Automated Non-Linear Analysis of Structures Using Visual Basic 6.0

Mrs. Deepthishree[1], Mr Manohar. K[2], Dr Premanand Shenoy[3]
[1, 2, 3] Department of Civil Engineering
[1, 2] Sahyadri College of Engineering & Management, Mangalore, India
[3] Chief Consultant, Roy & Shenoy, Mangalore, India.

Abstract- *In this thesis work an attempt is made to study the behavior of structures using non-linear analysis. Considering the changes in geometry on account of deformations during loading, a geometric non-linear analysis is presented. Similarly for a possible non-linear stress-strain behavior in the elastic region of stress-strain curve of the material analysis is presented for material non-linearity. A computer program is developed and presented for the analyses taking a 2D plane truss as example. The extent of deviation is also studied.*

Keywords- Non-linear analysis, Linear analysis, Visual Basic 6.0.

I. INTRODUCTION

A structure is an assembly of inter related or interdependent parts which forms a complex, unified whole which serves a common purpose. Hence structural system is designed and constructed to support and transmit applied lateral and gravity loads safely to the ground without exceeding the allowable stresses in materials. Based on the nature of application of load, amount of deformations and material behavior a linear or non-linear analysis is performed.

When a structure obeys Hook's law then it is said to behave linearly and linear analysis is carried out. Linear analysis assumes that stress is proportional to strain, the principle of superposition is valid and also the structure will return to its original position once the applied load is removed. However, in practice it is found that actual stress- strain relationship differs from the simple law of proportions. For most of the engineering materials, a linear relationship holds well with a fair degree of accuracy for lower stresses. Since linear behavior is simple to analyze and provides an excellent approximation for most of the materials for a usual range of stresses. When the displacements in a system of structural components are linear functions of applied load or stress then, structure exhibits a linear behavior. A linear analysis is not applicable when there are changes in structural properties, redistribution of forces due to formation of plastic hinges and amount of rotations.

In reality, the behavior of the structure is non-linear and it is mostly neglected since the divergences from linear response are usually smaller. The main aim of non- linear analysis is to arrive at the safe and satisfactory economic design which limits the maximum values of deformations to their preferred limits. The deviation in the linear and non-linear behavior is very distinct while plotted in a graph.The source of non-linearities in a structure is based on geometry, material etc.

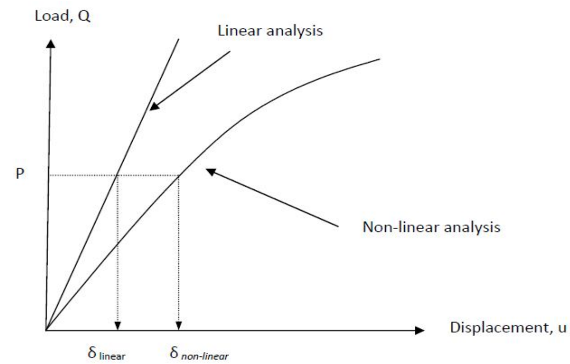


Fig.1 Linear analysis Vs Nonlinear analysis

Geometric nonlinearity is the change in geometry of the structure characterized by large deformations leading to non linear change of parameters in it. Usually it is assumed that deformation in the structure is small. Hence principle of superposition was valid, which means that during the loading process the geometry of the structure remains unchanged. But in actual there may be large deformations when maximum loading is reached. As the deformation increases with every load increment, the change in geometry causes the linear force – deformation relation to become nonlinear. Geometric non-linear analysis helps to predict the behavior of actual deformation in the structure

Young's modulus is the slope of the elastic region in the stress-strain diagram. In this diagram the graph is linear up to the proportionality limit beyond which it is non-linear. The yield strength and elastic limit occur around this point and material turns non-linear. When the stress – strain relationship of material is non linear, then structural behavior also becomes nonlinear. Material nonlinearity is often but not always characterized by a gradually weakening of structural members as an increasing force is applied, due to some form of internal decomposition of material of construction.

When the structure is loaded, it behaves linearly up to a limit where stress is directly proportional to strain, when the load is further increased stress no longer remains proportional to strain, with material still behaving elastically. In working stress method of design, materials are stressed within proportionality limit. Material non linearity is due to non-linear stress strain relationship. Hence it helps to predict the materials to their maximum extent in a structure and also for structural optimization.

II. ABOUT VISUAL BASIC 6.0

VB is a high level programming language evolved from earlier DOS version called as BASIC. It is a third generation event driven programming language developed by Microsoft. There are many versions of VB available in the market such as VB.net, VB 2005, VB 2008, VB 2010 etc.
A programmer can create an application using the components available in VB program. Since VB is a visual and event driven programming language, the programming is done in graphical environment (GUI). The program developer can drag and drop objects into the form and can also manually write the program code and modify its properties using properties window.

