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SOFTWARE FOR CALCULATING NODE CONNECTIONS MONOLITHIC REINFORCED CONCRETE BEAMLESS NON-CAPITAL OVERLAP WITH THE COMPOSITE REINFORCED CONCRETE COLUMN

The article touches upon the calculation procedure issue of connection nodes between beamless non-capital monolithic concrete slab and reinforced concrete column to provide bearing capacity in junctions between the slab and the column during design using software

The article deals with general calculation principles of connection nodes between beamless non-capital monolithic concrete slab and reinforced concrete column. On the basis of the algorithm to automate the calculation computer program was created in the programming language of Visual Basic for Applications (VBA). The language used for developing applications designed to manipulate databases and to customize the user interface. VBA a structured high-level programming language. In the language of VBA implemented the general principles of object-oriented programming.

Keywords: *computer technologies, beamless monolithic slab, composite reinforced concrete, shear, algorithm, software.*

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ПРОГРАМНЕ ЗАБЕЗПЕЧЕННЯ ДЛЯ РОЗРАХУНКУ ВУЗЛІВ З'ЄДНАННЯ МОНОЛІТНОГО ЗАЛІЗОБЕТОННОГО БЕЗБАЛКОВОГО БЕЗКАПІТЕЛЬНОГО ПЕРЕКРИТТЯ ЗІ СТАЛЕЗАЛІЗОБЕТОННОЮ КОЛОНОЮ

Розглянуто загальні принципи розрахунку вузлів з'єднання монолітного залізобетонного безбалкового безкапітельного перекриття зі сталезалізобетонною колоною. Надано алгоритми автоматизації розрахунку вузлів з'єднання монолітного безбалкового перекриття зі сталезалізобетонною колоною на зріз при продавлюванні за Eurocode та за розробленою методикою. Наведено структурно-логічну схему досліджень роботи вузлів з'єднання, виконано розрахунок монолітної плити на продавлювання за допомогою комп'ютерної програми за побудованим алгоритмом.

Ключові слова: *комп'ютерні технології, монолітне безбалкове перекриття, сталезалізобетон, зріз, алгоритм, програмне забезпечення.*

Introduction. Nowadays reinforced columns using is widely spread among natine builders.

Developing computing and software systems that take into account the physical and mechanical properties of concrete and steel, allow significantly facilitate the design of reinforced concrete frame buildings. It gives opportunity to analyze the work of the building frame in general, and its elements both taking into consideration graphs of concrete deformation even in stress-strain state.

The article provides the calculation procedure of connection between conrcete reinforced columns and monolithic reinforced slab. A software has been developed accorfing to the algorithm.

Publications and recent sources analysis. Issues of the slabs desing has been discovered by Azizov T. [8], Vatyn N. [9], Ivanov A. [14], Yagofarov H. [19], Taerve L. [6] fnd other scientists. Connection nodes between beamless monolithic slabs and columns has been learned by Dofman A. [12], Loleit A. [15], Storozhenk L., Nyzhnyk O. [17] and others. This issue is also deeply investigated by foreign scientists [7, 1, 2].

Unsolved aspects of the problem statement. One of the main problems in beamless monolithic slab and reinforced concrete column desing is providing carrying capacity is connections between slab and column, that are the most important elements. That is why a stress-state estimate is important in the connection nodes.

Issue formulation. During the design process a software development for calculation procedure of connection nodes between beamless monolithic slab and reinforced concrete column is required.

Main topic and results. A research flowchart of stess-stain state of connection nodes between monolithic reinforced beamless non-capital overlap and reinforced column has been created according to the analysis (Fig. 1).

Nowadays, it is important to meet the requirements of the protection of buildings from progressive damage in the event of the destruction of local supporting structures as a result of accidents.

Resistance against the demolition of buildings should be checked by calculation and provided by constructive measures. Calculation of stability of frame buildings must be performed in the most dangerous scheme of local destruction. This is the destruction of the column or columns with walls that abut on one area of the local damage.

During the problem solving a concrete column in a two channels steel cage was investigated. The load applied to the core and the cage. Disclosure of contact between the concrete core and steel cage makes possible evaluating the stress-strain state of crossing column [18]. To determine the intensity of the interaction forces of the core and the cage qz (x, y) the next equation is used [18]

$$q_z(x,y)(\delta_s - \delta_b) - (u_s - u_b) = 0 \ , \qquad (1)$$

where us, ub – moving on the brink of a contract from the vertical load in a concrete core and a cage, made from welded channels.

