UDC 624.012.45

EXPERIMENTAL STUDIES OF DEFORMABILITY AND FRACTURE RESISTANCE OF AIRFIELD SLABS ON MODELS

I. Korneieva[1], D. Kirichenko[1], O. Shyliaiev[1]
[1]Odesa state academy of civil engineering and architecture

Abstract. The results of experimental studies of deformability and crack resistance of models of aerodrome slabs made of reinforced concrete and steel-fiber concrete, made on the basis of serial slab PAG-18 taking into account the scale factor, are presented. Two series of slabs were tested - two models of reinforced concrete and two models with one-percent dispersed reinforcement. The load was applied in steps, the instrument readings were recorded twice at each step and the crack opening width was measured starting from the moment of the first crack formation. Dial gauges, deflectometer and microscope MPB-3 were used as measuring instruments. In accordance with the normative documents acting in Ukraine, one of two possible loading schemes was considered - with the loading by the concentrated force applied in the span part of a plate which had a hinged support along its short sides. Plate models were tested on a specially made stand. Each load step ended with a five-minute dwell time, at the beginning and the end of which readings were taken on the measuring instruments. The deformations at the same levels were measured with dial gauges. The process of crack formation was observed with a Brinell tube in the places of the greatest crack opening.

Breaking load for fiber concrete slab was 1.52 times higher than for reinforced concrete slab, and the moment of cracking initiation was 1.22 times higher. The process of cracking in the fiber concrete slab begins at higher loads than in the reinforced concrete slab. The initial crack opening width of the slabs is almost the same, and the final crack opening width of all the cracks in the fiber concrete slab is significantly lower than in the reinforced concrete slab.

The deformations in steel-fiber concrete slabs when the load is applied in the span, both for compressed and stretched fibers, are higher than in reinforced concrete slabs. The experimental studies indicate that dispersed reinforcement of airfield slabs with steel fiber leads to their higher crack resistance.

Keywords: reinforced concrete, fiber concrete, airfield slab, deformability, crack resistance, experimental studies

ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ДЕФОРМАТИВНОСТІ І ТРІЩИНОСТІЙКОСТІ АЕРОДРОМНИХ ПЛИТ НА МОДЕЛЯХ

Корнеєва І. Б.[1], Кіріченко Д. О.[1], Шиляев О. С.[1]
[1]Одеська державна академія будівництва та архітектури

Анотація. Наведено результати експериментальних досліджень деформативності та тріщиностійкості моделей аеродромних плит з залізобетону та сталефібробетону, виготовлених на основі серійної плити ПАГ-18 з огляду на масштабний фактор. Випробувано 2 серії плит – дві моделі із залізобетону та дві моделі з одновідсотковим дисперсним армуванням. Навантаження прикладалося ступенями, на кожній ступені двічі фіксувалися показання приладів, а також, починаючи з моменту утворення першої тріщини, вимірювалася ширина розкриття тріщин. В якості вимірювальних приладів використовувалися індикатори годинникового типу, прогиноміри та мікроскоп МПБ-3. Відповідно до діючих в Україні нормативних документів, розглянуто одну з двох можливих схем навантаження – при навантаженні зосередженою силою, прикладеною в прогонової частини плити, яка мала шарнірне обпирання за короткими сторонами. Моделі плит випробовувалися на спеціально виготовленому стенді. Кожна ступінь навантаження закінчувалася п’ятихвилинною

https://doi.org/10.31650/2618-0650-2021-3-2-64-74

витримкою, на початку і в кінці якої знімалися показання на вимірювальних приладах. Деформації на тих же рівнях вимірювали за допомогою індикатора годинникового типу. Процес тріщиноутворення спостерігався за допомогою трубки Брінелля у місцях найбільшого розкриття тріщин.

Руйнівне навантаження для фібробетонної плити виявилося в 1,52 рази більше, ніж для залізобетонної, а момент початку тріщиноутворення – в 1,22 рази. Процес тріщиноутворення у фібробетонній плиті починається при більш високих навантаженнях, ніж у залізобетонній. Початкова ширина розкриття тріщин у плитах практично однакова, а кінцева ширина розкриття всіх тріщин у фібробетонній плиті істотно нижче, ніж у залізобетонній.

