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MODEL OF CRACK GROWTH INFLUENCE ON ELASTIC DEFORMATION OF CONCRETE

Stolevich O.I.,
Odessa State Academy of Civil Engineering and Architecture
o.i.stolevich@gmail.com, ORCID: 0000-0002-4309-7194

Abstract. In our opinion, at present, the strain-deformed state and cracking in concrete and reinforced concrete elements and structures remains insufficiently studied. In particular, it effects on lightweight concrete. An important point in determining the stress-strain state is the consideration of the material properties in determining the stresses and, in the future, the use of the σ and ε dependencies for design and practical purposes. Therefore, the problem being solved is topical, and for its solution a complex of experimental and theoretical studies with the use of modern computer technology has been carried out.

The development of the methodology, followed by analysis of the experimental data and the model, allows obtaining a variety of results that can be used in research, forecasting of stress-strain state and cracking of concrete and reinforced concrete elements and structures.

The proposed computer model made it possible to determine and evaluate the influence of cracks on the deformation characteristics of expanded clay concrete. The solution of the problem in the finite element model of the construction was carried out by using two methods, depending on the design scheme.

When choosing the most appropriate design scheme, we considered several schemes, in which the criteria of adequacy of the model was the accordance of the initial modulus of elasticity of the model and the Poisson's coefficient to the experimental data. Expanded clay concrete was considered as a two-component material (aggregate-solution). In modeling, the change of the external longitudinal and transverse deformations was calculated, which were also measured in full-scale tests.

The growth of one crack was modeled by the removal of external bonds. The growth of several cracks was modeled by modifying the elastic modulus of the final elements.

One of the modeling results was the construction of graphs of the variation of longitudinal deformations and Poisson's coefficient as a function of the relative crack length.

Keywords: model, crack, methodology, diagram, deformation, concrete.

Introduction. The diagram «σ-ε» of concrete behavior has a deviation from the diagram of linearly-elastic material, which occurs due to inelastic deformations, which are caused by micro crack formation [1-3]. In a paper dealing with aspects of micro cracking formation H. Coven [4] points, that the elastic-viscous state of concrete can be preserved only for linear or minor nonlinear regularities in the strain stress dependencies. At high stress levels, the process of internal destruction, which must be taken into account, takes place [4-8]. According to H. Coven [4], most of the inelastic deformations of concrete can be explained by the destruction of its microstructure.

Purpose of the study. Study of the possibility of modeling the stressed-deformed state of expanded clay reinforced concrete beams under short-term and long-term loading with the use of computational complexes based on the finite element method in a nonlinear formulation.

Methods of research. Evaluation of the influence of longitudinal cracks of tearing on the change in elastic deformations of concrete was carried out using computer simulation of the behavior of a concrete prism with dimensions of 100 × 400 mm. The cracks of the separation in the finite element model of the structure were taken into account by using two methods depending on the design scheme:

– approximation of a concrete element with a crack of a continuous anisotropic solid equivalent in rigidity;

– modeling of concrete with cracks by means of a grid layout of finite elements (FE) along the cracks trajectory.

In order to choose the variant of the most adequate design scheme, we considered several schemes:

a) in the first scheme, a quarter of the prism was considered, with the possibility of spread of one vertical main crack (Fig. 1, a);

b) in the second scheme, half of the prism was considered, with the possibility of several vertical as well as inclined cracks spread (Fig. 1, b). In this case, according to the second scheme, it is possible to model not only a large aggregate, as in the first scheme, but also the presence of initial pores, cracks, different small defects that are initially present in the concrete. The size of the smallest defect we simulated was 0.05 mm;

c) in the third scheme, a quarter of the prism was considered with the possibility of several vertical cracks spread (Fig. 1, c). The adequacy criteria for the model were the correspondence between the initial modulus of the model elasticity and the Poisson's ratio to the experimental data.

