Minimum weight buildings design best evaluation using inequalities method. Automatic evaluation program - C.O.S.M.I.

First A. Geanina Cosmina ADAM, Second B. Gabriel Iulian MIHAI

***Abstract*—** This paper present the principles and use of an automatic evaluation program for minimum weight buildings design, based on inequalities method.

The automatic evaluation program that is being presented in this paper offers the values of the plastic moments of the pillars and beams sections, of the critical sections moments and the value of weight function (the function of the objective). The mathematical method that represents the basis of making the evaluation program is part of the linear programming methods and is called the simplex method.

The language in which the evaluation program was carried out is named JAVA.

***Keywords*—**automatic evaluation, calculation program, inequalities method, linear programming, mathematical methods, minimum weight, optimal calculation, optimum design.

I. Introduction

For an engineer, "doing one's best" should be a permanent objective when conceiving a building, when measuring an installation, etc. The expression is relative, according to the budget, security and other limitations, whose level will be the object of previous and often subsequent decisions.

The words "to maximize, optimization, etc." Are supposed to represent the idea of "the best possible". In the current life the possible options are usually limited to two (then we call them alternatives) or a few elements, of algorithm type that takes the decision, is reduced to presenting explicitly or not, all the possibilities that can take into consideration and assess their potential consequences and maintain the one that seems "the best" (but the best has a meaning only as long as a criterion of selection has been previously defined).

In the technical problems, the possible alternatives often represent a continuum and an exhaustive enumeration of possibilities cannot be conceived. This is the reason why we must find an algorithm that provides the best performance as possible, which is a method of determining the way to the best solution among all the possible ones.

The optimization may be defined as the science of determining "the best" solutions to certain problems that are mathematically defined, which are often models of the physical reality. It involves the study of the optimization for certain problems, determining the solution using algorithmic methods, the study of the structures of these methods and the computer checking of the methods having experimental data and real data. The optimization methods have a large applicability in almost any activity in which numerical information is processed: civil engineering, mathematics, economy, trade, etc.

The solving of the engineering problems is based on knowing the methods of mathematical calculation. For this purpose, a special importance is given to the mathematics branch called linear programming.

The linear programming is based in different calculation algorithms. The programming mathematical methods and especially their subclass – the models of linear programming – have an important place, both in engineering theory and practice.

Thus, one of the most known and used algorithm of mathematical calculation is the Simplex Primal algorithm.

The structure of the general model of linear programming consists, first of all, of the multitude of activities {A1, A2, ... An} that constitute the analyzed engineering system.

It is obvious that maximum efficiency means minimizing the effort and maximizing the result, the concept of optimum is defined, in this case, as a $x \in Rn$ program, that minimizes of maximizes an objective function, and, at the same time, respects all the restrictions from an engineering point of view.

In the engineering calculation, the Simplex Primal Method is used in strong relation with the

Inequalities Method that is used successfully in civil engineering design.

In the paper, the use instructions of the automatic calculation program "C.O.S.M.I." are presented, made by the authors of the present paper, aiming at solving the mathematical model of an optimal calculation problem from the engineering design field using the Simplex Primal Method and the Inequalities Method. The principles of making the

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F. A. Geanina Cosmina ADAM is with the "Ovidius" University, Hydrotechnical Department, 22B, Unirii St., Constantza, Romania (e-mail: adam_geanina@yahoo.com).

S. B. Gabriel Iulian MIHAI, is Executive Manager at S.C. Velacost S.R.L., 28, Medgidiei St., Constantza, Romania (e-mail: mihaigabriel79@yahoo.com).

"C.O.S.M.I." program are based on the Simplex Primal algorithm. The program was made in the Java programming language.

There was enough time for Java to be impressive and acquire a large recognition and use.

II. PRESENTATION OF THE SIMPLEX PRIMAL ALGORITHM AND INEQUALITIES METHOD

A. Simplex Primal algorithm

The Simplex algorithm (due to G.B.Dantzig, 1947) is applied to the problems of linear programming.

In order to be efficient, an algorithm for an optimization problem must have the following characteristics:

a) to possess a recognition criterion of the fact that the problem has admissible solutions;
b) to possess a recognition criterion of the fact that the problem has an infinite optimum;
c) to possess a recognition criterion if a solution is the best or not;
d) to pass from a basic admissible solution to one that is at least as good as it (a solution x is better than a solution y if f(x) > f(y) in a problem of maximum and f(x) < f(y) in a problem of minimum;
e) to pass from a solution to the best of the solutions, possibly at least as good as the following;
f) not to come back to an already analyzed solution;
g) to make a number of iterations that can be polynomials compared to the dimension of the problem.
h) not to introduce rounding errors (or not too big);
i) to be as easy as possible to implement.

The above conditions actually represent an ideal algorithm. At the beginning of the operational research, an algorithm that obeyed at least conditions b), c), d), e) and h) was actually enough. This algorithm was provided by G.B. Dantzig, in 1947, who called it SIMPLEX algorithm. Even today, it is the most efficient algorithm in terms of working speed, simplicity and computer implementation for the problems that actually appear in the economic and technical practice.

