UDC 624.011

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THE CONSTITUENT ELEMENTS STRUCTURES COVERING OF HYPERBOLIC PARABOLOID

Hypar is a hyperbolic paraboloid representing translational ruled developable anti classical surface, i.e., the surface of negative Gaussian curvature. Shaping of the parabolic elements corresponds to buckling of the shell and the main tensile forces are arranged in the ascending direction of parabolas, and the main compression force - in the direction of the descending parabola. Composite materials are formed from the combination of two or more layered materials, each having very different properties. ANSYS Composite PrepPost software provides all the necessary functionality for the analysis of layered composite structures. The paper discloses a possibility of using for shell covering negative curvature. Design solutions into constituent elements structures and computations such structures are presented.

***Keywords:** Hypar, negative curvature, negative Gaussian curvature, ANSYS Composite PrepPost , shell, software.*

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ПОКРИТТЯ ТИПУ ГІПЕРБОЛІЧНИЙ ПАРАБОЛОІД ЗІ ЗБІРНИХ ЕЛЕМЕНТІВ

Гіпар – гіперболічний параболоїд, що має трансляційну лінійчату нерозгортаючу антикласичну поверхню, тобто поверхню негативної гаусової кривизни. Формоутворення з параболічних елементів відповідає випинанню оболонки і головні зусилля розтягування розташовуються у напрямку висхідних парабол. Композиційні матеріали мають анізотропні характеристики, у зв'язку з чим їх часто використовують при вирішенні специфічних конструкторських завдань. ANSYS Workbench спеціалізований програмний продукт – ANSYS Composite PrepPost (ASP), у якого всі слойоні елементи дозволяють оцінювати міцність за допомогою різних критеріїв руйнування (критерій максимальних деформацій, напруги, цая-ву, хашин, гипотеза цая-хилл). Надається конструктивне рішення різних типів складових елементів, а також розрахунки таких конструкцій.

Ключові слова: від'ємна гаусова кривизна, оболонкові покриття, композиційні матеріали, ASP, критерії руйнування.

Introduction. The shell has low weight and at the same time very robust constructive form. The bending deformation property of shells due to the curvature of the surface has better performance comparatively to the plates. The middle surface of the shell – a hyperbolic paraboloid is ruled translational anti-classical surface, i.e. surface negative Gaussian curvature.

In building two types of shells are used:

– Shell with contour, composed of straight lines (with form of twisted rectangle or parallelogram);

– Shell with contour, composed of curved lines;

The middle surface of both types shells is identical –hyperbolic paraboloid. Shell with the contour of straight lines is widely used [1]. Shell of the constituent elements of certain sizes fill one petal (Figure 1) or petals system at shell size 36×24 м (Figure 2) [2-3].

