Optimal Design of Elements in Confirmation of Panel Buildings

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Abstract: – **The paper presents the possibilities for optimal design of elements in confirmation (joinery work) of multifunctional panel apartment buildings. The basic structure of the program system for optimal design of the profiles and glass plates of the joinery work is proposed. The usage of a basic structure of the system for optimal design of the profiles and glass plates of the joinery work is proposed. The usage of the described system will contribute to decreasing of the price, materials and time for design of joinery work.**

Keywords: – **Optimal design, joinery work, linear integer programming**

I. INTRODUCTION

The paper concerns the possibilities for optimal design of elements in confirmation (joinery work) for multifunctional panel apartment buildings. The research is motivated by the program "*Support of the Energy Efficiency of Multifamily Buildings*" Bulgaria. The object of this program is a set of 700 000 apartments in panel buildings with more than 2 million and 700 000 inhabitants. According to Regulation 7 for energy efficiency and energy saving, the main renovation and reconstruction of buildings requires the use of modern joinery work with certain qualities. The replacement of the old woodwork by joinery work made of modern materials (plastic or aluminum), is a basic stage in the process of panel buildings renovation. The result of the research is the study of a unified program system for joinery work for the purposes of renovation. The possibilities will be investigated for determination of the size of the modular joinery constructions that will decrease the material costs and the price of the joinery work, as well as lessening the time for modules design. The approaches for optimization of the size of the profiles and the glass, necessary for the production of different modules will be analyzed, with the purpose to to decrease the wastage, as well as to optimize the additional accessories of the joinery work (distantioners, persiennes, etc.). As a result, a modular system architecture will be proposed for optimal joinery design and construction of groups of panel buildings. Having in mind the national program of the MRDPW for renovation of these buildings, the economic effect from the realization of such a project will be found in decreasing of the time for contemporary joinery work design, decreasing in the resources of materials, labor and price of the joinery, increasing of the buildings energy efficiency (decrease of the heating expenses up to 40 %) and last, but not least – improvement of the living conditions.

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II. ANALYSIS OF DIFFERENT METHODS FOR OPTIMAL DESIGN OF PROFILES AND GLASS FOR JOINERY WORK

Cutting stock problems are encountered at the production stage of profiles and glass for joinery work. Cutting stock problems consist in cutting large pieces (objects), available in a stock, into a set of smaller pieces (items) in order to fulfil their requirements, optimizing a certain objective function, for instance, minimizing the total number of objects cut, minimizing the waste, minimizing the cost of the objects cut, etc. These problems are relevant in the production planning of many industries, such as paper, glass, furniture, metallurgy, plastics and textile industries. In the last four decades cutting stock problems have been studied by an increasing number of researchers [1-10]. The interest in these problems can be explained by their practical application and the challenge they offer to researches. For despite their apparent simplicity, they are, in general, computationally difficult to solve. The continuous growth of the prices of the materials and of the energy requires minimization of the production expenses for every element. The coefficient of usage K_u [10, 11] is used as a criterion of efficiency. In order to solve similar problems, a set of mathematical methods are proposed. The cutting stock problem is an optimization problem, or more precisely an integer linear programming problem that minimizes the total waste while satisfying the given demand [12].

$$\min \rightarrow \sum_{j=1}^{n}\sum_{i=1}^{p} c_{ji}x_{ji} \qquad (1)$$

$$\sum_{j=1}^{n}\sum_{i=1}^{p} a_{jik}x_{ji} = b_k,\ k = 1,...,q \qquad (2)$$

$$x_{ji} \geq 0,\ j = 1,...,n;\ \ I = 1,...,p \qquad (3)$$

where (1) is the objective function, (2) are constraints determining the number of pieces needed to complete the order and (3) are conditions of non-negativity of the variables.

One of the cutting stock problems is cutting out glass surfaces and profiles in the production of glass packets for windows, shop windows, doors, roofs and other for joinery work. The dimensions of the glass are different depending on the case considered. Depending on the type of the orders/requests, rod sheets which differ in size, width and

brands, are used for cutting out. That is why the portfolio of the orders is divided into groups, depending on the characteristics of the initial parameters [9, 10]. The cutting problem can be formulated in the following way: a number of items (glass for doors, windows, etc.) must be selected from the requests portfolio and depending on the size and type of the primary material, optimal cutting out must be done, with minimal loss of the material used. Since these losses have to be minimal, it is necessary to maximize K_u according to the formula [9-11]:

$$K_u = \frac{\sum_{r=1}^{n} S_r}{S_{eb}} \quad (4)$$

where the numerator is the sum of the areas in the requests portfolio and S_{eb} is the area or length of the source material. The maximal value of K_u = 1, but in real life it is hardly reached. Knowing the value obtained for K_u and comparing it with K_u = 1, we could make a conclusion about the optimality of the cutting. The scientific area, connected with the present study, is operational research. It includes a scientific approach for making an optimal decision under conditions of technical, economic and other constraints, connected with the definition of adequate mathematical models and the formulation and solution of the corresponding optimization problems.

