X POLISH CONFERENCE "COMPUTER METHODS IN MECHANICS"
Świnoujście, Poland 14 - 17 May 1991

CAD SYSTEMS. PROGRAM LCBLACHO FOR DESIGNING PLATE GIRDER BEAMS

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ABSTRACT

This paper presents a program LCBLACHO for designing multi-span plate girder beams of variable stiffness a' ng length.

Rationale is given for an iterative way of the optimization of plate girder beams oriented on a practical way of professional designing.

Basic design restrictions and the way of verifying strength conditions in plate girder sections taking into account web local stability are provided.

Program LCBLACHO is described with a special account of editors adjusted to the design of plate girders. Graphic values of the program are emphasized.

1. INTRODUCTION

Computer aided design consists in shaping and calculating structures using a computer in a way that permits optimization. Thus, modern CAD programs are not only graphic editors which serve for processing graphic data but they are also expert systems provided with expert knowledge base from a given area of design, and also a computer of design correctness together with an extended systems of prompts. Expert systems are oriented on specialization in a definite area of knowledge.

Program LCBLACHO from the package MicroCAD_MS [1] is a CAD program for designing multi-span welded plate girder beams. Plate girder beams are used as binding joists, crane beams, bridge beams or bended girders in other structures. In the process of plate girder design points of section stiffness variability and their dimensions are selected in such a way as to minimize the beam's mass fulfilling the design restrictions and conditions of strength and utility.

Design of plate girder beams is a classical example of multicriteria optimization (criterion of steel consumption, minimum of different elements, minimum workmanship), and multi-factor optimization (design parameters are not only the dimensions of sections but also the steplike distribution of these sections along the beam length, and the kind of material).

Restriction of the optimization of plate girders frequently cannot be formulated unequivocally because they must take into consideration a number of additional, individual restrictions, e.g. geometry of adjacent structures.

In such a situation the most effective is the traditional way of optimization which consists in iterative selection of one of the design parameters until the structural or strength restrictions are fulfilled. A quick calculation of the purpose function for many discrete design parameters makes possible optimal design of an element.

For such a purpose it is ideal to use the dialogue mode of calculations on microcomputers. In a short time the designer can analyze many variants and choose the optimal structure in every case of the rich list of practical design situations.

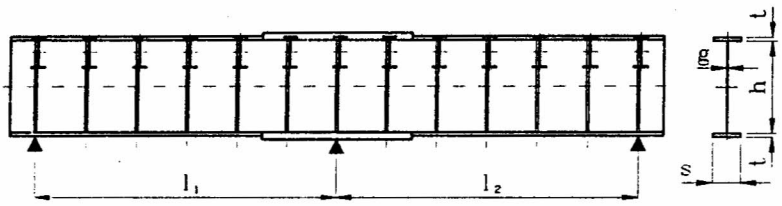

Fig. 1 Example of welded plate girder.

2. DESIGNING OF PLATE GIRDER BEAMS

The designing procedure of welded plate girders of variable sections (Fig. 1) is following [2]:

- selection of statical diagram
- specification of loads
- initial selection of plate girder sections
- selection of the points of section variation
- statical calculations
- verification of strength conditions with the stability of the beam and its elements, and also verification of displacements
- design of plate girder element, (ribbing, joints, bearings, etc.)

A number of **design and technological conditions** have been imposed on the design of the plate girder, including:

1) flange thickness
   $g+1<t<3.5\,g$ and $t<=30$ mm (steel 18G2A) or 40 mm (steel St3S),
2) thickness of the bended beam flanges $s=(1/3:1/5)h$
3) web thickness
   $g=(1/90:1/160)h$ and $g>=6$ mm
4) distance of points of section variations from support and ribs
   $c>=1$ m from support and $c>=30$ cm and $c>=20g$ from ribs
5) length of flange segments of uniform section $l>=2$ m
6) number of section variations
   $n<=3$ for one span and $n<=6$ for the whole beam.

