

Teaching Tool: Finite Element Analysis of 2D Truss Problem by VBA Program

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Abstract - Finite element method used for complex 2D truss problem needs computer program to help solving the solutions. The specific engineering programs are licensed and hard to be installed in every computer. But there is EXCEL in every computer. VBA program run on EXCEL was written to solve the 2D truss problem by using basic finite element concept. User inputs information into program: number of nodes, number of elements and their information, boundary conditions, and loads. VBA program automatically calculates information and shows results: stiffness matrix for each element and global stiffness matrix, deformation and reaction solutions, internal forces and normal stresses for each element, comparison picture of problem picture and deformation picture in color shades.

Keywords - 2D Truss, Excel, Finite Element, VBA

I. INTRODUCTION

A truss is an engineering structure consisting of straight members connected at their ends [1]. 2D Truss or plane truss is defined as a truss whose members and forces acting on lie in a single plane. Members of a truss are generally considered to be two-force members with normal stresses; compress or tension. The statically indeterminate truss problems are impossible to be solved by using

elementary mechanics method. The finite element theory is one of the method to solve this problem in the concept of direct formulation, $[K]\{U\} = \{F\}$. In complex 2D truss problem, computer program is used to help solving the solutions. Since the specific engineering programs are licensed and hard to be obtained, EXCEL has been chosen. VBA program run on EXCEL was written to automatically show the finite element procedure and solve the solutions.

II. METHODS AND PROCEDURE

VBA [3] program (Fig. 1) uses the concept of direct formulation, $[K]\{U\} = \{F\}$, which $[K]$ is Stiffness matrix, $\{U\}$ is Displacement matrix, and $\{F\}$ is Load Matrix, to solve the solutions. User inputs information of the problem into program and let the program to calculate information and show results. Program has 8 worksheets; Note sheet, Sheet1 – Sheet6, and Sample Info sheet. Note sheet is the instruction note show how to use the program. Sheet1 is the information template sheet which let user to input the problem information.

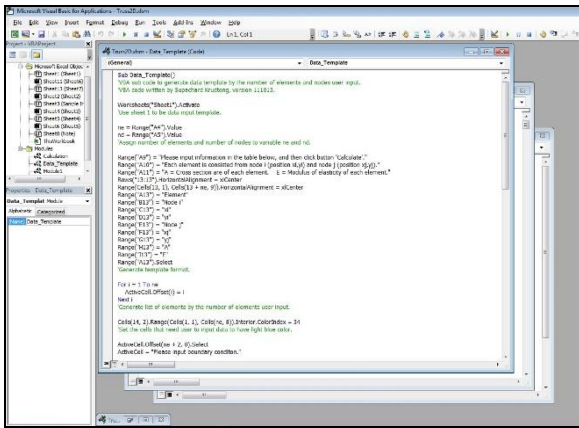


Fig 1. VBA Program

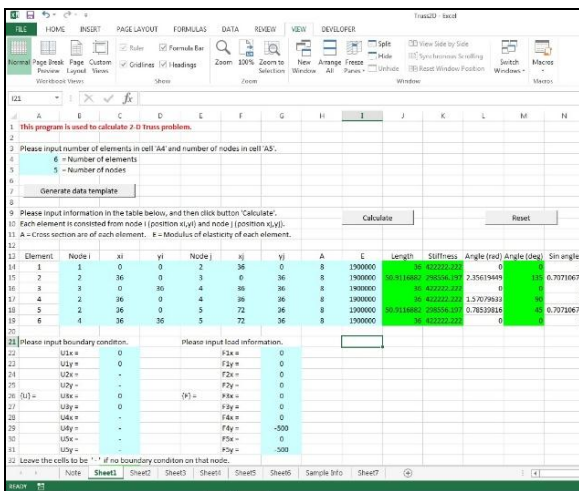


Fig 2. Sheet1: Data Template

First of all in Sheet1 (Fig. 2), user has to let program know the number of elements and number of nodes. Program will generate the data template according to the numbers user input. User input element information, boundary conditions, and load information in three light blue tables. Element information are node index, node coordinate, cross section area, and modulus of elasticity of each element. Boundary conditions are fixed conditions of each node in each x and y direction. Load information are loads act on each node in x and y direction. There is an example of 6 elements, 5 nodes truss in Sample Info sheet to help user to understand how to input the information into template.

III. RESULT

After user finish to input the problem information, click calculate button (Fig. 2) to

get solutions. The solutions are shown in worksheet Sheet2 – Sheet6. Sheet2 (Fig. 3) shows local and global stiffness matrices of each element, and global stiffness matrix of overall truss system in green matrix.

