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Optimization of the calculated scheme

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Abstract. Any calculation is preceded by the stage of creating a design scheme of a real design, which would most accurately respond to real operating conditions. The more optimally drawn up the calculation scheme, the less time consuming there will be stages of calculation and designing the corresponding design. There are practically no results of the use of such an approach in the calculations of building structures. This article an attempt is made to show the possibility and feasibility of using "search for solutions" (add-in for Microsoft Excel) at the stage of selecting the optimal parameters of the design scheme.

1. Introduction and literature review

Most often, the add-on "solution search" is used in solving optimization problems of the economy (simplex method, transport task, etc. [1, 2, 3]. There are practically no results of the use of such an approach in the calculations of building structures. The paper [4] considers a class of problems for covering an area with a set of geometric objects of a given figure. To formalize the problem, the concept of configuration space of geometric objects is used, the generalized variables of which are metric and placement parameters. The authors consider the method of solving the problem of optimizing the allocation of limited resources of the project as a problem of location of rectangular objects, where the placed objects have variable metric characteristics, which are subject to functional dependencies [5].

2. Literature review

Building structures are very diverse in its intended purpose and use. The reliability and safety of their work depends on many factors: the geometric sizes used by materials, external loads and their combinations, etc. All these parameters determine the internal efforts, stresses and deformations that arise in the structures that determine their strength, rigidity and stability [6, 7].

In order to ensure the strength, rigidity and stability of buildings and their structural elements, appropriate calculations are performed [9].

In the area of the theory of calculation of building structures there is a permanent refinement to the actual work of these structures, i.e. Create such calculation schemes that most accurately meet the actual operating conditions [10]. In solving these tasks, a huge role belongs to the introduction of a computer [9].

The study of operations implies mathematical modeling of economic processes [7, 8]. The integrity of the decisions made [1].

When solving a specific task, the use of methods for studying operations involves the construction of mathematical models for the decision-making tasks in difficult situations or under uncertainty. For a quantitative evaluation of the study, a mathematical model of the operation is required.

The operation model is a fairly accurate description of the operation with the help of a mathematical apparatus (various kinds of functions, equations, systems of equations and inequalities, etc.).



The operation model is an analytical dependence of the target function from dependent (controlled) variables, which in certain limits we can choose at our discretion and choose the range of their change.

The preparation of the operation model requires a deep understanding of the essence of the described phenomenon and knowledge of the mathematical apparatus. The efficiency of the operation is quantitatively expressed as a numerical value of the target function.

Among the models of research of operations should be noted primarily a large class of optimization models. Such tasks occur when trying to optimize the planning and management of complex systems.

Any calculation is preceded by the stage of creating a design scheme of a real design, which would most accurately respond to real operating conditions. The more optimally drawn up the calculation scheme, the less time consuming there will be stages of calculation and designing the corresponding design. If the effectiveness criterion represents a linear function, and the variables in the system of restrictions are also linear, then such a task is a linear programming task. Of the listed methods of mathematical programming, linear programming is the most common and developed [1,2,3].

"Solution Search" is an add-in for Microsoft Excel, which can be used in the tasks of calculating building structures. With it, it is possible to find the optimal value (maximum or minimum) of the formula contained in one cell, called the target, taking into account restrictions on variable values in other cells.

Simply put, using the "Solution Search" superstructure, you can determine the maximum or minimum value of one cell, changing other cells.

3. Materials of research

Analysis of the latest achievements and publications. Most often, the add-on "solution search" is used in solving optimization problems of the economy (simplex method, transport task, etc. [1, 2, 3]. There are practically no results of the use of such an approach in the calculations of building structures.

Consider the simplest building structure. To illustrate the idea of the proposed approach, a simple statically defined farm on two supports is intentionally selected (Figure 1). This is done in order to make the idea of the proposed approach due to the complexity and cumbersome.

In Kurs, construction mechanics known formula to determine the numerical value of the generalized internal power factor F along the corresponding line of influence [11]:

$$F = \sum q_i w_i + \sum P_i y_i + \sum M_i \tan \alpha_i . \quad (1)$$

Using the add-on "Decision Search", we define the optimal geometric dimensions of the farm at a given external load. As an optimization parameter, we select a minimum of force in individual farm rods [11]. For all selected rods, the target feature will look:

$$F = P/2 \times y_2 + P \times y_3 + \dots + P \times y_7 + P/2 \times y_8 , \quad (2)$$

where: y_2, y_3, \dots, y_8 - ordinates of the corresponding line of influence.

Now you can clarify the task. We find such values a, b, c, d at which the target function (2) will take the minimum value at a given external load $P = 100\text{kN}$.

Obviously, the real operating conditions of the design are imposed on variable values of certain limitations.

Let those restrictions be the following:

$d = 2.2$ m - throttle farm on supports;

$2(a + b + c) = 18$ m - farm persolem,

In addition, we will require the dimensions of a, b, c were a multiple 1.5 m.