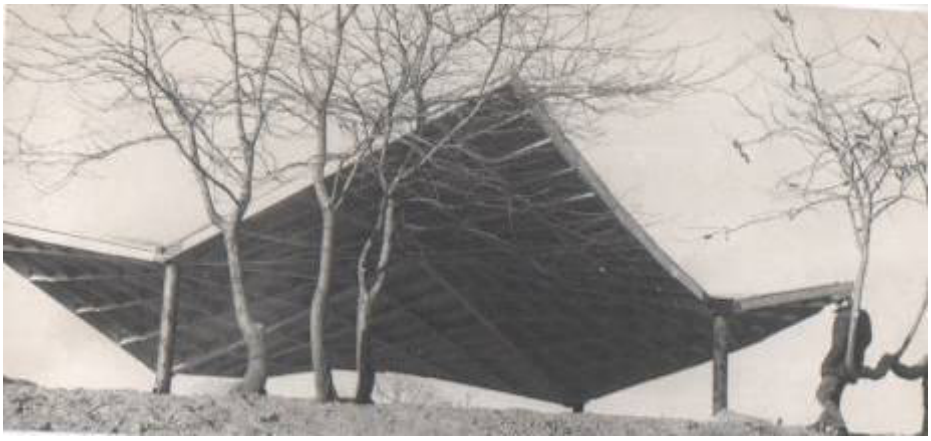

Figure 1 – General view of the shell 12×12 m

Figure 2 – A fragment of shell 36×24 m

Hyperbolic paraboloid surface causes certain difficulties for the approximation of the shell surface in the prefabricated components. Large resistance to this form shell buckling is explained by the main tensile forces located along the ascending direction of parabolas, and the main efforts of compression - in the direction of the descending parabola (Figure 3) and (Figure 4). The longitudinal joints are perpendicular compressive forces and focus on diagonals on the supporting part. Active load results in enhanced pressing element longitudinal of sandwich panels longitudinal edges are increasing. Parts shaping parabolic panels are detailed in the monograph [1].

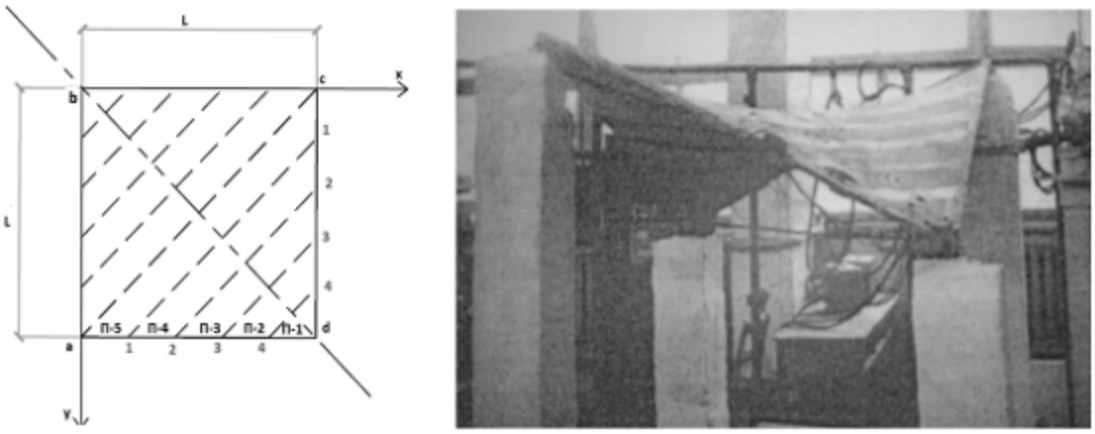

Figure 3 – The cutting surface of the shell to the petals parabolic prefabricated elements and shell parabolic profile size 1,5×1,5 m:

a – the ascending parabola (ac); b – the descending parabola (bd);
c – parabolic elements (П-1) – (П-5); d – the joints parabolic elements (1-1) – (4-4).

The problems of the construction industry are inextricably related with the reduction of material, labor and energy construction resources and buildings and structures operations. They are the cause of permanent searching new methods and improvement of existing design solutions. The most promising ways to address these problems, as well to achieve a significant reduction of the building and structures weigh while maintaining the highest strength and stiffness properties it is considering appropriate practical application of the construction lightweight design in the form of parabolic panels.