δs, δb – moving of the points on the brink of the core and the cage fron the single load:

$$\bar{q}(x,y) = 1 \qquad \text{at} \qquad x, y = \pm\frac{a_b}{2}, \qquad (2)$$

$$\bar{q}(x,y) = \frac{1}{x^2} \qquad (1)$$

in other brink points.

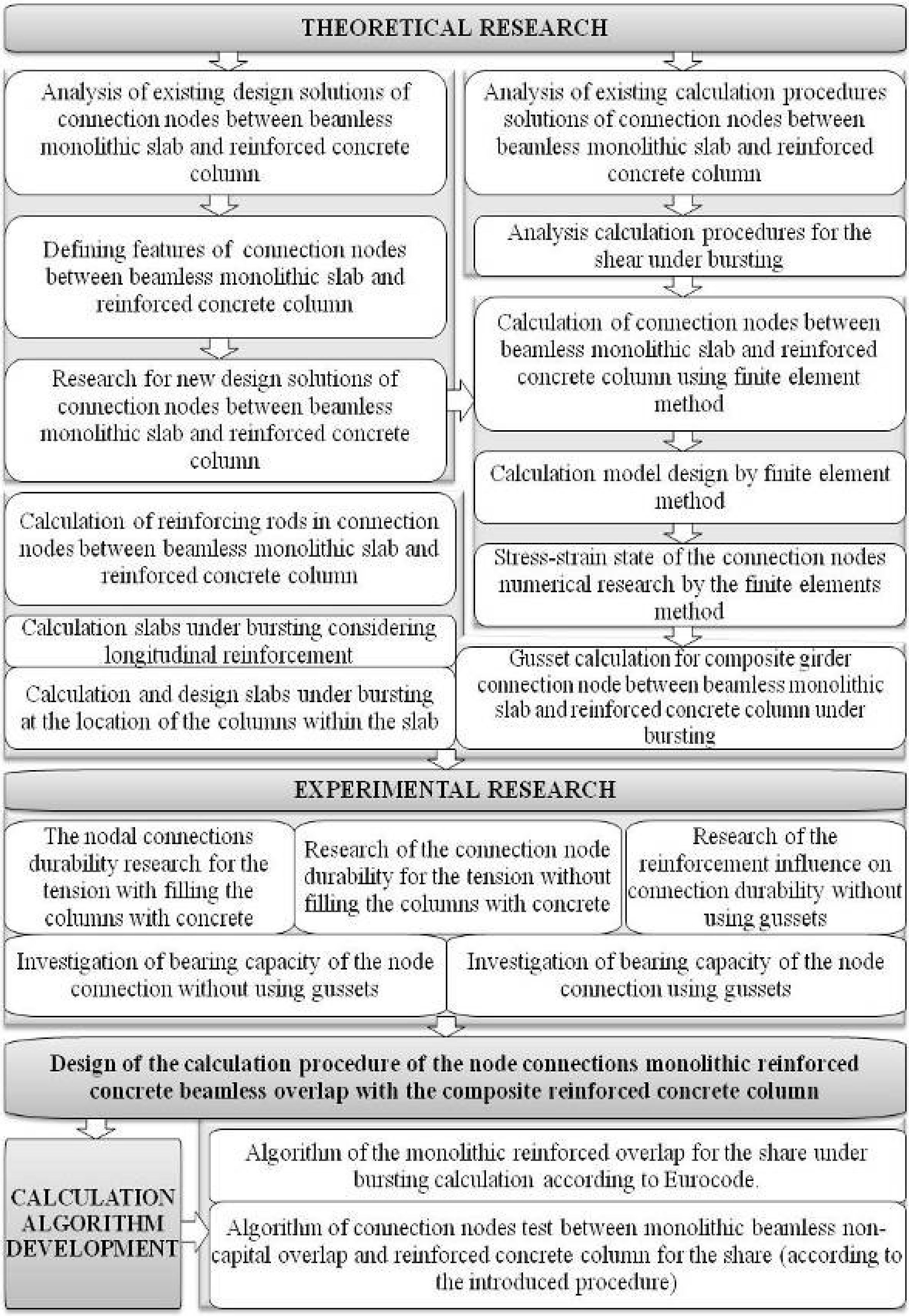

Figure 1 – Flowchart of connection nodes between monolithic reinforced beamless non-capital overlap and reinforced column

The equation of equilibrium in the intersection of the column is the next:

$$\frac{\partial \sigma_z}{\partial z} + Z = 0\,; \tag{4}$$

$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + Y = 0\,; \tag{5}$$

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + X = 0\,, \tag{6}$$

where X, Y, Z – elements of the bulk power.