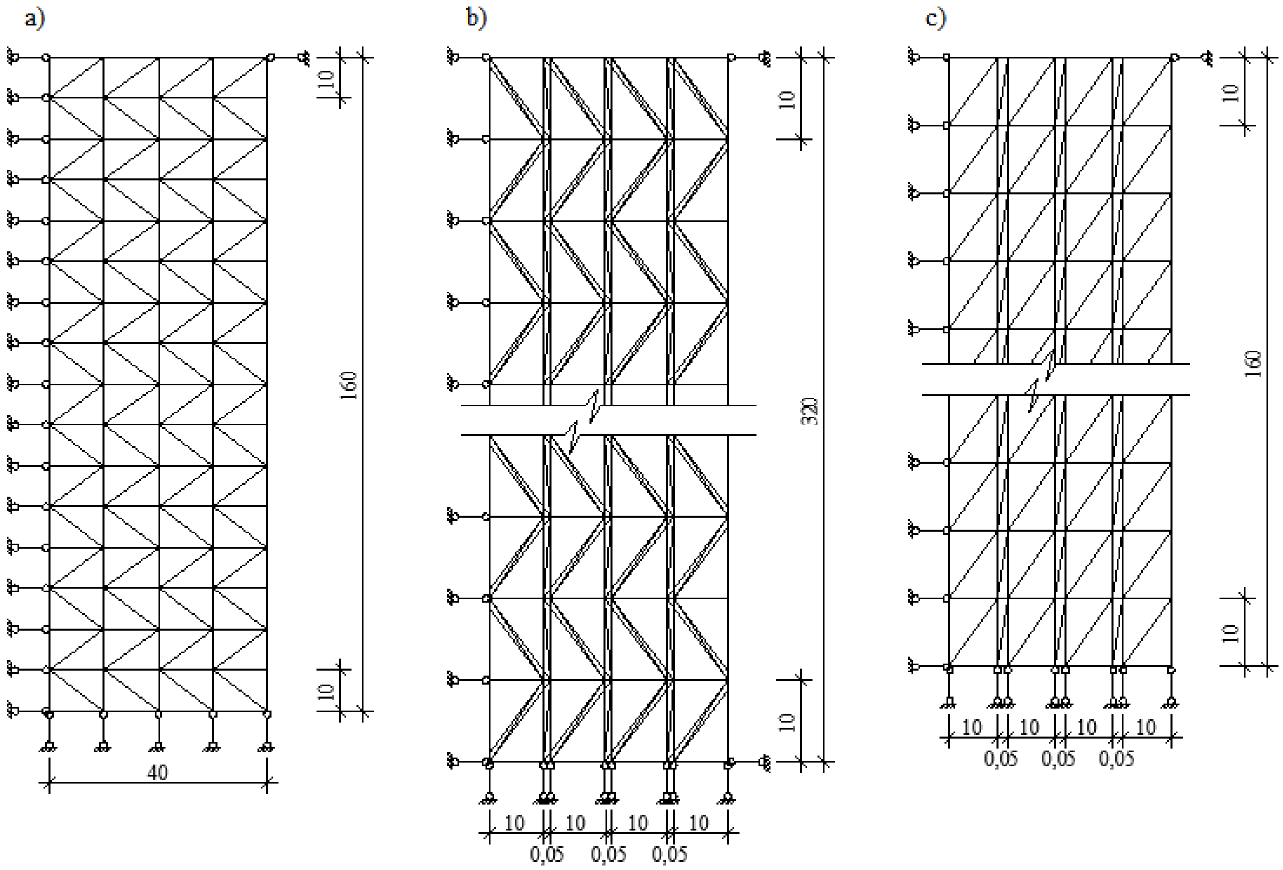

Fig. 1. Design scheme of concrete behavior modelling:
a – with one crack; b, c – with several cracks

Deformations and stresses at the tip of a crack in the general case can be obtained by superposition of three particular types of deformation: separation, transverse and longitudinal shear.

