NONLINEAR ANALYSIS OF REINFORCED CONCRETE CONSTRUCTION'S FRAGMENTS IN SCAD SOFTWARE

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1. Introduction

The objective of our research is the development of software for analysing the stress-strain state and bearing capacity of structural fragments, rather than individual structural elements - plates, walls, columns, beams, etc., because the stress-strain state of an individual beam or slab in many cases considerably differs from the stress-strain state of the same structural element, which works in conjunction with its neighbours. We conne ourselves to the consideration of structures consisting of thin-walled plates and shells, and also from spatial bars for which the Kirchhoff-Clebsch hypothesis is satisfied. Quadrilateral and triangular finite elements, taking into account the plasticity both in concrete and in reinforcement, and also taking into account the degradation of the concrete of the stretched zone during the appearance and propagation of cracks, are presented. The quadrilateral finite element (FE) was described in [1], triangular FE - in [2]. In presented paper we focus our attention on the consideration of the behaviour of entire fragments consisted on presented above shell finite elements as well as two-node finite elements of the spatial frame ($\mathscr{Bar}$3D) [3].

2. Problem formulation

Concrete is considered as an isotropic material, described by the relations of both the deformation theory of plasticity, formulated in terms of residual strains, and the relations of the plastic flow theory using the Drucker-Prager and Geniyev yield criteria [2], [3]. The degradation of the concrete in stretched zone due to appearing of cracks is modelled by the descending branch in the diagram $\sigma - \varepsilon$ (the deformation theory of plasticity) and by compression and translation of the yield surface, determined by the decrease of strength of concrete on tension σ_t during the increase of plastic deformations (plastic flow theory) [3]. In the compressed zone, softening is also taken into account after reaching the strength of concrete on compression σ_t.

The reinforcement is considered as the rods working on tension-compression and on transverse shear. For shell elements, the reinforcing rods are smeared in the plane of the given reinforcing layer, however, the reinforcing layers are taken into account discreetly along the thickness of the shell. Each reinforcement layer consists of rods of the same direction, located with the same step, and the direction of the reinforcing bars can be arbitrary with respect to the axes of the local coordinate system of the finite element. For the $\mathscr{Bar}$3D finite element, each reinforcing rod of the longitudinal reinforcement is taken into account discretely. For rebar, we use both the deformation theory of plasticity, formulated in terms of residual strains, and the theory of the plastic flow with von Mises yield criterion.

For the shell finite elements, the Mindlin-Reissner theory is used, and for the $\mathscr{Bar}$3D finite element, the S. P. Timoshenko shear model is applied. To eliminate the shear locking effect, the MITC approach for shell finite elements and the approximation of shear deformations at the midpoint for $\mathscr{Bar}$3D finite element is used. The governing relationships are obtained using the principle of virtual works, the formulation of which for the $\mathscr{Bar}$3D finite element is follows:

[3]SCAD Soft is an IT company, developer of SCAD FEA software, one of the most popular software in civil engineering in CIS countries, certicated according to regional building code.

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$$\iiint_V \delta\boldsymbol{\varepsilon}^T \boldsymbol{\sigma} dV + \sum_S A_S \int_0^a \boldsymbol{\varepsilon}_s^T dx\, \delta A = 0, \quad (1)$$

where $\boldsymbol{\varepsilon}, \boldsymbol{\sigma}$ are the strain and stress tensors for the $\mathscr{Bar}$3D finite element with taking into account of statical hypothesis of the Kirchhoff-Clebsch theory, $\boldsymbol{\varepsilon}_s$ and $\boldsymbol{\sigma}_s$are the strain and stress tensors for the s-th rebar rod, $A_s$is its cross-section area and δA is a virtual work of external forces. The linear shape functions are applied. To calculate the integrals over the volume of the finite element, triangulation of the cross-section domain is performed. We calculate the integrand expressions at the centers of gravity of the triangles, and at the midpoint along the length of the finite element.