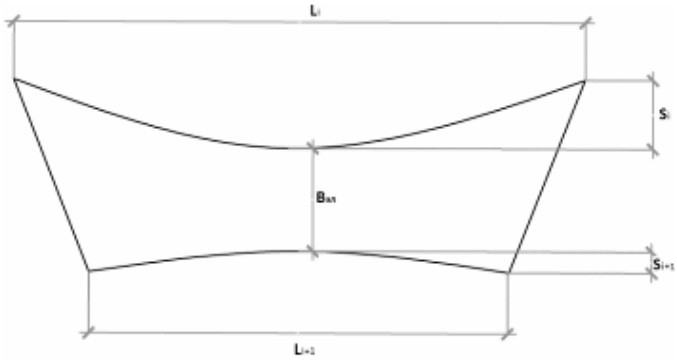

Figure 4 – General view of parabolic element

Review of the latest research sources and publications. Among the unique designs executed by individual projects and structures different from mass production in the first place by its shape, wooden hyperbolic shell are included. Such shell structures are received in Germany, England and several other European countries. Experimental study of shell hyperbolic from composite materials such as wood and plywood were investigated in a number of papers [1 – 7]. For example, in [2] presented testing data shallow shell model on quadratic plan, collected from 10 ribbed panels with twisted configuration were shown. Considering the fact that in Ukraine the construction of coverings experience with the use of combined structures is limited to only a few examples of shell hyperbolic, but it is possible to elaborate on the actual results of the their cost-effectiveness evaluation, performed in [5] and [6]. Particularly these works indicated that the two-piece shell construction plan dimensions of 2×10×10 m were fabricated by five qualified workers for only one month. By value, in practice shell structure can be compared with the design of modular panels of hyperbolic shell. The comparison shows that the shell is 30% more economical.

Problem statement. The aim of this work is to study the effect of forming on the carrying capacity and deformation property the shell in the shape of hyperbolic paraboloid. In this context, the authors assumed the construction of light metal-wood prefabricated hyperbolic coverings (Figure 5), composed from sandwich constructions of standard panels (Figure 3) and (Figure 4).

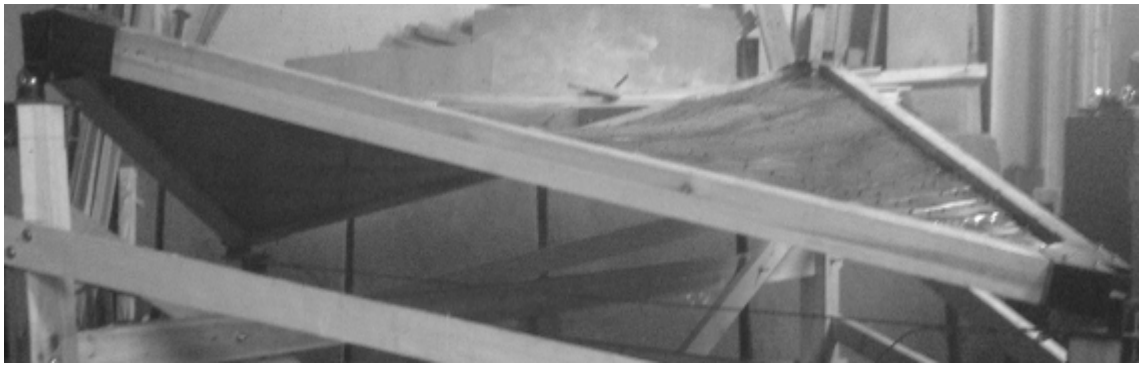

Figure 5 – Side view of the shell from a parabolic panel size 3×3×0,35 m in the laboratory of the department MW&PC, OSABA.

The effectiveness of structures created on the basis of sheet materials and nonflammable lightweight materials, is determined by their low weight, simplicity and speed of assembly, high operational reliability. Buildings erected by using light sandwich panels, have widely used in the world practice of building, which to some extent determines the relevance of their use. However, experience of design and operation discussed structures is insufficient relative to parabolic prefabricated elements (as the sandwich panels) (Figure 4). Sandwich panels consist of profiles skins exterior and interior, which are 0.4 mm thick, among that is an insulating layer of polyurethane foam, and specified step are cross wood elements. All panels are joined together through longitudinal frame timber elements, consisting of longitudinal and transverse members directed downward and upward parabolas.

The basic material and results. On the basis of calculations performed in the ANSYS software system [8 – 10], it was examined the influence shaping the shell (Figure 6) of the component elements considering pliability joints on the state of shell stress under the action of uniformly distributed load.

