ISSN 2413-1032

DEFORMATION OF STEEL FIBER CONCRETE SLABS THAT ARE COUNTER SUPPORTED UNDER RECURRING LOAD

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Abstract. *Experimental and theoretical researches were conducted tensely deformed to the state one, and two-layer concrete, reinforce-concrete and steel fiber concrete slabs under the action of the transversal loading.*

By the general picture of bandings of slabs at the repeated loadings, up to their destruction there is the by turn passing of three stages of work of construction. It is the stage the elastic work to appearance of the first crack, stage of exploitation, that works with cracks and stage of destruction.

At studied deformations of supported on four sides slabs under the action in loading the calculation of own experimental researches and comparison of the experimental bindings of the noted slabs with theoretical calculations after different methods and operating normative documents.

Keywords: *fiber, steel fiber concrete, composite material, deflection, slab.*

They have been searching for the most effective building materials lately. One of these materials is steel fiber concrete. Steel fiber concrete has been successfully used in building for several decades and that is why this material should be paid special attention.

From the point of view of new forms using combined layer constructions is very efficient. It has been proved in practice that the most effective and useful is using one and two-layer systems where the lower layer is made of reinforced concrete and the upper one from steel fiber concrete.

To compare how layer constructions work we conducted experimental research of strained-deformed conditions of one and two-layer concrete, reinforced and steel fiber concrete slabs under cross small-cycle load. The volume and characteristics of the experimental samples are shown in table 1. The type of the used steel fibers and their characteristics is given in table 2.

Table 1. Volume of the experimental research

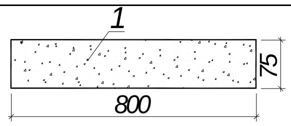
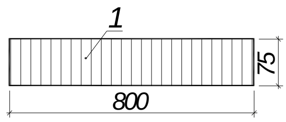
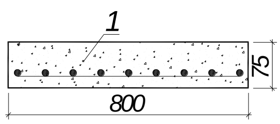
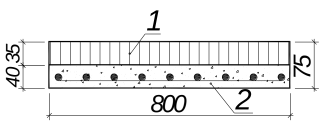
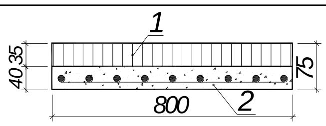
№ серії	Grade	Sample type	Number, unit	Crosscut	Composition
I	PB-1	Concrete slab	3		1 - concrete (throughout the full volume)
II	PF-1	Fiber concrete, fiber type Ф-1	3		1 – fiber concrete (throughout the full volume)
	PF-2	Fiber concrete, fiber type Ф-2	3		
III	PZ-1	Reinforced concrete slab, reinforcement Ø 5 mm class Bp-I	3		1 - concrete (throughout the full volume)
	PZ-2	Reinforced concrete slab, reinforcement Ø 8 mm class A500C	3		
IV	PFZ-1	Two-layer slab (iron+fiber concrete, fiber type Ф-1)	3		1 - fiber concrete 2 - reinforced concrete
	PFZ-2	Two-layer slab (iron+fiber concrete, fiber type Ф-2)	3		
V	PFZK-1	Two-layer slab (iron+fiber concrete, fiber type Ф-1, Ф-2 — cocktail	3		1 - fiber concrete (cocktail) 2 – reinforced concrete

Table 2. Characteristics of the fibers used in the experimental samples

№	Description	Diameter, mm	Length, mm	Height, mm	General view (rough drawing)
1.	Fiber made of wave-like wire, type F-1	1,0	50,0	2,0	
2.	Fiber made of wire with anchor ends, type F-2	0,75	30,0	2,9	

As samples we used slabs sized 800×800×75 mm.

