Automation of Working Drawings and Calculation of Reinforcement Weight in Concrete Structures

Zarbaf Amiraslanova
ANAS Cybernetics Institute, Baku, Azerbaijan
zarbaf2003@yahoo.com

***Abstract* — Problem of automation of development of working drawings and calculation of reinforcement weight in concrete structures is considered. Using of database is offered as an effective solution to the problem. Drawings are created automatically in AutoCAD by means of the database. Diameter, number, length of reinforcement and total weight of reinforcement for each diameter are also calculated automatically.**

Keywords: AutoLISP; AutoCAD; database; reinforcement; reinforcement design

I. INTRODUCTION

Reinforcement design is basically performed in AutoCAD based on static calculations of concrete structures. 'Reinforcement design' here refers to creating of reinforcement drawing with regard to its diameter, placement, step of distribution, protective coating etc. in compliance with corresponding standards. Characteristics of elements forming the structure (columns, beams, intermediate floorss etc.) are referred to repeatedly by design engineer creating reinforcement design. Characteristics are classification of reinforcement forming the element, i.e. diameter, step of distribution at certain intervals from one another, crossing spans, tilting spans and other such characteristics. They are searched in several drawings depending on the project development method, which leads to waste of extra time. As is obvious, a database of characteristics needs to be created to minimize time and labour consumption. At the same time, solution to the problem provides the foundation for reduction of project cost due to economical use of labour force [1].

Calculation of reinforcement consumption is one of the most important tasks both before the beginning of the work and after its completion, as well as in process. And those calculations are repeatedly referred to. In manufacture, reinforcement weight is as a rule calculated manually in compliance with working drawings. Calculations are made in Microsoft Excel lately, with data being input manually. Errors in process are not ruled out, which is also why the problem is extremely important.

II. PROBLEM STATEMENT

Originally provided data are characteristics of floor (name, level), column (name, width, length), beam (name, height), diameter, number and standard of reinforcement. AutoCAD drawing with extension .DWG showing lengths of column reinforcement, data and calculated reinforcement, Microsoft Excel file with extension .XLS showing weight and classification of reinforcements being used are required.

Regardless of standards, a lot of time is wasted on recurring steps in preparation of working drawings for construction of multistoried buildings. This time is spent on search of characteristics of columns, beams, intermediate floors in drawings, on calculations and creating of AutoCAD drawing on the basis of those calculations [1]. The task consists in minimization of time and labour consumption for reinforcement design, in automatic calculation of reinforcement weight and minimization of errors. With this purpose, the problem of automation of working drawings and calculation of reinforcement weight for column reinforcement according to British Standards is studied in the paper.

III. PROBLEM SOLUTION

Direct solution of the problem is possible in AutoCAD software application in dialog mode using AutoLISP programming language, with characteristics being keyed in. One must refer to several tables for each floor and respond to requests on each floor in dialog mode, which complicates the job of operator or engineer performing the task. In case of errors during responding to requests, the work has to be started over again. So, responding to requests is a very exhausting task on the whole. Instead, it would be easier to make the drawing in AutoCAD, and an effective method is offered for that. Characteristics are prepared in Microsoft Access database. Structure of record of column characteristics in Microsoft Access database is as follows: column ID, column name, floor, where column is located, width, length, diameter of reinforcement, reinforcement number, column tilt degree, stretching or shortening by floor [1].

Similarly, tables with characteristics of beam, eminence, etc. are created.

Those tables are limited to characteristics concerning the set task and do not provide extra information [1].

To select names of column and beams connected to the column at the given floor, a form is composed in Visual Basic Editor application in AutoCAD (saved as a file with extension .DVB) [2]. Upon completion of required operations, the data is transferred to AutoLISP, i.e. characteristics are saved as AutoLISP files (extension .LSP). Those files are open, read and processed in AutoLISP. Characteristics processing implies intervals between eminences, distance from the floor to the

beam, from the highest beam to the floor, from the floor to reinforcement in between eminences, etc. [1]. Crossings of reinforcement, intermediate floors and column distribution intervals of reinforcement placed across the width of the column, quantity of reinforcement, spacing, etc. are also processes. Thus, data is generated in the following way [3] (Fig. 1):

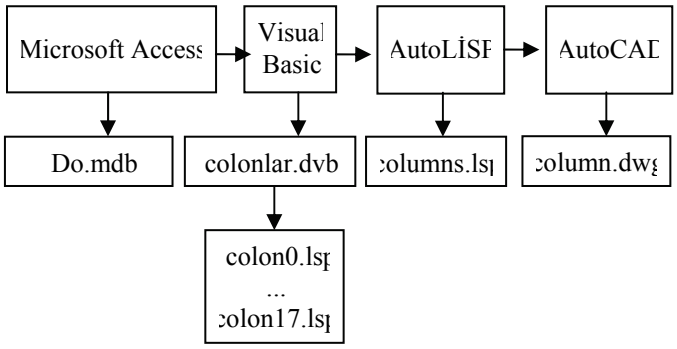


Figure 1.

