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Response of Semi Rigid Connections on Frame Behaviour

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Abstract:- It is obvious that real beam-to-column connections have some stiffness, in between the extreme cases of fully rigid and ideally pinned. Generally it is assumed that the joints and supports in the structure are pinned or rigid while performing analysis. Several papers prove that in actual framed structures, rigid connections have some degree of flexibility, while pinned connections have some stiffness. But assuming joints to be rigid or pinned may not give effective results. So semi rigid connection should be considered to obtain more accurate, reliable and also cost-effective results.

This paper presents analysis of a pinned, rigid, semi rigid jointed portal frame using a versatile program developed in FORTRAN language using stiffness matrix formulation, where analysis has been done without changing source program and only with a minimal change in data file. This paper describe in detail computer implementation of formulation of the program organization in the form of a flow chart. Numerical is presented to show the effect of joint flexibility on overall response of structures. Single story portal frame with semi rigid beam to column is analyzed by changing rotational spring stiffness. Results are presented to show variation of bending moment, shear force and axial force.

***Keywords**- Finite element method, Frame structure, Semi rigid connection, Program in FORTRAN*

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I. INTRODUCTION

Structural joints play a fundamental role in the global structures behavior. The actual joint response is usually situated between two extremes: pinned and rigid. The rigid behavior implies no change in the angle of members adjacent to the joint and transfer a major amount of bending moments, as well as shear and axial forces. On the other hand, pinned joints indicate that no bending moment transfer will occur among members connected by the joint because of free rotation movement between the connected elements that prevents the bending moment transmission [1]. It is mainly known that the great majority of joints does not show such idealized behaviour. These connections are called semi-rigid joints. In the intermediate case, semi-rigid joints, the bending moment to be transferred among members will be a function of their relative rotation change.

Extensive investigation over the past thirty years has been performed to estimate the actual behaviour of such joints. Various investigations have been made on semi-rigid connections including: review reports [2–4], numerical studies [1, 14, 15], and experiments performed [16, 17]. Along with semi rigid beam to column connections, column to foundation connections in steel frames has been studied [5], [6]. M. Brognoli *et. al.*[7] studied optimal design of semi-rigid braced frames via knowledge-based approach. To achieve this they used structural optimization on a system analysis rather than on a component analysis. Ayse Daloglu *et. al.*[8] and Alexandre A. Savio *et. al.*[9] studied optimize design of steel plane frames using genetic algorithm due to their ability of providing a solution to discrete optimum design problems. Aniko Csebfalvi *et. al.* investigate effects of semi rigid connections in optimal design of frame structures [10], [11]. Santiago Hernandez *et. al.* [12] gives design optimization of steel portal frames. For achieving semi-rigidity at joint, instead of modifying stiffness of adjacent beams, authors think a convenient way to add semi-rigidity at joint itself can be better option.

II. FORMULATION

Structural elements and joints are modeled taking into account some idealizations. In reality, structural connections should be rigid, semi rigid or pinned according to their moment-rotation curves. All three cases of joint connections can be modeled in the formulation [18].

Consider a semi rigid jointed frame as shown in “Fig. 1”, which consists of two elements: namely, beam element and spring element. The beam element, which constitutes beams and columns of frame, has six degrees of freedom per element and the spring element, which allows rotational displacement between beam and column at joint, has two degrees of freedom per joint. Displacement codes at semi rigid joint are shown in “Fig. 2” which allows joint relative rotation but restrains relative horizontal and vertical displacements.

Figure 1. Semi rigid jointed frame

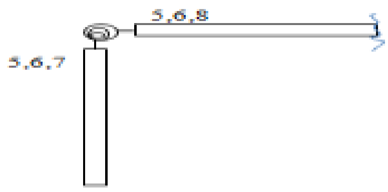

Figure 2. Details of semi rigid joint

The stiffness matrix of a beam or column element referred to member axes can be represented as

$$[Se]_m = \begin{bmatrix} \frac{EA}{L} & 0 & 0 & -\frac{EA}{L} & 0 & 0 \\ 0 & \frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & -\frac{12EI}{L^3} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{4EI}{L} & 0 & -\frac{6EI}{L^2} & \frac{2EI}{L} \\ -\frac{EA}{L} & 0 & 0 & \frac{EA}{L} & 0 & 0 \\ 0 & -\frac{12EI}{L^3} & -\frac{6EI}{L^2} & 0 & \frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{2EI}{L} & 0 & -\frac{6EI}{L^2} & \frac{4EI}{L} \end{bmatrix} \quad (1)$$

where, L, E, A, I are length, Young's modulus, Sectional area, moment of inertia respectively. The stiffness matrix given in (1) is then converted to structure coordinate system $[Se]_s$ using coordinate transformation.