The model of the linear programming problem contains type 1 restrictions as well as „performance" criterion that allows the assessment of each activity efficiency. According to the aim, we may choose as efficiency criterion an indicator that measures the effort, one that measures the result and one indicator representing a relation between result and effort (or effort on result). The following technical-economic restrictions may be written:

$$\begin{array}{l} a_{11}\cdot x_1 + a_{12}\cdot x_2 + \ldots + a_{1n}\cdot x_n \le b_1 \\ a_{21}\cdot x_1 + a_{22}\cdot x_2 + \ldots + a_{2n}\cdot x_n \le b_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ a_{m1}\cdot x_1 + a_{m2}\cdot x_2 + \ldots + a_{mn}\cdot x_n \le b_m \end{array} \tag{1}$$

or $A \cdot X \le B$

$$\text{where } A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix} \tag{2}$$

$$X = \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} \text{ and } b = \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix} \tag{3}$$

A problem of linear programming is, thus, a special case of the mathematical programming problems and taking into account the form of any linear function, it results that the general pattern of the linear programming problem is:

$$\begin{cases} \max(\min) f = c_1x_1 + c_2x_2 + \ldots + c_nx_n \\ a_{i1}x_1 + a_{i2}x_2 + \ldots a_{in}x_n \le b_i \\ a_{i1}x_1 + a_{i2}x_2 + \ldots a_{in}x_n = b_i \\ a_{i1}x_1 + a_{i2}x_2 + \ldots a_{in}x_n \ge b_i \\ i = 1, \ldots, n \\ x_1, x_2, x_n \le 0 \\ x_1, x_2, x_n \ge 0 \\ x_1, x_2, x_n \; any \end{cases} \tag{4}$$

Where cj (the values of the objective function), aij (the values of the restrictions) and bi (free terms) are actual constant values.

Any problem of maximum may be turned into one of minimum and vice-versa using the following relation:

$$\max f(x) = -\min(-x) \tag{5}$$

Any restriction of the type "≤" may be turned into a restriction of the type "≥" and vice-versa, using the following relation:

$$\alpha \le \beta \Leftrightarrow -\alpha \ge -\beta \tag{6}$$

Any restriction of inequality may be turned into equality, by introducing an additional non-negative, using the following:

$$\alpha \le \beta \Leftrightarrow \begin{cases} \alpha + x = \beta \\ x \ge 0 \end{cases} \tag{7}$$

and $\alpha \geq \beta \Leftrightarrow \begin{cases} \alpha - x = \beta \\ x \geq 0 \end{cases}$ (8)

B. Inequalities Method

The Inequalities Method used in the engineering design is included in the static methods and consists of determining the factor of proportionality for the loading at yielding, as being the highest of the λ values, for which, the static balance equations and the plastic leaking conditions of an analyzed system are simultaneously respected.

These static balance equations and the plastic leaking conditions (inequalities) represent the mathematical pattern of the design problem.

The method has the advantage of an easy solving by computer programming.

Also, the advantage of using this method consists of the easy and straight manner of writing the restriction relations. In the case of big problems, numerical computers may be used – having to solve linear or nonlinear programming problems – or analogical computers, which can also lead to determining accurately enough solutions for the problems of optimum like those that appear in the case of engineering design.

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III. DESCRIBING THE PROGRAMMING LANGUAGE USED IN MAKING THE INFORMATICS APPLICATION C.O.S.M.I. (JAVA LANGUAGE)

The “C.O.S.M.I.” program is made in the programming language “JAVA”.

James Gosling is unanimously recognized as being the father of the Java language.

Java is a high level programming language, developed by Java Soft, a company belonging to Sun Microsystems. Among the features of the language we may mention:

-simplicity - eliminates the overloading of the operators, the multiple inheritance and all the „facilities” that writing a confused code may lead to;

-robustness - eliminated the frequent sources of errors that appear in programming, by eliminating the pointers, automatic administration of the memory and eliminating the memory cracks by a method of collecting the „waste” that runs in the background. A Java program that passed compilation has the property that the „system won’t break” at its execution.

-completely oriented on objects – completely eliminates the procedural programming style;

-easiness in network programming;

-security -it is the safest programming language available at the moment, providing strict security mechanisms of the programs, by: dynamical checking of the code for detecting dangerous sequences, imposing strict rules for running the programs on computers that are at distance, etc;

- it is neuter from an architectural point of view;

-portability, in other words, Java is a language independent of the working platform, the same application, running, without changing it, on different systems, such as Windows, UNIX or Macintosh, which involves great savings to the companies that develop applications for the internet;

-provides a high performance of the octet code;

-allows programming with execution wires (multisided);

-is shaped after C and C++, the passage from C, C++ to Java is made very easily;

-allows the creation of Web documents improved with animations and multimedia.

The advantages of using the Java language:

- simplicity;
- orientation towards objects (object-oriented);
- static standardization;
- previous compilation followed by execution on the host;
- the possibility of launching several execution wires;
- waste collector;
- high security;
- extensibility;
- accuracy.

IV. EXAMPLE FOR USING THE INFORMATICS APPLICATION C.O.S.M.I. FOR SOLVING A PROBLEM OF LINEAR ANALYSIS

Definitions of the terms used:

Objective function: the function that minimizes or maximizes.

Best solution: A vector x is feasible (respects restrictions) and optimal (the maximum or minimum value is obtained).

*Restrictions***:** A set of equalities and inequalities, which the feasible solution should respect;

The basic solution: *x* from $(Ax = b)$is a basic solution if all the n components of x may be separated in m basic variables and n-m „non-basic” variables, so as that: all the m columns of A that correspond to the basic variables, form a non-singular basis and the value of each „non-basis” variable is 0.

The matrix of constraints A has m lines (constraints) and n column (variable).

Basis: The multitude of basic variables.

Basic variables: a variable from the basic solution (doesn’t have the value 0).

“Non-basis” Variable: A variable that is not in the basic solution (value = 0).

Compensatory Variable: A variable that is added to the problem in order to eliminate constraints $\geq$ or $\leq$.