To compare the deformation characteristics of slabs we tested one-layer (series I, II, III) and two-layer slabs (series IV, V), where steel fiber concrete layers were placed above (in the compressed zone), see table 1. In order to detect the degree of combined slab work we tested one-layer slabs of series I, II, III — concrete, steel fiber concrete and reinforced concrete. Steel fiber concrete has no additional reinforcement bar because the research of different authors proves inefficiency of such reinforcement.

To reinforce concrete slabs we used reinforcement Ø 5mm class Bp-I and reinforcement Ø 8 mm class A500C. The reinforcement bars in series III, IV, V are placed in the stretched zone with the protective concrete layer of 15 mm thick.

During the transversal loading of as one-layer so as two-layer slabs we used one calculation scheme – the slab is hinged supported by the counter line and evenly loaded with distributed load.

During the loading process the deflection was registered in the slab center and also deformations above the supports with the help of clock indictor of grading point 0,01 mm. The concrete deformation was detected on the lower and upper sides with the tensor-resistors of base 50 mm.

The deformation character of the tested samples in the crack zone depends on the crack scheme that is on the cracks orientation to the reinforcement direction, mutual crossing of cracks and appearance of cracks ether on one or both sides of the element (cross-cutting or not cross-cutting cracks). Cross-cutting cracks appear at a no-moment loaded condition or at additional action of little moments.

The accepted constrictive solutions and methods of testing realize different types of samples ruining: without cracks in the compressed zone and with cracks in the compressed zone.

The general picture of slabs deflection at the repeated load up to their ruin is a gradual passing through three stages (picture 1). They are a stage of elastic work up to the crack appearance, the exploitation stage that is work with cracks and the stage of sample ruining.

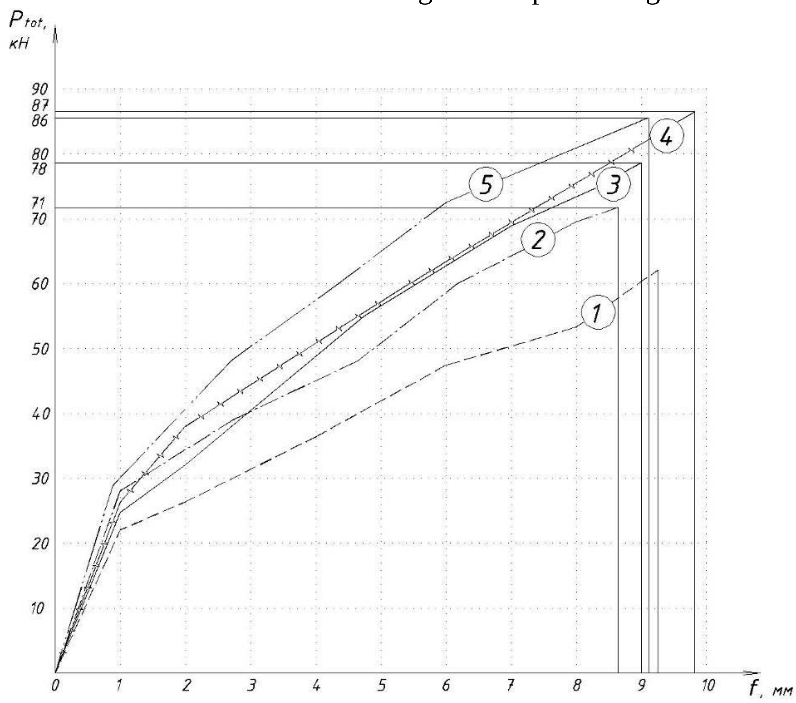


Fig. 1. The diagram of deflection in the center of the researched slabs.
1 — slabs of type PF; 2 — slabs of type PB; 3 — slabs of type PZ; 4 — slabs of type PFZ;
5 — slabs of type PFZK

In picture 2 we can see the photo of the breakage character of the experimental slab samples. The analysis of the slabs reinforcement scheme proves the predicted traditional character of slabs ruin loaded evenly. On the lower slab side the cracks directed to the angle bisectors and form the so called «envelope». The upper slab side is ruined along the crack lines depending on the material of the compressed zone. So, in slabs I, III series that had the compressed zone made of non-reinforced concrete the ruin took place along the crack lines that almost reproduced the crack lines of the lower slab sides. The slabs of series II, IV, V, where the compressed zone is steel fiber concrete was almost not ruined.