Деформації в плитах із сталефібробетону при додатку навантаження в прогонової частини, як для стиснених, так і для розтягнутих волокон вище, ніж у залізобетонній плити. Проведені експериментальні дослідження свідчать про те, що дисперсне армування аеродромних плит сталевою фіброю призводить до їх більш високої тріщиностійкості.

Ключові слова: залізобетон, фібробетон, аеродромна плита, деформативність, тріщиностійкість, експериментальні дослідження.

1 INTRODUCTION

Airfield slabs PAG are designed to form both temporary and permanent coatings for airfields and roads. Currently, such slabs are widely used for the arrangement of air transport runways, roads located on construction sites, bases for cranes and other industrial mechanisms and equipment. Being highly resistant to aggressive environments, the plates are widely used for arrangement of port areas, are a reliable coating for construction areas where special machinery on crawler tracks is actively moving. PAG slabs have proven themselves in the most adverse hydrogeological and climatic conditions, in regions where the temperature drops to - (50-60) C^o.

Structurally, the slabs are a solid reinforced concrete product of flat rectangular shape. The upper surface of the slabs is corrugated, which provides an increased coefficient of traction with the wheels of moving road and air transport. The construction of the boards includes special end caps that allow to weld the boards together. Depending on the thickness of the plate elements, which can be 140, 180 and 200 mm, we distinguish plates PAG-14, PAG-18, PAG-20.

Such slabs can be used repeatedly, which creates a significant economic effect.

Airfield slabs have a number of unique properties: high strength, frost resistance, low abrasion, high durability and crack resistance, seismic stability, etc.

Among the many mentioned factors determining the efficiency and durability of PAG slabs, the deformability and cracking resistance play the most important role, the study of which is given much attention during experimental studies. This paper describes the results of the experiment, which was conducted in the scientific laboratory of the Department of Structural Mechanics of the Odessa State Academy of Civil Engineering and Architecture - deformability and crack resistance of models of airfield slab PAG-18 under the span scheme of loading - one of the two schemes of loading, recommended by the acting in Ukraine norms [1, 2].

2 LITERATURE ANALYSIS AND PROBLEM FORMULATION

Most of the publications related to the calculations of airfield and road slabs, the authors proceed from the calculation scheme of the slab on a deformable elastic base [3 - 6]. The calculation results essentially depend on the accepted models of the slab, the base, and the model of their interaction.

The slab model is usually characterized by Kirchhoff hypotheses. In the vast majority of publications, the model of the interaction between the slab and the base is assumed to be bilateral: the motions of the contact points of the slab and the base are assumed to be the same. Models of the base are characterized by a variety. Currently, a significant number of such models are proposed, reflecting in different ways the actual behavior of the soil. The following schemes are most widely used: models with one and two bedding coefficients, models of elastic homogeneous isotropic half-space and half-plane, various combinations of these models. In this case, it is believed that since the pavement is built under a powerful artificial foundation, it experiences only elastic deformations, and the calculation of the pavement is made on this basis.

The problem of deformability and crack resistance of airfield slabs is not reflected in the domestic literature. If we talk about the publications of foreign authors, it should be noted the works [7 - 10], where the main attention is paid to the issues of crack resistance.

Despite the use of the slab model on an elastic base in theoretical studies of the stress state of airfield slabs, the experimental studies in the normative documents of most countries consider two loading schemes - when the load is a concentrated force applied in the middle of the span, and when the load is a concentrated force applied on the console. In both cases, the slab has a hinged support. This approach, in particular, is reflected in the aforementioned Norms of Ukraine [1, 2] and in GOST 25912-2015 [11], the standard which applies to prestressed reinforced concrete slabs made of heavy concrete and designed for the construction of precast fast-building pavements of airfields, roads, storage areas, including those recommended for use in harsh conditions of temperature and humidity cold climate and permafrost soils, and is valid in 7 countries of the former USSR.

3 RESEARCH GOAL AND OBJECTIVES

The purpose of this work is to experimentally investigate the deformability and crack resistance of airfield slab models made of reinforced concrete and steel-fiber concrete under the span loading scheme.

