STRUCTURAL ANALYSIS BY SPREADSHEET PROGRAMMING

Sandesh Kakade[1], Supriya Shinde[2], Swapnil Patil[3], Amruta Patil[4], Minakshi Pawar[5]

[1]*Department of Civil Engineering, Sanjay Ghodawat Group of Institutions, Atigre, Kolhapur*

Abstract – *Spreadsheet programming is used to store data and manipulating calculations using simple formulas. It is in tabular format consists of rows and columns. Structural analysis can be done by using spreadsheet programming. In this paper, spreadsheet programming is done for the structural analysis of elements like beams and frames. We can use such programming to prepare handbooks for structural systems under various loads and span lengths.*

Key Words: Spreadsheet programming; structural analysis.

1. INTRODUCTION

Greatest innovation in engineering in the last fifty years is computers and software. Computer software has changed the look out of structural engineers. Computer-aided drafting, analysis, and design software are becoming important tools for any structural engineering firm. Given the growth, extensive competition, and demands of the industry, a firm cannot survive if it does not take advantage of the powers and capabilities of the modem computer software offer. Computers have drastically reduced the efforts of engineers while communicating with co-workers, clients, architects, and construction managers. Computers also helped to improve the efficiency of the design delivery system, design changes issues, and concerns between all entities involved in a project. This spreadsheet software is aimed to minimize the repetitive efforts while doing hr structural analysis of systems.

1.1 VARIOUS METHODS OF STRUCTURAL ANALYSIS

1.1.1 Moment Distribution Method

The structural system is reduced to kinematical determinate form by this method. This is accomplished by assuming all the joints to be fully restrained. The end moment of all the members are computed for this condition of the structure (all the members having fixed ends). The joints are allowed to deflect (rotate) one after the other by releasing then successively. The unbalanced moment at the joint is shared by the members connected at the joint when it is released. Hardy cross method makes use of the ability of various structural members at a joint to sustain moments in proportion to their relative stiffness. Cross method provides an elegant and quick procedure to analyze continuous beams. The method can also be applied to frames with a few additional computations.

1.1.2 Flexibility Matrix Method

The force method of structural analysis, in which the member forces are used as unknowns, is appealing to engineers, since the properties of members of a structure most often depend on the member forces rather than joint displacements. This method was used extensively until 1960. After this, the advent of the digital computer and the amenability of the displacement method for computation attracted most researchers. As a result, the force method and some of the advantages it offers in non-linear analysis and optimization has been neglected.

Four different approaches are adopted for the force method of structural analysis, which will be classified as:

1. Topological force methods,
2. Algebraic force methods,
3. Mixed algebraic-combinatorial force methods,
4. Integrated force method.

1.1.3 Stiffness Matrix Method

Basically this method involves reducing the structure to its kinematically determinate form (all degrees of freedom restrained) as explained in the previous section. The structure can be analyzed by developing the individual matrices for each element of the Structure and assembling them to form global matrices. Though this method is systematic, and is generally encouraged, it often involves long matrix operation (repetitive multiplication) during the transformation from the local to the global system. The direct method (manual computations) is discussed first, and the computerized version of the method is presented later for a few typical examples. In the direct method, the D.O.F. are released one at a time and the forces developed in the system corresponding to all the D.O.F. are computed these forces developed in the system for unit displacements are the coefficients of the stiffness matrix by definition. The load matrix for the given loading system is developed in the same way as described for beams. The solution of the stiffness matrix system yields the displacements in the structure corresponding to the applied loading system.

2. STIFFNESS MATRIX/FORCE METHOD

Stiffness matrix method is the force method of analysis. Results through the method are very much accurate. It can be use for large number of spans. It is having small number of limitations as compare other methods.

2.1 Stiffness Matrix Method for Beams

In the force method of analysis, primary unknown are forces. In this method compatibility equations are written for displacement and rotations (which are calculated by force displacement equations). Solving these equations, redundant forces are calculated. Once the redundant forces are calculated, the remaining reactions are evaluated by equations of equilibrium. In the displacement method of analysis, the primary unknowns are the displacements. In this method, first force -displacement relations are computed and subsequently equations are written satisfying the equilibrium conditions of the structure. After determining the unknown displacements, the other forces are calculated satisfying the compatibility conditions and force displacement relations.

2.2 Stiffness Matrix Method for Trusses

Because the forces in each of its two main girders are essentially planar, a truss is usually modeled as a two-dimensional plane frame. If there are significant out-of-plane forces, the structure must be modeled as a three-dimensional space. The analysis of trusses often assumes that loads are applied to joints only and not at intermediate points along the members. The weight of the members is often insignificant compared to the applied loads and so is often omitted. If required, half of the weight of each member may be applied to its two end joints. Provided the members are long and slender, the moments transmitted through the joints are negligible and they can be treated as "hinges" or 'pin-joints'. Every member of the truss is then in pure compression or pure tension shear, bending moment, and other more complex stresses are all practically zero. This makes trusses easier to analyze. This also makes trusses physically stronger than other ways of arranging material because nearly every material can hold a much larger load in tension and compression than in shear, bending, torsion, or other kinds of force. Structural analysis of trusses of any type can readily be carried out using a matrix method such as the direct stiffness method, the flexibility method or the finite element method.