The stiffness matrix of a spring element can be represented as given in (2).

$$[K] = \begin{bmatrix} k & -k \\ -k & k \end{bmatrix} \quad (2)$$

where, k is rotational spring stiffness of spring. After both the stiffness matrices $[Se]_s$ and $[K]$ are formed. They are assembled together to represent the entire structure. The structure equilibrium equations are then solved. Then the displacements and internal forces and moments occurred in the structure including semi-rigid connections are easily be acquired using routine FEM procedure [13].

III. PROGRAM DEVELOPMENT

A computer program in FORTRAN language is developed based on the formulation developed [18]. The program allows rotational flexibility of joint by introducing a rotational spring at joint. Using this program pinned, rigid and semi rigid jointed plane frame has analyzed. For computer implementation of formulation [18], the program organization is shown in the form of a flow chart in "Fig. 3".

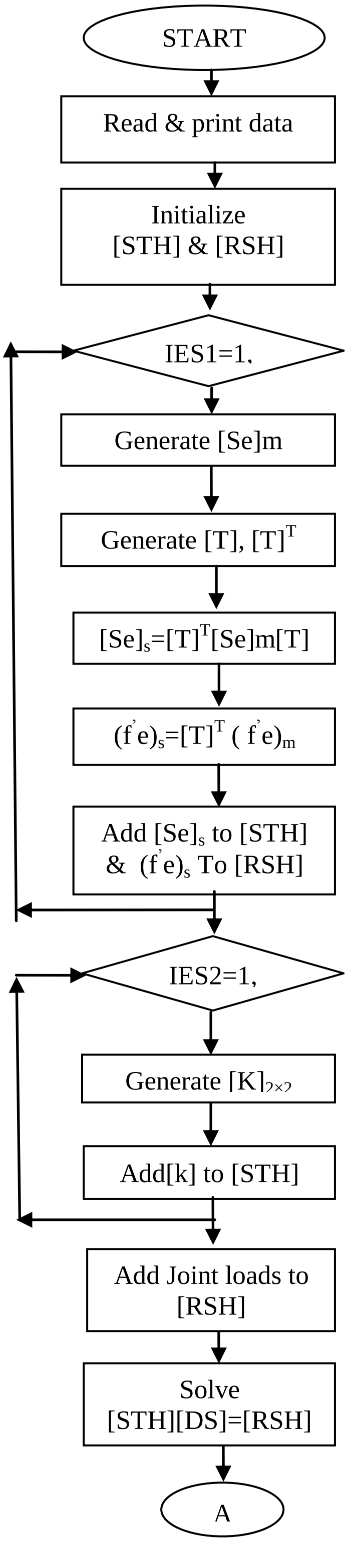

Figure 3. Flow Chart for Plane Frame continues….

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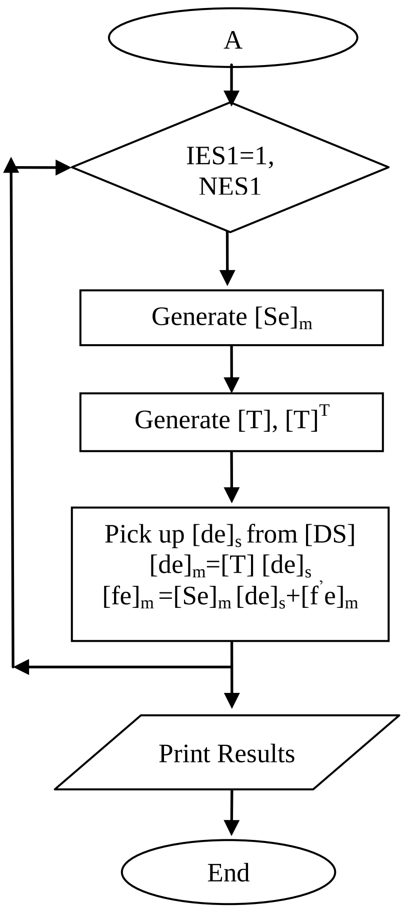

Figure 3. Flow Chart for Plane Frame

IV. NUMERICAL APPROACH

In this section finite element analyses are performed using program developed in FORTRAN language. Users can define semi-rigid connection entering either rotational spring stiffness or connection ratio or initial spring stiffness [18]. In this section of the study, performance of pinned, rigid and semi rigid jointed plane frame is studied.