To achieve this goal, it was necessary to solve the following tasks:

1. Analyze modern methods of studying the deformability and fracture resistance of airfield slabs.
2. Develop a design and produce models of an airfield slab based on the serial slab PAG-18.
3. Develop a test stand design.
4. Perform experimental studies of the deformability and fracture resistance of airfield slab models.
5. Perform processing and analysis of the experimental data obtained.

4 RESEARCH RESULTSS

Model of an airfield slab was made taking into account the scale factor on the basis of a serial slab PAG-18. The specimens are reinforced with a spatial framework consisting of two meshes (Fig. 1). For reinforced concrete and steel-fiber-concrete slabs, 5 mm diameter reinforcement of Vr-1 type was used.

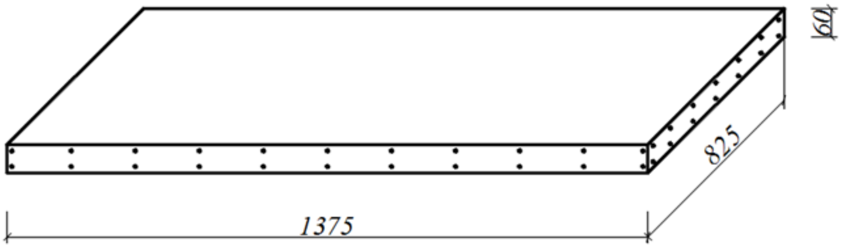

Fig. 1. General view of the slab

To conduct tests, a stand is made, the frame of which is four supporting pillars connected in pairs by beams. The model of the slab rests on the beams. The load was applied along the width of the slab in steps - 0.05 of the destructive load, along two concentrated vertical strips. Each stage of the load ended with a five-minute dwell time, at the beginning and end of which readings were taken on the measuring instruments. All tests were performed using a 100 kN jack and a 5-t dynamometer. The lower plane of the jack transmits the load to the two-level cross-beam system, and through it the load is distributed to the plate (Fig. 2).

Fig. 2. Test stand

The implemented load application diagram is shown in Fig. 3.

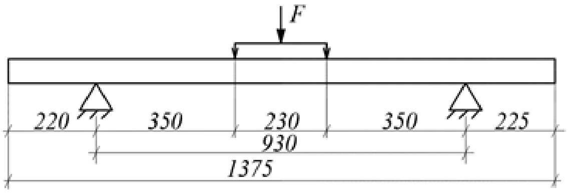

Fig. 3. Load application scheme

On the upper and lower surface of the plate, there were dial gauges with a base of 36 cm, the first four - in the compressed zone, and 5 and 6 - in the tensile zone (Fig. 4). The load cells were glued on the axis of symmetry under 2 and 4 indicators.

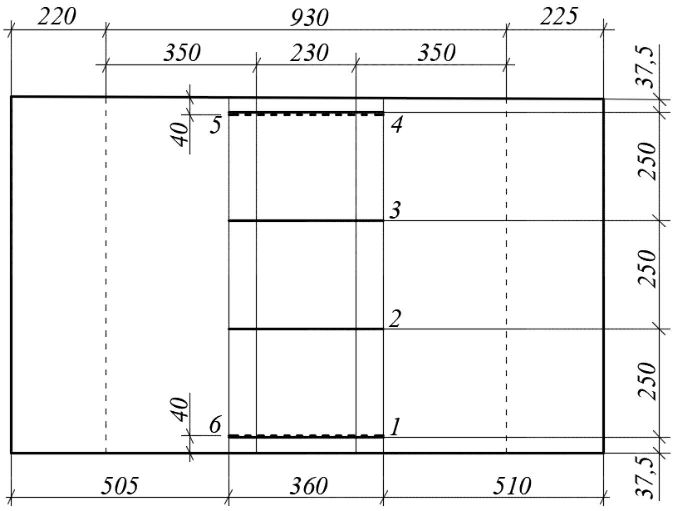

Fig. 4. Indicator layout

The main results of the tests are shown in Table 1.

Table 1

Test results.

Slab model	Start of cracking		Bearing capacity, kN	Limit moment at failure, kNm
	Load, kN	Moment, kNm		
Reinforced concrete	12,10	2,12	21,77	3,81
Fiber concrete	14,52	2,54	27,42	4,80

On the basis of indicator readings, plots of the dependence of the relative longitudinal strain on the load in reinforced concrete (Fig. 5) and fiber concrete (Fig. 6) slabs according to indicator readings were plotted.

