        | 3000x3000x150        | 20                   | 0.035                                | 390               |
| 8   |           | Beckett        | 3000x3000x150        | 30                   | 0.035                                | 340               |
| 9   |           | Beckett        | 3000x3000x150        | 30                   | 0.035                                | 345               |
| 10  | [5]       | Faulkner       | 3000x3000x150        | 20                   | 0.025                                | 240               |
| 11  |           | Faulkner       | 3000x3000x150        | 30                   | 0.050                                | 380               |
5. Calculation results and comparison of experimental and theoretical data

Eleven specimens were analyzed according to the following schedule:

1. Determination of ultimate bending moments according to [1] and [2].
2. Determination of ultimate point load according to [2].

Thus, for each specimen two ultimate point load values were obtained.

The results are presented in table 2.

Table 2. Calculation results (theoretical data).

| No. | Ultimate point load according to [2] (kN) | Ultimate bending moment calculated according to [1] | Ultimate bending moment calculated according to [2] |
|-----|----------------------------------------|---------------------------------------------------|---------------------------------------------------|
| 1   | 267.51                                 | 165.09                                            |                                                   |
| 2   | 269.30                                 | 166.28                                            |                                                   |
| 3   | 273.37                                 | 168.74                                            |                                                   |
| 4   | 233.94                                 | 144.27                                            |                                                   |
| 5   | 264.73                                 | 163.13                                            |                                                   |
| 6   | 290.18                                 | 180.53                                            |                                                   |
| 7   | 293.49                                 | 182.78                                            |                                                   |
| 8   | 291.58                                 | 180.91                                            |                                                   |
| 9   | 297.13                                 | 184.65                                            |                                                   |
| 10  | 262.42                                 | 163.30                                            |                                                   |
| 11  | 272.82                                 | 169.42                                            |                                                   |

Visual representation of theoretical values compared with experimental values can be seen on figure 1.

Figure 1. Experimental and theoretical ultimate point load values.
Theoretical ultimate point load values calculated with the use of ultimate bending moments according to [2] are much lower than experimental values. The average difference between these values equals to 41%. At the same time the use of ultimate bending moments calculated according to [1] leads to more accurate results. The average difference between experimental and theoretical values in that case equals to 5%.

In order to provide more accurate statistical description of obtained results the mean value correction factor $b$ and the coefficient of variation of the error terms $V_\delta$ can be calculated according to [6].

**Table 3.** Mean value correction factors and coefficients of variation of the error terms.

| | Ultimate point load according to [2] | Ultimate bending moment calculated according to [1] | Ultimate bending moment calculated according to [2] |
|---|---|---|---|
| $b$ | 1.093 | 1.764 |
| $V_\delta$ | 0.166 | 0.164 |

**6. Conclusions**

Design codes [1] and [2] provide methods for calculating ultimate point loads for SFRC slabs on ground. The point load itself is calculated according to [2] using ultimate bending moments for SFRC cross sections determined according to [1] or [2]. The best convergence between experimental and theoretical data is reached when ultimate bending moments are calculated according to [1].

This work is the first step to determine the reliability index of described methods of calculation of SFRC slabs on ground under a point load.

**References**

1. TCP 45-5.03-300-2015 “Steel fiber concrete products and structures. Design rules”. Republic of Belarus Architecture and Construction Ministry, 2015, 48 pp.
2. SP 29.13330.2011 “Floors”. Russian Federation Regional Development Ministry, 2011, 68 pp. Sorelli L G, Meda A, Plizzari G A 2006 Steel Fiber Concrete Slabs on Ground: A StructuralMatter *ACI Structural Journal* 103-S58 551-558.
3. Beckett D 1990 Comparative Study on Plain, Fabric Reinforced and Steel Fiber Reinforced Concrete Ground Slabs *Concrete* 3 43-45.
4. Faulkner H, Huang Z, Teutsch M 1995 Comparative Study of Plain and Steel Fiber Reinforced Concrete Ground Slabs *Concrete International* 1 45-51.
5. EN 1990:2002. Eurocode – basis of structural design, 119 pp.