UDC 624.073.7

T.N. Azizov, ScD, Professor
Uman State Pedagogical University named Pavlo Tychyna
N.M. Sribnyak, PhD, Associate Professor
A. O. Vavulin, master
Sumy National Agrarian University

ANALYSIS OF STRESS-DEFORMED STATE COVERAGE IN THE FORM OF DOME

The article presents an analysis of the stress-deformed state of thin-walled reinforced concrete shells-domes. The surfaces are outlined for similar geometric shapes. More rational form of the two possible is defined.

Keywords: *dome, umbellate dome, folded dome, PC "Lira", the Gaussian curvature, principal stresse.*

УДК 624.073.7

Т.Н. Азізов, д.т.н., професор
Уманський державний педагогічний університет імені Павла Тичини
Н.М. Срібняк, к.т.н., доцент
А.О. Вавулін, магістр
Сумський національний аграрний університет

АНАЛІЗ НАПРУЖЕНО-ДЕФОРМОВАНОГО СТАНУ КУПОЛЬНОГО ПОКРИТТЯ

В статті наводиться аналіз напружено-деформованого стану тонкостінних залізобетонних куполів-оболонок. Поверхні окреслені за подібними геометричними формами. Визначена більш раціональна форма з двох можливих.

Ключові слова: *купол, зонтичний купол, складчастий купол, ПК «Ліра», гаусова кривина, головні напруження.*

УДК 624.073.7

Т.Н. Азизов, д.т.н., профессор
Уманский государственный педагогический университет имени Павла Тычины
Н.М. Срибняк, к.т.н., доцент,
А.А. Вавулин, магистр
Сумской национальный аграрный университет

АНАЛИЗ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ КУПОЛЬНОГО ПОКРЫТИЯ

В статье представлен анализ напряженно-деформированного состояния тонкостенных железобетонных куполов-оболочек. Поверхности очерчены за схожими геометрическими формами. Определена более рациональная форма из двух возможных.

Ключевые слова: *купол, зонтичный купол, складчатый купол, ПК «Лира», гауссова кривизна, главные напряжения.*

Problem analysis and research. Such structures as shells is actual and architecturally expressive the constructions of covering. The main advantage of shell- covering is the ability to cut large span without intermediate supports, the possibility of combining the constructions that carry and fencing constructions.

It is important for the designer to find a geometric shape that fit well to requirements for the design. Nerve P.L. believed that «the load bearing capacity of construction is a function of its geometrical shape». Rational static work of thin-walled dome can be achieved by optimizing the shape surface. This is a difficult engineering task.

Really, shape of the shell has a decisive influence on its stress state. Calculation and work of shell substantially depend on the Gaussian curvature of the surface. Gaussian curvature is also associated with the linearity of surface. All surfaces in the geometry are divided into three types of surfaces: from parabolic, hyperbolic and elliptic points [1].

Shells with cylindrical or conical surfaces (surfaces with parabolic points) worse resist bending moments. In this case, the danger of deflection is significant. The shells must be properly fixed and reinforced or strengthened diaphragms.

Shells, that median surfaces are composed of hyperbolic points (hyperbolic paraboloid, hyperboloid with single cavity, conoid, part of the torus, etc.), better resist bending moments [1].

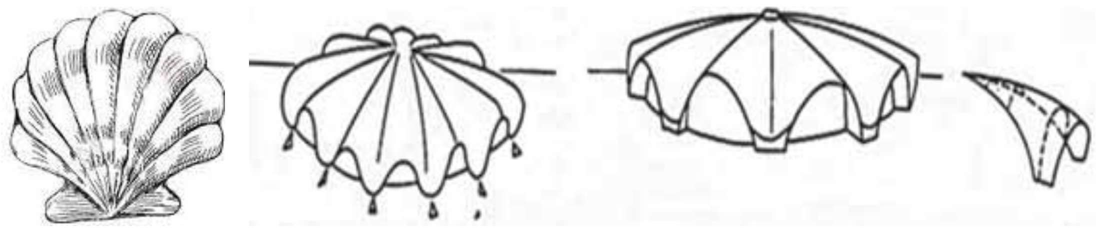
Shells, created in the form of positive Gaussian curvature, resist the load better, than the shells, formed on the surface of a zero or negative curvature. Therefore, probably, this is the justification that the geometry of the shells living nature usually similar to the shells of positive Gaussian curvature [1].