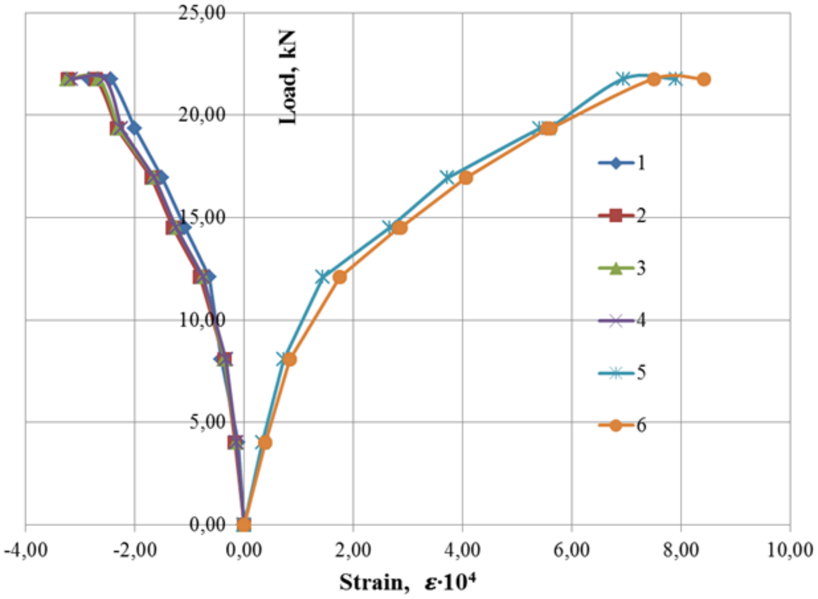

Fig. 5. Relative longitudinal deformation in the reinforced concrete slab according to indicator readings

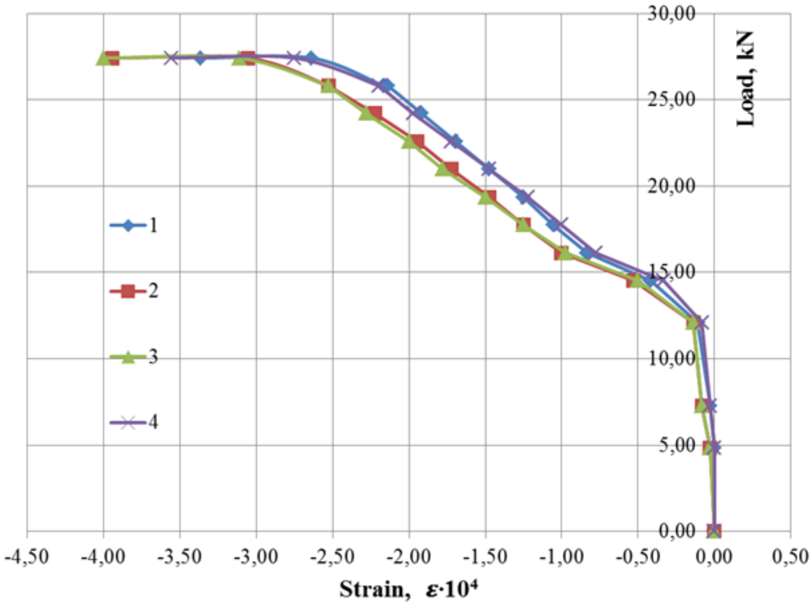

Fig. 6. Relative longitudinal deformation in the fiber concrete slab according to indicator readings

Plots of the dependence of the relative strain on the load in the compressed zone of reinforced concrete and fiber concrete slabs are shown in Fig. 7, 8, respectively.

