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EXPERIMENTAL STUDIES OF WELL CONNECTING RINGS

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Abstract. A methodology for conducting experimental studies of the bearing capacity and crack resistance of well rings is proposed. Reinforced concrete elements of annular cross-section are used in many engineering structures, such as wells for various purposes, pressure and non-pressure pipes, power line supports, water towers, etc. There are a number of problems in the production and operation of such reinforced concrete structures. First of all, these are technological problems that arise during the manufacture of products due to the difficulties of installing the annular spatial reinforcement frame in the design position. And at the operation stage, especially when it comes to wells, the main problem is crack resistance and the associated moisture resistance. An effective way to solve these problems is dispersed reinforcement of concrete with steel fiber. Assessment of this effectiveness requires additional research, primarily experimental. Such researches are very few, primarily aimed at studying well rings.

A special power platform design was developed and manufactured for testing. It was established that the nature of the ring deformation under the action of a load uniformly distributed along its perimeter can be divided into three stages. At the first stage, up to the load level corresponding to the beginning of crack formation, a linear dependence of the deformation of concrete fibers is observed. The magnitudes of relative deformations are practically the same. At the next two stages of loading, a sharp change in the rate of growth of deformations occurs. The load of the second stage increases by 35%, while the deformations due to the opening of cracks increase by 1.3 times. At the third stage – the stage of destruction – the load decreases (falls) by 4%, and the deformations increase almost twice, again due to the opening of already existing cracks. The results of the study provide an opportunity for further assessment of the influence of dispersed reinforcement of concrete with steel fibers on the bearing capacity and crack resistance of well rings.

Keywords: well ring, concrete, steel fiber concrete, experiment, stand, bearing capacity, deformation, crack resistance.

Introduction. Reinforced concrete elements of circular or annular cross-section are used in many engineering structures, such as wells for various purposes, pressure and non-pressure pipes, power line supports, water towers, etc. There are a number of problems in the production and operation of such reinforced concrete products. The main ones are technological problems that arise during the manufacture of products due to the difficulty of installing the annular spatial reinforcement frame in the design position. And at the operation stage, especially when it comes to wells, the main problem is crack resistance and the associated moisture resistance. It seems that an effective way to solve these problems is dispersed reinforcement of concrete with steel fiber [1, 2].

Analysis of the latest research and publications. Methods of research of concrete and fiber-reinforced concrete wells are the subject of many publications [3-9]. A special place is occupied by wells of cylindrical shape, which from the point of view of structural mechanics are long cylindrical shells. And the main research is devoted to theoretical issues of determining the bearing capacity and crack resistance of such shells. We note the works [10-13].

Design and calculation of wells is regulated by relevant regulatory documents. In our country, this is DSTU B V. 2.6-106: 2010 [14]. In several countries of the former USSR – Armenia, Kazakhstan, Kyrgyzstan – Interstate Standard [15]. In European countries – EN1992-1-4 [16].

Experimental studies of well connecting rings are covered very little, and this small review indicates that this area of work is relevant.

Purpose of the work. The purpose of the work is to develop a methodology for conducting experimental studies of well rings for subsequent assessment of the influence of dispersed reinforcement of concrete with steel fiber on their bearing capacity and crack resistance.

Materials and research methods. The samples were made of concrete and fiber-reinforced concrete. The amount of steel fiber in fiber-reinforced concrete is 1% of the product volume. Preliminary tests were carried out on prisms and cubes, measuring 100×100×400 mm and 100×100×100 mm, respectively, aged for 28 days. Two groups of prisms and cubes were made. One was made of ordinary concrete (with large aggregate sizes up to 10 mm) of class C20/25 and the second was made of anchor steel fiber. Each group consisted of nine samples. The prisms and cubes were made in accordance with regulatory documents [17]. The research used methods of mathematical statistics, experimental methods of mechanics, and the strain gage method.

Research results. The research was conducted on two series of circular rings. The first series consisted of rings made of ordinary concrete of class C20/25. When manufacturing the rings of the second series, steel anchor fiber was added to the concrete in a volume of 1% of the total volume of concrete. This volume of fiber was determined as optimal in the process of previous research.

For concreting the ring specimens factory-made metal formwork was used. The height of the rings is $H = 70,5\,cm$, the outer diameter is $d_2 = 83\,cm$, the inner diameter is $d_1 = 70\,cm$. The wall thickness is $\delta = 6,5\,cm$ (Fig. 1).