Indeed, at all times the man in the architectural and construction activity, consciously or intuitively, turned to nature. Nature helps to solve various problems man.

Bionic principles (principles embodiment forms of nature in man-made buildings and structures) are presented in the engineering works of P.L. Nerve, F.Otto, B.Fuler, R. Rykolye, Le Corbusier, M.S.Tupolev.

Effective constructive solutions borrowed from living nature. The maximum effect of strength, stability, reliability is achieved by such constructive solutions. At the same time there are a saving of material and light weight of construction. It is an indisputable fact that the surfaces like surfaces of living nature are both architecturally expressive and beautiful [8]. An example can be covering-shells with complex curved surfaces. These surfaces are not described mathematically (for example: mollusk shells, shells of turtles). Such shells are widely used in architecture.

It is in the dome constructions, as in the shells of positive Gaussian curvature, saves material. All opportunities of the surface geometry for covering large spaces also are used.



a **b**

Figure 1 – Analogy between the forms of nature and dome structures created by man: a- sea shell; b-wavy domes

Modern thin-walled domes belong to the most economical spatial constructions. At a thickness of the shell 1/600-1/800 span they allow block spans up to 150 meters.

In a folded dome material consumption much more than a smooth. However, the folded construction has several advantages: thanks to the open ends of the external waves ensured a full upper and lateral natural lighting of interior space. Expressive and surround form of construction enriches the composition of facades and interior of the building.

Thus, wavy dome is an interesting shape from the viewpoint of static work. This is due to its similarity of form shells living nature. Such a rational form "deserves" for research and analysis of the stress state.

Research stress-deformed state of the reinforced concrete spatial covering of trade exhibition center (fig. 2) by numerical methods is the **aim of the article**. This research is also scientific part of the master's graduate work.

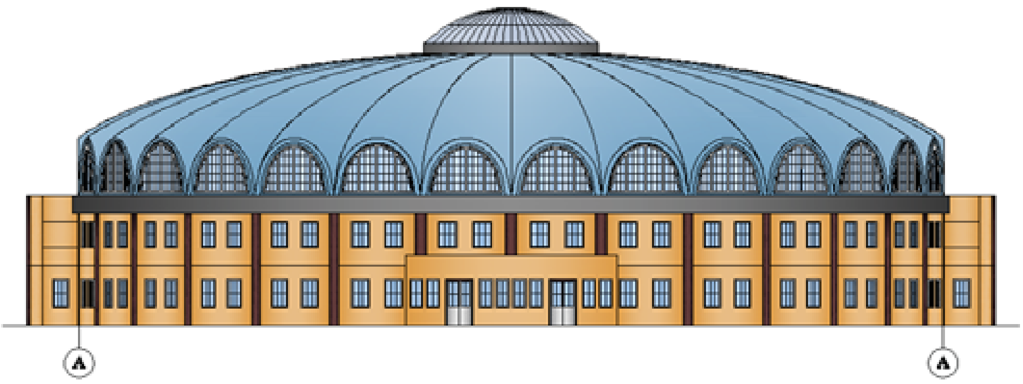
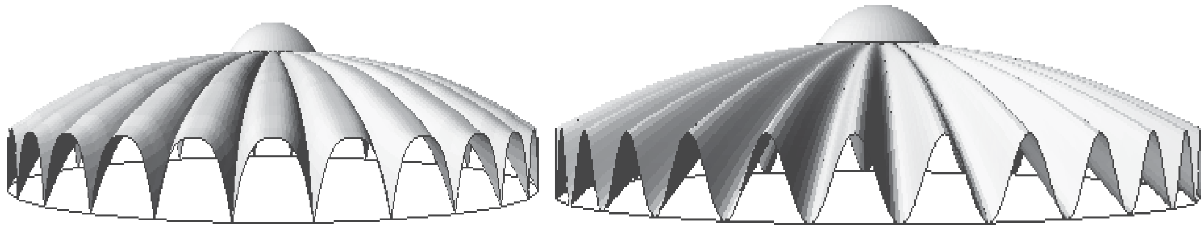