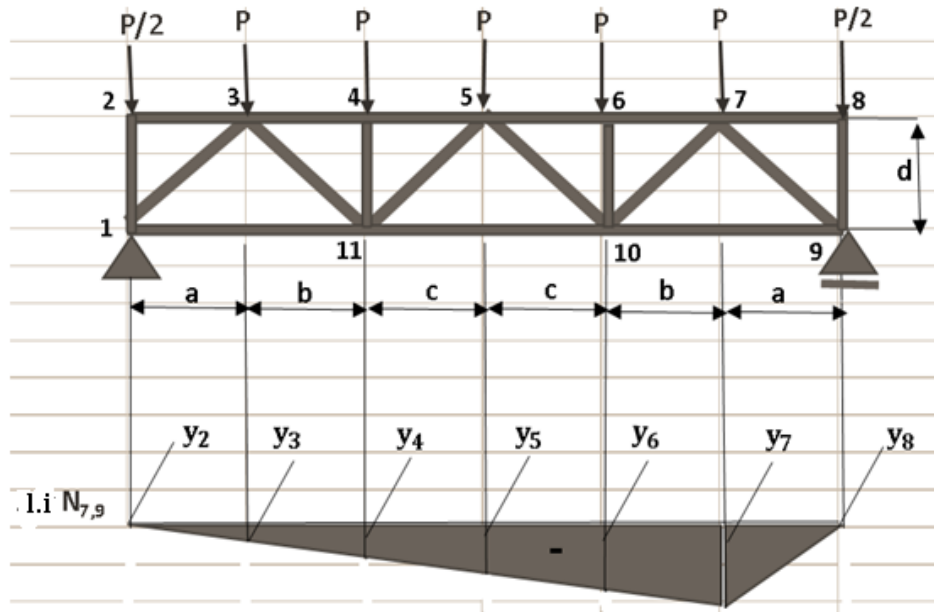


Figure 1. Calculated scheme and the line of influence of the longitudinal force.

$$y_2 = 0,$$

$$y_3 = \frac{a \times \sqrt{a^2 + d^2}}{2 \times (a + b + c) \times d},$$

$$y_4 = \frac{(a + b) \times \sqrt{a^2 + d^2}}{2 \times (a + b + c) \times d},$$

$$y_5 = \frac{(a + b + c) \times \sqrt{a^2 + d^2}}{2 \times (a + b + c) \times d},$$

$$y_6 = \frac{(a + b + 2c) \times \sqrt{a^2 + d^2}}{2 \times (a + b + c) \times d},$$

$$y_7 = \frac{(a + 2b + 2c) \times \sqrt{a^2 + d^2}}{2 \times (a + b + c) \times d},$$

$$y_8 = 0.$$

The selected restriction system is entered into the solution search parameters table (Figure 2).

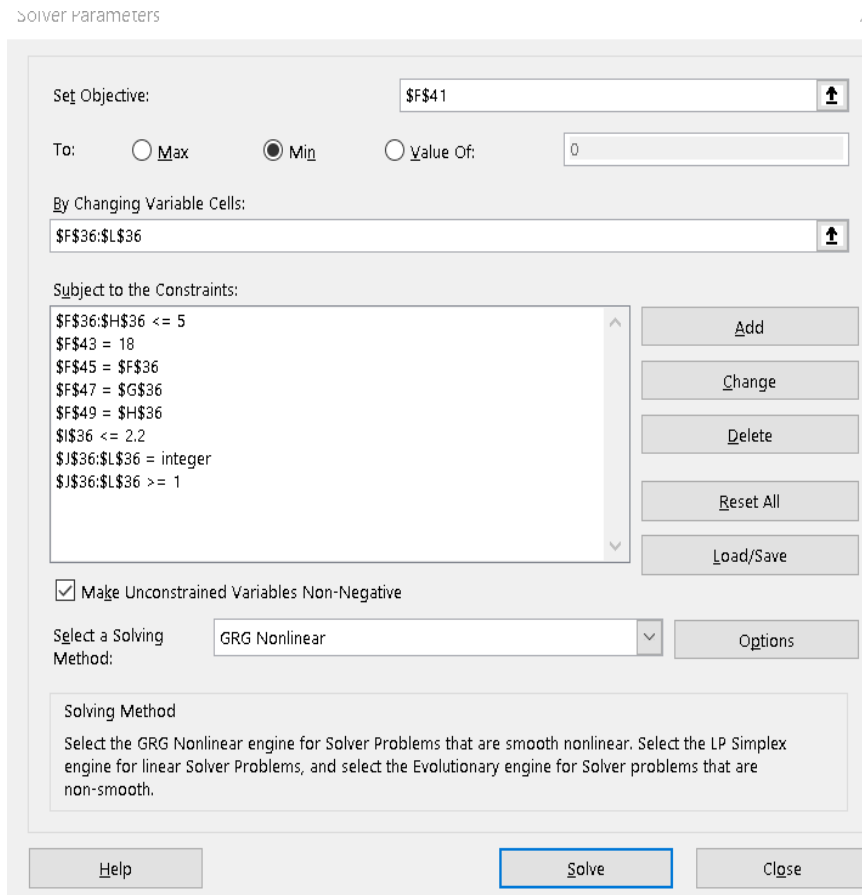


Figure 2. Table of solutions search parameters.

