Use of information technologies when designing multilayered plates and covers with filler of various types

T A Golova¹, I A Magerramova¹, S A Ivanov²

¹ Balakovo Institute of engineering and technology - branch of the Federal state Autonomous institution of higher education "national research nuclear University "MEPhI", 140, Chapaev St., Balakovo, 413800, Russia
² Voronezh State Technical University, 84, 20 let Oktyabrya St., Voronezh, 394006, Russia

E-mail: emelyanova-tanya@mail.ru

Abstract. Calculation of multilayered plates and covers does not consider anisotropic properties of a construction. Calculation comes down to uniform isotropic covers and definition of one of intense and deformation conditions of constructions. The existing techniques consider work of multilayered designs by means of various coefficients. The article describes the optimized algorithm of operations when designing multilayered plates and covers with filler of various types on the basis of the conducted researches. It is dealt with a development engineering algorithm of calculation of multi-layer constructions of walls. Software is created which allows one to carry out assessment of intense and deformation conditions of constructions of walls.

1. Introduction

Today in the field of the theory of calculation of multilayered anisotropic covers, many questions remain open though the way of their solution is put to a certain extent by achievements of the theory of uniform isotropic covers. Elastic coefficients of isotropic and anisotropic bodies seldom differ one from another. In this case the main equations of a transversely isotropic cover distinguish from an isotropic cover only in other coefficient of cross shift [3, 14]. The basic equation of the orthotropic plane preserves the same structure, but instead of two, six elastic constants appear; during anisotropy with one plane of symmetry (general anisotropy), structures of main equations of isotropic and anisotropic covers are various. The set of results of anisotropic deformation belongs to orthotropic covers, and it is most often supposed that the main directions of orthotropy coincide with lines of a curvature of a median surface.

Multilayered constructions (covers, plates) are formed of a matrix of various composite materials. Coefficients of rigidity and pliability of such materials are defined by properties of components of composite material and the internal structure. To calculate and to study interrelation of macroscopic characteristics of a multi-layered construction, let us apply mechanics of composites [2, 11].
2. Methods of estimating mechanical properties of composite materials of multilayer constructions

In modern mechanics of composite materials, there are two main approaches to assessment of their mechanical properties - structural (micromechanics) and phenomenological (macromechanics). The micromechanics establishes connection between mechanical characteristics of composite material and properties of the components composing it, their volume content, the form, the structure, the nature of interaction; it analyzes processes of formation and development of cracks (a zone of significantly nonlinear deformation) and other defects. Besides, it also studies the mechanism of transfer and redistribution of efforts between a filler and binding.

The second direction in mechanics of composites is based on the phenomenological approach to a supposition that a composite is a continuous, macroscopic homogeneous environment. It is considered that the sizes of a filler are small in comparison with geometrical parameters of designs, and the arising fields of tension and deformations are smoothed. It allows operating in calculations with the standard integrated characteristics (average tension, deformations), acquired in tests of samples from composite material.

In some cases, fibers are bent owing to improving manufacturing techniques of material. Complex physical and chemical processes occur at the interface between the binder and reinforcing materials, which resulted in a change in the characteristics of components as a result of their interaction, the formation of cracks and delaminations at the interface and so on [6, 11, 13].

Experiments with many composite materials have allowed one to find many phenomena which are not described within a linearly elastic idea of deformation [1, 7, 11, 15, 16, 17]. The main features of the behavior of composite materials during loading include: significant non-linearity charts of deformation of materials, dependence on the nature of the diagrams of the stress state and material structure, the difference of diagrams of uniaxial tension and compression, the first and subsequent loading and others. Theories of nonlinear deformation and destruction of modern composites are far from being ultimate, even if they are about the most widespread and very representative class of composites with a fragile polymeric matrix. This "engineering" description of work of nonlinearly deformed materials with the broken continuity is carried out using the entire possible range of loading uniformly by means of usual integrated characteristics - modules of deformations and coefficients of the cross deformations. It is received as a result of a special processing of experiments for each type and level of tension, that is by a reduction of real material to continuous not linearly deformable environment.

3. Optimization of multilayer constructions design

If one considers anisotropy features of materials of multilayered constructions, as well as the nature of their work, then it is possible to obtain the optimized algorithm of operations during designing multilayered plates and covers with a filler of various types:

1) definition of characteristics of a filler of the given rigidity, durability and mass characteristics;
2) definition of critical loadings and check of the general stability;
3) definition of intense and deformation conditions of a plate (or covers) and its durability check;
4) calculation of local stability of elements of plates or cover and performance check of preservation conditions of the bearing ability in case of loss of local stability elements of a three-layer construction;
5) satisfaction of a durability criterion of a filler and contacting with the bearing layers;
6) determination of parameters of the multilayered plates and covers meeting conditions 1-5.

