International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Analysis and Design of a Multistory Steel Structure with Semi-Rigid Connection

Shubham Kulkarni[1]
[1]PG Scholar, D.Y. Patil school of Engineering and management, Pune, India

Prof. Vishwajit Kadlag[2]
[2]ProfDr.D.Y. Patil school of Engineering and management, Pune, India

---***---

Abstract - Generally, structure frameworks are designed by assuming that end connection is fully rigid or pinned. Full strength of the beam section is never fully utilized due to the fact that support moments are always higher than the span moments and hence selection of a suitable section depends on support moments. By providing connection flexibility, the support moments can be reduced and span moment increased hence leading to smaller sections resulting in economy. This can be achieved by providing semi-rigid connections. In this work rigid frame model and semi rigid frame model are analysed and designed and compared in the prospect of tonnage and connection Moment-Rotation relationship for Semi Rigid joints are found by developing Microsoft Excel Worksheets. Further analysis of the structure with Semi Rigid joints is to be carried out using STAAD Pro. Software.

Key Words: *semi-rigid connection, moment-rotation relationship, unstiffened top and seat angle connection, initial rotational stiffness, semi rigid structure model.*

1. INTRODUCTION

Moment required to cause unit rotation is called as "Rotational Stiffness." As we know, in pinned connection, at supports, moment is always zero so that stiffness of a pinned connection is also zero. Similarly, in rigid connection, at supports, angle of rotation is always zero so that stiffness of a rigid connection is infinity. But in semi-rigid connection, at supports, moment and angle of rotation will not be equal to zero. This means moment and angle of rotation both will be exist together with having some values.

1.1 NECESSITY OF SEMI RIGID CONNECTION

By providing connection flexibility means semi-rigid connection, support moment can be reduced and span moment can be increased. This means we can transfer the support moment towards the mid-span of the beam.

See Fig. 1.1, in which support moment is transferred towards mid span of beam.

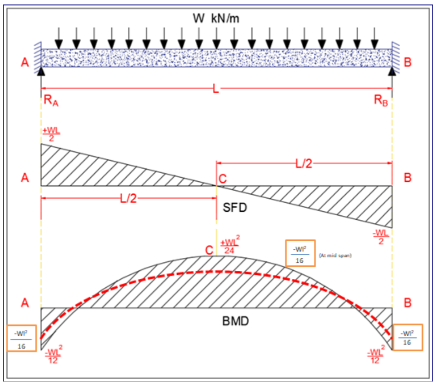

Fig. 1.1 Fixed beam v/s Semi rigid beam

1.2 OBJECTIVES OF STUDY

- To use connection flexibility in real practice. As currently all connection are assumed to be rigid or pinned.
- To achieve section economy by controlling support moment as mid span moment. This means to the support moment towards the mid-span of the beam.
- To reduce overall economy of structure and to reduce construction cost of structure.
- To compare the tonnage of structure designed with connection flexibility with structure designed with rigid and pinned connection. Results are expected to less tonnage in case of semi rigid model.
- To Develop Moment Rotation Relationship for semi rigid connection to achieve excellence in optimum flexibility of joint.

2. PRELIMINARY REMARKS

The joints are assumed to be "rigid", and there is no relative rotation of one member with respect to the other. In fact, this has been the main underlying assumption in most of our frame analysis. At the other extreme, we assume the joints to be hinged in the case of truss structures. Thus, at the supports of steel structures, it is assumed that either ideally fixed or ideally pinned conditions exist. In reality, many "rigid" connections in steel structures permit a certain amount of rotation to take place within the connections, and most "pinned" connections offer a small amount of restraint against rotation. Thus, if a more accurate analysis of such structures is desired, it is necessary to consider the connections as being flexible or semi – rigid.

3. METHODOLOGY

The geometric configuration of G+2 industrial steel building located in Nashik is taken in this dissertation. The data required for design structure is provided by "SOK Solution, Pune" Two models are developed in STAAD. Pro software.