Concrete was considered as a two-component material (aggregate-solution). With the growth of the crack, in modeling the change in the external longitudinal and transverse deformations was calculated. They were also measured in full-scale tests. The growth of one crack was modeled by the removal of external bonds. The growth of several cracks was produced by modifying the elastic modulus of the final elements. The relative crack length was taken as the ratio of the current crack length to the total length of the sample.

Main results of the study. One of the modeling results was the formation of longitudinal deformations graphs variations and Poisson's ratio depending on the relative crack length.

Graphical interpretation of the research results is shown in Fig. 2-6.

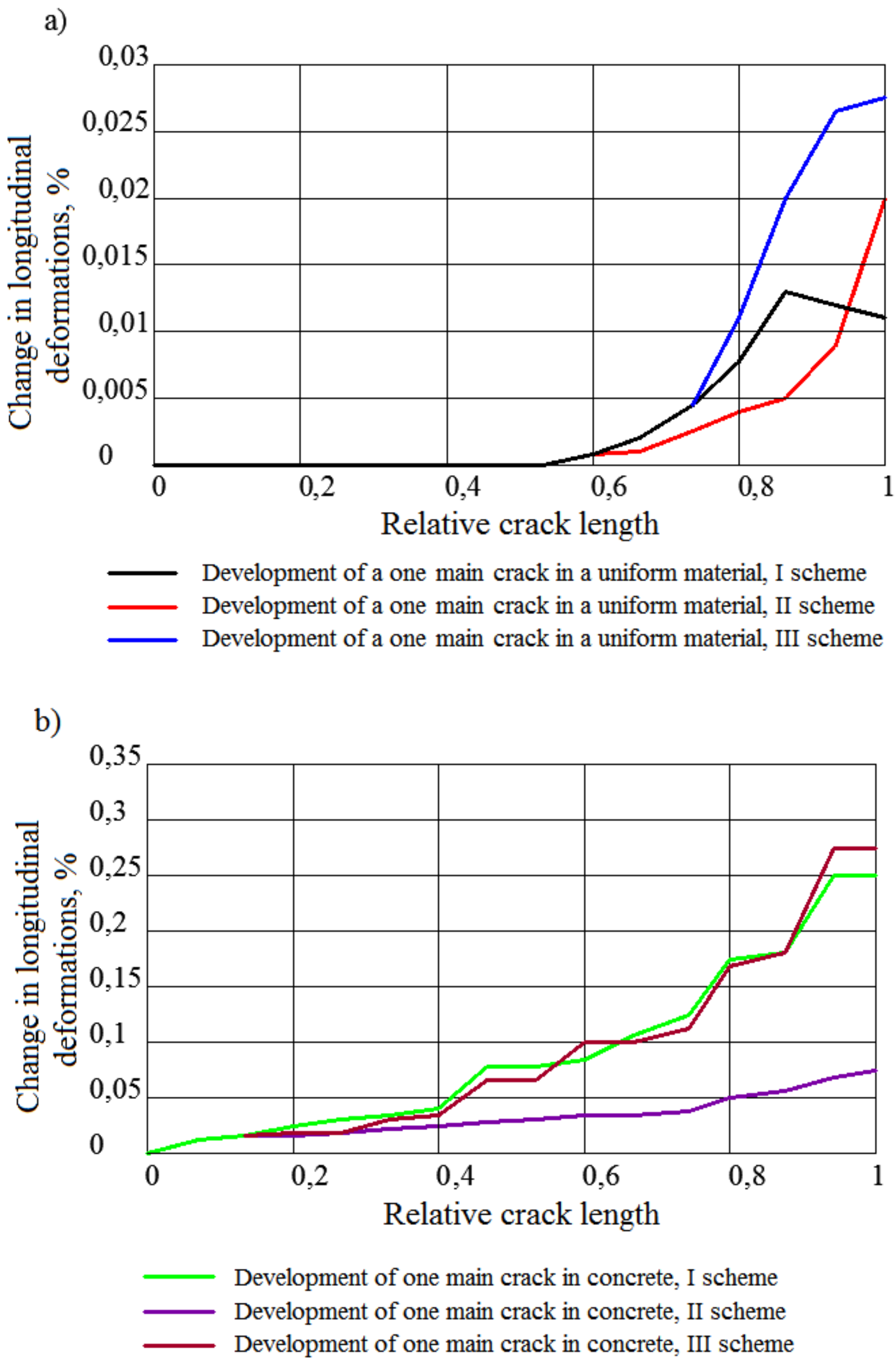

Fig. 2. Change in longitudinal deformations depending on the growth of one main crack:
a – in a uniform material; b – in an nonuniform material (concrete)

As the stresses increased, we took into account the accumulation of plastic deformations, affecting the development of longitudinal deformations. The account is made by summation of deformations with decreasing tangential elastic modulus of the solution part at each stage is identical to its change in full-scale tests. The result of modeling for expanded clay concrete of class C12 / 15 as an example is shown in Fig. 6.

The simplest and most adequate design scheme is the first scheme, with the help of which the behavior of concrete can be described qualitatively. Reducing the size of the FE I scheme up to 0.2 mm, which was done in the future, did not change the obtained conclusions.

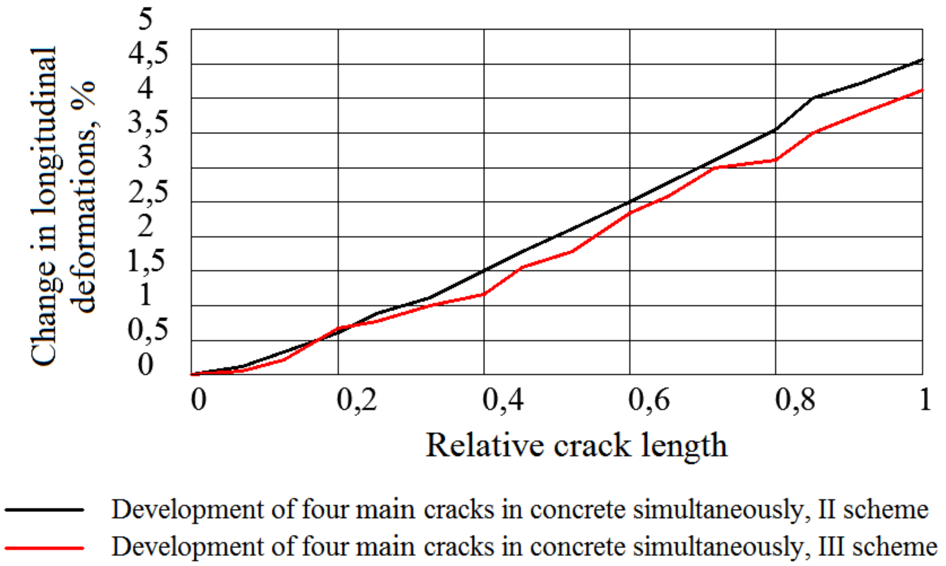

Fig. 3. Change in longitudinal deformations depending on the growth of four main cracks in concrete