Strength conditions should be checked in all the fields of the plate girder, whereas:

1) it is necessary to check the conditions of plastic load bearing capacity in places of rib fixing, i.e. under each concentrated force including the supports (areas P in Fig. 2)

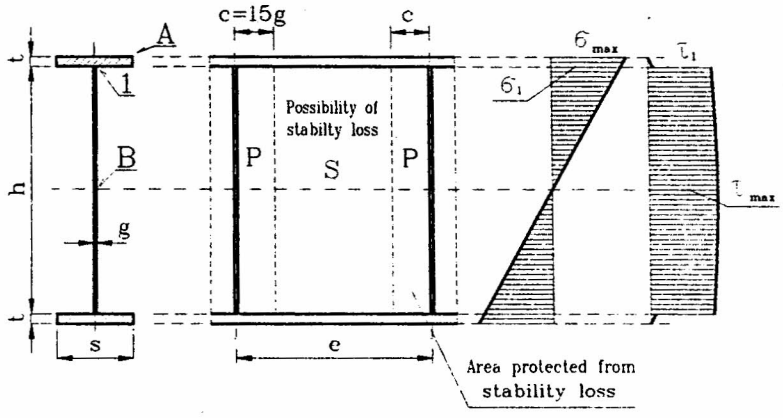

Fig. 2 Stresses in cross section of plate girder.

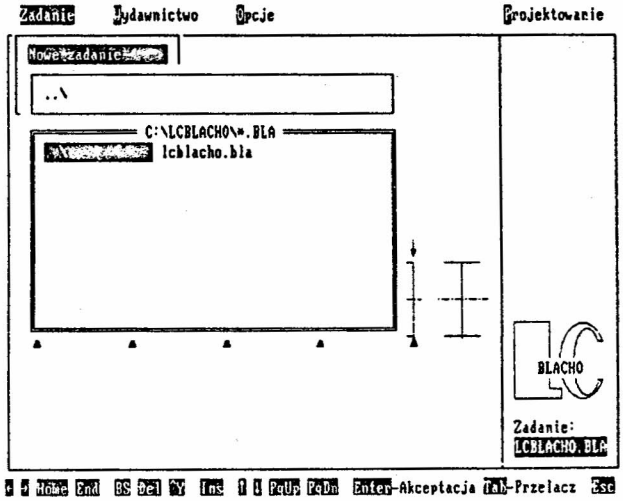

Fig. 3 Selection of a working file.

2) it is necessary to check the conditions of critical load-bearing capacity (web local stability) in each plate distinguished by ribs of thickness e (area S in Fig. 2). It is assumed that the web is protected from stability loss at the width of 15 g on either side of the rib. Stability coefficients should be calculated in a way compatible with current regulations [3] taking into account random imperfections of the material and geometry.

Another restriction is also the condition of not exceeding admissible deflections.

3. DESCRIPTION OF THE PROGRAM LCBLACHO

Figs. 3 through 7 represent the screens of the program LCBLACHO. The main options of the program are listed in the upper line of the menu:

Problem - Edition of the working file names with system operations, change of names, reading in or writing under another name, deleting of working files etc. (see Fig. 3 where the moment of selection of a working file is shown).

Edition of results file - Edition, viewing, formatting and printing of fragments or the whole file.

Options - configuration of program, including access paths, coefficient of screen shape, writing/reading of configurations to/from the file.

Designing - Basic options of plate girder design.

In Fig. 4 is shown a screen during **introduction of data** concerning typical one to nine-span plate girders without cantilevers loaded with forces concentrated in equal intervals. Typification of plate girders allowed to minimilize the number of introduced data. However, it is possible to set different parameters for each span. Loads are set as distributed ones, and the program changes them automatically into concentrated ones taking into consideration set intervals between single forces. Load always acts simultaneously on all the spans, and the variable load can act only on selected spans.

In Fig. 5 is shown an editor which makes possible to illustrate the envelope of bending moments and to edit the number matrix together with the illustration of a place on the beam which is related to the chosen magnitude. The envelope of sectional forces, the envelope of support reactions as well as the deflection is calculated for all possible load schemes. Load schemes are generated and illustrated on the screen.