Having analyzed the deflection results of the different series slabs in the compressed zone we came to the conclusion that it was sensible to take the triangle form of tension diagram for series I, II, and the rectangle one for series III, IV, V.

The criterion of thin slabs ruining one must consider splitting into flat parts joined along the crack lines with plastic hinges.

The deflection analysis allowed establishing process regularities depending on constructive characteristics of the tested slabs. Despite the fact that strength and deformation characteristics of one-layer and two-layer slabs were close to each other we could observe tendencies to differ in their exploitation characteristics.

So, it was established that one-layer slabs had bigger deflections than one-layer ones had. Whereas one-layer slabs in the stretched zone were more elastic in comparison with one-layer non-reinforced slabs made of steel fiber concrete. It was caused by the increase of elasticity module of steel fiber concrete in comparison with heavy concrete and with a smaller width of crack opening.

Two-layer slabs had general deflections of 12-20% smaller than one-layer slabs had. It was conditioned by the increased mentioned module of elasticity due to the layer of steel fiber concrete. This tendency to deflection remains at the exploitation load level — $(0,7\ldots0,8)P_u$

Studying deformations of the counter supported slabs under the action of repeated small-cycle even load we give the results of our own experimental research and its comparison with the theoretical calculations of different methods.

First of all we checked the correspondence of the received deflections by the elasticity theory formula. Based on the formula (1) of B. G. Galerkin for a square slab supported on the counter the slab center deflection under the evenly distributed load is:

$$f = 0,04706 \frac{ql^4}{E_i h^3}, \qquad (1)$$

where q - evenly distributed load;

l - calculated slab span;

h - slab height;

$E_i = E_c = E_f$ - elasticity module corresponding to heavy concrete and steel fiber concrete.

To compare the results of slabs deflection we applied the technique of V. N. Murashev who used the formula of B. G. Galerkin and expressed cylindrical rigidity through inelasticity per unit of the slab width. Such a technique is recommended by Construction Norms and regularities 2.03.01-84.