III. METHODOLGY

Non - Linear Analysis

In any structures the deflections under loading are large enough to cause significant changes in its geometry, so that the conditions of equilibrium need to be based on the deformed shape of the structure. The non – linear analysis can be done using the following methods.

i. Incremental Method
ii. Iterative Method
iii. Incremental – Iterative Method

Incremental – Iterative Method

If the solution is path dependant or tracing of the loading path is desired, an incremental method incorporated with iterative method is more effective. Here, the load is applied incrementally and after each increment, successive iterations are performed. Apparently the method yields high accuracy at the price of more computational effort.

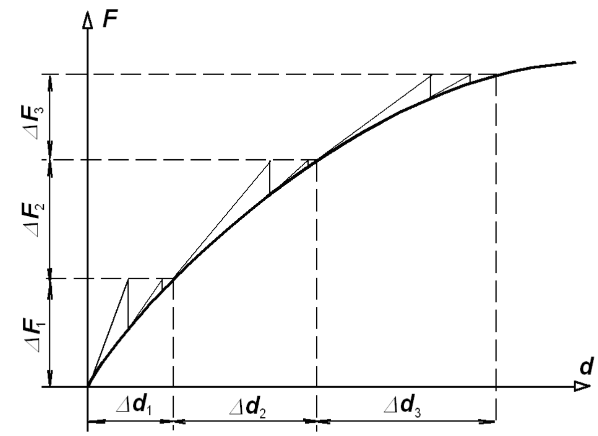


Fig 2: Incremental - Iterative Method

IV. DESIGN PROCEDURE

Step by Step Procedure (Algorithm) for 2D truss Analysis

Step 1:- Read the values of inputs required for truss analysis. They are read the number of nodes, number of members, number of materials, number of supports and number of loaded joints.

Step 2:- Read the values of material properties such as Young's Modulus (E), Yield stress (f_y) and unit weight of the material.

Step 3:- To define the member connectivity read the values of back node, forebode, area and material applied to the member.

Step 4:- Read the values of degree of freedom to define the support conditions.

Step 5:- Read the values of load acting on the structure along x and y directions.

Step 6:- Generate individual element stiffness matrices.

Step 7:- Assemble the global stiffness matrix.

Step 8:- Apply the boundary conditions to assembled global stiffness matrix.

Step 9:- Solve for unknown displacements.

Step 10:- Find the forces in members and also the reaction at the supports

IV. CASE STUDY

A truss is considered with a large span and pinned support conditions. The loads are applied at joints of truss. To develop a computer program initially the nodes and truss members are numbered in an ascending order. Every member is connected by two nodes and it may be a horizontal, vertical or inclined. Based on the nodal numbering, input files are created by specifying the nodal coordinates and the member connectivity, which helps to fix a position for node and the order in which members are connected with node. Then, the support conditions and the loads are specified on the structure For a geometric non –linear analysis the loads are incremented, at every increment and the deformations are noted. Before applying the next increment the structure is updated with the deformed geometry .The process is repeated with changed geometry every time till all the load increments are applied and the total deformation is obtained.

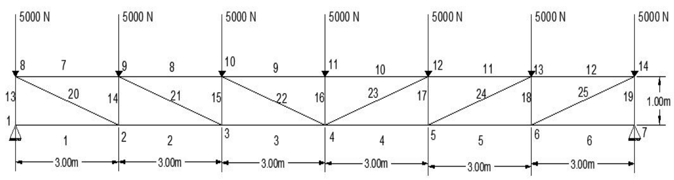
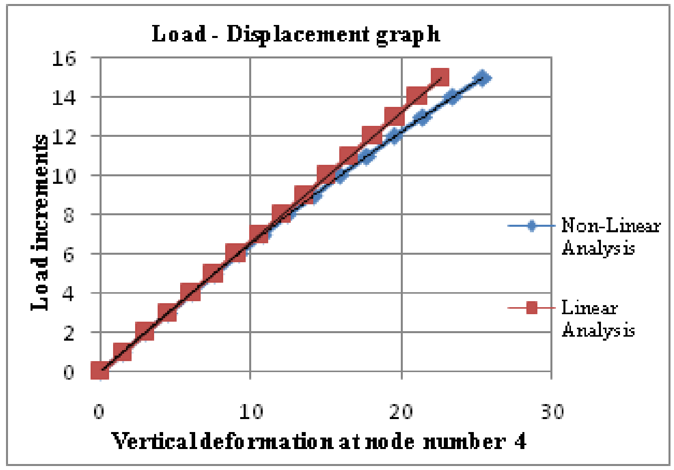


Fig 3: Large span truss with pin joint

After the analysis, results are obtained in an output file. Output file contains the results for number of iterations specified with the details of deformations at x and y axis, the forces in the members, change in member length, nature of forces, stresses etc. The deformation at the central bottom chord node 4 is noted to get the highest deflection.
The result tabulation obtained for linear and non-linear analysis using geometric non-linearity for node 4 is listed in the table below.

