УДК 624.012.45

CONCRETE DEFORMATION DIAGRAMS

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Key words and phrases: basalt; bearing capacity; design strength of reinforcement to tension; elastic modulus of steel; endurance; fabric of lateral reinforcing; glass-fiber-reinforced plastic; modulus of sand fineness; relative deformation; stability; steel; synthetic fibers; ultimate strength of concrete.

Abstract: Experimental examination of influence of steel fibers and fabrics of lateral reinforcing on character of fracture and deforming of concrete at a uniform axial compression of models is carried out. It is shown, that the application of fibers results in inappreciable increase of strength of concrete, and lateral reinforcing on the contrary raises essentially. It is necessary to note, that the introduction of fibers and fabrics in concrete results in essential increase of values of relative deformations correspondent to maximal strength of concrete. It also considerably increments limiting values of relative deformations, that is especially important for operation of statically indefinable constructions.

The calculation of reinforced concrete constructions in the first group of limiting states (bearing capacity, stability, endurance) in view of the nonlinear theory of resistance of reinforced concrete is based on a series of statements: equilibrium equations of interior and exterior forces in limits of an element limited by normal section; the rectilinear law of partition of strains on the height of an element; the diagrams of concrete and reinforcement deformation [1, 2, 3].

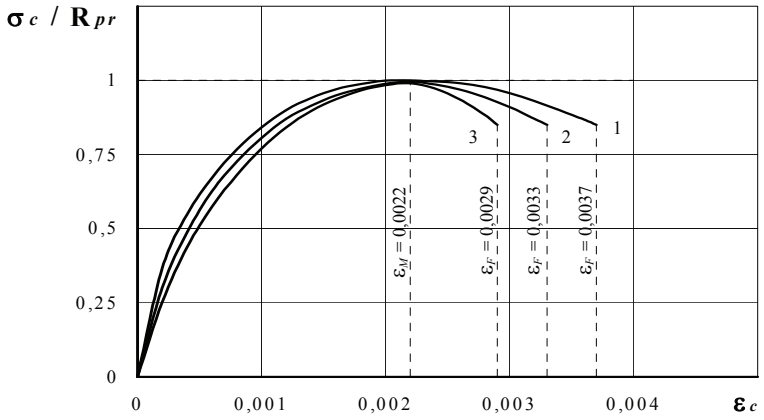

Fig. 1 Dependencies $\sigma_C = f(\varepsilon_C)$, accepted in the recommendations EKB–FIP for concrete by strength: *1* – 20 MPa; *2* – 40 MPa; *3* – 60 MPa

To build-up the diagrams of concrete deformation short-time modes of loading at fixed increase of strain are usually used. On Fig.1 the diagrams of stress (σ_C) dependence on relative deformation of concrete (ε_C) for different classes according to the accepted recommendations EKB–FIP, with the account of a descending curvilinear part of branch of the diagram, are shown [4]. On the graph the values of relative deformation $\varepsilon_M = 2{,}2 \cdot 10^{-3}$ correspondent to maximal strength of concrete are shown and also limiting values of strains correspondent to stress on a descending branch equal to 0,85 from ultimate strength of concrete. Differences for different classes of concrete consist of limiting values of strength of concrete, at the same value of relative deformation $\varepsilon_M = 2{,}2 \cdot 10^{-3}$, correspondent to maximal stress in concrete. Thus in accordance with the increase of concrete class, the initial elastic modulus of concrete rises and the relative limiting strains diminish.

In the literature quite many works describing diagrams of concrete deformation at a uniform axial compression [1, 2, 3, 4] are known, however there are not enough diagrams "σ - ε " for fibrous concrete and concrete with lateral reinforcing.

An examination of influence of steel fibers and lateral reinforcing fabrics on character of fracture and concrete deformation at a uniform axial compression of models in the shape of cubes with the sizes 100×100×100 mm and prisms with the sizes 120×120×400 mm was carried out.

The fibrous concrete is usually fine-grained concrete reinforced by incidentally oriented steel, glass-fiber-reinforced plastic, basalt, synthetic and other fibers with a diameter 0,08 … 0,6 mm and length 15 … 85 mm.

In experiments the steel fibers of a wire with a diameter of 0,6 mm and length 25 … 35 mm, with an elastic modulus of steel equal to $1{,}5 \cdot 10^5$ MPa, with ultimate strength of steel equal to 2250 MPa, and relative elongation – 0,055, in content up to 1 % of mass were used. Samples in the shape of cube were made at the different cement-sandy(C/S) ratios: 1/1; 1/2; 1/3; 1/4 and water-cement (W/C) ratio 0,55. In total 36 models were manufactured and tested. For manufacture of fine-grained concrete the sand from the quarry "Laski" was utilized with the Abram's fineness modulus 1,7 - 1,9 and Portland-blastfurnace slag cement grade M400 of the Lipetsk cement factory.