Within the frame of the present study, a brief comparison of available methods for optimal design of the profiles and glass for joinery work, used in practice by Bulgarian companies, is proposed:

- Software program PVC 3.2.2 – gives the possibility to solve the problem for optimal design of different profiles of PVC joinery.
- Software for optimal cutting out of glass packets – GlassOptimizer is a program for glass sheets cutting with optimization of the remainders and additional computations for glass packets.
- Software for ALU joinery work design – AluDesign is automized software for the design and production of aluminum joinery elements. It aids the design of windows, doors, terraces, etc.
- Software for PVC joinery work – PVCDesign is automized software for the design and production of PVC joinery work.

Since, there is no unified system for optimal design of joinery work the authors propose a basic components of such structure.

III. BASIC STRUCTURE OF THE PROGRAM SYSTEM FOR OPTIMAL DESIGN

After acquisition of sufficient data about the size of different elements (doors and windows) in the different types of the panel buildings apartments (bachelor's apartment, one-room apartment, two-rooms apartment, three-rooms apartment and four-rooms apartment) and the detailed analysis of the data collected, it was established that the dimensions of certain elements in different apartments are quite close. This gives the possibility to unify them, since the differences within the range of ±20 mm are acceptable.

Following the above conclusions, the large number of elements in the panel apartments (about 28 in number) may be reduced to the following unified modules:

- Module 1 – a door with dimensions 2200/730
- Module 2 – two-wings window with dimensions 1700/2100
- Module 3 – one-wing window with dimensions 1400/1400
- Module 4 – two-wings window with dimensions 2050/1370
- Module 5 – two-wings window with dimensions 2800/1700 (Fig. 8e), for elements T6, F4.
- Module 6 – a door 650/2000
- Module 7 – a front entrance door with dimensions 2200/3200
- Module 8 – a rear entrance door with dimensions 2400/2500

The analysis of the realized study and the acquired database for dimensions of the elements in the windows and doors in different buildings and apartments in panel buildings show that all modules can be reduced to several unified modules. This leads to the conclusion that a project for optimal technology in the design of joinery work in panel buildings could be accomplished by the following steps:

- definition of the unified modules of joinery in panel apartment buildings;
- determining the size of the joinery work on the basis of the optimization problems solved;
- formulation of the requests towards the profiles manufacturers with respect to optimal dimensions of the initial materials.

All these steps will decrease the joinery price by decreasing the loss of the material, or the so called wastage. Furthermore, the time for realization of a large request by the use of unified modules will be decreased too. Up to the present moment there is no data about the application of a similar approach towards the problem of optimal joinery design. The existing approaches towards the design of joinery work, used in competitor companies, are reduced to automation of the offers for joinery production and optimal cutting of the corresponding glass packets for separate requests. The innovative technology developed can be suggested on the market after modification with respect to the specifics of the construction types and joinery dimensions.

The basic structure of the system for optimal design of the joinery work in panel buildings renovation is shown in Fig. 1. The brief description of the proposed structure is summarized as follows:

- entry of the request and different computations – the order parameters are given – number of the apartment buildings, number of the floors, number of the different types of apartments; and computation of the total number of the types of

apartments, elements, staircase windows and entrance doors;