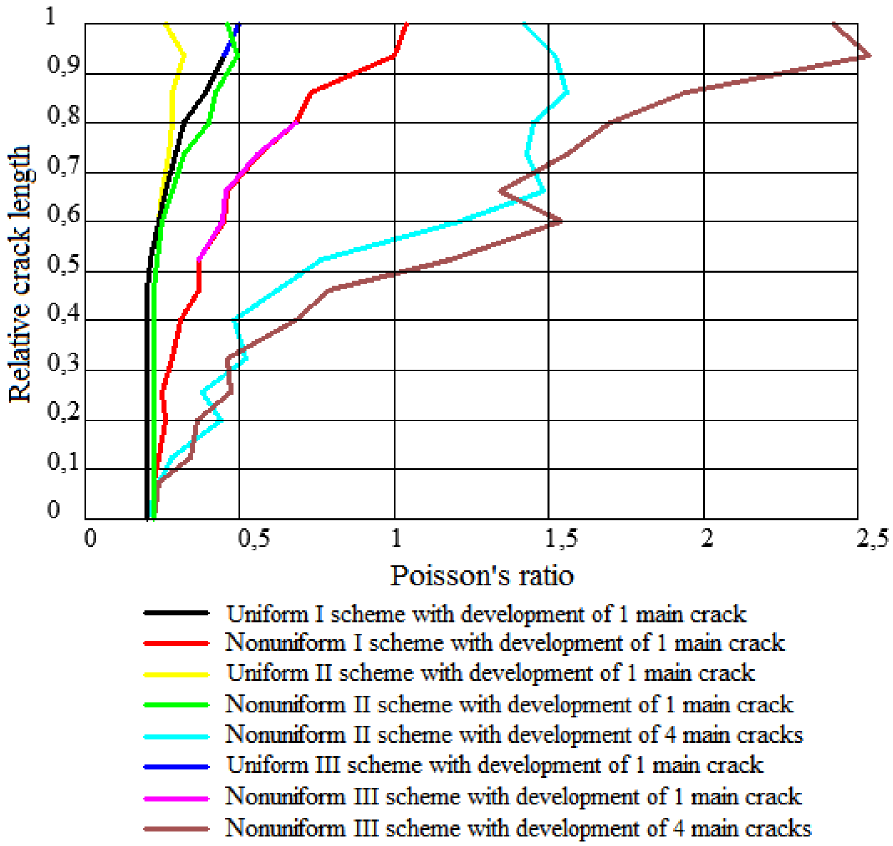

Fig. 4. Change in the coefficient of transverse strains

Our results are analogous to the results of mathematical modeling of the development of a longitudinal crack obtained in study [2]. The fact that the longitudinal deformations change insignificantly with the growth of the crack the author explained by the application of a short-term load.

From the foregoing it follows that the process of plastic deformations flow in concrete cannot be explained solely by the formation of cracks in the separation, as they begin to affect the magnitude of longitudinal deformation significantly only before destruction.

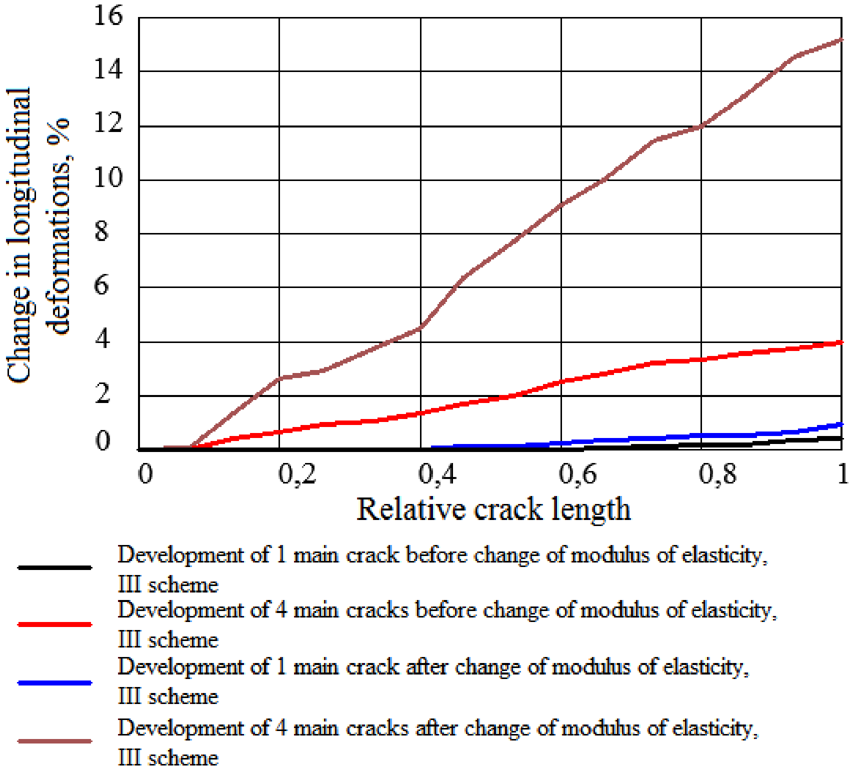

Fig. 5. The result of modeling the effect of crack growth on longitudinal deformations with change the modulus of elasticity of expanded clay concrete solution part