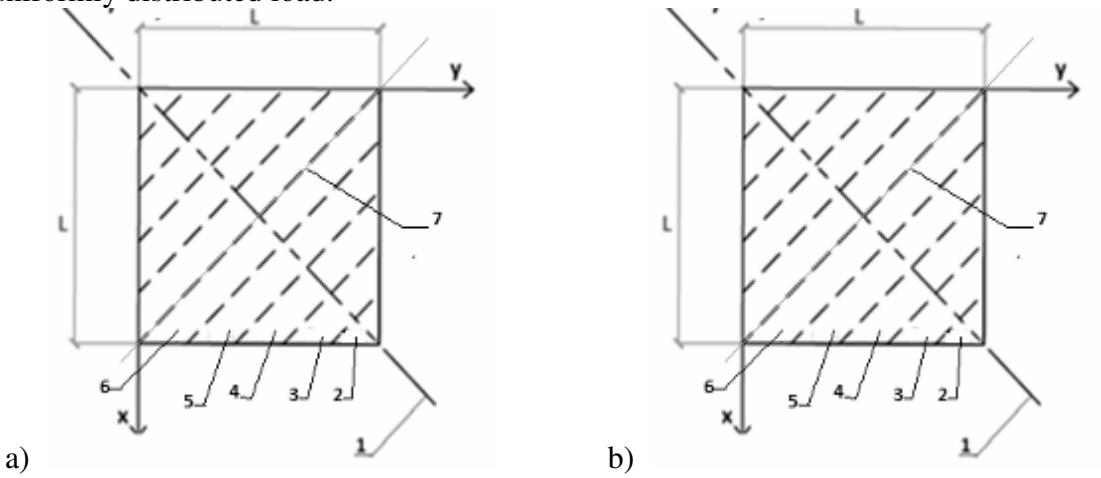

Figure 6 – Comparison calculation models of two types of compound shell
a – shell from the parabolic elements;
b – shell from asymptotic elements as the a twisted rectangle;
1 – Diagonal axis of symmetry; (2-6) – Panels 1; 7 – Symmetry of typical panel axis

Examination of presented diagrams and graphs shows:

– Figure 7. The curves represented the maximum deflection under load for shell from the parabolic elements and asymptotic (in the form of a twisted rectangle) with the same suppleness in the joints of the elements. Comparison of deflection shells graphs shows that, vertical displacement increase considerably almost twice in comparison 2nd and 3th shells, thus shell from the parabolic elements perceives the load better than relatively asymptotic elements. Also in Figure 8. contour plots of displacements in z were depicted, which shows that the biggest deflections in three shell available at points is close to a quarter of the span. From the deflections distribution in (Figure 9) it is noted a great similarity between the first and 3th shells that substantially demonstrates the commitment of the 1st shell work as rigid shell, due to increase in the active load and clamping parabolic elements.