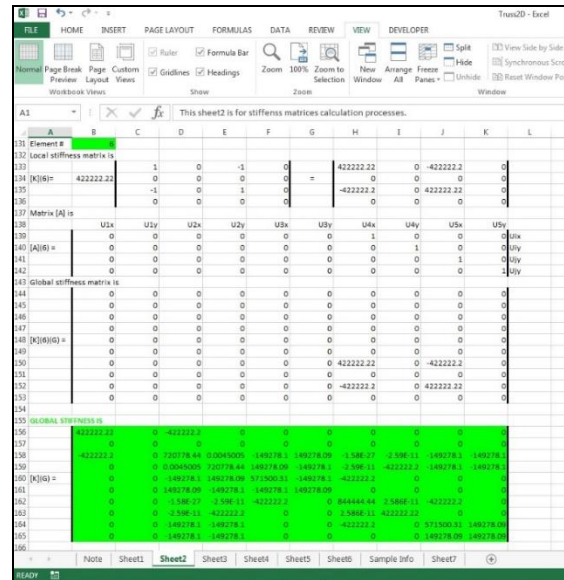


Fig 3. Sheet2: Stiffness Matrices

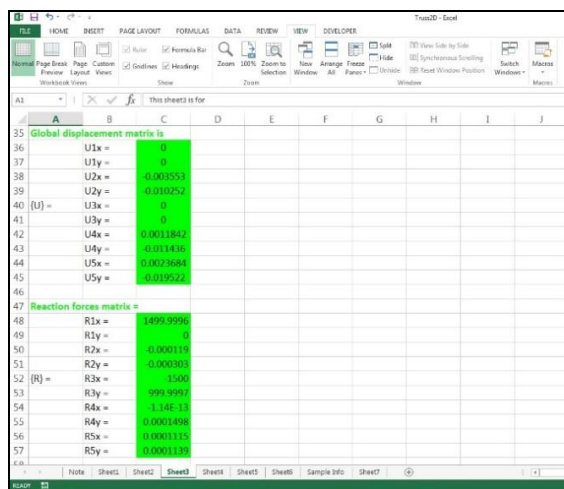


Fig 4. Sheet3: Displacement and Reaction Solution

Sheet3 (Fig. 4) shows displacement solutions and reaction forces of each node in x and y direction.

Sheet4 (Fig. 5) shows the internal force and normal stress of each element. Positive value is compressed element, and negative value is element in tension.

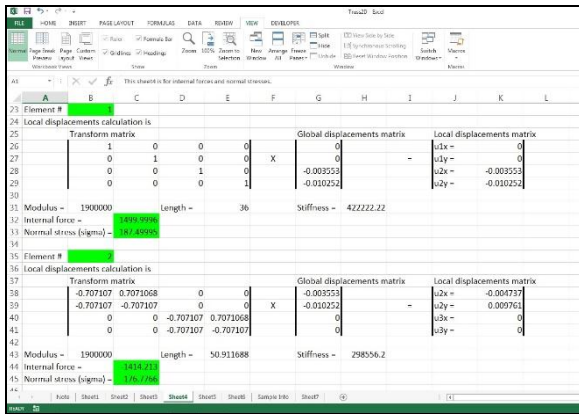


Fig 5. Sheet4: Internal force and Normal Stress Solutions

Sheet5 is the calculation of node coordinates which are used to draw the picture in Sheet6. Sheet6 (Fig. 6) shows the comparison picture of problem picture and deformation picture in color shades. Picture with black dash line is the initial truss. Picture with color full line is deformed truss. Red shaded lines are compressed element, and Blue shaded line are element in tension.

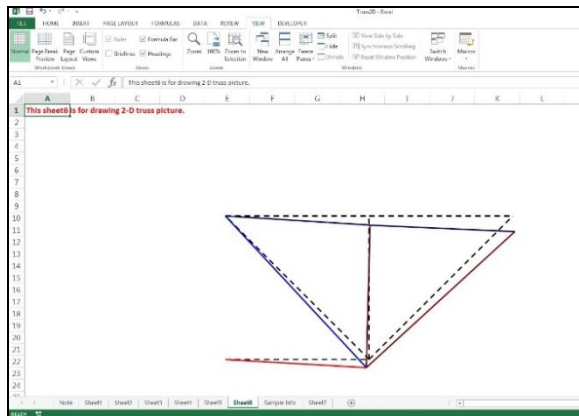


Fig 6. Sheet6: Comparison Picture

IV. DISCUSSION

Program shows the finite element calculation procedure of 2D truss problem very well. It shows how to build the stiffness matrices both local and global in Sheet2 systematically. In Sheet3, program reduces the size of global stiffness matrix by the order of boundary conditions to calculate for solutions. Pictures in Sheet6 are easy to understand and delineate.

A drawback of the program is according to the limitation of EXCEL. A single EXCEL worksheet may contain a maximum of 65,472 array [5] which is equivalent to 255x255 stiffness matrix size. This means 2D truss problem may have the maximum node is 127 nodes (two degree of freedom, x and y direction in each node). The more nodes problem have, the bigger template user has to input data, and the more computer resource is needed. The number rounding system in EXCEL need to be discussed since it leads to the small error of solutions. Example from the sample provided in program, the reaction forces matrix solution (Fig. 4) shows the force 1499.99955 lb from the theoretical solution is 1500.00 lb or the force of -1.137E-13 lb from the theoretical solution is 0 lb.

REFERENCES

(Arranged in the order of citation in the same fashion as the case of Footnotes.)

- [1] Moaveni, S. (2008). "Finite Element Analysis: Theory and Application with ANSYS". 3rd Ed., Pearson Prentice Hall. New Jersey, USA.
- [2] Logan, D.C. (2012). "A First Course in the Finite Element Method". 5th Ed., Cengage Learning. Connecticut, USA.
- [3] Walkenbach, J. (2010). "Excel 2010 Power Programming with VBA". Wiley Pub. New Jersey, USA.
- [4] Chapra, S.C. (2003). "Power Programming with VBA/EXCEL". Prentice Hall. New Jersey, USA.
- [5] Microsoft Support website. (2015). <<https://support.microsoft.com/en-us/kb/166342>>.
- [6] Babacan, T. (2011). "Excel FEM_3D (for Excel 2003)". <https://www.excelcalcs.com/repository/strength/finite-element/excelfem_-3d-%28for-excel-2003%29/>.
- [7] Newton Excel Bach Blog. (2009). <<https://newtonexcelbach.wordpress.com/2009/02/15/frame-analysis-with-excel-4-2d-frame-analysis/>>.