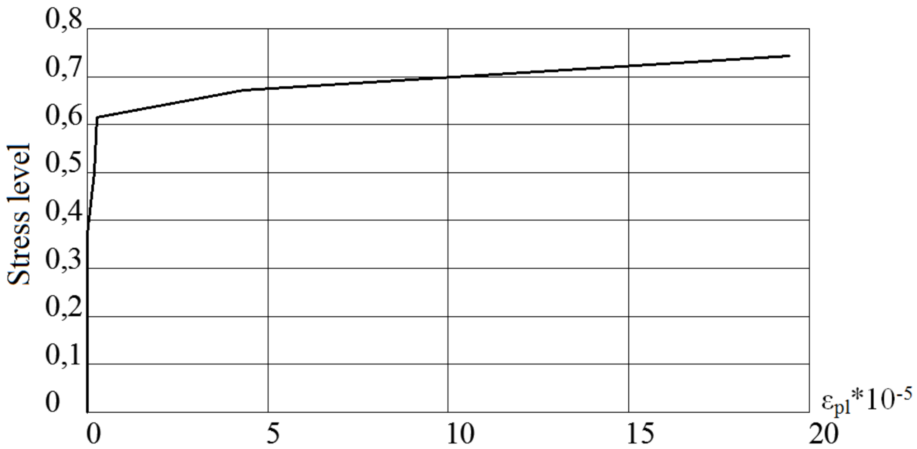

Fig. 6. Dependence of changes in plastic longitudinal deformations on stresses with taking into account the accumulation of deformations as the crack grows

Conclusions:

1. As a result of an increase in the length of one main crack of the separation the growth of relative longitudinal deformations was not more than 0.3%, in both uniform and nonuniform material. In the two-component model considered as an aggregate and a solution part, a decrease in the modulus of elasticity of the solution part doubled the longitudinal deformation due to crack growth by only 1%. The change in transverse deformations in concrete was reliably modeled by the growth of the longitudinal crack of the separation.

2. According to schemes I and III, a more accurate change in the Poisson's ratio was modeled. The calculated curves are similar to data, obtained with full-scale tests of prisms. The growth of several cracks during the modeling led to an increase in longitudinal deformations by 4.6% in comparison to deformations of the model without cracks. After a decrease of the modulus of elasticity of the solution part by two times, the increase in longitudinal deformations was 15%. At

the same time, the opening of the width of the extreme main crack and the "closing" of the remaining cracks were simultaneously observed, which indicated the impossibility of propagation of several main cracks along the ends of prisms in the conditions of straining of deformations. This is also confirmed by the character of prisms destructions under central compression. The Poisson's ratio with the development of several cracks reached a value of 2.4, which is not confirmed in practice.

3. The influence of the growth of one main crack on the change in deformations was 3.4%, with taking into account the accumulation of plastic deformations.

4. In the two-component model of concrete behavior under consideration, the curvature of the diagram is due to a change in the inelastic characteristics of the solution part (located between the cracks), not because of the growth of cracks.

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МОДЕЛЬ ВПЛИВУ ЗРОСТАННЯ ТРІЩИНИ НА ПРУЖНІ ДЕФОРМАЦІЇ БЕТОНУ

Столевич О.І.,
Одеська державна академія будівництва та архітектури
o.i.stolevich@gmail.com, ORCID: 0000-0002-4309-7194

Анотація. На наш погляд, в даний час як і раніше недостатньо вивченим залишається напружено-деформований стан і утворення тріщин в бетонних і залізобетонних елементах і конструкціях. Особливо це торкається легких бетонів. Важливим моментом при визначенні напружено-деформованого стану є облік властивостей матеріалу при визначенні напружень та в подальшому використання залежності σ і ε в розрахункових, проектних і практичних цілях. Тому вирішувана задача є актуальною, а для її вирішення проведено комплекс експериментально-теоретичних досліджень із застосуванням сучасної обчислювальної техніки.