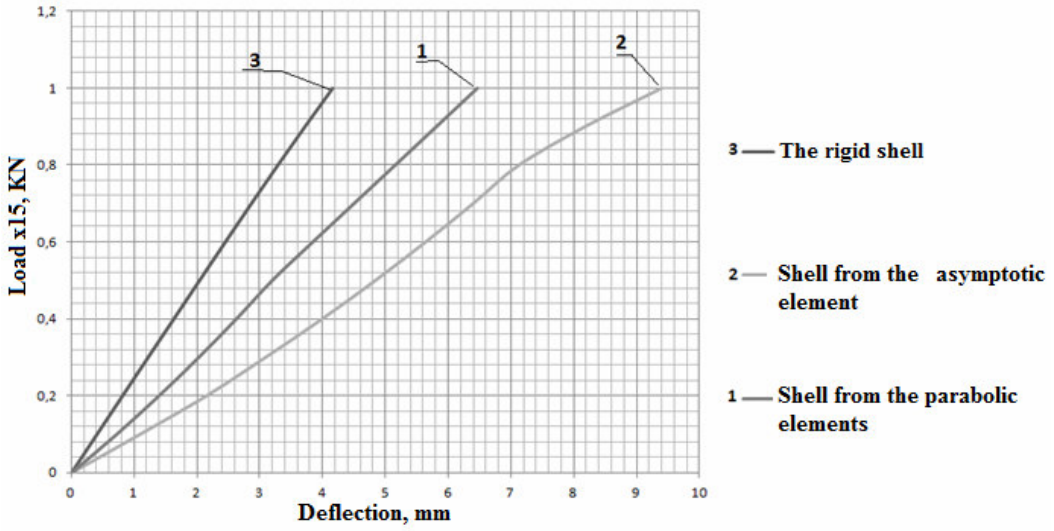

Figure 7 – The dependence of the load-deflection

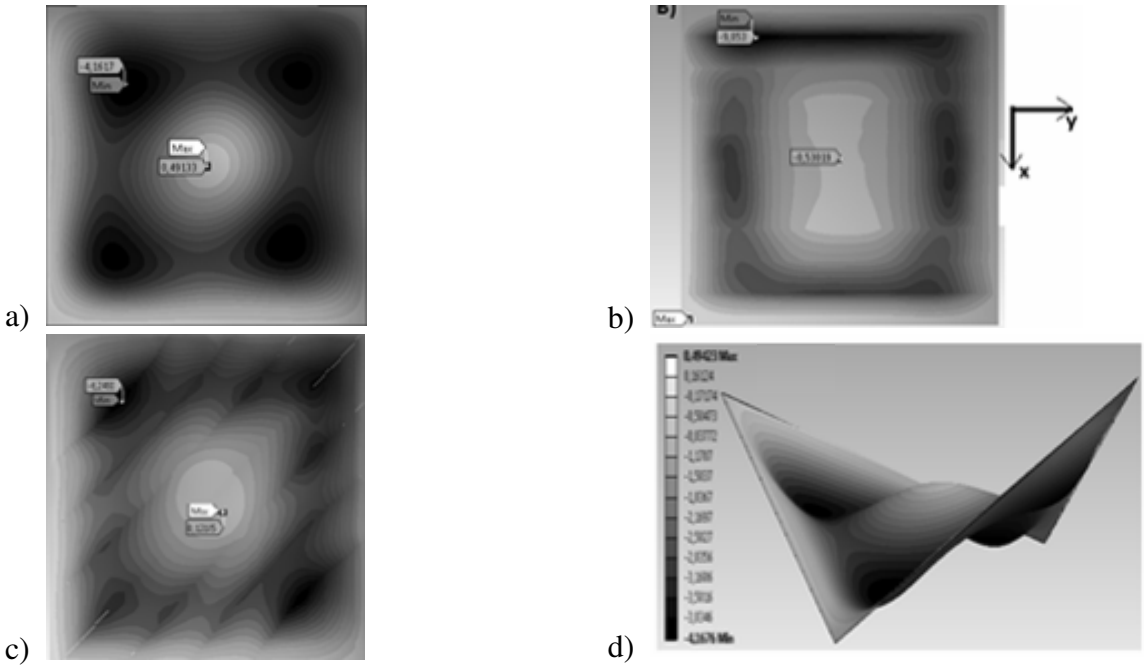

Figure 8 – Displacement contour plots in the direction Z
a – Rigid shell; b – Shell from the asymptotic elements;
c – Shell from the parabolic elements

– Figure 9 is characterized by elastic-plastic structure work area, and it is observed in the elastic deformation stage, large proximity works of first and 3th shells, while the 2nd shell experiences the most effort. Similarly, in (Figure 10) the main compressive stress, easily visible individuality stress distribution between the first and 3th shells is represented.