Tangent tensions τxz, τyz are not included [18]:

$$\frac{\partial}{\partial z}\left[(\lambda + 2G)\frac{\partial u_z}{\partial_z} + \left(\frac{\partial u_y}{\partial y} + \frac{\partial u_x}{\partial x}\right)\right] = Z\,; \tag{7}$$

$$\frac{\partial}{\partial x}\left[(\lambda + 2G)\frac{\partial u_x}{\partial x} + \lambda\left(\frac{\partial u_y}{\partial y} + \frac{\partial u_x}{\partial x}\right)\right] + \frac{\partial}{\partial y}\left[G\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)\right] = X\,; \tag{8}$$

$$\frac{\partial}{\partial y}\left[(\lambda + 2G)\frac{\partial u_y}{\partial y} + \lambda\left(\frac{\partial u_x}{\partial x} + \frac{\partial u_z}{\partial z}\right)\right] + \frac{\partial}{\partial x}\left[G\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)\right] = Y\,. \tag{9}$$

Since the research takes into account the work of a single reinforced column and it's combination with a beamless non-capital monolithic slab, it's necessary to include into the evaluation equality conditions on the brink of connection between the column and the slab (electis analogies mathod by Lame):

$$\left.\begin{aligned} (\lambda + 2G)\frac{\partial^2 u}{\partial x^2} + G\frac{\partial^2 u}{\partial y^2} + (\lambda + 2G)\frac{\partial^2 \upsilon}{\partial x \partial x} = 0; \\ (\lambda + 2G)\frac{\partial^2 u}{\partial y^2} + G\frac{\partial^2 u}{\partial x^2} + (\lambda + 2G)\frac{\partial^2 u}{\partial x \partial x} = 0. \end{aligned}\right\} \tag{10}$$

So, the problem of elasticity plane (plane strain) in the movements is solved. This equation shows that the action of concentrated load on the concrete slab intersection of main transverse forces arising stretching stress that is bigger than concrete tensile resistance.
Calculation of the stability of the building must be executed on a special combination of loads, including permanent and long loads at the most dangerous scheme of local destruction.
Resistance against the progressive destruction of the building will be provided, if the next condition will be met for each element:

$$F \leq S \tag{11}$$

where F – efforts in structural elements;

S – the estimated carrying capacity.

In calculating the stability of steel buildings for the most dangerous pattern of local destruction of estimated moments and transverse forces increase by $10 - 20\%$.

To solve the problems discovered in the paper, the calculation model of a building with beamless monolithic reinforced. was additionally created. Columns step is - 6 m (Fig. 2).

For the calculations the next systems are used: Ansys, Cosmos, Robot Millennium, Monomah and others. The most popular and reliable are Lira-Windows and SCAD (ProductGUID=EA03D845-6AB9-4E9E-B5CD-45B755E42C46) [10], that were used to solve the problem (Fig. 3).

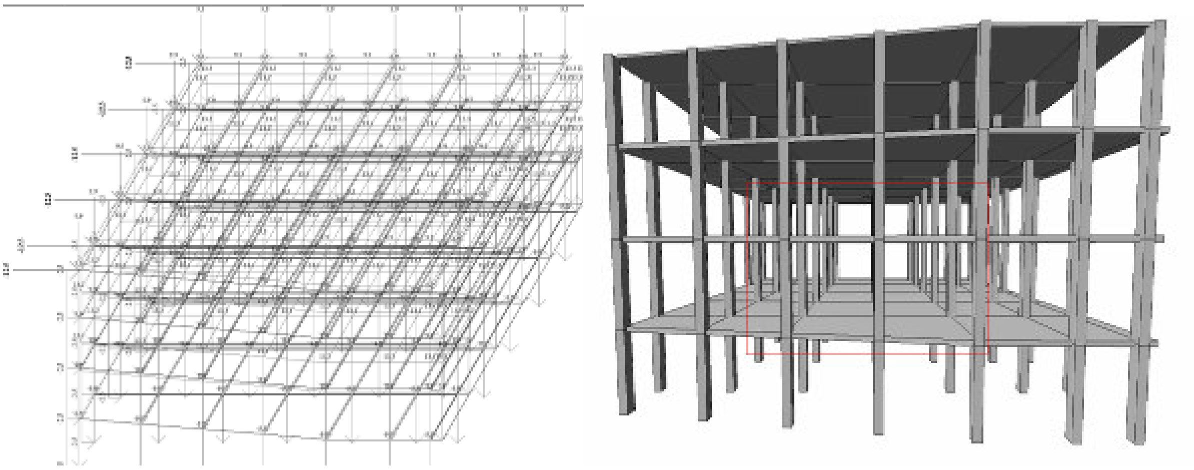

Figure 2 – The design model of the three-story building with beamless reinforced concrete overlap

a) b)