In Fig. 6 is shown the **editor of the envelope of load bearing capacity** which serves to choose the points of stiffness variation of the plate girder along its length. Edition is possible by means of *direction* keys or by means of writing the value by hand. Determination of the points of section variation is done by means of mutually crossing threads: the vertical one which determines the position of the section place, and the horizontal one which determines the possible load bearing capacity of the plate girder segment measured by a pure bending moment. The displacement jump of these, corresponding to single pressing of the *direction* keys, can be arranged by the designer in an arbitrary way.

The coordinates of the beginning and the end of the plate girder segment of constant load-bearing capacity must be determined along the length of the plate girder. The coordinates are regarded as the final ones and are not corrected during calculations. Only load-bearing capacities of the sections are optimized in the further part of the system.

Fig. 7 shows an editor which makes possible a selection of the dimensions of the beam sections. Optimization of the project consists in iterative selection of web height and/or thickness, or flange width and/or thickness in each element of the beam set earlier. The value of the function of purpose which is the beam weight, is displayed currently in the lower part of screen. Also structural and strength restrictions are verified simultaneously.

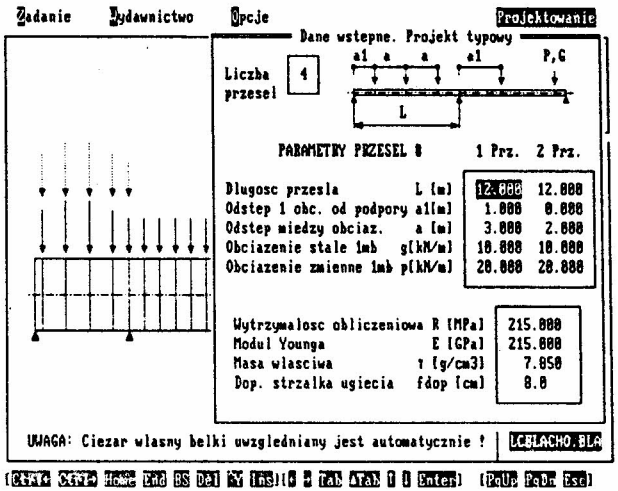

Fig. 4 Introduction of data.

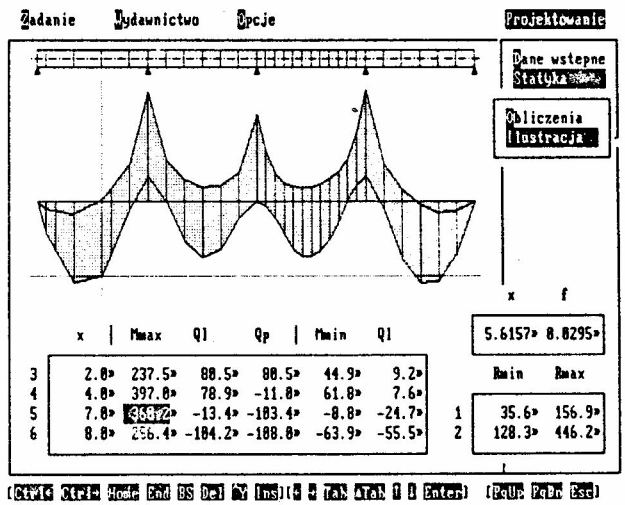

Fig. 5 Editor of the envelope of bending moments.

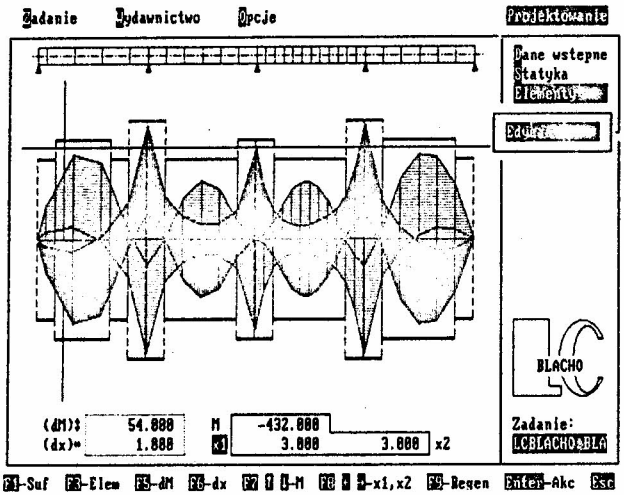

Fig. 6 Editor of the envelope of load-bearing capacity.