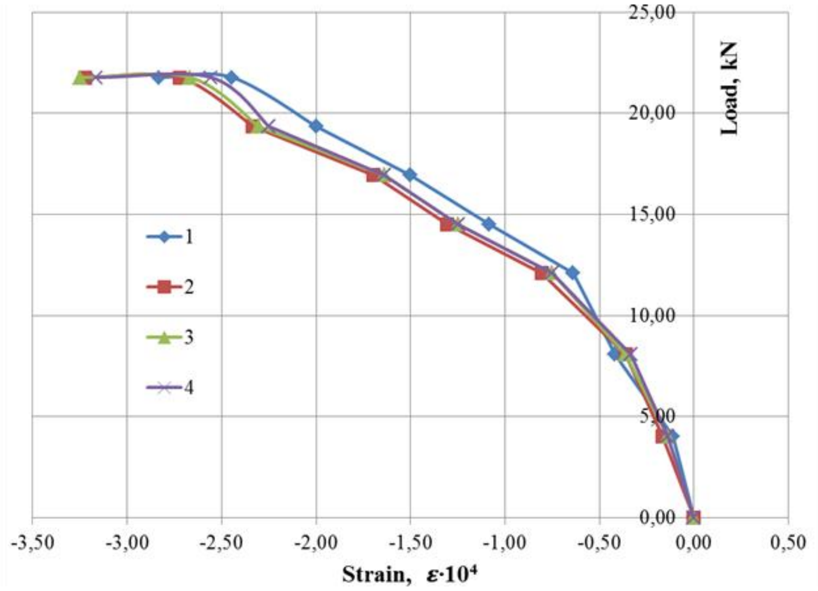

Fig. 7. Deformations in the compressed zone of the reinforced concrete slab according to indicator readings

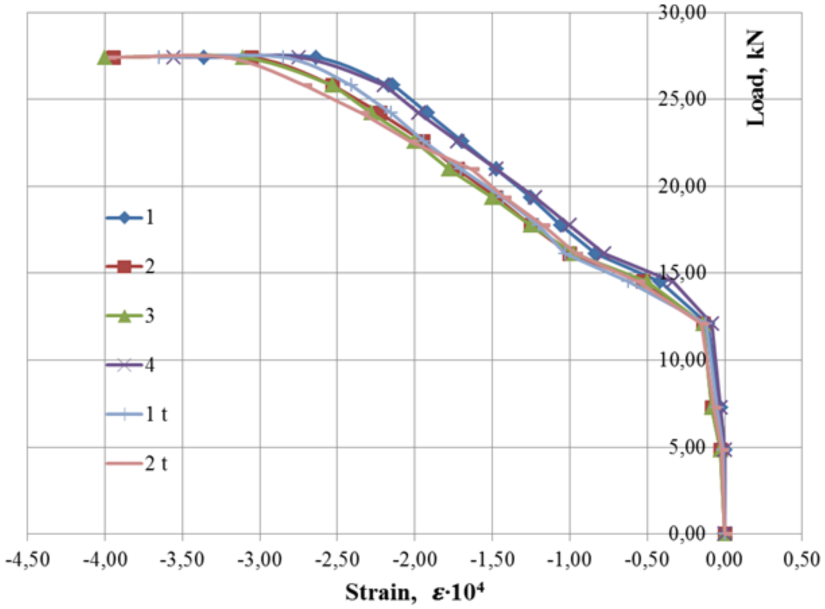

Fig. 8. Deformations in the compressed zone of the fiber concrete slab according to the readings of indicators and strain gauges

Using the readings of two deflectometers, we plotted the deflections versus load for reinforced concrete (Fig. 9) and fiber concrete (Fig. 10) slabs, which have the same character as the deformation plots.