ISSN 2413-1032

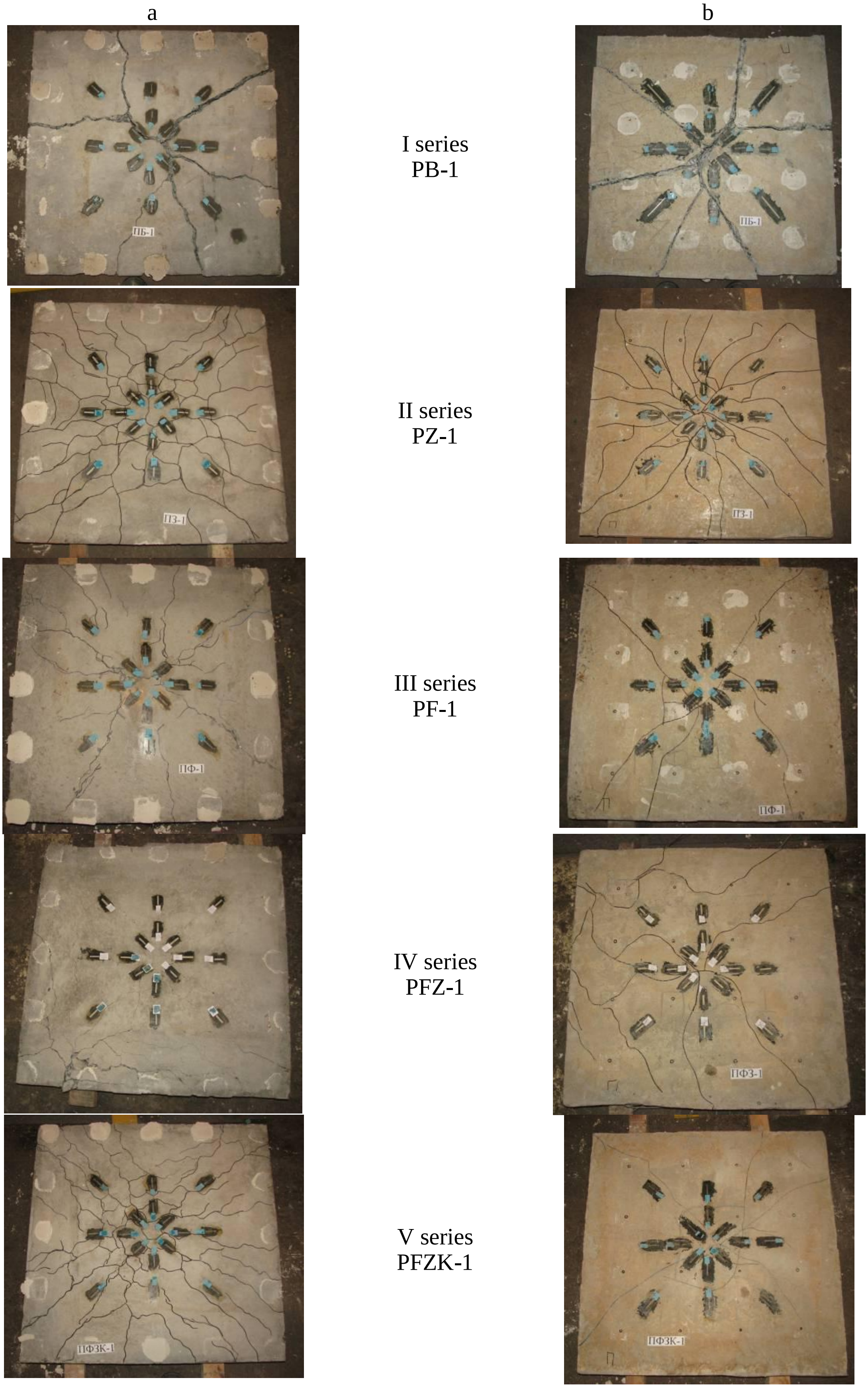


Fig 2. The general view of ruin character of the upper and lower slab surfaces.
a — the lower slab surface; b — the upper slab surface

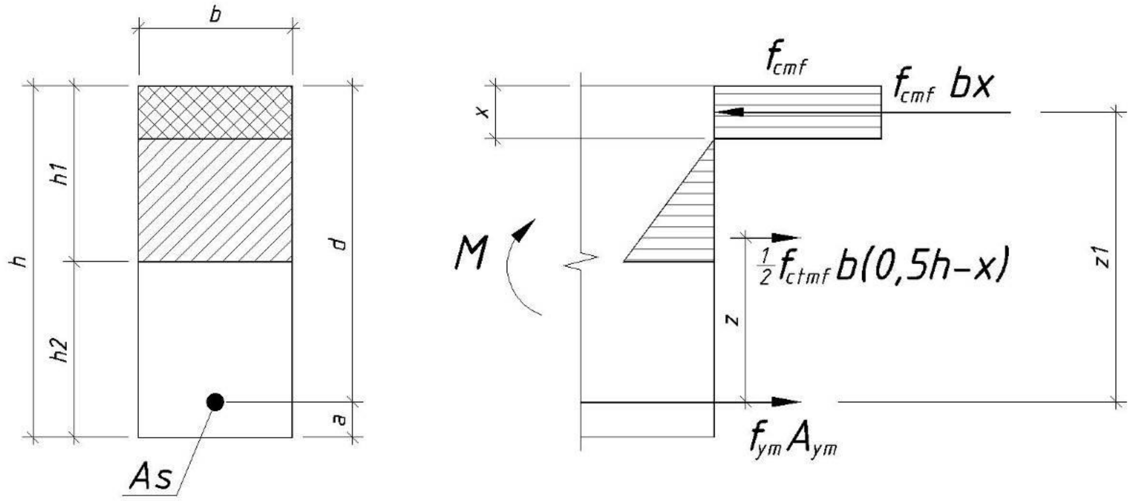


Fig. 3. The stress scheme in the slab crosscut.