Розробка методики, з подальшим аналізом експериментальних даних і моделі дозволяє отримати різноманітні результати, які можливо використовувати при дослідженні, прогнозуванні напружено-деформованого стану та тріщиноутворення у бетонних і залізобетонних елементах і конструкціях.

Запропонована комп'ютерна модель дозволила визначити і оцінити вплив тріщин на деформативні характеристики керамзитобетону. Рішення завдання в кінцево-елементній моделі конструкції нами проводилось з використанням двох методів в залежності від розрахункової схеми.

При виборі варіанту найбільш адекватної розрахункової схеми нами розглядалися кілька схем, в яких критеріями адекватності моделі служила відповідність початкового модуля пружності моделі і коефіцієнта Пуассона експериментальним даним. Керамзитобетон розглядався як двокомпонентний матеріал (заповнювач-розчин). При моделюванні обчислювалась зміна зовнішніх поздовжніх і поперечних деформацій, які заміряли і в натурних випробуваннях.

Зростання однієї тріщини нами моделювалось видаленням зовнішніх зв'язків. Зростання декількох тріщин виробляли шляхом зміни модуля пружності кінцевих елементів.

Одним з результатів моделювання була побудова графіків зміни поздовжніх деформацій і коефіцієнта Пуассона в залежності від відносної довжини тріщини.

Ключові слова: модель, тріщина, методика, діаграма, деформація, бетон.

МОДЕЛЬ ВЛИЯНИЯ РОСТА ТРЕЩИНЫ НА УПРУГИЕ ДЕФОРМАЦИИ БЕТОНА

Столевич О.И.,
Одесская государственная академия строительства и архитектуры
o.i.stolevich@gmail.com, ORCID: 0000-0002-4309-7194

Аннотация. На наш взгляд, в настоящее время по-прежнему недостаточно изученным остается напряженно-деформированное состояние и образования трещин в бетонных и железобетонных элементах и конструкциях. Особенно это касается легких бетонов. Важным моментом при определении напряженно-деформированного состояния является учет свойств материала при определении напряжений и в дальнейшем использования зависимости σ и ε в расчетных, проектных и практических целях. Поэтому решаема задача является актуальной, а для ее решения проведен комплекс экспериментально-теоретических исследований с применением современной вычислительной техники.

Разработка методики, с последующим анализом экспериментальных данных и модели позволяет получить различные результаты, которые можно использовать при исследовании, прогнозировании напряженно-деформированного состояния и трещинообразования в бетонных и железобетонных элементах и конструкциях.

Предложенная компьютерная модель позволила определить и оценить влияние трещин на деформативные характеристики керамзитобетона. Решение задачи в конечно-элементной модели конструкции нами проводилось с использованием двух методов в зависимости от расчетной схемы.

При выборе варианта наиболее адекватной расчетной схемы нами рассматривались несколько схем, в которых критериям адекватности модели служила соответствие начального модуля упругости модели и коэффициента Пуассона экспериментальным данным. Керамзитобетон рассматривался как двухкомпонентный материал (наполнитель-раствор). При моделировании исчислялось изменение внешних продольных и поперечных деформаций, которые замеряли и в натурных испытаниях.

Рост одной трещины нами моделировался удалением внешних связей. Рост нескольких трещин производили путем изменения модуля упругости конечных элементов.

Одним из результатов моделирования было построение графиков изменения продольных деформаций и коэффициента Пуассона в зависимости от относительной длины трещины.

Ключевые слова: модель, трещина, методика, диаграмма, деформация, бетон.

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