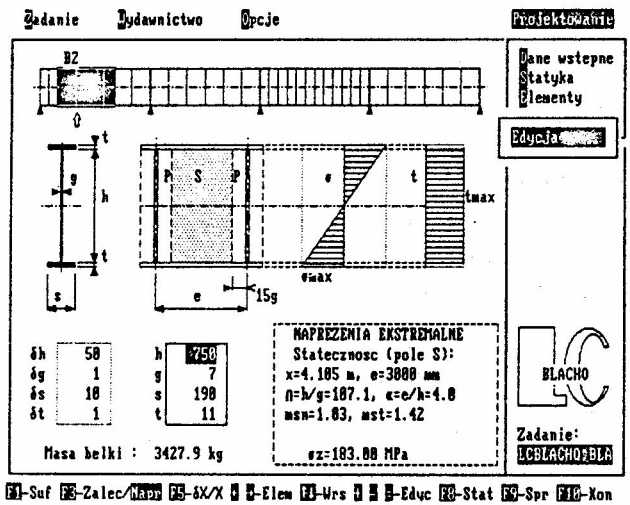

Fig. 7 Selection of the dimensisons of beam sections.

Design parameters can be changed by key "+","-". The pitch of sheet thickness that of web height and flange width have been set in a standard way to recommended values although the designer can change these pitches.

In a separate window of the screen information is provided simultaneously concerning extreme stresses in an element being currently edited. The window shows automatically information whether the load-bearing capacity of the section is limited by plastic stresses near a rib, or by the stability loss of the inter-rib field. Also, a set of design recommendations concerning a given dimension can be displayed in this window at any time. The arrow in the beam view shows places along the length of the element which limit its load bearing capacity.

When the edition is over, repeated statical calculation and the verification of design and strength conditions are performed in each element. Only after a correct design the editor is complete together with the saving of the design.

The program has been provided with an extended **help** which contains program description and also the manual of plate girder design.

Edition of results consists in:

- viewing the whole working file which contains data and design result,
- formatting of the file for printing, i.e. arrangement of page ends, headers on even and uneven pages,
- printing the whole files, its fragments or selected pages with a possibility of imposing the following parameters of printing: left margin, printing quality, number of copies, number of the first page, printer's port.

4. CONCLUDING REMARKS

This paper presents a CAD program for designing multispan welted plate-girder beams subjected to the action of statical permanent and variable loads.

The principal part of the program is an adjustment of the beam load-bearing capacity to the envelope of sectional forces so that the beam mass be minimized by fulfilling structural strength and operational restrictions. Optimization is performed in an iterative way oriented on practical professional designing.

On account of its value, particularly on account of the program environment, including auxiliary options and graphic illustrations - program LCBLACHO can become a standard in its class and can be used in teaching design of metal structures.

ACKNOWLEDGEMENTS

Program LCBLACHO is a part of the library **BASK** [4] developed in the framework program RPI-14 coordinated by Faculty of Civil Engineering, the Technological University of Warsaw. Constructions of the program was sponsored by Ministry of National Education.

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STRESZCZENIE

W pracy przedstawiono program LCBLACHO do projektowania wieloprzeslowych belek blachownicowych o zmiennej sztywnosci po dlugosci.

Uzasadniono iteracyjny sposob optymalizacji belek blachownicowych zorientowany na praktyczny sposob projektowania profesjonalnego.

Podano zasadnicze ograniczenia konstrukcyjne i sposob sprawdzania warunkow wytrzymalosciowych w przekrojach blachownic z uwzglednieniem statecznosci miejscowej srodnika.

Opisano program LCBLACHO, ze szczegolnym uwzglednieniem edytorow dostosowanych do projektowania blachownic. Uwypuklono walory graficzne programu.