According to scientific papers published recently, one might say that many tasks are carried out in CAD/CAE/CAM system with use of database [4]. However, these tasks use data from different tables and limited to quantity of requests for AutoLISP dialog mode. Instead of simply creating a main form in Visual Basic, problem solution through AutoLISP dialog mode in AutoCAD leads to waste of extra time and labour. We believe that this method is optimal solution to the problem.

Let us consider the problem of automatic calculation of reinforcement weight by the example of calculation of reinforcement in the foundation of structure.

According to British Standards [5], column reinforcement in vertical direction from the upper level of the foundation lies throughout 40Ø (changes depending on purpose) in the foundation, with a minimal tilt of 450 mm (Ø being reinforcement diameter, if Ø=16 mm, 40Ø=40x16=640 mm). But reinforcement tilt with allowance for protective coating must not exceed height (H) of the foundation (40Ø<=H-PP). Otherwise, 40Ø–(H-PP) = L1, that is, if reinforcement is installed at (H-PP) mm in the foundation, the tilt has to be (L1+450) mm. According to British Standards, protective coating in the foundation is 120 mm (PP = 120). This rule is applicable to design of reinforcement in the foundation [5].

Lengths of column reinforcement lying throughout intermediate floors height are calculated by a special rule. That calculation rule is considerably complex in British Standards compared with other standards. For instance, lengths of reinforcement located in the right and in the left sides of the column are calculated in different ways. On one side of the column, reinforcement length [6] according to the standards is calculated as 2/3 of the intermediate floors height (IFH), on the other as 1/3 IFH+50Ø, where IFH is height of the biggest beam connected with the column after deduction from the intermediate floors height, or, in the absence of beam, the distance remaining after deduction from flooring thickness (Fig. 2). Reinforcement is distributed equally in both sides. With a 90 degree tilt, reinforcement shortening according to the corresponding table in the standards must be taken into account. With reinforcement length with allowance for the part located in the foundation (40Ø<=H-PP), L=(40Ø + 450 + 2/3 IFH – r) mm; (40Ø>H-PP), L=(L1 + 450 + 2/3 IFH – r) mm. Here, r is reinforcement shortening at a 90 degree tilt. It should be noted that data (PP, 40Ø, H, ...) and calculation rules are obtained from static calculations made according to British Standards and can change depending on the project, which is why the data is stored in memory as global variables [7]. That also makes it possible to make alterations to calculation rules.

It is obvious from the above-mentioned that reinforcement parameters indicating diameter, number, length of reinforcement used in column (beam, flooring, etc.) are often repeated. To distinguish between those parameters, they are automatically numbered [7].

By means of the prepared system, diameter, number and length are transferred to Microsoft Excel via AutoLISP. Quantity of reinforcement is calculated in Microsoft Excel automatically and saved as a file. Calculation is performed depending on reinforcement diameter for a certain weight per one meter. The file contains diameter, number, length of

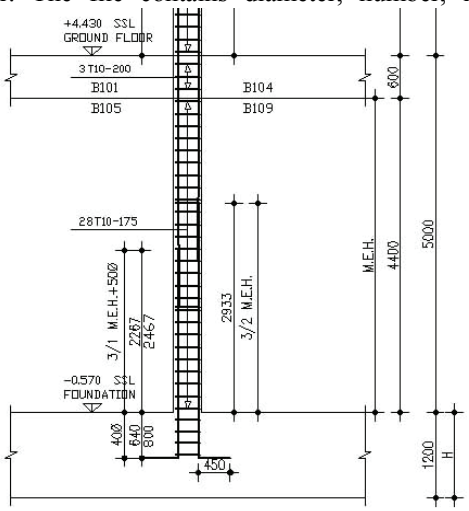


Figure 2. C37 column development and steel design automatically drawn in the main form in AutoCAD after pressing OK button

reinforcement being used. After classification of reinforcement being used is collected into one file, reinforcement weight for each diameter and the total weight are calculated.

IV. Functional Description of the Developed Software Module

After selection of input of the column name in the main form, its width and length from Microsoft Access database appears there. Shown on the right side of the form is the list of supporting forms corresponding to the number of levels for input of beams connected to the column for each level. When a level is selected, the corresponding form opens (Fig. 3). The form shows characteristics of the level, width and length of the column on the level (width and length of the column possibly varying from level to level), default characteristics of column

reinforcement are saved in temporary variables and are not visible in the form.