Figure 2 – Trade and Exhibition Centre

The coating is a wavy dome on a round plan. It is supposed to investigate two options of covering. Coatings are visually similar, but have differences in the geometry of the surface (fig. 3).

The main material. Usually the surface of component elements of the shells is accepted as cylindrical shells in the global construction practice. More rationally accept the surface elements of shells in the form of surfaces of positive curvature. This is due to the increased resistance of the coating. The corner areas of coating, where there are principal tensile stresses, are reduced. Take it in the form of cylindrical surfaces is not rational.



a b

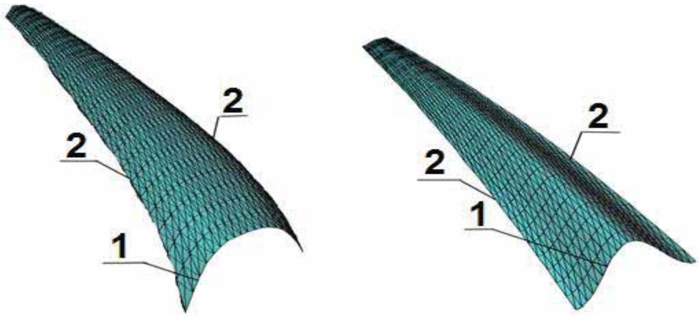
Figure 3 – The calculation schemes of wavy concrete domes:
a- umbellate dome; b- folded dome

The dome has the cutting in the direction of the meridians. The construction consists of thirty identical elements — waves that look like the surface of a double Gaussian curvature (fig. 4). Convexity of waves in both directions — the meridional direction and the transverse direction is directed upward. Projection length of the element on the horizontal axis is 24,5 meters; width of the wave – 6,3 meters, wave height – 10,7 meters; weight is about 2,5 tons.

The height of the upper light transmission dome is 3 m, and the diameter of its base is 12 m. Thus, the total height of the construction is 13,7 m, and the overflight of the construction — 60 m.

Segments of cover (waves) are thin-walled concrete shells.Shells are connected by neck raised face each other and framed by reinforcement ribs. The efforts of raspor are perceived by lower reinforced concrete support ring in the shell.

The difference in the geometry of surfaces is only in the equation that describes a curved line. This line is a generatrix of single wave. In the first case (fig. 4,a) generatrix line is a parabola, and in the second case (fig. 4,b) is a segment of a sinusoid, which is limited to one period.



a b

Figure 4 – Formation surface of the wave dome (the surface of the transfer):
a – generatrix is a parabola; b – generatrix is sinusoid;
1 – curve generatrix; 2 – curves guiding

Ribs frame concrete dome waves. The support ring perceives the raspor of construction. The ribs and the support ring are approximated by rod FE (finite elements) of general form in the calculation scheme. Thin-walled reinforced concrete wave-shells and filling of the upper dome are approximated by the lamellar finite elements.

As characteristics of stiffness for FE were adopted:concrete class B35 with characteristics: Rb = 19,5 MPa , Rbt = 1,3 MPa , E=3,45·10^{6} MPa, ρ = 2,45 t/m^{3}, μ = 0,2. Class A 400 [3] is adopted for armature. Material filling the upper of the dome is plexiglass with the following physical and mechanical characteristics: ρ = 1,19 t/m3, μ = 0,2, thickness — 6 cm.