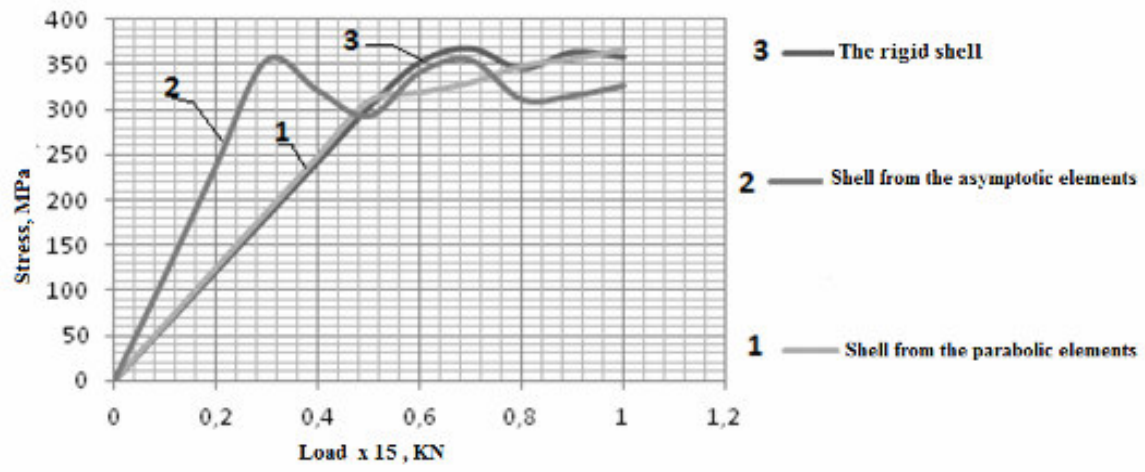

Figure 9 – The dependence of the maximum equivalent stresses the Von Mises on the load

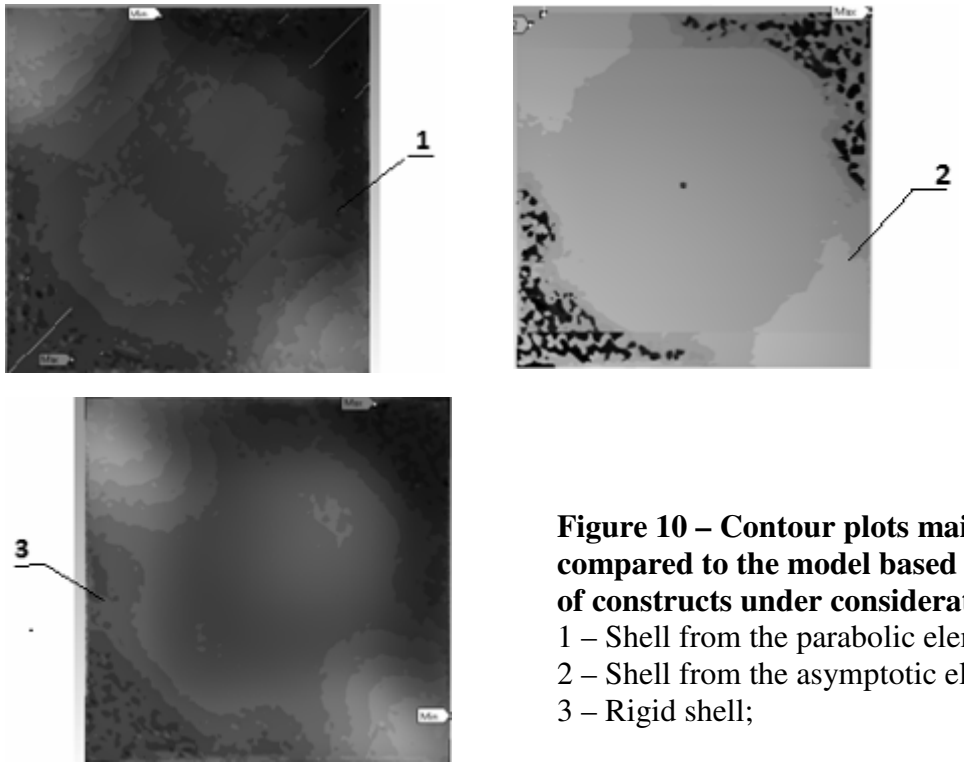

Figure 10 – Contour plots main stress, compared to the model based on three types of constructs under consideration shell:
1 – Shell from the parabolic elements;
2 – Shell from the asymptotic elements;
3 – Rigid shell;

– It is shown in (Figure 11) that the main compressive stress is much increased to bottom support, and reaches the highest value at points close to them, and they decrease in shells field, and they has decreasing character.