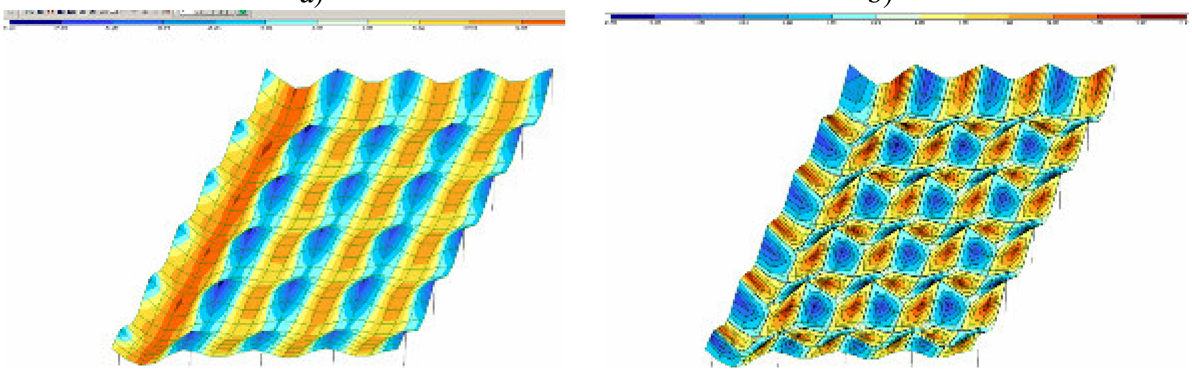

Figure 3 – The frame calculation results in «Lira-Windows»:
a) isosurface of efforts on Mx; b) isosurface of efforts on My

The next calculation steps were introduced:
– static calculation of building according to design and resistance of materials for the 1st and 2nd groups limit state. Stiffness characteristics of materials - conventional, accepted separately for slabs and columns;
– determing of reinforced slab by static calculation, adjusting zone of the slabs reinforcing at maximum span moments and the principle of its continuity and symmetry in stretched areas while preserving the estimated reinforcing over-slab zones;
– implementing of three-linear deformation diagrams for concrete and two-line diagram for reinforcements according to [5] and regulations [11].

The design is considered as a system of frames with rigid nodes located in two mutually perpendicular directions [16, 4].

In the monolithic structure each frame consists of columns and slaps stripe, which width equals to the distance between the midpoints of the two spans adjacent to the appropriate number of columns.

Problem of plates system bending was solved by finite elements method.

Efforts for calculating the upper reinforcement over the supports are determined by the width of leaning plates (Fig. 4).

Internal efforts that are obtained from the static calculation, include torque Mxy. Determination of the design points is done according to normative document [3].

If the My<Mx, torque calculation is similar to ($x \leftrightarrow y$).

Figure 4 – Considering width of the leaning in determining torques

The beamles building should be calculated under loading, evenly distributed throughout the slab or it’s part.

The load acting on the slabs may be reduced to approximately equivalent uniformly distributed load on bending moments, transverse forces or deformations depending on the boundary conditions used for the calculation. The actual nature of the load should be taken into account during calculating the individual parts of buildings (for example, shear).

Buildings are calculated for strength, deformation and crack opening under the action of static load. Dynamic analysis and calculation of endurance are performed if needed.

Strength (carrying capacity) of the frame elements is determined based on the calculation of frames taking into account redistribution efforts.

Algorithm for determining the torque is written as (Fig. 5):