Fig. 1. Sample preparation: metal formwork and sample

To test the rings, a special force platform was mounted, the appearance of which is shown in Fig. 2.

Fig. 2. Force platform for testing

The load is applied to the ring under study 1 in two mutually perpendicular directions, which is carried out by two hydraulic jacks with a capacity of 2.500 kNm^2 and is controlled by exemplary dynamometers 3 of the Tokar system of similar capacity. Uniform loading of the rings in height is ensured by four vertically arranged traverses 5 (Fig. 3).

During the tests, the load, which is simultaneously applied in two mutually perpendicular planes, and the deformations of individual concrete fibers were recorded. The load was applied in steps of 0.1 from the destructive one, the value of which was determined in the process of previous trial tests. Each load step was followed by a five-minute hold. The process of crack formation was monitored between the load steps. The deformations of individual concrete fibers were measured using time-type indicators with a division value of 0.001 mm. The deformation measurement base was 24 cm. Indicators were installed in characteristic zones around the outer perimeter of the ring. The destructive load was taken to be the value at which the ring lost its ability to resist the load.

Fig. 4 presents the relative deformations of four indicators located in the load transfer zones, i.e. in the locations of the traverses (Fig. 3). From the results presented in Fig. 4, it follows that the readings of all indicators located in the middle part of the ring, from the beginning of the load to the failure, change practically according to the same law (synchronously). The latter indicates the uniformity of the load along the perimeter of the ring.

The nature of deformation, shown in Fig. 4, can be divided into three stages. At the first stage, up to the load level of 36 kN, which corresponds to the beginning of crack formation, a linear dependence of the deformation of concrete fibers is observed. The values of relative deformations are practically the same. At the next two stages of loading (Table 1), a sharp change in the rate of growth of deformations occurs (the angle of inclination of the curves changes significantly). The load of the second stage increases by 35%, while the deformations due to the opening of cracks increase by 1.3 times. At the third stage – the stage of destruction – the load decreases (falls) by 4%, and the deformations increase almost twice, again due to the opening of already existing cracks.