2.3 Stiffness Matrix Method for Frames

1.The first step for frame analysis is to determine if the structure is structurally sound. Please refer to Determinacy, Indeterminacy and Stability on how to determine this step.

2.Next, perform the Calculation of Support Reactions Once the support reactions are found you can move on to solving the whole frame.

3. To solve the whole frame you must first break the frame into individual members and solve the reactions.

4. Once all the forces are determined, you may now construct your shear diagram.

It is easiest to start at the left side and work your way to the right. The shear diagram starts at zero unless there is a reaction force at the support, which in most cases there is for frame analysis . Refer to the sign convention stated earlier in order to determine if the shear is negative or positive. Once this is determined, you may start constructing your diagram.

5. Draw Bending Moment diagram.
It is easiest to start at the left side and work your way to the right. The moment diagram starts at zero unless there is a reaction moment at the support, which in most cases there is for frame analysis.

These figures (Fig. 1 and Fig. 2) show what the shear and moment diagrams would look like according to the directions of forces in Figure.

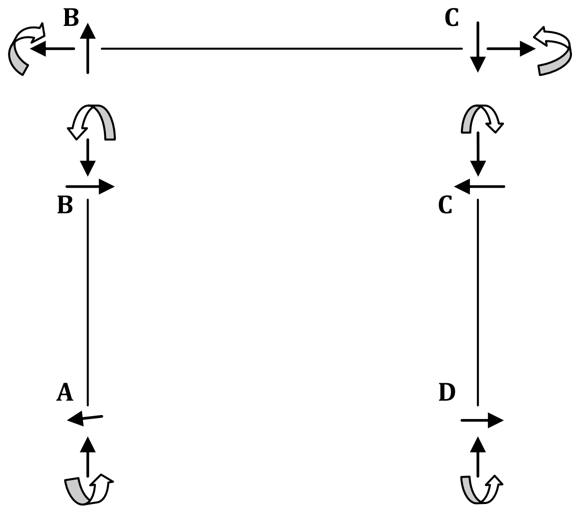


Fig -1: Frame separated in Members

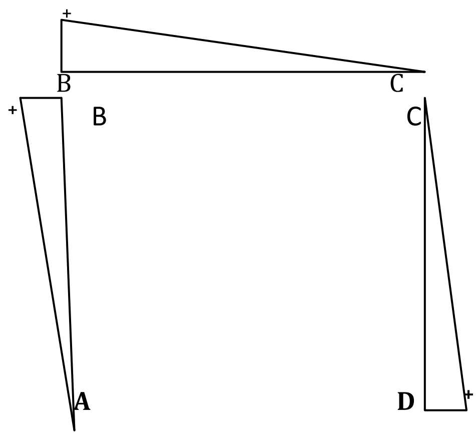


Fig-2: Example Shear Diagram using the forces from Figure

2.4 Advantages of Stiffness Matrix Method

1. This method suitable for general computer applications should be systematic and involve repetitive computations.

2. It would be advantageous for each element of the frame (between two joints) as an individual member, and develop the stiffness and load matrix.

3. Stiffness matrix method is used for all types of structure.

4. Stiffness matrix method is advantageous for solving large set of equilibrium equations.

3. STRUCTURAL ANALYSIS IN SPREADSHEET

First of all we solved the problems of various members such as beam, truss and frame by using stiffness method in spreadsheet programming and it is interconnected values from first to last.

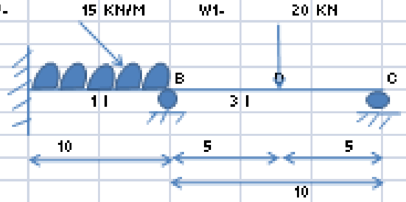
PROBLEM I

TYPE - BEAM

STEP 1 GIVEN DATA

W-	20 KN	L_{AB}-	10 M	I_{AB}-	1 I
UDL-	15 KN/M	L_{BD}-	5 M	I_{BC}-	3 I
		L_{DC}-	5 M	L_{BC}-	10 M

W- 15 KN/M W1- 20 KN



STEP 2 CALCULATIONS OF FIXED END MOMENTS

M_{ab}-	w*l^2/12	-125 KN.M
M_{ba}-	w*l^2/12	125 KN.M
M_{bc}-	w*l/8	-25 KN.M
M_{cb}-	w*l/8	25 KN.M