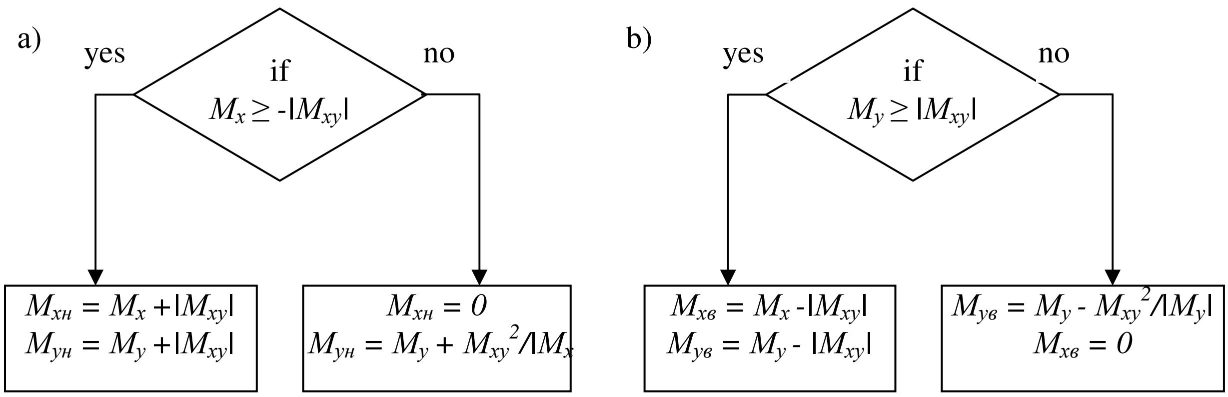

Figure 5 – Determining torques Mxy (case My > Mx):
a – bottom reinforcement (Mхн , Mун); b – bottom reinforcement (Mхв , Mув)

In addition, the calculation of the strength of boards should include:

– the calculation of bursting;

– calculation for scrapping a panel along or across the slab, where panel is a part of the slab bounded by grid lines columns frame;

– calculation for simultaneous scrapping of the adjacent panels of different rows.

Calculation for scrapping a single panel is not required. Calculation for scrapping a single transverse or longitudinal slab stripes is mandatory.

The introduced procedure for connection nodes between monolithic beamless slab and reinforced column calculation includes two stages:

1. To check work of the connection node between monolithic reinforced beamless non-capital slab and reinforced columns for the shear the calculation algorithm improvement has been introduced according to the current regulations on the basis of the formula (12) [11, 13].

$$F \le 1{,}125 \cdot R_{bt} \cdot u_m \cdot h_o \sqrt{1{,}1 + 0{,}7\mu} \quad (12)$$

2. Calculation of the connection node between monolithic beamess non-capital slab and reinforced columns for the shear along the column body (according to the procedure).

To check work of the connection node for the shear under bursting it is necessary to determine a length of the calculated perimeter using the next formula:

$$u_i = 2(a+b)+4\pi \cdot h_o. \quad (13)$$

If the applied load is uneven, then a plate bending moment occurs, which applies in formulas for determining the eccentricity in Y and Z:

$$\left.\begin{aligned} e_y &= \frac{M_{edy}}{V_{ed}} \\ e_z &= \frac{M_{edz}}{V_{ed}} \end{aligned}\right\}, \quad (14)$$

where ey and ez – eccentricity on the axis y and z;

Medy – bending moment acting on the plate in the Y-axis;

Medz – bending moment acting on the plate in the Z-axis;

Ved – the total lateral force acting on the estimated length of the perimeter.

To determine the geometric parameters of the perimeter of the bursting pyramid the next formulas can be used:

$$\left.\begin{aligned} b_x &= a + 4 \cdot h_o \\ b_y &= b + 4 \cdot h_o \end{aligned}\right\}, \quad (15)$$

where a, b – geometric parameters of a reinforced column;

ho – working plate height.

Load eccentricity to the rectangular column is the following:

$$\beta = 1 + 1{,}8\sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_y}\right)^2}. \quad (16)$$

If load eccentricity is less than 1.15, the 1.15 is taken and the total lateral force acting on the length of the critical perimeter is determoned,

$$\upsilon_{Ed} = \beta \frac{V_{Ed}{}^2}{u_i d}. \quad (17)$$

To determine the reinforcement coefficient the next coefficients is used:

$$k = 1 + \sqrt{\frac{200}{d}}. \quad (18)$$

The coefficient should be less or equal 2.

Reinforced coefficient is the following:

$$\rho_l = \sqrt{\rho_{lx} + \rho_{ly}} \le 0{,}02. \quad (19)$$

The strength of plates without transverse reinforcement under bursting is determined:

on reinforcement (according to the proposed formula)

$$V_{Rd,s} \le 1{,}125 \cdot f_{ctd} \cdot u \cdot h\sqrt{1{,}1 + 0{,}7\rho}; \quad (20)$$

on concrete

$$V_{Rd,c} = 0{,}4 \cdot f_{ctd}.$$

To automate the process of testing the connections between monolithic beabess non-capital slab and reinforced columns for the bursting (according to the procedure) a software has been developed. The software development includes steps shown on Fig. 6 – 8.