The calculation results are presented in Figure 3.

	a	b	c	d	i	j	k
	1.5	3	4.5	2.2	1	2	3
y	0	0.10086	0.30258	0.60516	0.90774	1.109461	0
P	50	100	100	100	100	100	50
	302.5802	Target function					
	18	2(a+b+c)					
	1.5	1.5*i					
	3	1.5*j					
	4.5	1.5*k					

Figure 3. Numerical values of controlled variables and target function.

The value of the target function corresponds to the minimum value of the longitudinal force in the rod 7-9 ($N_{7-9}(\min) = -302.6\text{kN}$) at $a = 1.5\text{m}$, $b = 3\text{m}$, $C = 4.5\text{m}$.

Similar results were obtained when searching for a minimum of effort in rods 10-11 and 5-6 (Figure 4, 5).

	a	b	c	d	i	j	k
	1.5	3	4.5	2.2	1	2	3
y	0	0.340909	1.022727	2.045455	1.022727	0.340909	0
P	50	100	100	100	100	100	50
	477.2727	Target function					
	18	2(a+b+c)					
	1.5	1.5*i					
	3	1.5*j					
	4.5	1.5*k					

Figure 4. Numerical values of controlled variables and target function.
For N₁₀₋₁₁ (min)

	a	b	c	d	i	j	k
	1.5	3	4.5	2.2	1	2	3
y	0	0.170455	0.511364	1.022727	1.534091	0.5113636	0
P	50	100	100	100	100	100	50
	375	Target function					
	18	2(a+b+c)					
	1.5	1.5*i					
	3	1.5*j					
	4.5	1.5*k					

Figure 5. Numerical values of controlled variables and target function.
For N₅₋₆ (min)

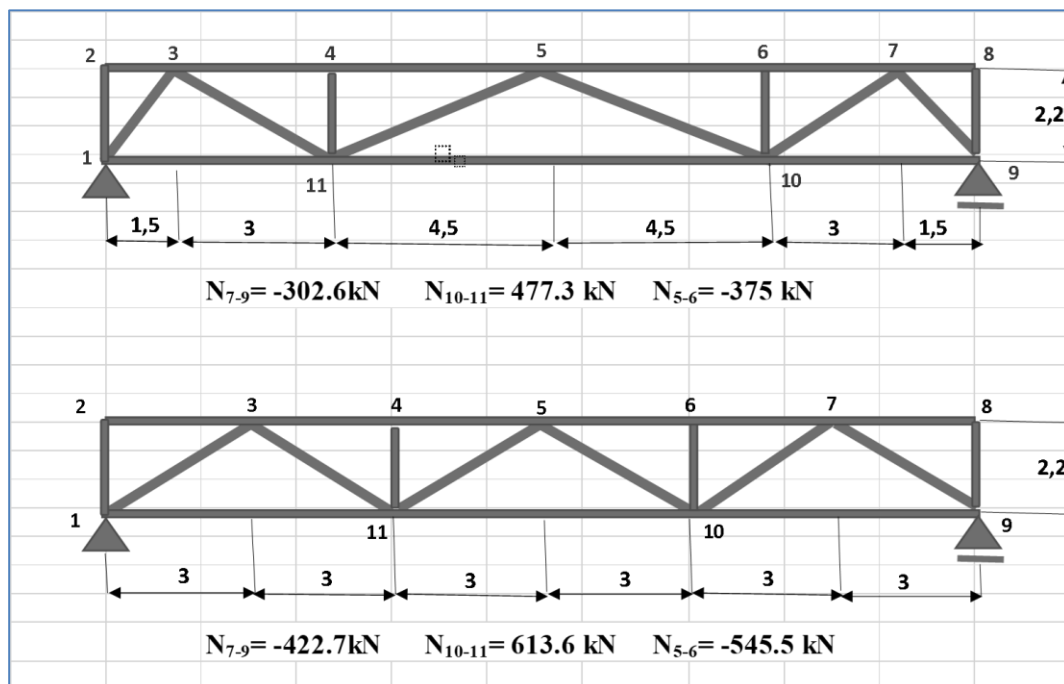


Figure 6. Comparative analysis of the calculated schemes.

4. Conclusions. This article shows the possibility and feasibility of using "search for solutions" at the stage of selecting the optimal parameters of the design scheme. After the calculated scheme is determined, more powerful generally accepted means of calculating building structures can be attracted for its complete calculation [9].

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