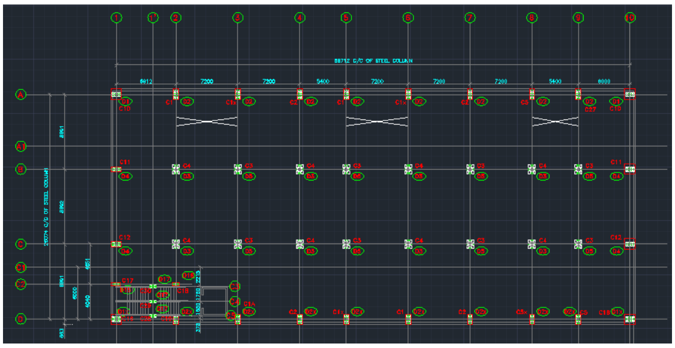

Fig. 3.1 Plan dimensions in Auto CAD

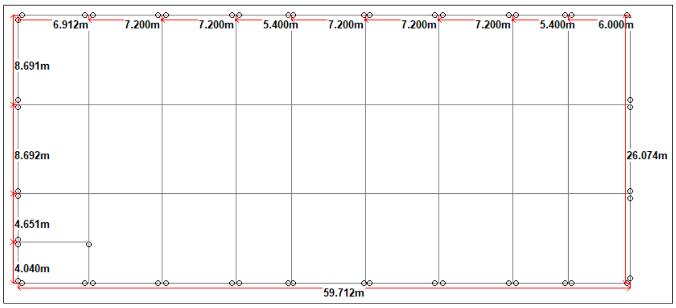

Fig. 3.2 Plan dimensions in STAAD.Pro

As per above figures, overall plan dimension is 59.712 meters in global X direction and 26.074 meters in global Z direction.

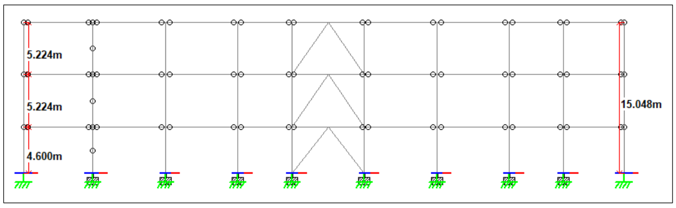

Fig. 3.3 Side elevation in STAAD.Pro.

In model 1, output is sizes of beams and columns that are capable for given loadings and all load combinations considering the building as rigid. In model 2, optimisation of the structure is carried out considering the building as semi rigid. This means, minimum sizes of beams and columns are found out that can resist all the moments and deflections experienced by the structure due to application of loadings and all the load combinations. Aim of the dissertation is to reduce the cost of construction of multi-storey steel buildings that are used in industrial sectors. So the percentage of saving steel is necessary to find out.
Analysis is based on different factor given below:

• Top story displacement: It is the lateral deflection or predicted movement of a structure under lateral loads due to wind and earthquake. Permissible limit: H/500 for wind load H/250 for seismic load

• Storey drift: It is defined as ratio of displacement of two consecutive floors to height of that floor. Permissible limit: 0.004h …. Where- h= storey height

• Time period: It is period of a structure of its damped free vibration i.e. time period of vibrating at a specific frequency which is based on the mass as well as the stiffness of the thing. Ta= 0.085 $h^{0.75}$ for steel frame building.

3.2 STEEL TONNAGE OF RIGID STRUCTURE

Profile	Length	Weight (kN)
ISMB 500 ST	240.77	402.799
ISMB 600 ST	498.19	589.371
ISMB 600 TB	89.42	126.399
ISMB 600 TB	399.79	780.069
ISMB 600 TB	17.38	23.234

Table 3.1 Steel tonnage for rigid structure

Further this tonnage is reduced with the help of semi rigid connection concept.

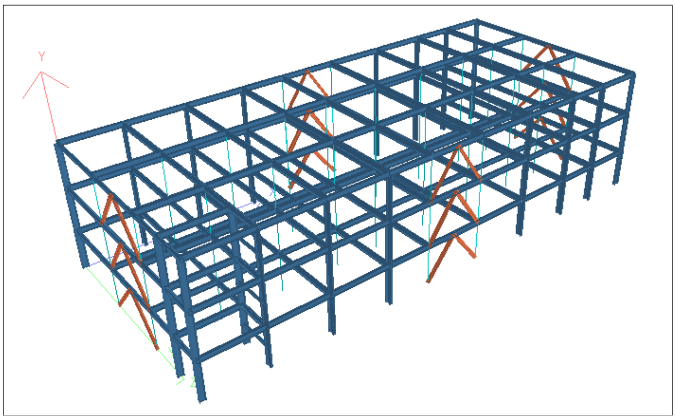
Fig. 3.4 3D model of structure in STAAD Pro.