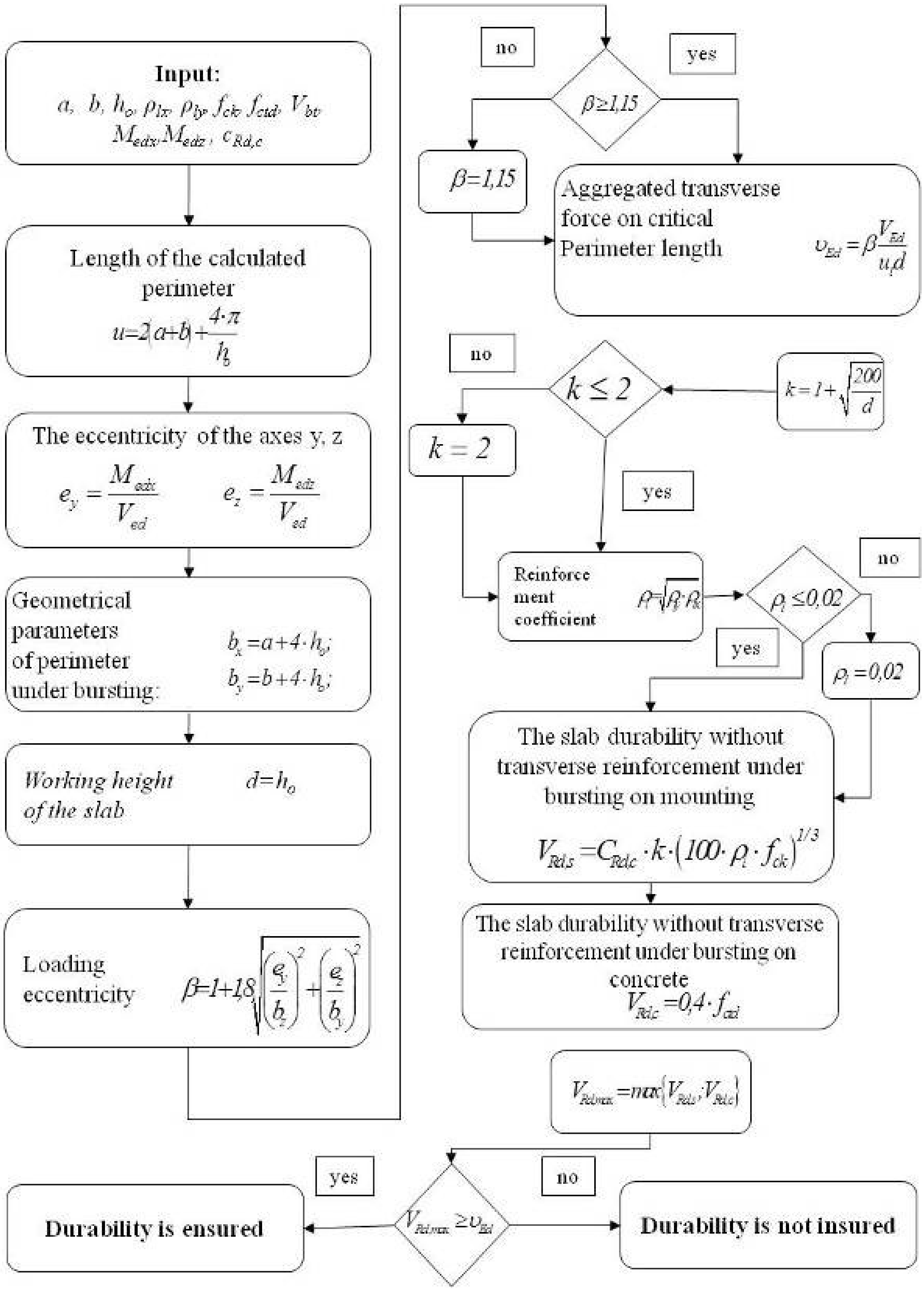

Figure 6 – Calculation algorithm of monolithic reinforced overlapunder bursting according to Eurocode No. 2: EN 1992-1: 2001 (Final Draft, April, 2002) Eurocode-2: Desing of Concrete Structures – Part 1: General Rules and Rules for Building