Artificial variable: A variable added to an LP problem (Linear Programming) in stage 1 in order to find a feasible solution.

The “C.O.S.M.I.” program may solve any problem of linear programming, from the calculation, it results both the value of the unknown elements $(x_1, x_2, \ldots x_n)$as well as the value of the objective function.

The accuracy of the results may be obtained depending on the choice made from the program options.

Also, both the minimum value of the objective function and the maximum value may be obtained according to the aimed result.

It is required to solve the linear programming problem below using the automatic program of calculation “C.O.S.M.I.”:

$$[\max] f = 7 \cdot x_1 + 8 \cdot x_2 \tag{9}$$

$$\begin{cases} 2 \cdot x_1 + x_2 \leq 5 \\ x_1 + 2 \cdot x_2 \leq 4 \\ x_1, x_2 \geq 0 \end{cases} \tag{10}$$

The example is made with the purpose of underlining the practical way of using the “C.O.S.M.I.” program.

The running of the program is made after the following steps:

-the folder „Simplex Solving” is copied from the CD. The „Java” program is installed by double click on the file “j2sdk-1_4_2_15-windows-i586-p”. Then, from the folder “Update Java” the file “ jre-6u2-windows-i586-p 1” is installed.

Observation: The program was made in Net Beans 5.5.1.

-enter the folder„ build”, „classes” and double clock on the file „test HTML Document” and the next page will appear:

Fig. 1

- click on „New Problem” and the next page will appear:

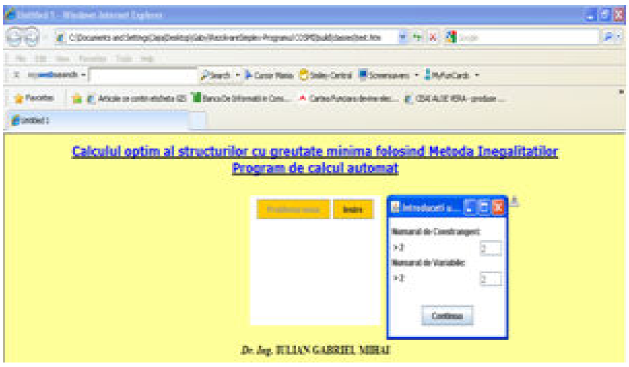

Fig.2

For the option ”number of constraints” the number of model equations are introduced. In the considered example, we have two equations.

For the option “number of variables”, the number of variables from the equations of the mathematical model are introduced, that is 2.

“Maximizing” is selected (if it is not selected), because we are interested in the maximum of the objective function (the program may also find out the minimum of the objective function).

In the first line, the values of the objective function are introduced, that is 7 next to x1, 8 next to x2.

For the option “conditions” the two equations of the formed system appear. Next to each unknown elements x the values of the unknown elements are introduced from the system equations starting with the first line that corresponds to the first equation as well as the free terms in the box on the right. If the free term is 0, this is no longer introduced.

After introducing the values of the unknown elements and those of the free terms, the following page is obtained:

Fig. 3

Having all the values of the unknown elements introduced, as well as those of the objective function, we may pass to the data processing so as to obtain the problem solutions.

Click on “Preprocessing” and the following page will appear:

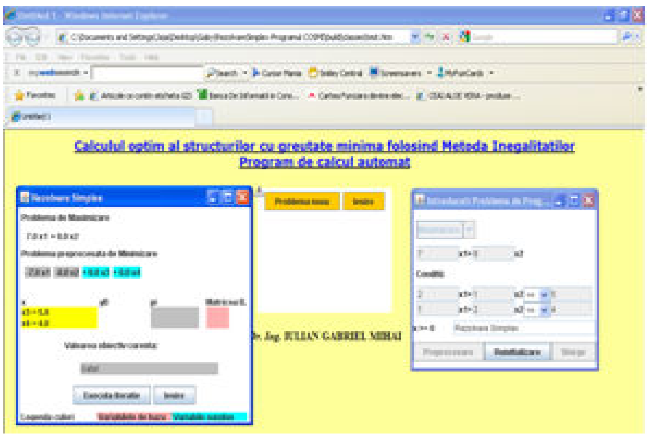

Fig. 4

At this moment, the program will perform the iterations according to the number of unknown elements of the problem. This operation takes more or less according to the complexity of the problem.

The program may solve problems with a great number of equations and unknown elements but this requires a more complex computer.

Double click several times on the option „Perform iteration" and the values of the unknown elements and the value of the objective function will appear, that is the following page:

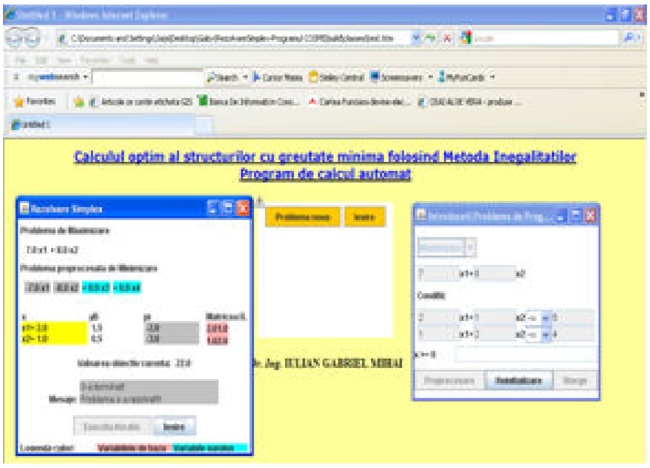

Fig. 5

It is noticed that the program succeeded in solving the problem of linear programming, having as result the values of the unknown elements, that is:

$$x_1 = 2 \qquad x_2 = 1 \tag{11}$$

Also, the value of the objective function resulted:

$$f_{\max} = 22 \tag{12}$$

V. MINIMUM WEGHT BUILDINGS DESIGN USING INEQUALITIES METHOD

A. Determination of minimum weight solution for a frame with one opening

For the frame from the figure 6 a, it is considered:

$$F = 1, L = 1 \tag{13}$$

It will be noted:

$$Mp_{(1)} = Y_1 \quad and \quad Mp_{(2)} = Y_2 \tag{14}$$,

which are the necessary plastic bending moments for the columns and beams.