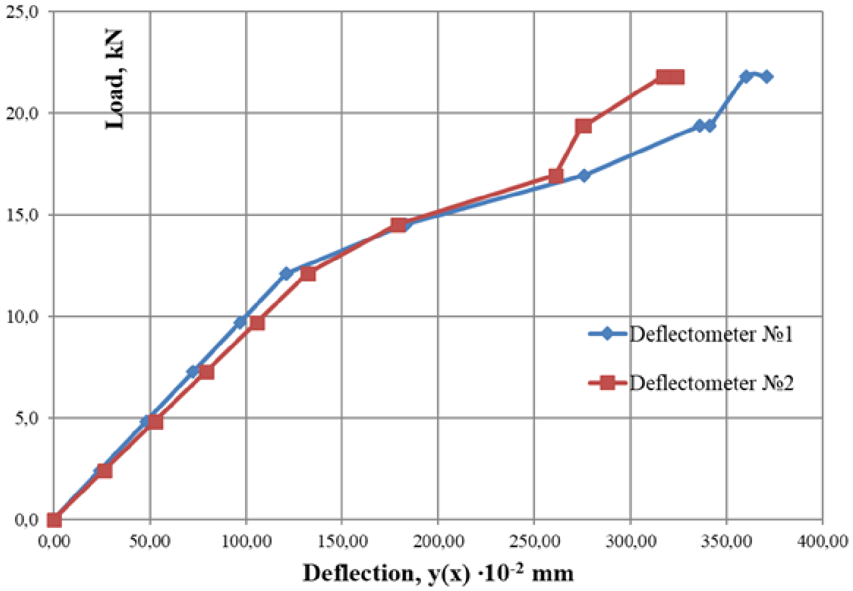

Fig. 9. Deflections in a reinforced concrete slab

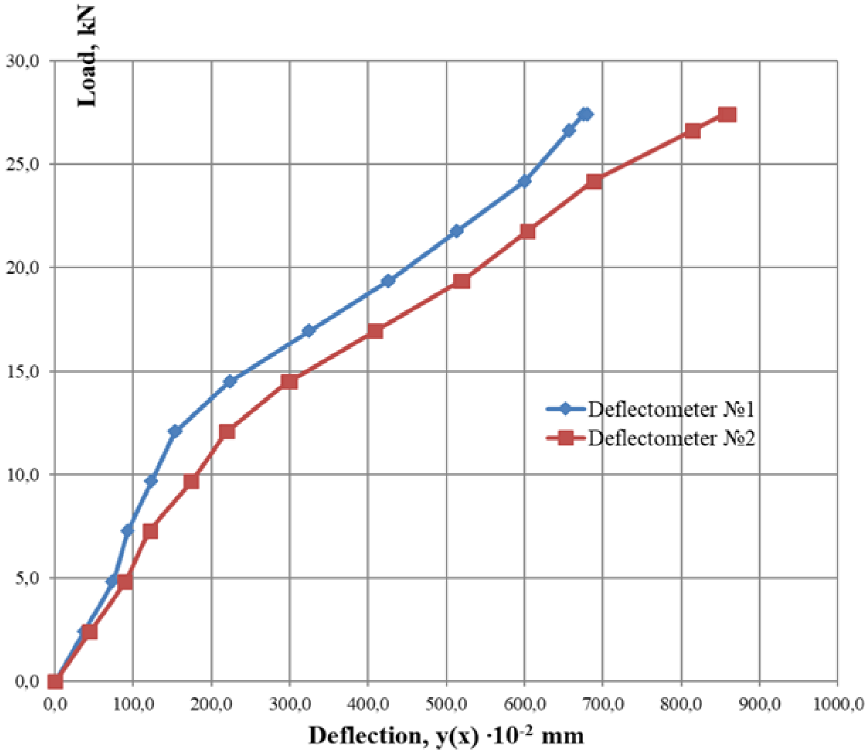

Fig. 10. Deflections in the fiber concrete slab

5 DISCUSSION OF THE RESULTS OF THE STUDY

Table 2 shows the sequence of crack formation in reinforced concrete and fiber concrete slabs with increasing load, and Table 3 shows the crack opening width.

Table 2

Sequence of crack formation in the slabs with increasing load.

№ of load step		Load, kN		№ of crack		Minimum height of compressed zone, sm	
RC slab	SFC slab	RC slab	SFC slab	RC slab	SFC slab	RC slab	SFC slab
0	0	0,00					
1	1	4,03					
2	2	8,06	7,26				
3	3	12,10	12,10	1		18	
4	4	14,52	14,52	2, 3	1	10	22
5	5	16,94	16,13				
6	6	19,35	17,74		2, 3		15
7	7	21,77	19,35				
	8	13,00	20,97				
	9	14,00	22,58				
	10	15,00	24,19				
	11	16,00	25,81				
	12	17,99	27,42				

Table 3

Crack opening width with increasing load.

№ of crack		Bending moment, kNm		Initial crack opening width, mm		End crack opening width, mm	
RC slab	SFC slab	RC slab	SFC slab	RC slab	SFC slab	RC slab	SFC slab
1	1	2,12	2,54	0,05	0,05	0,7	0,3
2	2	2,54	3,10	0,1	0,1	0,2	0,15
3	3	2,54	3,10	0,1	0,05	0,3	0,1

Before the first crack appears, the deflection of the reinforced concrete slab is 19.6 % for the reinforced concrete slab and 11.0 % for the fiber concrete slab from that recorded at the end of the tests.