Issue statement	• The purpose of the software is to check the connection between monolithic beamless non-capital overlap and reinforced columns for the shear using the proposed formula.
Issue analysis and design	• At this step inputs and results were determined, revealed constraints on their values, made a formal description of the problem and the mathematical model suitable for solving the problem using computer.
Development and the algorithm selection	• Based on the mathematical description of the problem the solving algorithm was created (picture. 8).
Design if the general program structure	• The solving model was created with further specification and division into subprograms, defined the software architecture and the way of data storage
Coding	• According to the algorithm a software was developed using Visual Basic for Applications (VBA) (picture 9). This programming language is used for applications development, used for interacting with data bases and adjusting the user's interface. VBA is a structured high level programming language. In the VBA language the general principles of object-oriented programming are implemented.
Software adjustment and testing	• Performed a verification check of the calculation of connection nodes between monolithic beamless non-capital overlap and reinforced columns for the shear
Results analysis	• Actual results meet the experiment data results

Figure 7 – Steps of the software development

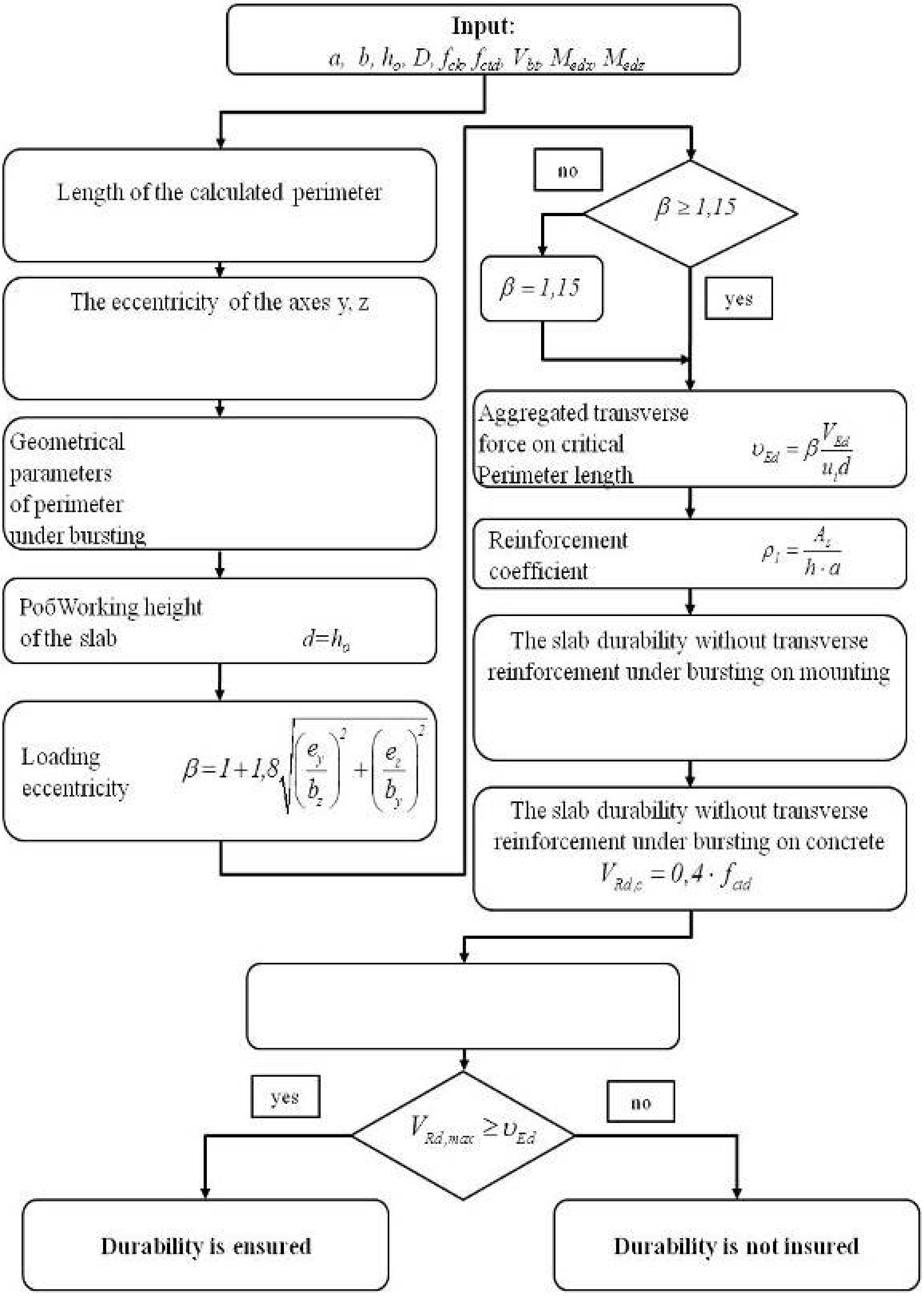

Figure 8 – Testing algorithm of connection between beamless non-capital monolithic slab and reinforced concrete column under bursting according to the introduced procedure

Summary:

1. Calculation methodology of the connections includes calculation for the shear under bursting and for the shear along the column.