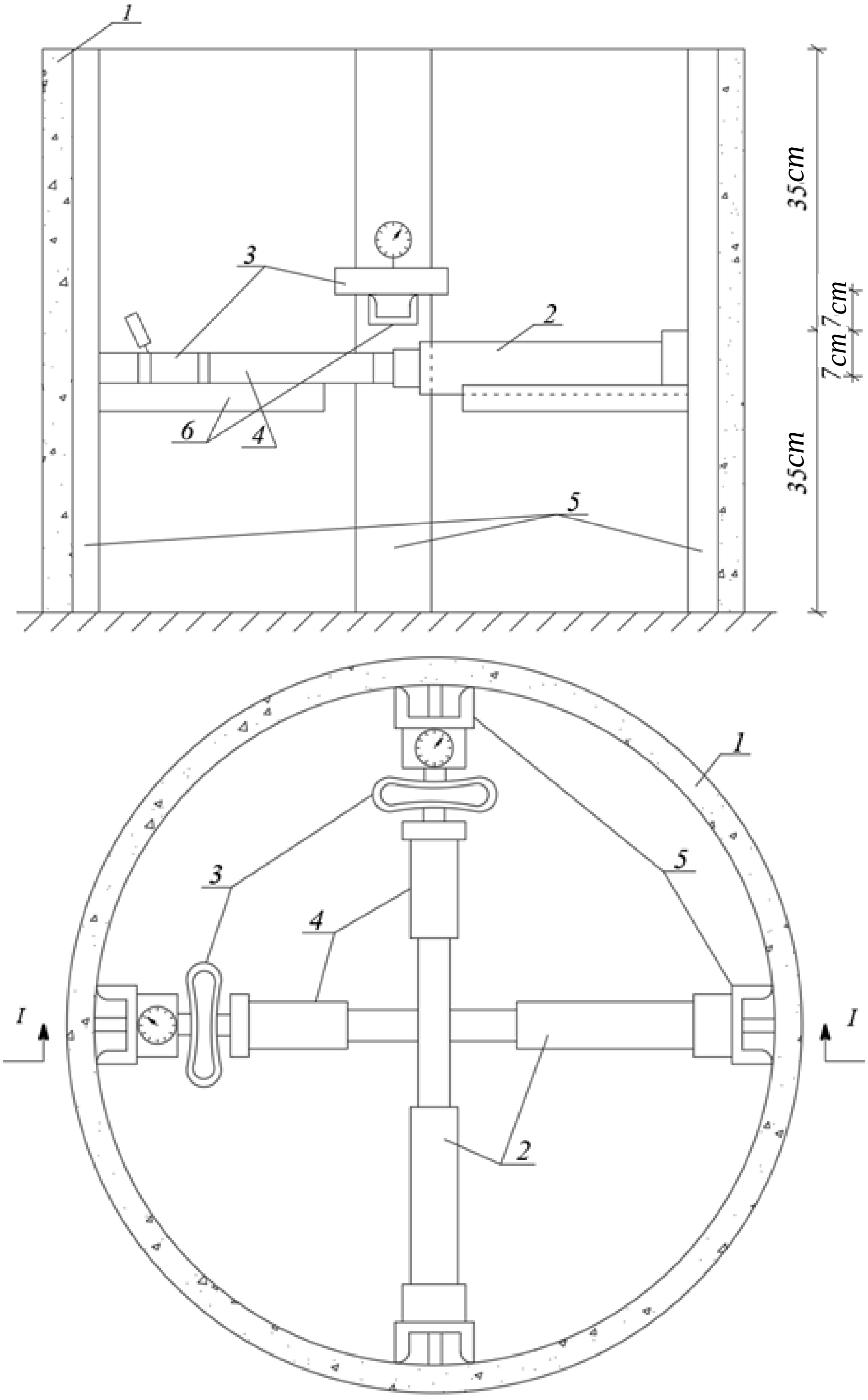

Fig. 3. Power platform diagram:
1 – concrete ring; 2 – hydraulic jacks; 3 – dynamometers; 4 – transfer rods; 5 – channels reinforced with plates; 6 – guide rod (channel)