Adopted two types of load: of dead weight of construction and snow load for Kharkov - 182.4 kg/m2 [4]. Load was specified in two versions: uniformly distributed over whole surface the shell and applied only ½ field of shell (partial loading is possible if a strong wind effect on the one hand and the accumulation of snow cover in a certain area of covering).

After performing static calculation of both schemes in the software package "Lira 9.4", let us examine the tension changing and move nodes. Tensions and deformations are researched in the cross section of the shell on the interval equal to ½ its diameter.

Character of deformation of shells is presented in fig. 5-6.

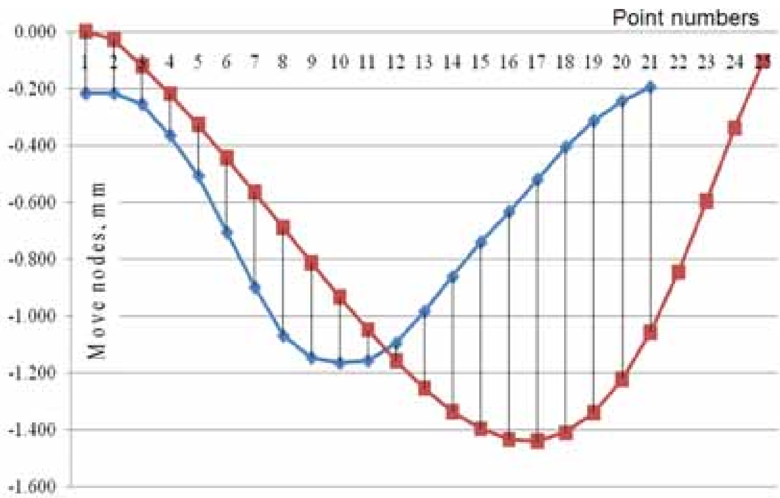


Figure 5 – Moving nodes of shells along the Z axis in a symmetrically load: umbellate dome; folded dome

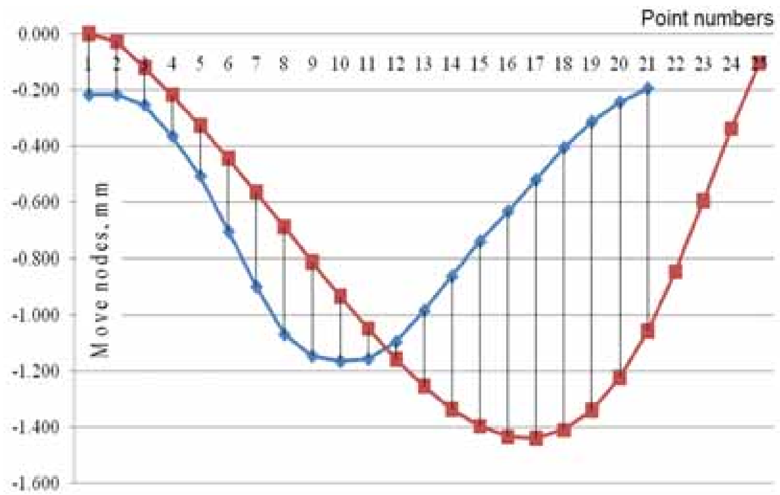


Figure 6 – Moving nodes of shells along the Z axis for a un symmetrically load: umbellate dome; folded dome

Distribution of the major stresses in the cross-section of shell is shown in fig. 7-10.