2. Calculation of stress-strain state of the connections showed the convergence of theoretical and experimental investigation within 10%.

3. The introduced engineering calculation procedure of the connection nodes between beamless monolithic slab and reinforced concrete column including features of stress-strain state takes into account work of monolithic reinforced slab for the shear under bursting and calculation of the reinforcing rods for the shear along the column increasing the carrying capacity of connections by 10%. The difference between the results of the calculation of the existing and proposed method is 5%.

4. For the introduced connection nodes under bursting calculation procedure the automatization of the calculation is provided within Visual Basic for Applications environment (Fig. 9).

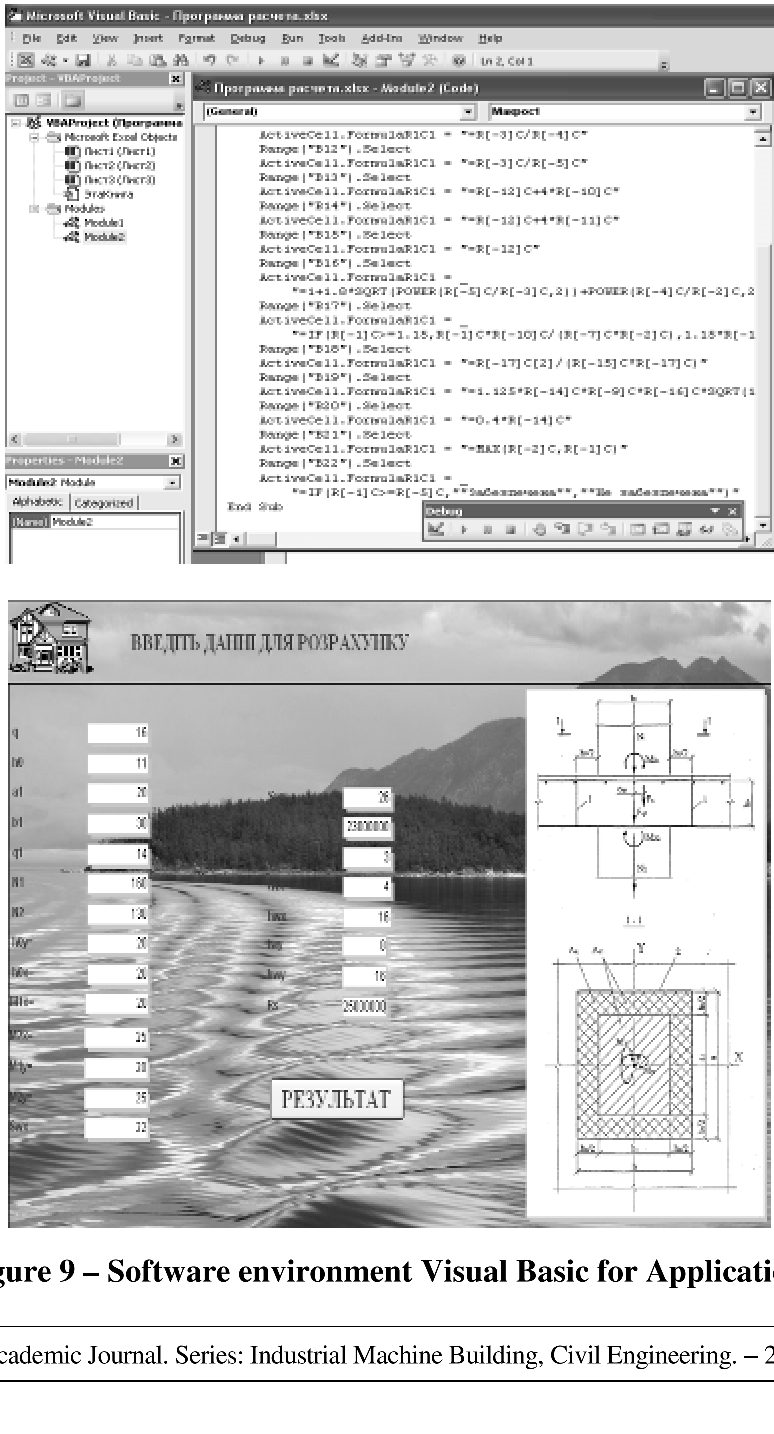

Figure 9 – Software environment Visual Basic for Applications

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