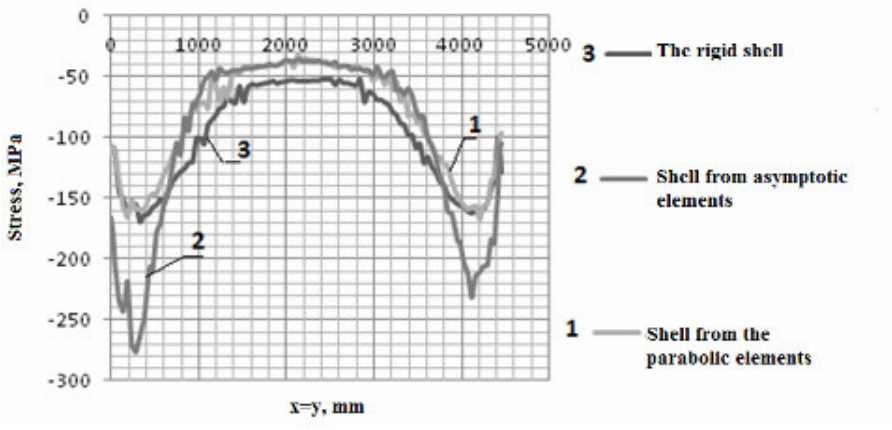

Figure 11 – The diagram of the main compressive stress in the shell along the line x = y

– From (Figure 12) in the middle zone of shells, the normal value of the stress is low, but in marginal zone they grow to the clamped edges, and may become of the same order of magnitude as the shear stress (Fig. 13). As a result, there is high probability formed biaxial compression zone.

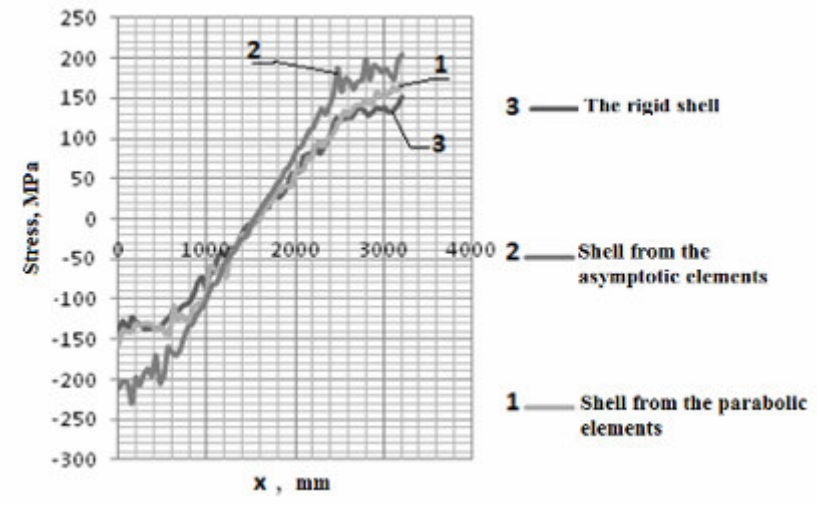

Figure 12 – The diagram of normal stresses in the shell along the line y = 0,03L

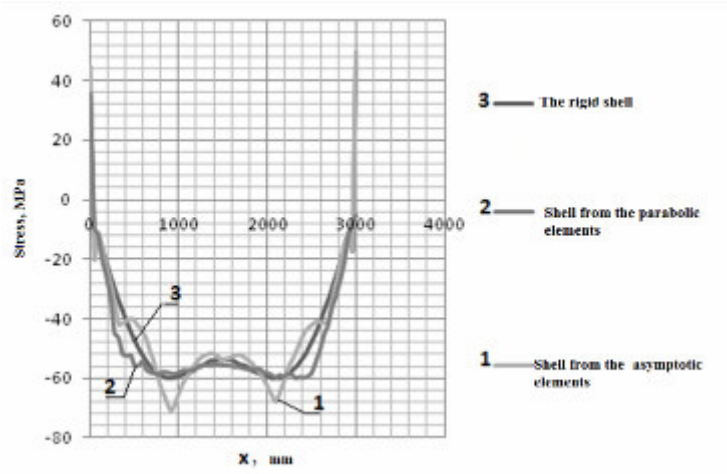

Figure 13 – The diagram of shear stress in the shell along the line y = 0,5L

Conclusions. Under uniformly distributed load, work shell using parabolic and asymptotic elements is substantially different. The use of parabolic panels unlike asymptotic, enhances compression in joints under conditions uniform load distribution.

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Received 04.03.2017