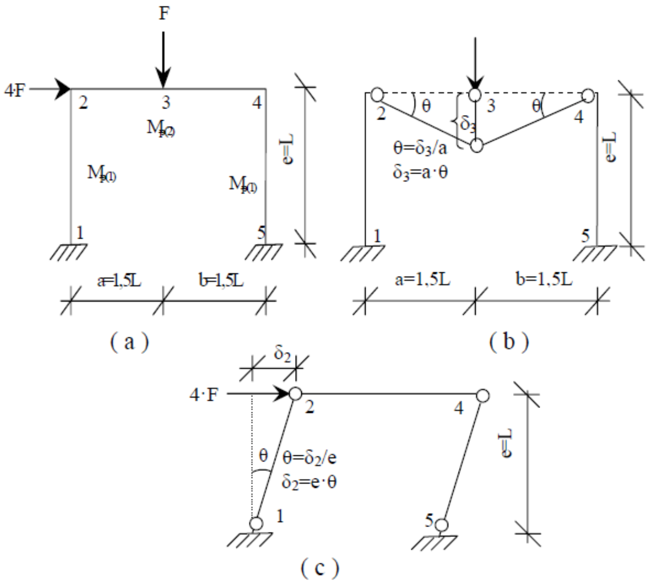

Fig. 6

Will be noted the bending moments in the five critical cross-sections (1, 2, 3, 4, 5) of the frame, as:

$$M_3 = Y_3; M_4 = Y_4; M_5 = Y_5; M_1 = Y_6; M_2 = Y_7 \tag{15}$$

The relations which compose the mathematical model of the minimum weight frame design problem by inequalities method are the following:

1) Statically equilibrium relations:

a) bar equilibrium (figure 6.b):

$$M_2 \cdot \theta + M_3 \cdot \theta + M_3 \cdot \theta + M_4 \cdot \theta = F \cdot \delta_1 \tag{16}$$

$$\text{or: } M_2 + M_3 + M_3 + M_4 = F \cdot a \tag{17}$$

having the established notations:

$$Y_7 + Y_3 + Y_3 + Y_4 = F \cdot 1{,}5 \cdot L \tag{18}$$

$$\text{or: } Y_7 + 2 \cdot Y_3 + Y_4 = 1{,}5 \tag{19}$$

b) displacement equilibrium (figure 6.c):

$$M_1 \cdot \theta + M_2 \cdot \theta + M_4 \cdot \theta + M_5 \cdot \theta = 4 \cdot F \cdot \delta_2 \tag{20}$$

$$\text{or: } M_1 + M_2 + M_4 + M_5 = 4 \cdot F \cdot e \tag{21}$$

having the established notations:

$$Y_6 + Y_7 + Y_4 + Y_5 = 4 \cdot F \cdot L \tag{22}$$

or: $$Y_6 + Y_7 + Y_4 + Y_5 = 4 \tag{23}$$

2) Plastic yielding conditions:

$$\begin{aligned} &-Y_1 \le Y_6 \le Y_1; \\ &-Y_1 \le Y_7 \le Y_1; \\ &-Y_2 \le Y_7 \le Y_2; \\ &-Y_2 \le Y_3 \le Y_2; \\ &-Y_2 \le Y_4 \le Y_2; \\ &-Y_1 \le Y_4 \le Y_1; \\ &-Y_1 \le Y_5 \le Y_1. \end{aligned} \tag{24}$$

These relations can also be written:

$$\begin{aligned} &Y_1 + Y_6 \ge 0; \\ &Y_1 + Y_7 \ge 0; \\ &Y_2 + Y_7 \ge 0; \\ &Y_2 + Y_3 \ge 0; \\ &Y_2 + Y_4 \ge 0; \\ &Y_1 + Y_4 \ge 0; \\ &Y_1 + Y_5 \ge 0. \end{aligned} \tag{25}$$

respectively:

$$\begin{aligned} &Y_1 - Y_6 \ge 0; \\ &Y_1 - Y_7 \ge 0; \\ &Y_2 - Y_7 \ge 0; \\ &Y_2 - Y_3 \ge 0; \\ &Y_2 - Y_4 \ge 0; \\ &Y_1 - Y_4 \ge 0; \\ &Y_1 - Y_5 \ge 0. \end{aligned} \tag{26}$$

3) Weight function:

$$X = \sum_1^n l_i \cdot M_{p(i)} \tag{27}$$

so: $$\begin{aligned} X = 2 \cdot Mp_{(1)} + 3 \cdot Mp_{(2)} + 0 \cdot M_3 + 0 \cdot M_4 + \\ + 0 \cdot M_5 + 0 \cdot M_1 + 0 \cdot M_2 \end{aligned} \tag{28}$$

or: $$\begin{aligned} X = 2 \cdot Y_1 + 3 \cdot Y_2 + 0 \cdot Y_3 + 0 \cdot Y_4 + \\ + 0 \cdot Y_5 + 0 \cdot Y_6 + 0 \cdot Y_7 \end{aligned} \tag{28}$$