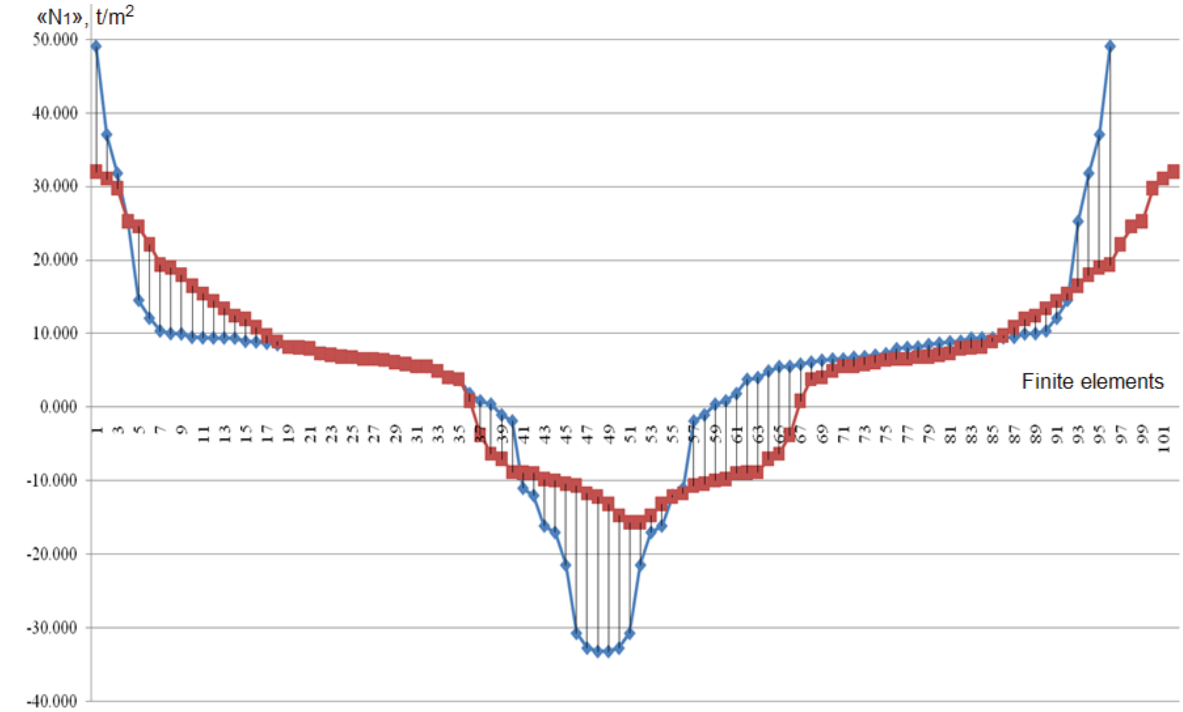


Figure 7 – Diagrams the major stresses «N_1» with symmetrically loading domes by snow load: umbellate dome; folded dome