The breaking load for the fiber concrete slab was 1.52 times greater than for the reinforced concrete slab, and the moment of the beginning of cracking was 1.22 times greater.

6 CONCLUSIONS

As follows from the given results, the cracking process in the fiber concrete slab begins at higher loads than in the reinforced concrete slab. The initial crack opening width in the slabs is almost the same, and the final crack opening width of all the cracks in the fiber concrete slab is significantly lower than in the reinforced concrete slab.

The deformations in steel fiber concrete slabs when the load is applied in the span, both for compressed and stretched fibers, are higher than in reinforced concrete slabs.

According to the given results, it can be seen that at the initial stages of load application in the span of the plates, the deflections increase linearly. The curves get non-linear for aerodrome slabs of reinforced concrete when the load reaches the level of 10÷25 kN, for steel-fiber-concrete slabs - 15÷30 kN. In reinforced concrete slabs the non-linearity starts a little earlier and is more clearly expressed.

Thus, the experimental studies indicate that dispersed reinforcement of airfield slabs with steel fiber leads to their higher crack resistance.

References

1. DSTU B. V.2.6–137:2010 (HOST 25912.2–91. MOD). (2001). *Konstruktsii budynkiv i sporud. Plyty zalizobetonni poperedno napruzheni PAH–18 dlia aerodromnoho pokryttia. Konstruktsiia*. [Constructions of houses and buildings. Reinforced concrete slabs prestressed PAG-18 for airfield pavement. Construction]. [Chynnyi vid 2011–07–01]. TOV NTK "Budstandart". (Informatsiia ta dokumentatsiia). [in Ukranian].
2. DSTU B.V.2.6-122:2010. (2011). *Plyty zalizobetonni z nenapruzhenoiu armaturoiu dlia pokryttia miskykh dorih*. [Reinforced concrete slabs with unstressed reinforcement to cover city roads]. [chynnyi vid 2011-07-01]. K.: Minrehionbud Ukrainy. [in Ukranian].
3. Dolgachev, M. V., Lovcov, A. D. (2012). Modelirovanie vzaimodejstviya plastiny i grunta pri ego vypuchivanii i prosadke. [Modeling the interaction of a plate and soil during buckling and subsidence]. *Vestnik Tihookeanskogo gosudarstvennogo universiteta*. 1(24). 131–139. [in Russian].
4. Saburenkova, V. A., Stepushin, A. P. (2015). *Metody rascheta konstrukcij aerodromnyh pokrytij: ucheb. posobie*. [Methods for calculating the structures of aerodrome pavements: textbook. allowance]. M.: MADI. [in Russian].
5. Barmekova, E. V. (2019). Strength analysis of variable rigidity slabs on elastic support with variable subgrade ratio. *Vestnik Tomskogo gosudarstvennogo arkhitekturno-stroitel'nogo universiteta*. Journal of Construction and Architecture. 1. 201–208. doi.org/10.31675/1607-1859-2019-21-1-201-208.
6. Rodchenko, O. (2018). Computer technologies for concrete airfield pavement design. Aviation. 21(3). 111–117. doi:10.3846/16487788.2017.1379439.
7. Caliendo, C., Parisi, A. (2010). Stress-Prediction Model for Airport Pavements with Jointed Concrete Slabs. *Journal of Transportation Engineering*. 136(7). 664–677. doi:10.1061/(asce)te.1943-5436.0000151
8. Mehta, Y., Cleary, D., Ali, A. W. (2017). Field cracking performance of airfield rigid pavements. *Journal of Traffic and Transportation Engineering* (English Edition). 4(4). 380–387. doi:10.1016/j.jtte.2017.05.010
9. Smith, K. D., Roesler, J. R. (2004). Review of Fatigue Models for Concrete Airfield Pavement Design. *Airfield Pavements*. doi:10.1061/40711(141)16
10. McNerney, M. T. Kim, J., Bescher, E. P. (2017). Construction, Instrumentation, and Performance of a Double Sized Slab Designed for Airport Runways. *Airfield and Highway Pavements 2017*: Airfield Pavement Technology and Safety.
11. HOST 25912-2015. (2015). *Plity zhelezobetonnye predvaritel'no napryazhennye dlya aerodromnyh pokrytij*. Tekhnicheskie usloviya. [Reinforced concrete slabs prestressed for airfield pavements. Specifications]. № 25912-2015. [in Russian].