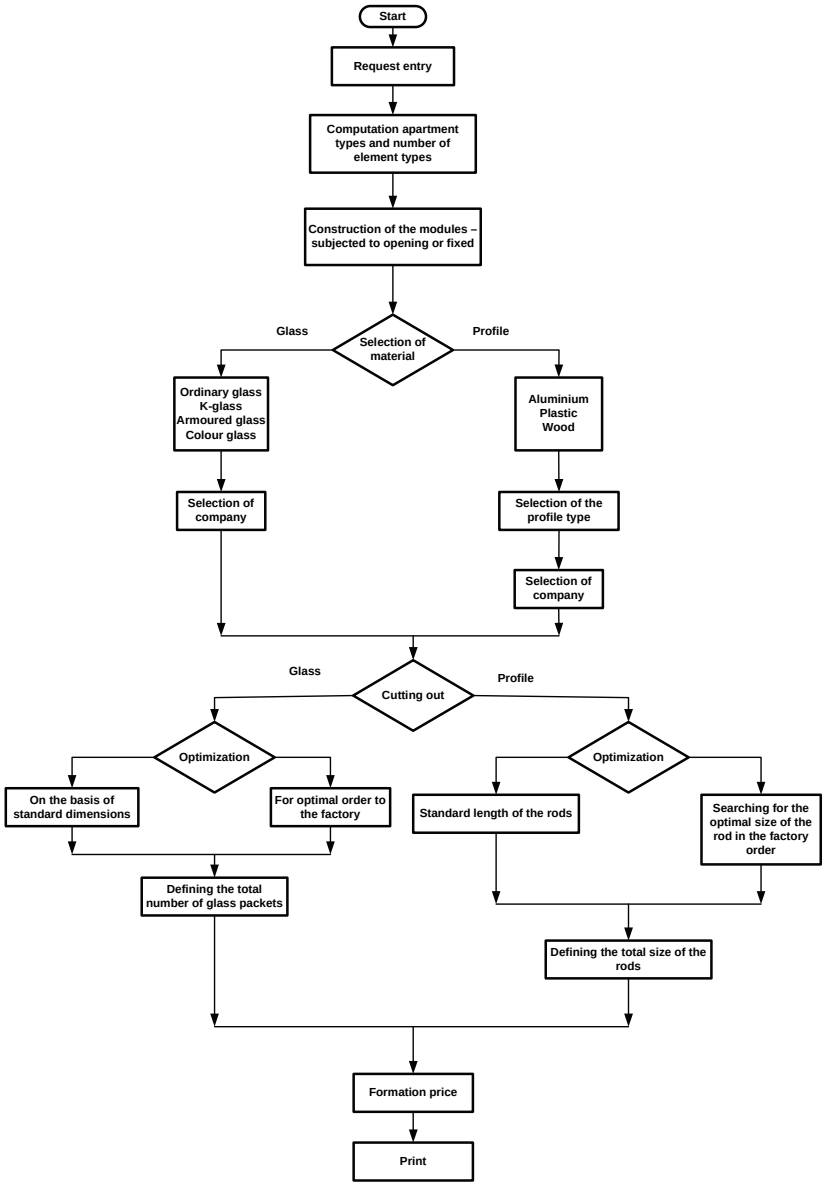

Fig. 1

- analysis and determination of the unified modules and defining the type of the unified modules – subjected to opening or fixed;
- type of the modules – subjected to opening or fixed – depending on the requests each module is divided into two parts – subjected to opening and fixed, and their number is computed;
- selection of the material – the algorithm divides here into two branches;
- profile – selection of Al, PVC, wood, type of the profile and manufacturing plant;
- glass – type of the glass – ordinary glass, K-glass, armoured glass, colour glass and producing company;
- cutting out – this is a very important element in joinery production. In the modular system proposed two elements of cutting are pointed out: glass and profiles, but enhancing the system possibilities, some other elements of production could be additionally cut out such as distancioners, persiennes, etc.

As a result of the system execution an optimal design of joinery work made of contemporary materials (plastic, Al) is available. The technology is based on the formulation of models [6, 11] and the mathematic optimization problems [7-10], and contributes to the optimal design of unified modules of joinery work for panel apartment buildings.

Optimizing the joinery cutting out requires the development of new mathematic models and methods implemented in a software system. It could be combined with the software products already available on the market, or be used as a new integrated library. Two approaches for optimization of the glass cutting out are proposed:

- on the basis of the standard dimensions – considering the available different types of glass sheets to do optimal cutting with respect to minimal quantity of the wastage;
- for optimal order/request towards the manufacturing plant – the optimization problem here is the inverse – on the basis of the given request (that has to be quite large), an optimal variant for the production of a glass sheet is searched for, that will ensure minimal wastage.

The optimization in profiles cutting out is accomplished in a similar way:

- with respect to the standard length of the rods – having in mind several standard lengths of the rods, made of Al and PVC, offered by the producing factories, for smaller in volume requests, the optimal cutting out of the suggested length is realized with respect to the criterion for minimal waste.
- searching for optimal dimensions of non-standard rods in the special requests towards the manufacturing plant, when the order is large (over 50 apartment buildings).

At the end, the total number of the modules and glass packets is determined, their price is computed and the module types with their dimensions are printed.

IV. CONCLUSIONS

EC policy connected with energy consumption in buildings, as well as the Bulgarian law for energy efficiency and the regulations referred to it, require the application of some actions, when repairing buildings, that lead to increase in their energy efficiency. These actions lead to decrease in the expenses of fuel and electrical energy, raising the comfort in such buildings, lengthening their exploitation period and increasing their price. The buildings with low energy consumption have easy support and maintenance, which guarantees low expenses and at the same time smaller ecological influence. The closest alternative of the modular system offered for optimal design of joinery work for panel apartment buildings is the replacement of the existing woodwork by qualitative aluminum or plastic joinery elements. This development will aid the renovation of the widely spread in Bulgaria panel buildings in accordance with the European standards. In some East European countries (for example East Germany), such renovation has been completed, but there is no data about the use of mathematic optimization models and methods for joinery design. Having in mind that the renovation process will cover a large volume and the requests will include large groups of apartment buildings, neighborhoods and cities, the advantages of the current proposal may be resumed as follows:

- decrease in the expenses for joinery work manufacturing (up to 25 %), thanks to the optimized dimensions of the modules;
- decrease of the time for joinery design, as a result of the use of optimal unified modules;
- decrease of the heating expenses (up to 40 %), as a result of the use of contemporary joinery, that will contribute to the decrease of the noxious gas, emitted in atmosphere by the sources of heat energy, i.e. smaller ecological influence;
- improvement of the quality of life of the inhabitants in the renovated flats.

The expected time of investment return, connected with the development of the innovative service proposed, will depend on the time for replacement of the joinery work in more than 50 multistory apartment buildings. Taking into account that above 700 thousand buildings are to be renovated, the turnover expected is of the order of millions BGL. The rate of profit is comparable to the expected effect of materials saving when renovating groups of apartment buildings, namely up to 20%. This rate does not include the time saving in design and the decrease of the heating funds in the renovated apartment buildings (up to 40 %).

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