3.3 MODELING OF MOMENT-ROTATION (M-Θr) RELATIONSHIP CURVE FOR ISMB 600 TB

Moment-Rotation relationship curve is found out for beam sections ISMB 600, ISMB 600 with top and bottom plate 250 x 6 mm and ISMB 600 with top and bottom plate 250 x 20 mm using Microsoft excel worksheet. These curves are as follows:

Equations for moment & rotation:-

Name			Denotation	Equation
Moment in Connection			M	$[R_{ki}*\theta r]/[\{1+(\theta r/\theta o)^n\}^{1/n}]$
Ref. Plastic Rotation			θo	M_u/R_{ki}
where,	R_{ki}	=	Initial Connection Stiffness	
	θr	=	Angle of Rotation	
	n	=	Shape Parameter	

To verify the moment-rotation relationship curve of the top and seat angle connection, following data was assumed:

Input Parameters of the Connection (all input parameters are in kilo-Newton & Meter)

	L_1	L_2	t	unit
Using Top Angle ISA (L_t x L_t x t_t)	0.1 5	0.1 5	0.0 1	m
Using Bottom Angle ISA (L_s x L_s x t_s)	0.1 5	0.1 5	0.0 1	m
C/S Area of Angle (a)			**0.0029**	m^2
Gauge Distance (g_t')			0.09	m
Radius at Root (r_1)			0.012	m
Radius at Toe (r_2)			0.008	m

Other Parameters to be Considered

Using Beam Section	**ISMB 600**	
Width of Beam or Column Flange (lt)	0.25	m
Total Depth of Beam Section (d)	0.612	m
Yield Strength of Steel (fy)	250000	kN/ m^2
Modulus of Elasticity (E)	2.00E+08	kN/ m^2
Diameter of Nut (D) for M16 Bolt	0.024	m

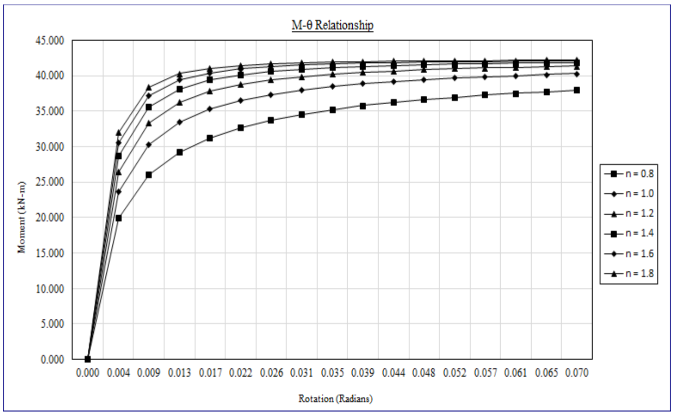

Fig. 3.4 Moment rotation relationship curve for MB600TB

As per above curve, for the shape parameter n = 0.8, moment is 0 kN-m when the rotation is 0 radians and moment is 31.270 kN-m when the rotation is 0.070 radians. For the shape parameter n = 1.8, moment is 0 kN-m when the rotation is 0 radians and moment is 34.808 kN-m when the rotation is 0.070 radians. This means all the curves for shape parameters between 0.8 and 1.8 with the increment of 0.2 having the moment greater than 0 kN-m and less than 34.808 kN-m for the rotation 0 radians to 0.070 radians. So, Moment-Rotation relationship curve for beam section ISMB 600 ensures that the beam is behaving neither rigid nor pinned. This means, the beam is behaving as Semi-Rigid.

After finding the moment rotation relationship for introduced beam section and using top and seat angle connection, it is further used in structure model to check the practical feasibility and following results are extracted.

Similarly for other beam sections moment rotation relationship curve is developed.