A. Performance of pinned, rigid and semi rigid jointed plane frame

A Single bay Single story semi rigid jointed plane frame is analyzed. Finite element models of rigid and semi rigid jointed frames and loading conditions are shown in "Fig. 4" and "Fig. 5" respectively. Young's modulus used in analyses is 2.0×10^{11} N/m^2. Sectional dimensions for beam and columns are 0.2m x 0.4m. The value of spring stiffness K has been taken from 0 to ∞. Displacement codes at joints are also shown in "Fig. 4" and "Fig. 5". Rigid jointed frame "Fig. 4" consists of three beam elements only and semi rigid jointed frame "Fig. 5" has additional two spring elements. Results of shear force, axial force and bending moments are given in the form of graph as shown in "Fig. 6, 7, 8".

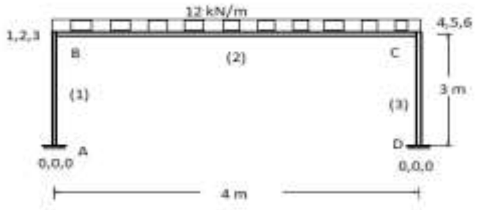

Figure 4. Rigid jointed plane frame

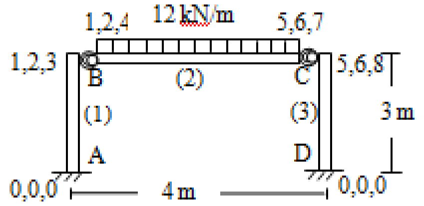

Figure 5. Semi rigid jointed plane frame

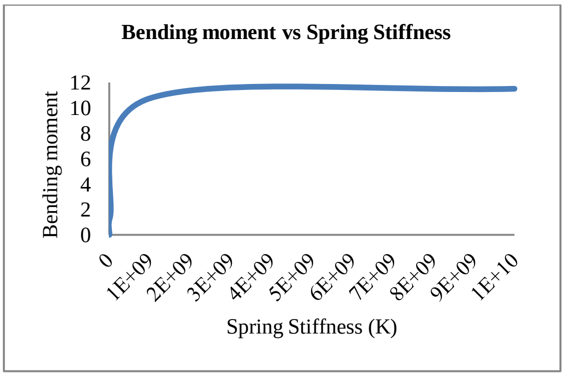

Figure 6. Relationship between Bending moment and Spring Stiffness

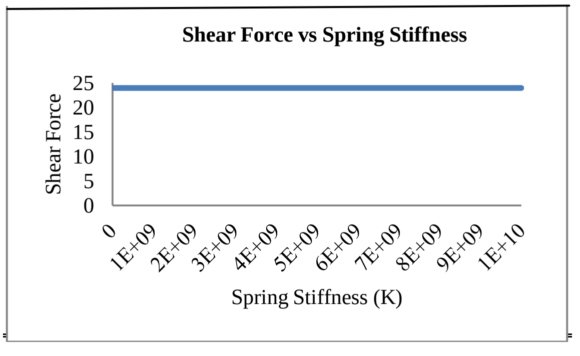

Figure 7. Relationship between Shear Force and Spring Stiffness

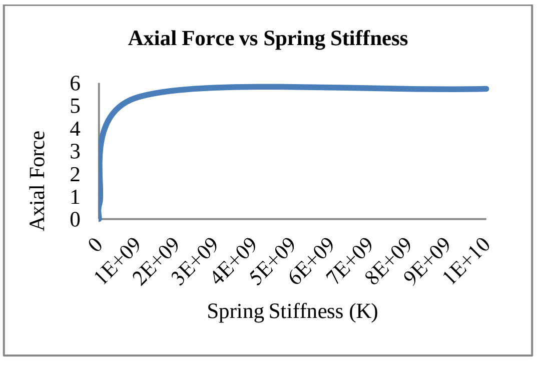

Figure 8. Relationship between Axial Force and Spring Stiffness

V. CONCLUSIONS

From the analysis it is seen that shear forces does not changes with changing rotational spring stiffness. They are not dependant on rotational spring stiffness while axial forces and bending moments are increases with increase in rotational spring stiffness. The values are changes in the value of pinned and rigid connection. Axial forces and bending moments are linearly varied in between the values of pinned and rigid connection of the K having range of 1.0E07 to 1.0E09. A finite element program in FORTRAN language, in which the users can model semi-rigid connection with either rotational spring stiffness or connection ratio, has developed. It is clearly distinguished from this study that semi-rigid beam-to-column connections are more efficient on general structural behavior than pinned and rigid connections to joints.

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