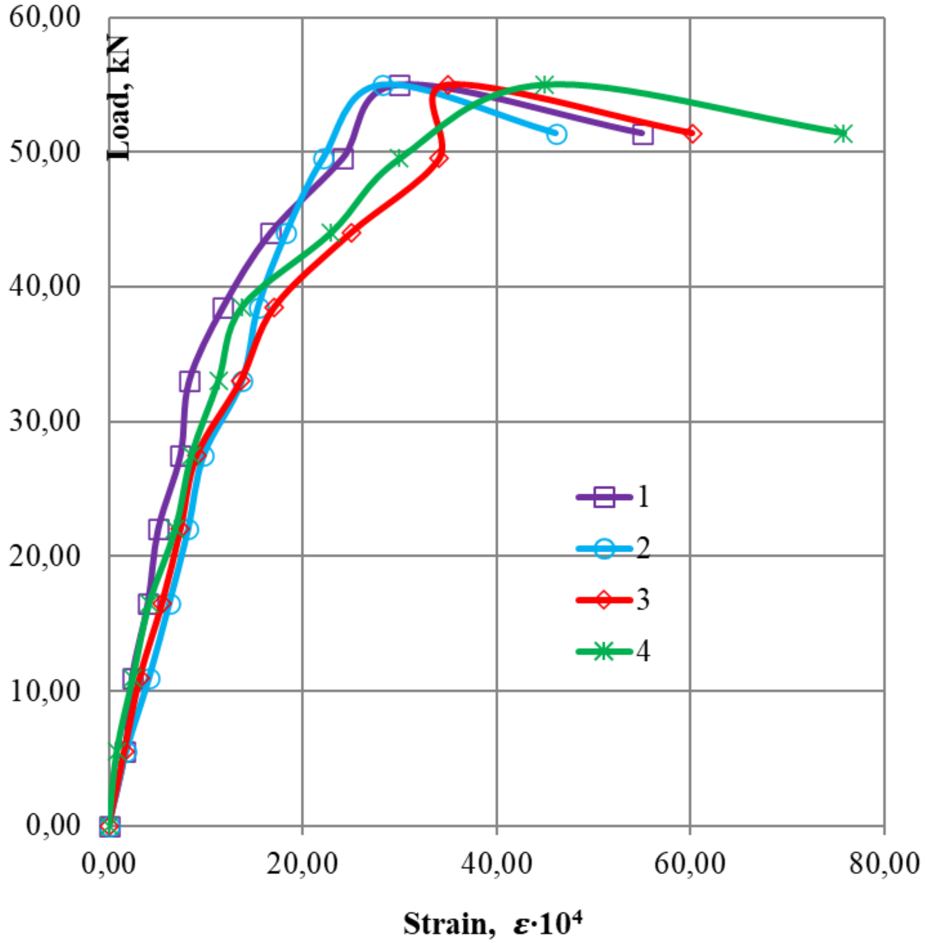

Fig. 4. Graph of the dependence of relative deformation on load

Table 1 – Relative deformation indicators

Load, kN	Indicators performance			
	1	2	3	4
0.00	0.00	0.00	0.00	0.00
5.50	1.70	1.80	1.60	0.83
11.00	2.40	4.17	3.20	2.50
16.50	4.05	6.25	5.50	4.17
22.00	5.10	8.20	7.40	6.88
27.50	7.40	9.80	9.10	8.54
33.00	8.30	13.75	13.60	11.30
38.50	11.80	15.40	17.10	13.75
44.00	16.70	18.30	25.00	22.92
49.50	24.10	22.08	34.10	30.00
55.00	30.00	28.20	35.00	45.00
51.40	55.00	46.10	60.20	75.80

Conclusions. Thus, a methodology for conducting experimental studies of the bearing capacity and crack resistance of well rings has been proposed. It has been established that the nature of the ring deformation under the action of a load uniformly distributed along its perimeter can be divided into three stages. At the first stage, up to the load level corresponding to the beginning of crack formation, a linear dependence of the deformation of concrete fibers is observed. The magnitudes of relative deformations are practically the same. At the next two stages of loading, a sharp change in the rate of deformation growth occurs. The load of the second stage increases by 35%, while the deformations due to the opening of cracks increase by 1.3 times. At the third stage, the stage of destruction, the load decreases (falls) by 4%, and the deformations increase almost twice, again due to the opening of existing cracks. The results of the study provide an opportunity for further assessment of the influence of dispersed reinforcement of concrete with steel fibers on the bearing capacity and crack resistance of well rings.

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ КОЛОДЯЗНИХ КІЛЕЦЬ

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Анотація. Запропоновано методику проведення експериментальних досліджень несучої здатності та тріщиностійкості колодязних кілець. Залізобетонні елементи кільцевого перерізу використовуються в багатьох інженерних спорудах, таких як колодязі різного призначення, напірні та безнапірні трубопроводи, опори ліній електропередач, водонапірні башти тощо. Існує ряд проблем у виробництві та експлуатації таких залізобетонних конструкцій. Перш за все, це технологічні проблеми, які виникають при виготовленні виробів через труднощі встановлення кільцевого просторового арматурного каркаса в проєктне положення. А на етапі експлуатації, особливо якщо це стосується колодязів, основна проблема – тріщиностійкість і пов'язана з нею вологостійкість. Ефективним способом вирішення цих проблем є дисперсне армування бетону сталевою фіброю. Оцінка такої ефективності потребує додаткових досліджень, насамперед експериментальних. Таких досліджень, насамперед спрямованих на вивчення колодязних кілець, дуже мало.

Для випробувань була розроблена та виготовлена спеціальна конструкція силової платформи. Встановлено, що за характером деформації кільця під дією навантаження, рівномірно розподіленого по його периметру, можна виділити три етапи. На першому етапі до рівня навантаження, що відповідає початку тріщиноутворення, спостерігається лінійна залежність деформації волокон бетону. Величини відносних деформацій практично однакові. На двох наступних стадіях навантаження відбувається різка зміна швидкості зростання деформацій. Навантаження другого ступеня зростає на 35%, а деформації внаслідок розкриття тріщин збільшуються в 1,3 рази. На третій стадії – стадії руйнування – навантаження зменшується (падає) на 4%, а деформації збільшуються майже вдвічі, знову ж таки за рахунок розкриття вже наявних тріщин. Результати дослідження дають можливість для подальшої оцінки впливу дисперсного армування бетону сталевими фібрами на несучу здатність і тріщиностійкість колодязних кілець.

Ключові слова: колодязне кільце, бетон, сталефібробетон, експеримент, стенд, несуча здатність, деформація, тріщиностійкість.

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