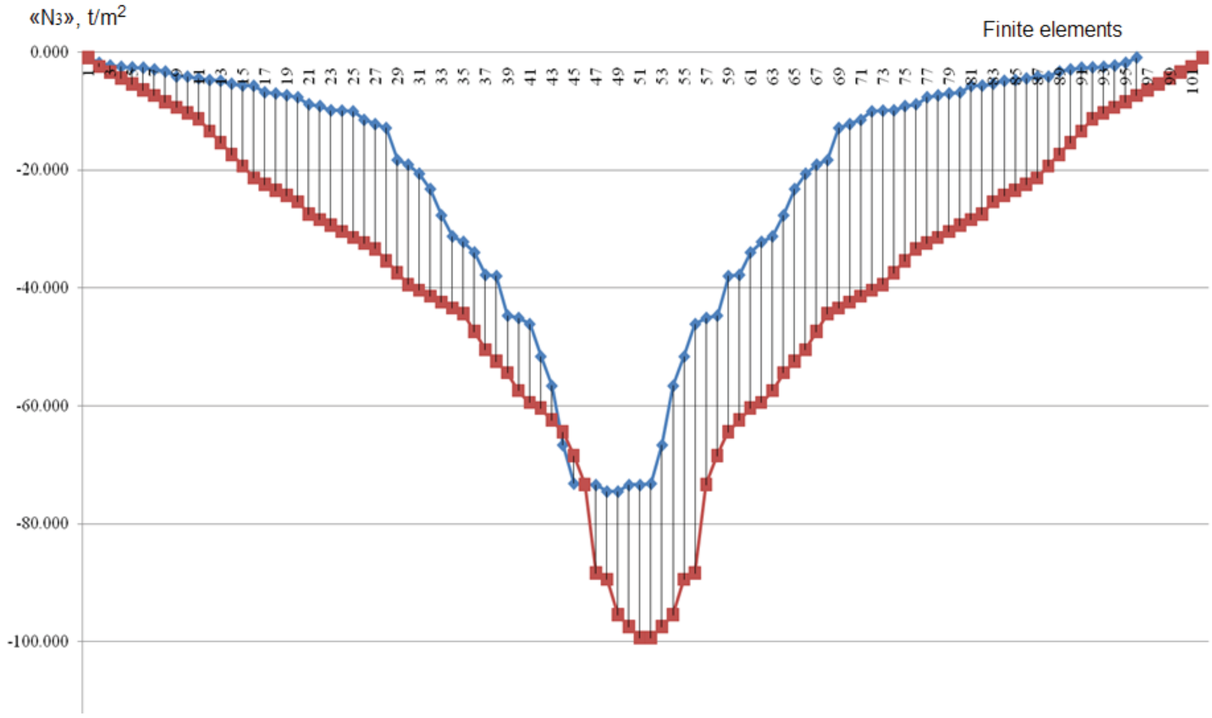


Figure 8 – Diagrams the major stresses «N_3» with symmetrically loading domes by snow load: umbellate dome; folded dome

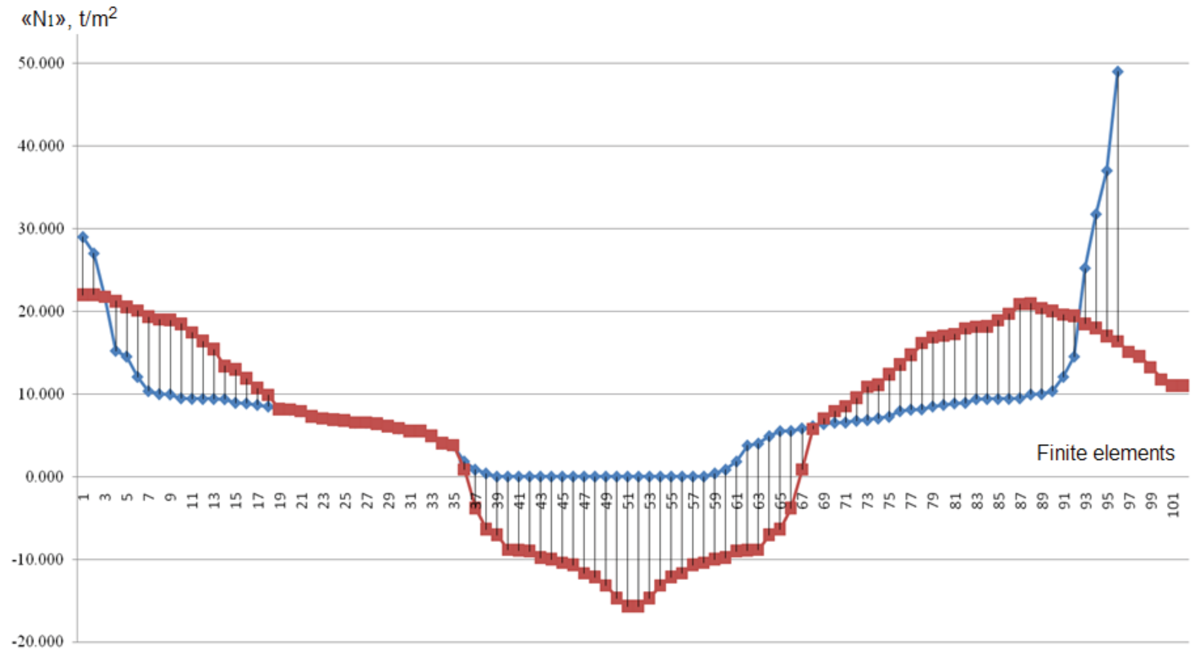


Figure 9 – Diagrams the major stresses «N_1» with unsymmetrical loading domes by snow load: umbellate dome; folded dome