3. Numeric results

Figure 1 shows a fragment of a multistorey building, the design model of which is taken from the collection of SCAD Soft problems. The walls are loaded by the weight of above-located floors. In addition, the evenly distributed pressure is applied to the floors. All loads vary in proportion to a single parameter. The curve 1 corresponds to deformation theory of plasticity and curves 2 and 3 - to plastic flow theory, where we use the Drucker-Prager yield criterion for floors and beams and the Geniyev yield criterion for walls. The Geniyev yield criterion presents a non-circular paraboloid in the space of principal stresses \cite{third}. The parameter $\alpha \in (0.532, 0.577]$, where $\alpha = 0.532$ corresponds to maximal deviation of paraboloid from circular shape and $\alpha = 0.577$ corresponds to circular paraboloid.

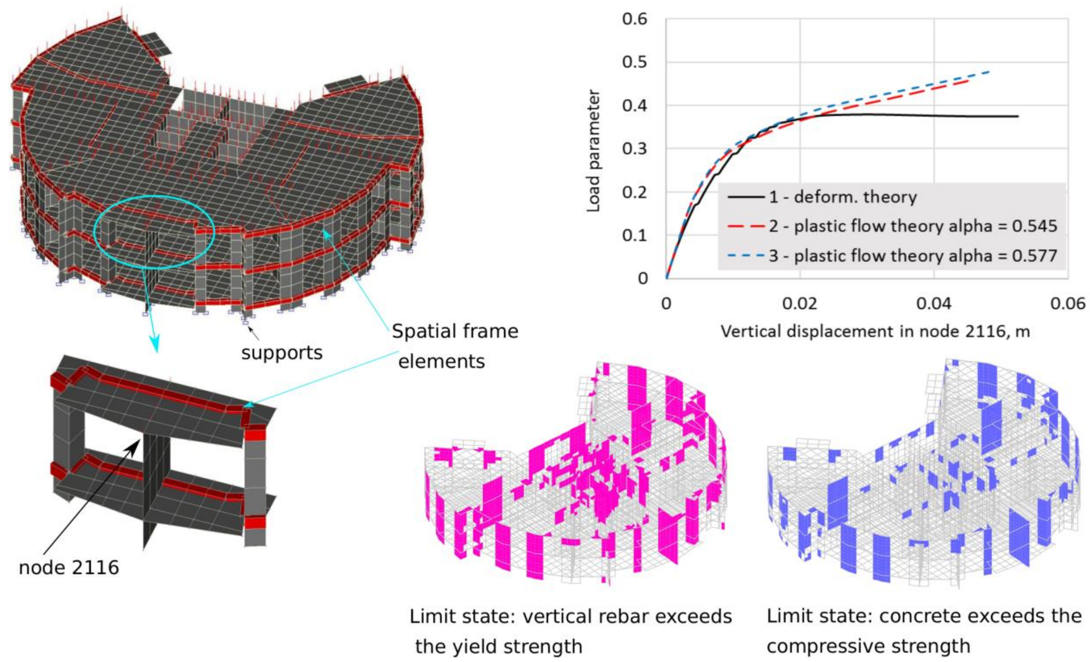

Figure 1 Fragment of multi-storey building

References

[1] S.Yu. Fialko. Quadrilateral finite element for analysis of reinforced concrete floor slabs and foundation plates, *Applied Mechanics and Materials*, 725 - 726, 820 835.

[2] S. Yu. Fialko and V. S. Karpilowskyi (2018). Triangular and quadrilateral at shell finite elements for nonlinear analysis of thin-walled reinforced concrete structures in SCAD software. In: Petraszkiewicz and Witkowski (eds). *Shell Structures: Theory and Applications* Volume 4., Taylor and Francis Group, London, 367-370.

[3] С. Ю. Фиалко Применение метода конечных элементов к анализу прочности и несущей способности тонкостенных железобетонных конструкций с учетом физической нелинейности, *СКАД СОФТ и АСВ*, Москва, 2018 (in Russian).