Setting targets of optimization of multilayer plates and covers includes the formulation of the basic equations, the optimized criterion of quality, restrictions for functions of a state and necessary control variable.

The criterion of quality (the main optimizing functionality) of multilayered plates and covers is most often determined by the mass of multilayered constructions «m» or their cost «C». Functions of a
status «α» (phase variables) in tasks of optimization of multi-layer constructions are components of intense and deformation conditions (tension, deformation, relocation of the bearing layers and filler).

By optimization of parameters of multilayered plates and covers, let us impose restrictions like equalities and inequalities.

For the numerical solution of problems, let us use various methods based on the calculation of variations and mathematical programming. This algorithm was used to create engineering calculation of a multilayer plates type of multilayer walls [8]. It includes assessment of the stability and shift efforts of an element of multilayered constructions. It is a distinctive feature of the known calculation algorithms. [4, 9, 10, 11, 17]. Considering labor input of calculations of definition of an intense and deformation condition of a multilayered wall, it is necessary to use the developed engineering algorithm of calculation, which scheme is shown in Figure 2. For the calculations in this algorithm, software has been developed. It takes into account the characteristics and dimensions of the cross section, and the conditions of their fastening [12].

![Diagram](image)

**Figure 1.** A scheme of computer calculation of parameters of an optimum three-layer plate or cover: 
- H — block of the initial approach; 
- B_ν — block of formation of a gradient of the operating function; 
- B_u,v,w — block of the solution of a problem of determination of parameters of intense and deformation conditions of a multilayered plate or cover; 
- T — block of the comparison.
4. Development of the software product

On the basis of the analysis of programming languages and software platforms for the development of the new program, platform Microsoft .NET Framework 4.0 using object-oriented language C# was selected. This language has static typification, supports polymorphism, operator overloading and all the modern tools of programming windows applications. An important aspect of the choice of a programming language is existence of the built-in web-browser, which greatly simplifies the task of dynamic information display using HTML. The possibility of generation of reports in the form of HTML pages allows one to combine graphical and text information in a convenient type for the user.

The program consists of three forms: «Main», «Options» and «Help». In the form «Main», let us set the main menu and the web-browser, through which the final results of calculations are displayed. The main menu is developed with MenuStrip control, which is a drop-down list and includes sections "File" and "Help". The menu items "File" can create a new calculation, open the previous results and save the current calculation. The menu "Help" opens a form, which is available HTML-page with a description of all the features of the program (Figure 3). The form «Options» offers the collection of initial parameters and consists of a single-line text input field.
In the beginning, the program displays the form «Main» in the web-browser, which contains the information on the basic features of the program. Let us select "File" - "New" for a new calculation in the main menu. The window «Options» (Figure 4) must specify the type of connection (articulated or rigid), and then turn in the appropriate fields to make the values of input data. The operation "Calculate" is performed after filling the text input fields. If the user does not fill in all the fields, the calculation is not performed and the bottom of the form displays a message informing about the lack of some parameters. When all the parameters have been entered, the program calculates and evaluates VAT multilayer walls of low-rise buildings, and then generates a HTML-file with the results of calculations for strength, stability and shift forces. The web-document is saved and named as last.htm in the current directory with exe-file, and a link to the file is transmitted in the address bar of the web-browser form «Main». The form «Options» is automatically hidden, and in the main window the user makes the final calculation, which can be saved (Figure 5). To save the results in the main menu, let us select the action program "File" - "Save", then – the last.htm file will be copied and renamed with the current date and time. With every new calculation, the last.htm file is overwritten. Let us select "File" in the main menu "Open" and select the file to view the results of previous calculations.

Figure 3. «Help» window (in Russian).

Figure 4. «Options» window (in Russian).

Figure 5. Calculation result (in Russian).

5. Conclusion
In conclusion, for the calculation of multilayer constructions, it is possible to use methods of elasticity theory and mechanics of composite materials. Research of intense and deformation conditions of efforts among their components along with the calculations leads to the following
conclusion: deformation state is described by the generalized Hooke law and the need to consider the total anisotropy plates.

The optimized algorithm has been proposed in the design of multi-layer plates and shells with a filler of various types that takes into account the nature of construction work and the anisotropy of covers. The software "VAT rank multilayer walls of low-rise buildings" has been developed. It allows one to reduce significantly labor input of calculations of durability, stability, and the influence of shift efforts on the bearing ability of the construction, and to choose necessary material of a design to provide the corresponding conditions of reliability of the building.

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