Using a usual computation program for solving linear problems, will be obtained the following results:

• plastic bending moments values:

$$\begin{aligned} Y_1 = Mp_{(1)} = 1{,}625 \\ Y_2 = Mp_{(2)} = 0{,}375 \end{aligned} \tag{29}$$

• value of moments from critically sections:

$$\begin{aligned} &Y_3 = M_3 = 0{,}375; \\ &Y_4 = M_4 = 0{,}375; \\ &Y_5 = M_5 = 1{,}625; \\ &Y_6 = M_1 = 1{,}625; \\ &Y_7 = M_2 = 0{,}375. \end{aligned} \tag{30}$$

• value of the weight function:

$$X = 4{,}375 \tag{31}$$

Knowing the values of plastic bending moments on the columns and beams will be established the cross-section of bars:

a) the column:

$$Mp_{(1)} = \sigma_c \cdot W_{column} \tag{32}$$

so: $$W_{column} = \frac{Mp_{(1)}}{\sigma_c} \tag{33}$$

or: $$W_{column} = \frac{b_{column} \cdot h_{column}^2}{4} \tag{34}$$

Will be imposed:

$$h_{column} = 1{,}5 \cdot b_{column} \tag{35}$$

and results: $$\frac{b_{column} \cdot \left(1{,}5 \cdot b_{column}\right)^2}{4} = \frac{M_{p(1)}}{\sigma_c} \tag{36}$$

where: $$b_{column} = \sqrt[3]{\frac{4 \cdot Mp_{(1)}}{2{,}25 \cdot \sigma_c}} \tag{37}$$

b) the beam:

$$Mp_{(2)} = \sigma_c \cdot W_{beam} \tag{38}$$

so: $$W_{beam} = \frac{Mp_{p(2)}}{\sigma_c} \tag{39}$$

or: $$W_{beam} = \frac{b_{beam} \cdot h_{beam}^2}{4} \tag{40}$$

It will be imposed:

$$h_{beam} = 1{,}5 \cdot b_{beam} \tag{41}$$

and results: $$\frac{b_{beam} \cdot (1{,}5 \cdot beam)^2}{4} = \frac{Mp_{(2)}}{\sigma_c} \tag{42}$$

where: $$b_{beam} = \sqrt[3]{\frac{4 \cdot Mp_{(2)}}{2{,}25 \cdot \sigma_c}} \tag{43}$$

$$h_{beam} = 1{,}5 \cdot \sqrt[3]{\frac{4 \cdot Mp_{(2)}}{2{,}25 \cdot \sigma_c}} \tag{44}$$

B. Determination of minimum weight solution for the frontal frame, of a industrial hall, with two openings

For an easier understanding, the presentation will be performed by using an example of evaluation such as:

The value of the minimum weight function will be determined, the values of the plastic moments of the pillars and beams sections and the values of the moments from the critical sections of the bar for the frame in figure 7, which represent the frontal frame of the industrial hall from figure 8.

Slope of the roof beams are neglected, being very small.

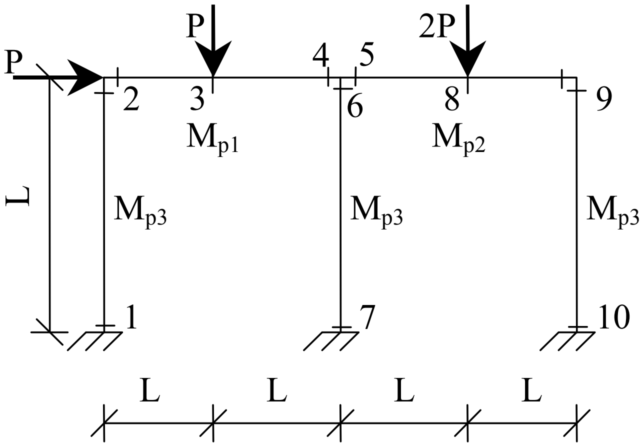

Fig. 7

Numerical data: $$P = 3; L = 3 \tag{45}$$

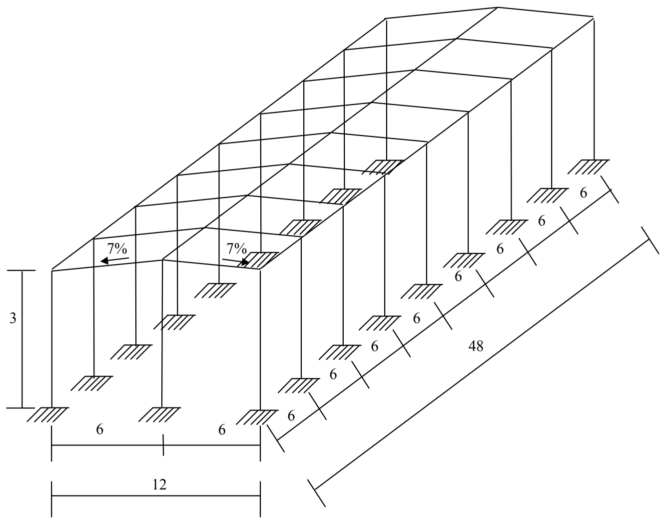

Fig.8

The plastic moments on the beams and pillars will be marked as follows:

$$\begin{aligned} Mp_1 &= x_1; \\ Mp_2 &= x_2; \\ Mp_3 &= x_3. \end{aligned} \tag{46}$$