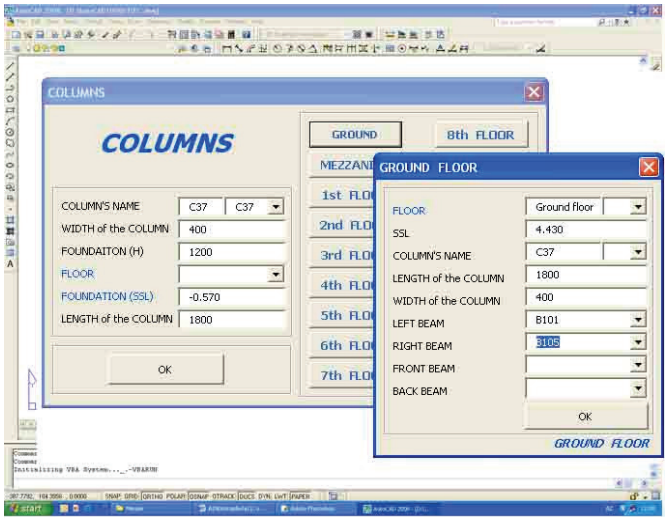


Figure 3. When GROUND button is pressed, GROUND FLOOR form opens

Data being input are controlled by the system. If during opening of a supporting form, floor height is keyed in manually and does not remain by default, then height should not be less than the minimal characteristic of intermediate floors. (Minimal characteristic, indexing… are global variables) [1].

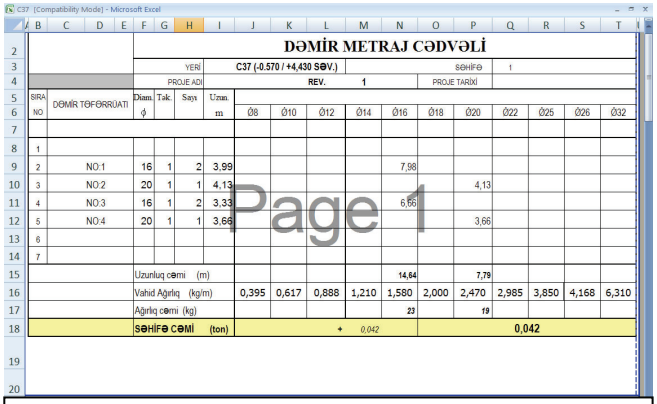
Structure elements (name of intermediate floors, name of beams, etc.) in construction drawings are usually indexed for each floor. In this case, elements corresponding to each floor in the current project can also be controlled if necessary by activating of indexing in global variables in the main form. In column reinforcement design specifically, particular emphasis is put on indexing of beams connected with the column. If beam name is shown incorrectly, a report of incorrect input is displayed and one can reselect a beam or key it in. The operation is repeated until the correct variant is selected. To create a column development to a certain level, corresponding number of supporting forms is completed. After all data is input, OK button is pressed [1].

V. CONCLUSION

Characteristics of column, beam, floor are transferred from the database and processed in AutoLISP. On their basis, development of the column and beams is created in AutoCAD automatically by means of the developed system (Fig. 2). Depending on the floor, up to which data is input, column is design automatically for each floor together with names of beams connected with the column, lengths of reinforcement at the floors, characteristics of levels, reinforcement details (number, diameter, step of distribution, length). Thus, a ready drawing is created, which means that the task is fulfilled within a minimum time span. Therefore, the work, which can be performed by a highly qualified design engineer in 1-1.5 hour for each floor in AutoCAD, is done by an inexperienced operator in 15-20 minutes. 15-20 minutes are used for study of drawing plan, input or selection of names of beams [1].

Further, the listed characteristics are transferred from AutoLISP to Microsoft Excel, where reinforcement weight is calculated automatically. Microsoft Excel file consists of 4 sections: title, reinforcement details, reinforcement lengths, end result (total length and total weight of reinforcement for each diameter of reinforcement being used, total weight of designed reinforcement). The file shows the data being transferred and values being calculated (Fig. 4).

Title section contains information on the project (project title, location, column name), number of calculation, page number, meaning of reinforcement details received from AutoLISP, reinforcement weight from the previous page (weight in Page 1 is equal to 0), diameters of reinforcement used in the project, weight per 1 meter for each diameter, etc. Reinforcement details section contain characteristics of reinforcement details transferred from AutoLISP, such as number of details, diameter, reinforcement number, length, number of repeats. Length of each reinforcement detail for corresponding diameter is calculated in the reinforcement lengths section. At the end of the page, total length of the used reinforcement for corresponding diameter is calculated, as well as reinforcement weight for the total length, total weight of reinforcement for the details in the page, the current weight being calculated together with the previous page. Thus, the end result is a document (file) containing reinforcement classification (diameter, length, number) used in the column in the current project, and reinforcement weight for each diameter, and the total reinforcement weight [7].



Fiure 4. Page 1 of the Microsoft Excel file

After making certain alterations to the system, one can apply it to any building with concrete structures designed according to different standards. Thus, software has been developed, which automatically creates a development of columns and beams and design of reinforcement used in the column in AutoCAD system, using a database. Similarly, reinforcement weight is calculated automatically and saved as an Excel file. The system can be used in any project with concrete structures regardless of the purpose.

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