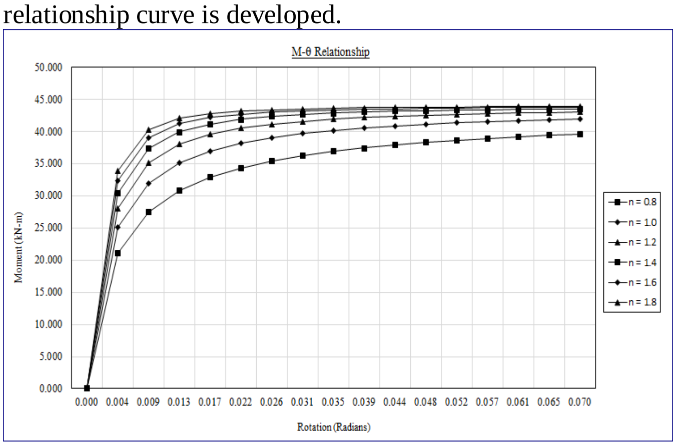

Fig. 3.5 Moment rotation relationship curve for MB600TB 250 x 6

As per above curve, for the shape parameter n = 0.8, moment is 0 kN-m when the rotation is 0 radians and moment is 37.953 kN-m when the rotation is 0.070 radians. For the shape parameter n = 1.8, moment is 0 kN-m when the rotation is 0 radians and moment is 42.175 kN-m when the rotation is 0.070 radians. 44 This means all the curves for shape parameters between 0.8 and 1.8 with the increment of 0.2 having the moment greater than 0 kN-m and less than 42.175 kN-m for the rotation 0 radians to 0.070 radians. So, Moment-Rotation relationship curve for beam section ISMB 600 with top and bottom plate 250 x 6 mm ensures that the beam is behaving neither rigid nor pinned. This means, the beam is behaving as Semi-Rigid.

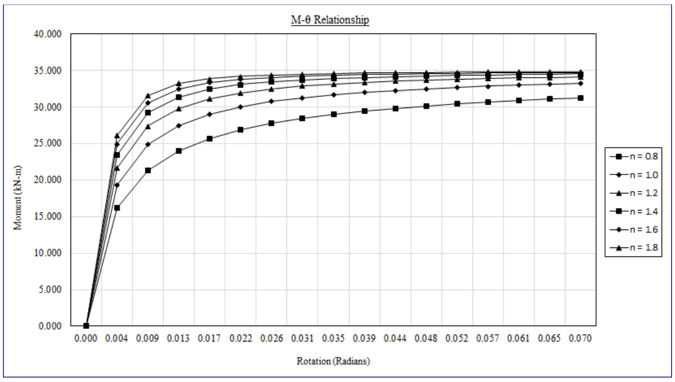

Fig. 3.6 Moment rotation relationship curve for MB600

As per above curve, for the shape parameter n = 0.8, moment is 0 kN-m when the rotation is 0 radians and moment is 39.649 kN-m when the rotation is 0.070 radians. For the shape parameter n = 1.8, moment is 0 kN-m when the rotation is 0 radians and moment is 43.896 kN-m when the rotation is 0.070 radians. 45 This means all the curves for shape parameters between 0.8 and 1.8 with the increment of 0.2 having the moment greater than 0 kN-m and less than 43.896 kN-m for the rotation 0 radians to 0.070 radians. So, Moment-Rotation relationship curve for beam section ISMB 600 with top and bottom plate 250 x 20 mm ensures that the beam is behaving neither rigid nor pinned. This means, the beam is behaving as Semi-Rigid.

By using Moment rotation relationship curve for different beams section to be used with their connection details like top and seat angle same structure is designed in STAAD Pro by providing connection flexibility in software. Following results are found.

Fig. 3.7 and 3.8 shows the bending moment diagram for same frame in structure and for same load combination of governing seismic case. Fig. 3.7 is showing bending moment diagram for rigid connection frame in which support moment is very high than span moment hence beam member will be designed for heavy support moment. It can be observed that rigid connection attracts more moment and make the joint moment heavy. On opposite side fig. 3.8 shows the bending moment diagram for semi rigid frame. After providing connection flexibility support moment can be transferred to the span of beam. Hence the beam member will be designed for evenly distributed moment; hence economy of section can be achieved.

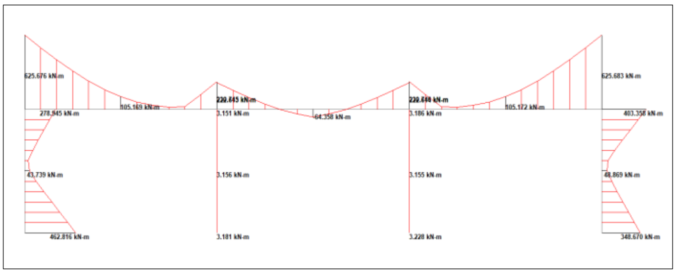

Fig. 3.7 Moment diagram of rigid frame

Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

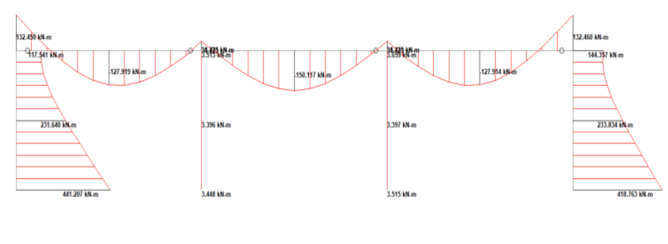

Fig. 3.8 Moment diagram of Semi rigid frame

4 RESULTS AND DISCUSSIONS

The analysis of model 1 (Rigid structure), model 2 (Semi-rigid structure) is carried out using STAAD. Pro software. The following parameters were considered for analysis:

- Maximum Storey displacement
- Steel consumption
- Moment-Rotation relationship curve

Deflection of Structure in cm		
Story	Rigid	Semi rigid
GS	0.0653	0.0749
1st	0.1080	0.1391
2nd	0.1297	0.1067

Table 4.1 Deflection of Structure

For the building structure with Semi Rigid Joints, the displacement of each story is greater than a similar building structure made with rigid joints. If the problem of drift occurs in upper stories, can be controlled by increasing the distance from the face of the beam flange to the nearest bolt centerline in order to restrict the rotation of the beam.

Profile	Length	Weight (kN)
ISMB 500 ST	240.77	402.799
ISMB 500 ST	498.19	424.80
ISMB 600 ST	50.40	59.624
ISMB 600 TB	278.11	393.105
ISMB 600 TB	160.70	239.488
ISMB 550 TB	17.38	27.453

Table 4.2 Steel Tonnage required for semi rigid structure

Profile	Length	Weight (kN)
ISMB 500 ST	240.77	402.799
ISMB 600 ST	498.19	589.371
ISMB 600 TB	89.42	126.399
ISMB 600 TB	399.79	780.069
ISMB 600 TB	17.38	23.234

Table 4.3 Steel tonnage for rigid structure

4.1 CONCLUDING REMARKS

Maximum storey displacement is within permissible limit for Rigid structure and Semi-Rigid structure. Storey displacement for Semi-Rigid structure is little higher than the Rigid structure as connection flexibility is provided in rigid joints, For braced structure displacement is very less as bracing provide more stiffness. By providing connection flexibility, percentage steel saving is up to 25%. Moment-Rotation relationship curve for all beam sections ensures that beam is acting like Semi-Rigid.

- Top and Seat angle type of Semi-Rigid connection is used for the connection of beam and column joint.
- Two types of structures is modeled in STAAD.Pro software namely as “Rigid Structure” (Model-1) and “Semi-Rigid Structure” (Model-2).
- Initial rotational stiffness is worked out and Moment-Rotation relationship curve is developed for the three beam sections using Microsoft excel worksheet.
- The relation of Moment-Rotation relationship curve ensures that top and seat angle connection behaves as a Semi-Rigid connection after deformation.
- Percentage of saving of the steel is estimated by considering Semi-Rigid structure (Model-2). Overall saving of the steel is estimated as 25%.
- Economy of an industrial steel building is achieved by saving the steel.

REFERENCES

[1] “Indian institute for steel development and growth”, chapter 39.

[2] Wai-Fah Chen, Sumio G. Nomachi, “Moment-rotation relation of top and seat angle connections”, unpublished.

[3] N. Kishi, W. F. Chen, “Data base of steel beam to column connections”, AISC engineering journal, Vol. 24, Chicago, 1987.

[4] Y. Goto, W.F. Chen, “On second order elastic analysis for design”, journal of structural engineering, ASCE, Vol. 113, New York, 1987

[5] N. Kishi, W. F. Chen, “Semirigid steel beam to column connections: data base and modeling”, journal of structural engineering, ASCE, Vol. 115, 1989.

[6] N. Kishi, W. F. Chen, “Moment-rotation relations of semirigid connections with angles”, journal of structural engineering, Vol. 116, no. 7, July 1990.

[7] E. M. Lui, W. F. Chen, “Stability design of steel frames”, 1991.

[8] AISC, Manual of steel construction, load and resistance factor design, second edition, Vol. 1 and 2, Chicago, 1993.

[9] S. Toma, W. F. Chen, “Advanced analysis of steel frames”, 1994.

[10] Seung-Eock Kim, Se-Hyu Choi, “Practical advanced analysis for semi-rigid space frames”, international journal of solids and structures, 2001.

[11] J. G. Yang, G. Y. Lee, “Design specifications for low rise steel frames with double angle connections”, Korea research foundation, 2005.

[12] J. G. Yang, S. S. Jeon, “Analytical models for the initial stiffness and plastic tensile load capacity of a double angle connection”, international journal of steel structures, 2008.

[13] Jae-Guen Yang, Seong-Sam Jeon, “Analytical models for the initial stiffness and plastic moment capacity of an unstiffened top and seat angle connection under a shear load”, international journal of steel structures, August 2009.