The moments from the critical sections will be marked as follows:

$$\begin{aligned} M_4 &= x_4; \\ M_5 &= x_5; \\ M_6 &= x_6; \\ M_7 &= x_7; \\ M_8 &= x_8; \\ M_9 &= x_9; \\ M_{10} &= x_{10}; \\ M_{11} &= x_{11}; \\ M_{12} &= x_{12}; \\ M_{13} &= x_{13}. \end{aligned} \tag{47}$$

There will be written:

1) The static balance relationships using the mechanic virtual work principle:

a) bar balance:

$$x_{12} + 2 \cdot x_{13} + x_4 = P \cdot L = 3 \cdot 3 = 9 \tag{48}$$

$$x_5 + 2 \cdot x_8 + x_9 = 2 \cdot P \cdot L = 2 \cdot 3 \cdot 3 = 18 \qquad (49)$$

b) movement balance:

$$x_{11} + x_{12} + x_7 + x_6 + x_9 + x_{10} = P \cdot L = 3 \cdot 3 = 9 \qquad (50)$$

c) knot balance:

$$x_4 + x_5 + x_6 = 0 \qquad (51)$$

2) Plastic flow conditions:

$$\begin{aligned}
&-x_3 \le x_{11} \le x_3;\\
&-x_3 \le x_{12} \le x_3;\\
&-x_1 \le x_{12} \le x_1;\\
&-x_1 \le x_{13} \le x_1;\\
&-x_1 \le x4 \le x_1;\\
&-x_2 \le x_5 \le x_2;\\
&-x_3 \le x_6 \le x_3;\\
&-x_3 \le x_7 \le x_3;\\
&-x_2 \le x_8 \le x_2;\\
&-x_2 \le x_9 \le x_2;\\
&-x_3 \le x_9 \le x_3;\\
&-x_3 \le x_{10} \le x_3.
\end{aligned} \qquad (52)$$

The program imposes that inequalities (52) to be transformed into equalities, according to the following model:

Example:

$$-\varepsilon \le x \le \varepsilon \quad \text{that is} \quad |x| \le \varepsilon . \qquad (53)$$

So: $x_{11} = |x_{11}| \le x_3, \quad \text{that is} \quad \begin{cases} x_3 - x_{11} \ge 0 \\ x_{11} - x_3 \le 0 \end{cases} \qquad (54)$

To transform the relationship $x_{11} - x_3 \le 0$ into an equality an aleatory variable will be added:

$$x_{11} - x_3 + x_4 = 0 \qquad (55)$$

As a consequence, the transformation of relationships (52) from inequalities into equalities is performed by adding an aleatory variable to each inequality. Thus, the relations (52) are included into the following pattern:

$$\begin{aligned}
&x_{11} - x_3 + x_{14} = 0;\\
&x_{12} - x_3 + x_{15} = 0;\\
&x_{12} - x_1 + x_{16} = 0;\\
&x_{13} - x_1 + x_{17} = 0;\\
&x_4 - x_1 + x_{18} = 0;\\
&x_5 - x_2 + x_{19} = 0;\\
&x_6 - x_3 + x_{20} = 0;\\
&x_7 - x_3 + x_{21} = 0;\\
&x_8 - x_2 + x_{22} = 0;\\
&x_9 - x_2 + x_{23} = 0;\\
&x_9 - x_3 + x_{24} = 0;\\
&x_{10} - x_3 + x_{25} = 0.
\end{aligned} \qquad (56)$$

The function of the objective (the function of weight) has the following expression:

$$X = \sum_{i=1}^{n} l_i M p_i \qquad (57)$$

For the example taken into consideration, the function of weight is the following:

$$\begin{aligned} X = 2 \cdot L \cdot Mp_1 + 2 \cdot L \cdot Mp_2 + L \cdot Mp_3 + L \cdot Mp_3 + \\ + L \cdot Mp_3 = 6 \cdot X_1 + 6 \cdot X_2 + 9 \cdot X_3 \end{aligned} \qquad (58)$$

The relations (48), (49), (50), (51) and (57) form a mathematical model that will be solved using the elaborated evaluation program.

The program development will be performed in the following steps:

The „Simplex Solution” folder is copied from the CD. The „Java” program is installed by double click on the file „j2sdk-1_4_2_15-windows-i586-p”. Then, from the „Update Java” the file „ jre-6u2-windows-i586-p1” is installed.

Observation: The program was performed in Net Beans 5.5.1.

Enter folder „build” → „classes” and then double click on the file „test HTML Document” and the next page will appear:

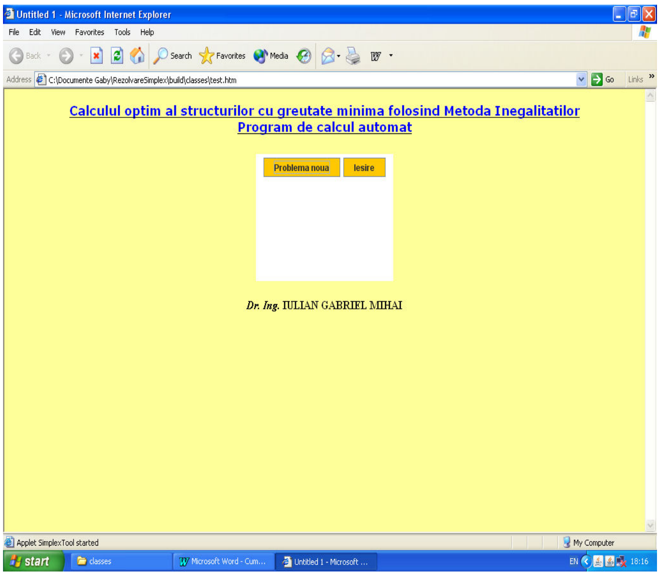

Fig. 9

Click on „Problemă nouă" (New Problem) and the following page will appear:

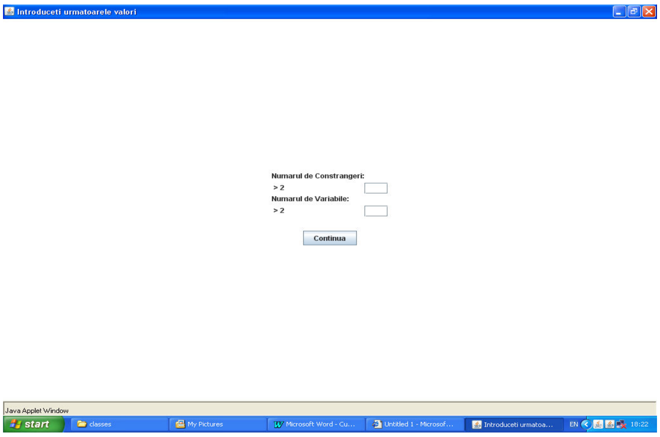

Fig. 10

For the option called "number of restrictions", we shall introduce the number of equations of the model. In the following example we have the equations (48), (49), (50), (51) and (66), that is 16 equations.

For the option called „number of variables" we shall introduce the number of variables from the equations (48), (49), (50), (51) and (66), that is 25.

Click on "continue" and the following page will appear:

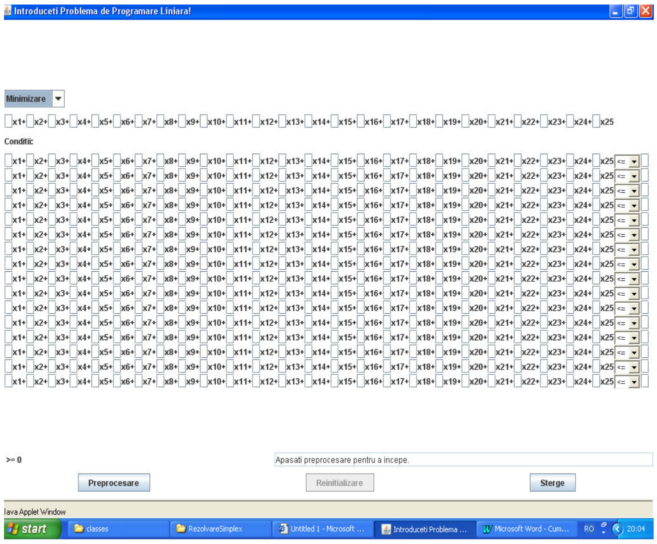

Fig. 11

Select "Minimization" (if it is not selected) because we are interested in the minimum of the objective function. (The program can find out the maximum of the objective function, too).

In the first line, we introduce the coefficient of the objective function, that is 6 for x1, 6 for x2 and 9 for x3.

For the option called "conditions" there will appear the 16 equations from the system formed of equations (48), (49), (50), (51) and (66). For each unknown x, we shall introduce the coefficients of the equations (48), (49), (50), (51) and (66), starting with the first line that corresponds to the first equation and the free terms in the right box. If the free term is 0 it will not be introduced. Before the box containing the free term we shall select „=".

After introducing the coefficients of the unknown and the free terms we shall obtain the following page:

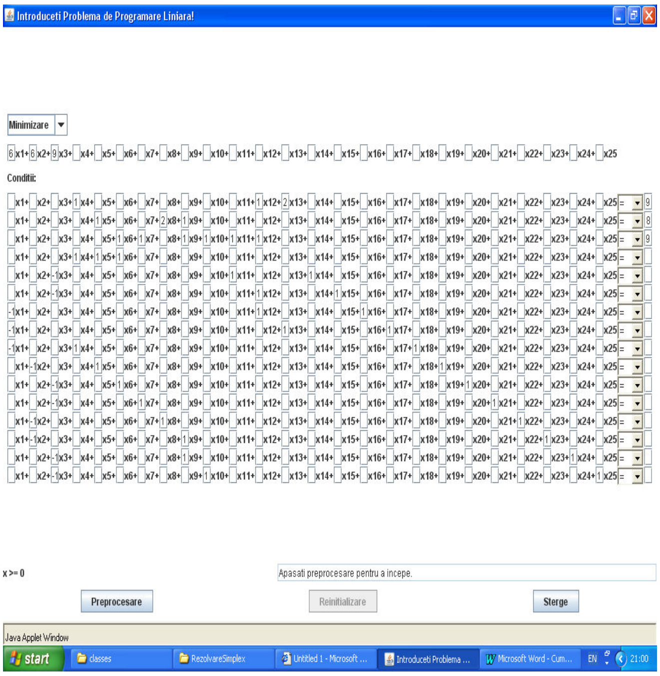

Fig. 12

Click on "Preprocessing" and the following page will appear:

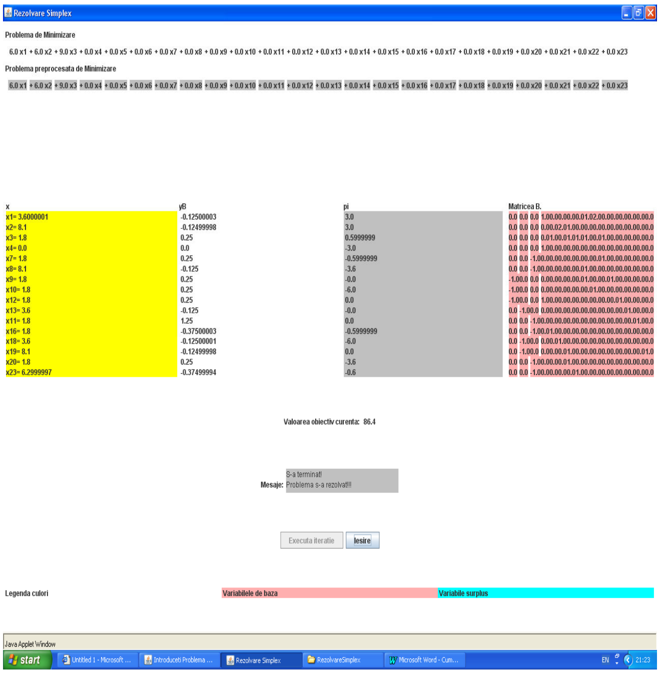

Fig. 13

Double click several times on the option called "Perform repetition" and the values of the unknown will appear that is of the moments and the value of the objective function, respectively the following page:

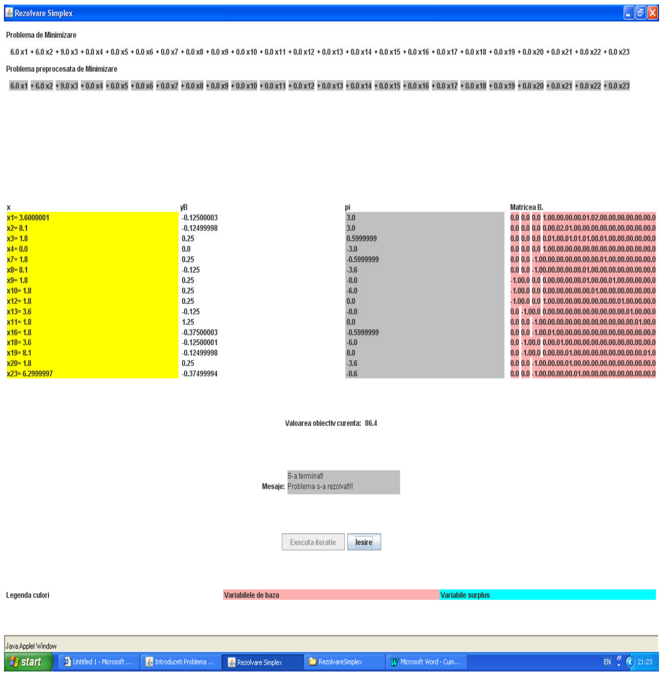

Fig. 14

The results obtained:

The results obtained:

$$\begin{array}{ll} x_1 = Mp_1 = 3{,}6; & x_{13} = Mp_{13} = 3{,}6; \\ x_2 = Mp_2 = 8{,}1; & x_{14} = Mp_{14} = 0; \\ x_3 = Mp_3 = 1{,}8; & x_{15} = Mp_{15} = 0; \\ x_4 = Mp_4 = 0; & x_{16} = Mp_{16} = 1{,}8; \\ x_5 = Mp_5 = 0; & x_{17} = Mp_{17} = 0; \\ x_6 = Mp_6 = 0; & x_{18} = Mp_{18} = 3{,}6; \\ x_7 = Mp_7 = 1{,}8; & x_{19} = Mp_{19} = 8{,}1; \\ x_8 = Mp_8 = 8{,}1; & x_{20} = Mp_{20} = 1{,}8; \\ x_9 = Mp_9 = 1{,}8; & x_{21} = Mp_{21} = 0; \\ x_{10} = Mp_{10} = 1{,}8; & x_{22} = Mp_{22} = 0; \\ x_{11} = Mp_{11} = 0; & x_{23} = Mp_{23} = 6{,}29; \\ x_{12} = Mp_{12} = 1{,}8; & \end{array} \tag{59}$$

and the weight function value:

$$X = 86{,}4 \tag{60}$$

For checking we shall proceed in the following manner:

We shall replace the values of the plastic moments x_1, x_2, x_3 in the expression of the objective function:

$$6 \cdot x_1 + 6 \cdot x_2 + 9 \cdot x_3 = 6 \cdot 3{,}6 + 6 \cdot 8{,}1 + 9 \cdot 1{,}8 = 86{,}4 \quad (61)$$

so the value obtained by calculation.

We shall introduce into the relations (48), (49), (50), (51) and (66) the values of the unknown found and we must obtain the free term in the respective relation.

VI. Conclusion

In the paper it was presented the usefulness of using the mathematical methods in solving the optimal calculation problems from the field of engineering.

These problems are specific to engineers, and it is aimed at obtaining the best solution that could lead to finding the minimum consumption of material in accomplishing an objective according to the criterion followed in the design.

Thus, we may talk about the criterion of the minimum cost.

The function of minimum cost is reduced to the function of minimum cost of labor.

The interest of the designer in making a long-term investment in a design is projected in the study of the optimization problems based on rehabilitation. A balanced design may be obtained, by optimizing an objective function, which expresses both security and economy.

In the civil engineering, the field of construction, the optimization of the weight function is aimed at, which supposes making a structure with a minimum cost, minimum weight, but which offers the conditions of maximum security.

The mathematical methods used in this paper are modern, efficient methods that suppose knowing them thoroughly.

The “C.O.S.M.I.” program was made in a modern programming language and secure from all points of view, being easy to use.

Thus, solutions to some linear programming problems are obtained, used in the field of engineering.

It must be mentioned the fact that the obtaining of best solutions in an engineering calculation was an will remain a preoccupation of the engineers, the aim being to obtain some structures (in the case of constructions), pieces (in the mechanical, electrical field) etc. with a minimum cost of material, but which respects all the requirements of security and quality.

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