Under load and rigidity the deflection f looks as follows (2):

$$f = \frac{1}{248} \times \frac{ql^4}{B} \approx 0,004 \frac{ql^4}{B} \quad (2)$$

The rigidity of reinforced concrete crosscut at bending is detected by the stretched zone of one-layer slab (3):

$$B = \frac{E_s}{\psi_s} z \times A_s (d - x), \quad (3)$$

where A_s - square of the working reinforcement;

E_c - initial elasticity module;

d - usable height of the bending element;

ψ_s - coefficient that accounts the work of the stretched concrete with cracks;

$\tilde{o}$ - height of the concrete compressed zone in the regular crosscut with a crack and it is established by the formula (4);

$$x = \frac{\varepsilon_c}{\varepsilon_c + \varepsilon_{su}} h, \quad (4)$$

where ε_c - relative deformation of the compressed concrete;

h - total height of steel fiber concrete crosscut (working height of the reinforced concrete crosscut);

$\varepsilon_{su} (\varepsilon_{ftu})$ - limited relative deformation of the stretched reinforcement (stretched steel fiber concrete);

z - distance from the load center of the stretched reinforcement to the point of the concrete in the compressed zone under the even (5);

$$z = d - \frac{x}{3} \quad (5)$$

For the steel fiber concrete slab the formula (3) is as follows:

$$B_f = \frac{E_s}{\psi_s} z \times b \times x(h - x) \quad (6)$$

Doing the calculations of two-layer slabs we change the elasticity module of one material into the given E_{red} , taking into account the height of the stretched zone of each material. By analogy we calculate the square of the stretched zone A_{red} , the support moment W_{red} and etc.

According to State Standard of Ukraine B V.1.2-3 the relative slabs deflection is standardized. The limited deflections are regulated by the constructive, physiological and technological requirements. For the elements of building constructions and structures the vertical deflection under permanent, short-term and long-term stress must not be over 1/150 of span.

We calculated deflection of counter supported slabs for one-layer and two-layer slabs and compared the results with the experimental data. It is necessary to remember to agree the described calculation parameters with the material properties: concrete, steel fiber concrete, reinforcement.

The calculation results are shown in table 3, where the analytical calculations are compared with the experimental data.

Table 3. Comparison of calculated and experimental slabs deflection

№ of series	Grade	Stress calculation, кН P_u	Deflection calculation, f, mm			Experimental deflection that correlate to 0,75 P_u f, mm
			by the formula (1)	by the formula (2)	According to State Standard of Ukraine B V.1.2-3 1/150L	
I	PB-1	46,6	0,22	4,28	4,66	4,98
II	PF-1	51,2	0,21	4,21		5,92
	PF-2	49,7	0,20	4,23		4,91
III	PZ-1	62,4	0,26	4,96		4,15
	PZ-2	84,8	0,21	4,75		4,06
IV	PFZ-1	64,5	0,31	4,58		3,83
	PFZ-2	65,1	0,32	4,62		3,79
V	PFZK-1	65,3	0,30	4,61		3,87

The received data gives us possibility to analyze how the experimental samples are affected and deformed depending one layers made of different material, different characteristics of heavy concrete, steel fiber concrete and reinforcement.

As it is proved by the received data (table 1), the suggested calculations by the analytical methods according the current regulating documents and the experimental data they lack the required accuracy and demand the improvement of calculation technique. The maximum error is within limits of 13-20%.

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