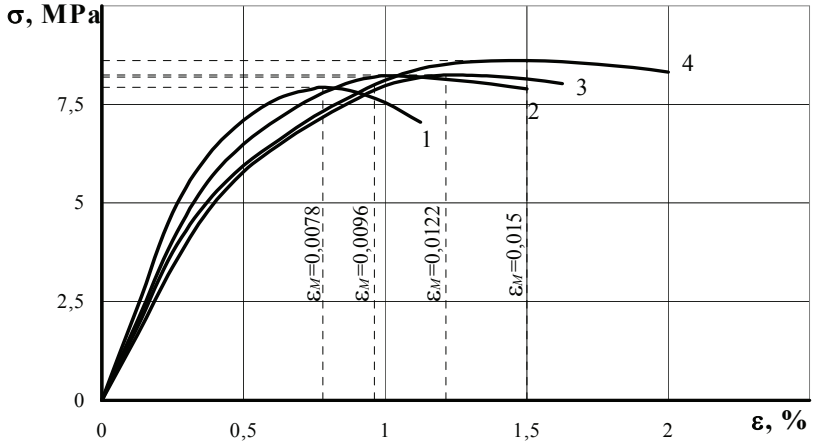

Fig. 2 The diagrams " σ – ε " of uniform compression cubes from concrete at *C*/*S* = 1/3 with different percentage of steel fibers by weight:

1 – $\mu_{S,F}$ = 0 % (without reinforcing); *2* – $\mu_{S,F}$ = 0,33 %; *3* – $\mu_{S,F}$ = 0,67 %; *4* – $\mu_{S,F}$ = 1,0 %

The experiments have shown, that the character of fibrous concrete models fracture (deforming) at uniform short-time compression with the increase of reinforcement percentage has the tendency to inappreciable increase of strength at an axial compression (3 … 8 %), and the deformation diagram after reaching maximal stress in concrete remains practically horizontal with development of considerable relative deformations making ε = 1 % and more (Fig. 2). It is connected with the fact that after formation of longitudinal cracks and segregation of cube on several separate parts, the model, nevertheless, prolongs to perceive a loading, affixed on it, through cross deformations by steel fibers. It is necessary to pay attention to increase of values of relative deformations correspondent to maximal strength of fibrous concrete models (ε_M = 9,6 · 10^{-3} … 15 · 10^{-3}) in comparison with a sample-prototype (ε_M = 7,8 · 10^{-3}).

For determination of influence of lateral reinforcing on the mechanism of fracture and distorted state of concrete the prisms reinforced by welded cross fabrics and without them were manufactured. The fabrics were made of a wire with a diameter of 2 mm with design resistance to tension R_S = 650 MPa. They were made with different sizes of meshes: 20×20, 30×30, 40×40 mm and were set up with steps: 50, 80, 100, 150 mm. The prisms were made of heavy concrete of a class B15 with maximal grains size of 20 mm in industrial conditions. In total 14 models were manufactured and tested.

The trials of prisms for short-time compression have shown, that the introduction of lateral reinforcing fabrics results in considerable increase of concrete strength (35 … 97 %) at inappreciable increase of values of relative deformations correspondent to maximal stress (ε_M = 6·10^{-3} … 7,5·10^{-3}) (Fig. 3). Similarly to cubes of fibrous concrete the diagram of prisms deformations with lateral reinforcing after reaching maximal stress remains practically horizontal. It is explained by constraining effect of lateral reinforcement interfering development of cross deformations of concrete.

The application of fibers or lateral reinforcing fabrics promotes the change of the performances of the diagrams of uniform compression of concrete results in considerable increase of limiting values of relative deformations, that is especially important for operation of statically indefinable constructions.