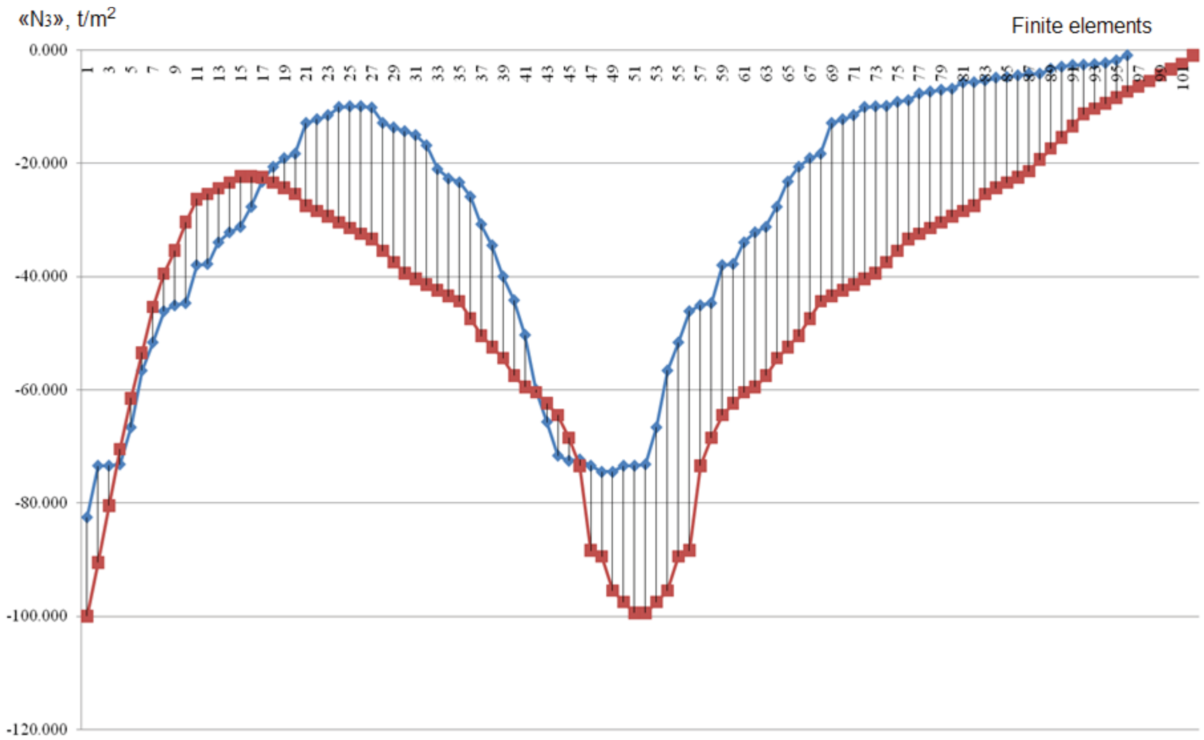


Figure 10 – Diagrams the major stresses «N_3» with unsymmetrical loading domes by snow load: umbellate dome; folded dome

The **conclusions** and analysis of the stress-deformed state of structures.

1. The complicated stress-deformed state appears in wavy reinforced concrete shells of both types.

2. In general, shell exposed compressive stress in the case of uniformly distributed load, and in the case of an asymmetric load.

3. The stresses are distributed throughout the shell thickness evenly. Stress intensity is distributed over the surface of shells symmetrically, evenly for symmetrical snow load.