Література

1 ДСТУ Б. В.2.6–137:2010 (ГОСТ 25912.2–91, MOD). Конструкції будинків і споруд. Плити залізобетонні попередньо напружені ПАГ–18 для аеродромного покриття. Конструкція. [Чинний від 2011–07–01]. ТОВ НТК "Будстандарт", 2011. 8 с. (Інформація та документація).
2 Плити залізобетонні з ненапруженою арматурою для покриття міських доріг. ДСТУ Б.В.2.6-122:2010. [чинний від 2011-07-01]. К.: Мінрегіонбуд України, 2011. 23 с. (Національний стандарт України).
3 Долгачев М. В., Ловцов А. Д. Моделирование взаимодействия пластины и грунта при его выпучивании и просадке. Вестник Тихоокеанского государственного университета, 2012. № 1(24). С. 131–139.
4 Сабуренкова В. А., Степушин А. П. Методы расчета конструкций аэродромных покрытий: учеб. Пособие. М.: МАДИ, 2015. 128 с.
5 Barmekova E. V. Strength analysis of variable rigidity slabs on elastic support with variable subgrade ratio. Vestnik Tomskogo gosudarstvennogo arkhitekturno-stroitel'nogo universiteta. Journal of Construction and Architecture. 2019. (1). 201–208. https://doi.org/10.31675/1607-1859-2019-21-1-201-208.

6 Rodchenko O. Computer technologies for concrete airfield pavement design. Aviation. 2018. 21(3). 111–117. doi:10.3846/16487788.2017.1379439.
7 Caliendo C., Parisi A. Stress-Prediction Model for Airport Pavements with Jointed Concrete Slabs. Journal of Transportation Engineering. 2010. 136(7). 664–677. doi:10.1061/(asce)te.1943-5436.0000151
8 Mehta Y., Cleary D., Ali, A. W. Field cracking performance of airfield rigid pavements. Journal of Traffic and Transportation Engineering (English Edition). 2017. 4(4). 380–387. doi:10.1016/j.jtte.2017.05.010
9 Smith K. D., Roesler J. R. Review of Fatigue Models for Concrete Airfield Pavement Design. Airfield Pavements. 2004. doi:10.1061/40711(141)16
10 McNerney M. T., Kim J., Bescher E. P. Construction, Instrumentation, and Performance of a Double Sized Slab Designed for Airport Runways. Airfield and Highway Pavements 2017: Airfield Pavement Technology and Safety. 2017
11 ГОСТ 25912-2015 Плиты железобетонные предварительно напряженные для аэродромных покрытий. Технические условия, 2015. № 25912-2015.

Korneeva Irina
Odessa State Academy of Civil Engineering and Architecture
Ph.D., Associate Professor
Didrihsona str.,4 Odessa, Ukraine 65029
korneevairinaborisovna@gmail.com
ORCID: 0000-0002-0104-6938
Kirichenko Daria
Odessa State Academy of Civil Engineering and Architecture
Postgraduate
Didrihsona str.,4 Odessa, Ukraine 65029
sunnyderypeople123@gmail.com
ORCID: 0000-0002-8484-0925
Shyliaiev Oleksii
Odessa State Academy of Civil Engineering and Architecture
Ph.D.
Didrihsona str., 4, Odessa, Ukraine 65029
shyliaiev@gmail.com
ORCID: 0000-0002-1102-883X

For references:
Korneieva I., Kirichenko D., Shyliaiev O. (2021). Experimental studies of deformability and fracture resistance of airfield slabs on models. Mechanics and Mathematical Methods. 3 (2). 64–74

Для посилань:
Корнєєва І. Б., Кіріченко Д. О., Шиляев О. С. Експериментальні дослідження деформативності і тріщиностійкості аеродромних плит на моделях. Механка та математичні методи, 2021. Том 3. Вип. 2. С. 64–74