Features of modeling of energy profile of construction

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Abstract. Presentation and realization of the task of rationalization of structural parameters of reinforced concrete shells is presented. As a criterion for this task an energy principle is adopted, according to which it is assumed that from the whole set of possible values of the desired parameters of the system with a constant volume of material, the number of external and internal connections, the potential energy of deformation (DER) after the reconstruction will reach the lower limit on a rational combination of values of geometric parameters. The energy principle is taken as a criteria on for this task, according to which it is believed that out of numerous possible values of the searched parameters of the system with the constant amount of material, number of external and internal connections, the strain potential energy (SPE) after the reconstruction will reach the lower limit on the rational connection of the geometrical parameters describing the system. The determined interconnection of the rational parameters of the constructive anisotropic shell between SPE of the system of internal and external rational parameters: with ribs step value of about $l \approx 1000$ mm SPE reaches the lower limit.

1 Problem setting

The roofing of buildings and structures accepts essential loading which causes an essential stress-strain behavior (SSB) of the system. Therefore, it would be reasonable to consider such types of roofing which could accept, evenly distribute and transfer such loading to the supports. For this purpose, the most suitable would be the shells of different Gaussian curvature made of the reinforced concrete.

However, searching for the rational constructions of shells which accept the mentioned types of loading, is quite topical, but logically unsolved problem.

Besides, as the reinforced concrete is quite a heavy material, it would be essential to study the methods of its lighting. One of such methods is the embedment of the hole-forming insertions inside the construction, made of the foam polystyrene which at the same time form the shell angle cover. At the same time, giving some geometry to the angle fins

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(due to the changing of the insertion forms), the most acceptable force distribution may be insured, which constitutes a given bearing capacity with the limited use of material.

To sum up, it may be stated that creating the methodology of forming the internal geometry with further experimental verification is the topical issue essential for the construction practice. Its solution will allow increasing the level of reliability of such systems, their durability and due to the rationalization of their construction parameters - realize the minimization of material consumption.

Key methods of calculating the reinforced concrete construction elements according to the main provisions of the deformation models were offered to the draft construction norm of Ukraine.

The shells made of the reinforced concrete and the stress-strain behavior of the reinforced concrete with the use of the calculation models were studied by the following scholars: A.Y. Barashykov, V.M. Bondarenko, O.I. Veinberg, H.M. Gasiy, Y.O. Klimov, H.A. Molodchenko, M.V. Savitskyi, L.I. Storozhenko, H.K. Khaidukov, A.A. Gvozdev, V.V. Shugaev, A.L. Shagin, V.S. Shmukler.

Despite numerous works in this sphere as of now unfortunately, there are no works of non-linear numerical study of two-zone anisotropic shells with the fins in different directions. The mentioned references provide the created theories and engineering methods of the shells calculation [1, 2].

We managed to somewhat specify and transform the notion of the “rational construction” with the help of interesting ideas and studies by H.V. Vasylykov and V.S. Shmukler [3, 4].

Modeling of the stress-strain behavior, geometrical parameters considering the energy principles of anisotropic shells are considered in the works [5-9].

The objective is the rationalization of the parameters of reinforced concrete constructive anisotropic shells. Research the revolutionary type of construction which has the specified external and calculated internal geometry; provide the mathematical modeling of the process of deforming the constructive anisotropic shell with different types of external and internal impacts.

2 Main material

V.S. Schmuckler in his work [10] stated that “for the regulated systems with the constant material volume, number of external and internal connections (external parameters) under the influence of the static external loading - dead weight, the strain potential energy (SPE) after the reconstruction will reach the lower limit on the rational combination of the geometrical parameters values.

$$U = \inf_{\alpha} U(\alpha^k), \quad k = 1, 2, \dots, \infty, \quad (1)$$

where U – is SPE ; k - number of the comparison variant; $\alpha \in M$; M – variety of the acceptable values of the external geometrical parameters.

The approach realization presupposes the construction of interconnection between the system strain energy value and one or a group of the geometrical parameters. Setting the similar task in numerical form is possible when applying the calculation software

complexes, however, the operation presupposes the formation of a big amount of models which complicates the process to some extent.

The work presents the setting and realization of the task of rationalization of the constructive parameters of suggested concrete shells. As a criterion the energy principle was taken, according to which out of the whole variety of possible values of the searched parameters of the system with the constant material volume, number of external and internal relations, strain potential energy (SPE) after the reconstruction will reach the lower limit on the rational combination of the geometrical parameters values describing the system.

The vector of control parameters of this system is introduced into the analysis:

$$\{x\}^T = \{H, B, V, R, L, l, q, \delta, \Delta, h\} \quad (2)$$

where H is a rising height, B is a shell length; V – material volume; R – curve radius, L is a shell passage, l – fin spacing, q – external loading, δ – plate thickness, Δ – fin thickness; h – height of the shell section.

Besides, the parameters H, B, R, L, q – are represented as the external ones, and the parameters l, δ, Δ, h – as internal ones.

The inner fins spacing of the shell l is taken as variable parameter (fig. 1).

Fig. 1. Fins grid variation. Fin spacing a) 1000 mm; b) 1500 mm; c) 2000 mm; d) 2500 mm.

The remaining attributes of the calculation models are given similarly to the previously accepted, except for δ – plate thickness, and the rising height H , taken as 3.8 m. The stability of the material volume, in this case, is provided for the selection of the corresponding value Δ – fin thickness.

As it is seen from the diagram, if the fin spacing approaches $l \approx 1000$ mm SPE reaches the lower limit. Thus, the suggested approach allows determining the rational parameters of the reinforced concrete elements with the complex external and internal geometry.

The given analysis is extended due to studying the distribution of the strain energy density (internal parameter) in this case, the following dependency will constitute the criterion

$$e \rightarrow \text{const}, \quad (3)$$

where e is a density of the strain potential energy (DSPE). The field SPE (Lira PC) leveling was realized due to giving the complex form to the hole-forming insertions. In this case, the fins grid is not orthogonal. The area density of the potential energy depending upon the shell fin spacing with the chief beam 9000 mm are shown in fig. 2.

Fig. 2. The area density of the potential energy depending upon the shell fin spacing with the chief beam 9000mm with the rising height 2,250 mm: a) fin spacing 1000 mm, fins thickness 100mm; b) fin spacing 1500 mm, fins thickness 137.7 mm; c) fin spacing 2000 mm, fins thickness 169.9 mm; d) fin spacing 2500 mm and fins thickness 207.3 mm.

3 Conclusion

The work provides numerous studies of the two-zone anisotropic shells with the fins in different directions. The interconnection is determined of the rational parameters in the constructive anisotropic shell between SPE of the system of external and internal rational parameters: If the fin spacing approaches ≈ 1000 mm SPE reaches the lower limit.

The energy criterion is applied, as to the rationalization of the external constructive parameters of the reinforced concrete constructive anisotropic shells. According to the results of the study, it was determined that (for considered specific conditions) if $H \approx 3.8$ m, the potential strain energy approaches the lower limit. The obtained results were verified through the analysis of natural vibration frequencies of the system for all H values and assessment of maximum bearing capacity (q_{max}) of the shell.

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