4. Strength terms of compression and expansion of shells are performed. Maximum principal compressive and tensile stresses do not exceed the calculated resistances of the accepted class of concrete, both for the compression and tension.

5. The shell thickness is 10 cm is sufficient for the perception of stresses in it.

6. In symmetric loading:

– maximum compressive stresses in the corner area of the umbellate dome by 22,3% more than in the folded dome; in the middle zone they are more than by 96% higher than in the folded dome;

– maximum tensile stresses in the center area of the umbellate dome is 22,3% that less than in the folded dome;;

– in the corner area of folded dome the tensile stresses at 93,5% higher than the similar stresses in umbellate dome;

Thus, given the nature of the stresses distribution and the absolute value, an effective construction is the construction of the umbellate dome.

7. In asymmetrical loading:

– maximum compressive stresses in the corner area of the umbellate dome by 22,3% more than in the folded dome;

– tensile stresses in the corner area of the umbellate dome exceed on 80% similar maximum tensile stresses in the folded dome;

– tensile stresses in the central part of umbellate dome on 97% lower than in the folded dome.

8. Tensile stresses are the most dangerous for concrete. Comparing these stresses, it can be concluded that in both schemes of loading higher values of tensile stresses arise in the folded dome. Their magnitude is insignificant - around 25% for symmetrical and 17% for a nonsymmetric load.

9. An factual maximum deflection of umbellate dome is 1,17 mm with symmetric loading; and 2,05 mm for unsymmetrical loading.

An factual maximum deflection of folded dome is 1,43 mm with symmetric loading; and 2,77 mm for unsymmetrical loading.

Deflections of reinforced concrete elements do not exceed the values given in [5] for spatial constructions.

So the condition of the stiffness for spatial construction is performed.

The deformability of the umbellate dome is somewhat smaller than the folded dome for both options loadings. This is evidenced by the graphics of deflection (see fig. 5—6).

So, in terms of static work, **efficient construction** is an umbellate dome (fig. 3, a).

References

1. *Sribnyak N.M. Analysis of the stress state of the shell formed by the surface of the hyperbolic paraboloid / N.M. Sribnyak // Bulletin SNAU. Series "Building". Iss. 9 (11), 2006 [Text]: Scientific-Methodological magazine.-106 p. – Sumy, 2006.*
2. *Sribnyak N.M. Investigation of the stress-deformed state of concrete folded dome / N.M. Sribnyak, A.O.Vavulin // Proc. of the conference of teachers and students SNAU (20-29 April 2010). — in 3 volums / Vol III. [Text]: Abstracts - 302 p. - Sumy, 2010.*
3. *SP 52-101-2003. Concrete and reinforced concrete structures without prestressing reinforcement - M.: GUP " NIIZhB", FGUP ZPP, 2004. – 53 p.*
4. *DBN B.1.2-2: 2006. Load and impact. Design standards. K.: Ministry of Construction of Ukraine, 2006. -78 p.*
5. *DSTU B V.1.2-3: 2006. Deflections and moving. Requirements engineering. Kyiv: Ministry of Construction of Ukraine, 2006. - 15 p.*
6. *SP 52-117-2008. Reinforced concrete spatial construction of covers and ceilings. Part I. Methods of calculation and design. Moscow: FGUP " NITs" Building ", 2008. – 143 p.*
7. *Architectural bionics. / Y.S. Lebedev, V.I. Rabinovich, E.D. Polozhay et al.; Under the editorship Y.S. Lebedev. - M. Stroyizdat, 1990. — 269 p.*
8. *Bionic research pavillion part of the current naturalizing architecture exhibition in frac center in France. [Electronic resource]. URL: http://www.archisearch.gr/article/1354/bionic-research-pavillion-part-of-the-current-naturalizing-architecture-exhibition-in-frac-center-in.htm. (Date of access 06.03.2014)*

Надійшла до редакції 17.02.2014