Table 1: Tabulation for Linear and Geometric Non-Linear Analysis

Vertical Displacement At Node 4		
Number of Iteration	**Linear Analysis**	**Geometric Nonlinear Analysis**
0	0	0
1	1.504653	1.504653
2	3.01314688	3.009306
3	4.53123664	4.513959
4	6.06459148	6.018612
5	7.61892252	7.523265
6	9.19989061	9.027918
7	10.81305298	10.532571
8	12.46381888	12.037224
9	14.15721651	13.541877
10	15.89793359	15.04653
11	17.68987217	16.551183
12	19.53591638	18.055836
13	21.43736514	19.560489
14	23.39353518	21.065142
15	25.40080731	22.569795



Graph 1: Graph showing linear and Non-Linear behavior

V. CONCLUSIONS

A computer program is developed using VB 6.0 for non-linear analysis of a structure and it is successfully run to get the desired results. Linear analysis gives accurate results only when deformations are very small, the geometry of the structure is not changed much and E value is constant.

The program was modified to adopt Geometric non-linear analysis and the results clearly showed deviation from linear behavior. As the load on the structure increased, displacement values also increased for linear and non-linear analysis. In large span structures where deformations can be large, geometric nonlinearity should be considered to get the actual behavior. It is observed that, non linearity due to change in geometry along with material nonlinearity will yield actual results beyond proportionality limit.

Based on the material non-linear analysis, it is found that material non-linearity will be effective only if some limiting stress in material of a member, crosses proportionality limit for initial value of E. Using the types of non-linearities optimization of structures can be done by modifying material and their geometric properties.

Optimization of structures can be done considering actual behavior of structures, modifying the geometry thus, exploiting the capacity of materials leading to their optimum use thus, conserving valuable natural resources.

REFERENCES

[1] Y.B.Yang and Liang –Jenq Leu, Constitutive laws and forces recovery producers in non-linear analysis of trusses,Computer methods in Applied mechanics and Engineering,Vol 92, Nov 1991 , pp 121-131

[2] A.D.Tzamtzis and P.G. Asteris , Finite Element Analysis of Masonry Structures: PartII- Proposed 3-D Nonlinear Microscopic Model, North American Masonry Conference, June 2003, pp. 146-155

[3] M.Rezaee Pajand and M.Taghavian Hakkak, Nonlinear Analysis of Truss Structures

[4] Using Dynamic Relaxation, 22 - Vol. 19, No. 1, December 2006.

[5] Estefane George Macedo de Lacerda, Daniel N. Maciel, Ada C. Scudelari, Positional Finite Element Method Applied To Nonlinear Geometric Plane Trusses, Iberian Latin-American Congress on Computational Methods in Engineering, November 10-13, 2013

[6] Premanand Shenoy, P. Mahadevappa, Innovative Applications of Shells and Space Structures, International Symposium on Shells and Space Structures, Vol 2, 1988, pp 865-878

[7] R. Duris and J. Murin, A nonlinear truss finite element with varying stiffness, Applied and Computational Mechanics 1 (2007), pp. 417 – 426

[8] N.G.Fook Heng, Geometric Non-linear Analysis of truss structure, April 2010

[9] Marcelo Greco and Carlos Eduardo Rodrigues Vicente , Analytical solutions for geometrically nonlinear trusses, Revista Escola de Minas, vol. 62, No 2, April 2009, pp. 205-214

[10] Glenn A. Hrinda, Geometrically Nonlinear Static Analysis of 3D Trusses Using the Arc-Length Method, 2011

[11] Ever Coarita and Leonardo Flores, Nonlinear Analysis of Structures Cable – Truss,

[12] IACSIT International Journal of Engineering and Technology, Vol. 7, No. 3, June 2015, pp160-169

[13] A.Ghali, Structural Analysis (1997), 4th ed. E & FN Spon. London. UK. Pp 698-699

[14] Claudio Borri, Geometrically non-linear behavior of Space Beam structure. Journal of Mechanics. Vol 1-4, 1985. 1-27

[15] Abdulkadir Baba Hassan, Matthew Sunday Abolarin, Onawola Hassan JIMOH, The Application of Visual Basic Computer Programming Language to Simulate Numerical Iterations , Leonardo Journal of Sciences , Issue 9, July-December 2006, pp. 125-136

[16] C.S.Reddy , Basic Structural Engineering, Tata Mc Graw Hill Education Private Limited, 3rd Edition, 2011

[17] C.K.Wang, Intermediate Structural Analysis, Mc Graw Hill Education (India) Private Limited, Indian Edition, 2010

[18] Ashok.K.Jain, Advanced Structural Analysis with Finite Element and Computer Applications, Nem Chand and Bros,Roorkee, 2nd edition,2006