SPAN MOMENTS

M_{AB}-	$WL^2/8$	187.5 KN.M
M_{BC}-	WL/4	50 KN.M

DISPLACEMENT MATRIX

$[D] = \begin{bmatrix} \theta_b \\ \theta_c \end{bmatrix}$

STEP : GENERATION OF STIFFNESS MATRIX EQUATION

$[D] = [-P] * [K]^{-1}$

[D]= UNKNOWN OR REDUNDANT MATRIX
[-P]= RESTORING MOMENT MATRIX OR FIXED END MATRIX
[K]= STIFFNESS MATRIX

▪ TO FIND [-P]

$[-P] \begin{bmatrix} \text{EXTERNAL MOMENT AT 'B'} - \text{RESTORING MOMENT AT 'B'} \\ \text{EXTERNAL MOMENT AT 'C'} - \text{RESTORING MOMENT AT 'C'} \end{bmatrix}$

$[-P] \begin{bmatrix} -100 \\ -25 \end{bmatrix}$

▪ TO FIND $[K]^{-1}$

$[K] = \begin{bmatrix} K11 & K12 \\ K21 & K22 \end{bmatrix}$

$K_{11} = \frac{4E(2I)}{L_{AB}} + \frac{4EI}{L_{BC}} = 1.6\ EI$

$K_{22} = \frac{4EI}{L_{BC}} = 1.2\ EI$

$K_{12} = \frac{2E(I)}{L_{BC}} = 0.6\ EI$

$K_{21} = \frac{2E(I)}{L_{BC}} = 0.6\ EI$

$[K] = \begin{bmatrix} 1.6 & 0.6 \\ 0.6 & 1.2 \end{bmatrix} * EI$

$[K]^{-1} = \frac{1}{|K|} * adj(k)$

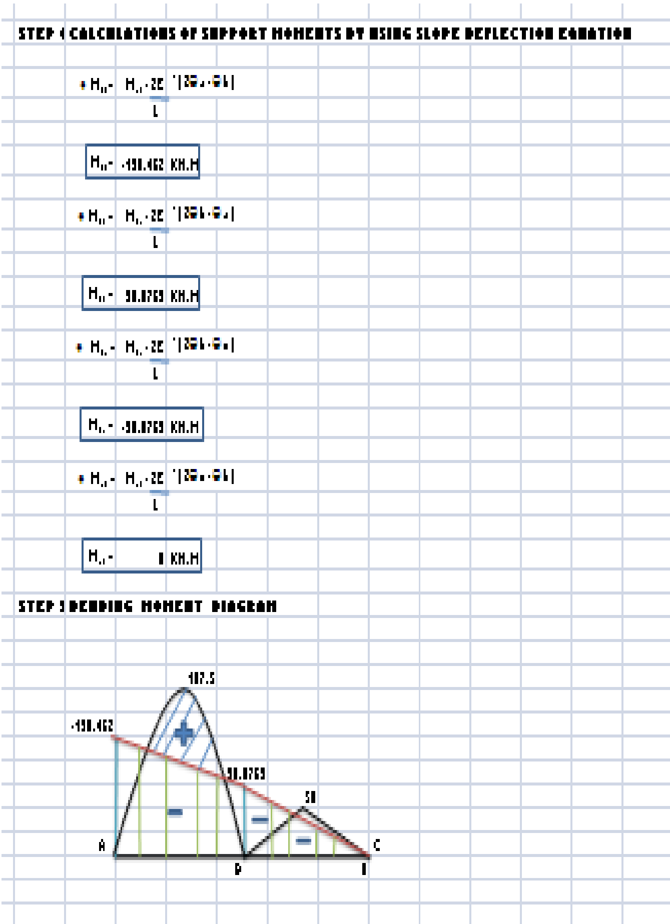
$|K|\ 1.56\ E^2I^2$

$[D] = \frac{1}{1.56} \begin{bmatrix} 1.2 & -0.6 \\ -0.6 & 1.6 \end{bmatrix} X \frac{1}{E^2I^2}$

$[D] = \begin{bmatrix} 0.7692 & -0.3846 \\ -0.3846 & 1.0256 \end{bmatrix} \begin{bmatrix} -100 \\ -25 \end{bmatrix} \frac{1}{EI}$

$\begin{bmatrix} \theta b \\ \theta c \end{bmatrix} = \begin{bmatrix} -67.308 \\ 12.821 \end{bmatrix} * \begin{bmatrix} 1 \\ EI \end{bmatrix}$

$EI\theta b = -67.308$
$EI\theta c = 12.821$



4. CONCLUSIONS

1. We use Stiffness matrix method for analysis of various structures. For accuracy and repetitive calculations we use spreadsheet.
2. It will be reliable to teachers for assessment of problems.
3. Changing the span length and load in spreadsheet it gives result in very short time, as it is not possible by manual calculations.
4. Spreadsheet calculates and store data in a large amount for various structural systems.

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