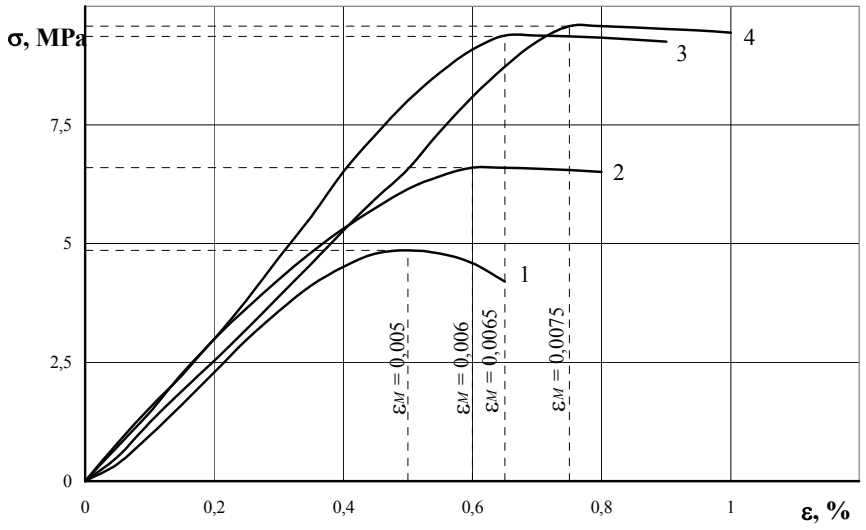

Fig. 3 Diagrams " σ – ε " of uniform compression of prisms with different percentage of lateral reinforcing fabrics:
1 – $\mu_{S,XY}$ = 0 % (without reinforcing); *2* – $\mu_{S,XY}$ = 0,16 %; *3* – $\mu_{S,XY}$ = 0,28 %; *4* – $\mu_{S,XY}$ = 0,35 %

References

1. Chaika. V. P. The performances of the diagrams of concrete nonuniform compression. // Concrete and reinforced concrete. - 1994. - No1. - Pp. 17-19.

2. Zalesov A. S., Chistyakov E. A., Laricheva I. Y. Deformation calculated model of reinforced concrete devices by action of the bending moments and longitudinal forces. // Concrete and reinforced concrete. - 1996. - No 5. - Pp. 16-18.

3. Nazarenko V.G., Bohrovskix A.V. The diagram of deforming of concrete with the account of descending branch. // Concrete and reinforced concrete. - 1999. - No 2. - Pp. 18-22.

4. Baikov V. N., Gorbatov S. V., Dimitrov, Z. A. Building-up of dependence between stress and strains of compression concrete on system of normalized indexes. // News of high schools. A series: construction and architecture. - 1977. - No 6. - Pp. 15-18.

Диаграммы деформирования бетона

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Ключевые слова и фразы: выносливость; модуль крупности песка; модуль упругости стали; несущая способность; относительная деформация; предел прочности бетона; расчетное сопротивление арматуры растяжению; стальные, стеклопластиковые, базальтовые, синтетические фибры; сетки косвенного армирования; устойчивость.

Аннотация: Проведены экспериментальные исследование влияния стальных фибр и сеток косвенного армирования на характер разрушения и деформирования бетона при однородном осевом сжатии образцов. Показано, что применение фибр приводит к незначительному увеличению прочности бетона, а косвенное армирование, наоборот, существенно ее повышает. Следует отметить, что введение фибр и сеток в бетон приводит к существенному увеличению значений относительных деформаций, соответствующих максимальной прочности бетона. Это также значительно увеличивает предельные значения относительных деформаций, что особенно важно для работы статически неопределимых конструкций.

Diagramme des Deformierens des Betons

Zusammenfassung: Es sind die experimentalen Untersuchungen des Einflusses der Stahlfibern und der Netze der indirekten Bewehrung auf den Charakter der Zerstörung und das Deformieren des Betons bei der gleichartigen axialen Kompression der Muster durchgeführt. Es ist gezeigt, daß die Anwendung der Fibern zur unbedeutenden Vergrößerung der Haltbarkeit des Betons anführt, und daß die indirekte Bewehrung im Gegenteil sie wesentlich erhöht. Es ist betont, daß die Einführung der Fibern und der Netze in den Beton zur wesentlichen Vergrößerung der Bedeutungen der relativen Deformationen, die der maximalen Haltbarkeit des Betons entsprechen, anführt. Es vergrössert auch bedeutend die Höchstwerte der relativen Deformationen, was für die Arbeit der statisch unbestimmten Konstruktionen besonders wichtig ist.

Diagrammes de la déformation du béton

Résumé: Sont citées les études expérimentales de l'influence des fibres d'acier des réseaux de l'armaturage indirecte sur le caractère de la destruction et de la déformation du béton au cours de la compression axiale homogène des échantillons. On a montré que l'emploi des fibres aboutit à l'augmentation insignifiante de la rigidité du béton et inversement, l'armaturage indirecte l'augmente considérablement. Il est à noter que l'introduction des fibres et des réseaux dans le béton mène à l'augmentation considérable des grandeurs des déformations relatives qui correspondent à la rigidité maximale du béton. Cela augmente également les grandeurs de limite des déformations relatives ce qui est surtout important pour le fonctionnement des construcrtions qui ne sont pas définies statistiquement.