Comparative Analysis of Steel Structure with Rigid and Semi Rigid Joints Using Analysis Tool ETABS

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ABSTRACT

Generally, in steel structure the connection between beam and column are designed as moment connection and pinned connection, but in actual condition the structure behaves between these two conditions, resulted into semi-rigid condition which is intermediate stage between rigid and pinned joints. Effect of semi-rigid connection on multi-story multi-bay frame is accomplished in this paper. The present study introduces the effect of static and dynamic loading on high rise steel structure of G+12 story with 4m, 6m and 8m three bay span length. Structure is analyzed under two different condition of partial release of semi-rigid connections which is derived by fixity factor of values 0.5 and 0.75 in this study. The analysis is done commercially available software ETABS. From the non-linear analysis, the story displacement and story drift are obtained. The overall performance of the structure from the analysis, semi-rigid joints display more story displacement and story drift compared to rigid joints. To overcome the results, bracing system is introduced at different location of periphery of structure. These brace frame structure consist of X- bracing and diagonal bracing. Again, comparative analysis is to be performed in ETABS on these three-bay span lengths. It is found that braced semi-rigid frame structure perform quite well as compared to unbraced frame structure.

Keywords: Multi-story Multi-bay frame, Semi-rigid connections, Fixity factor, Brace frame, Rigid Connections.

I. INTRODUCTION

The 2001 Bhuj earthquake of India was an eye opener. It made thousands of people lose their lives and rendered millions to lose their houses. The effect was so wide spread that it not only affected the people in the vicinity of the epicenter but also those living in a metro city Ahemdabad, about 250 km away from the epicenter were badly affected. A major damage was observed in RC framed structures which were in the range of G+3 to G+ 7 storeys. Further, most of the buildings were having a normal grid of 3m x 3m column spacing with a standard storey height of 3m. One important parameter concerned with the seismic behavior is the storey drift which should not exceed a permissible value. This fact is evident from the inclusion of a clause related to specifying a permissible value of storey drift in all country codes related to earthquake engineering including the Indian code IS 1893, 2002.

Types of Steel Beam Connections

Steel beam connections can likewise be required for slanted joints, pillars unusual to sections and association with segment networks. These are classed as extraordinary connections and are treated separately. Steel beam connections come up with various sorts. Presently steeloncall have given the explanation of the considerable number of sorts of steel beam connections in the below section.

Bolted framed connections

Regularly, the connection is planned dependent on the heaps toward the end of the beam. It is required to take quality, type and size of latches and quality of base materials into thought while the connection is designed. The minimum length of connection angle ought to be at any rate half of the bar clear web profundity. This measure is indicated to guarantee adequate firmness and soundness. There are different standard sizes of bolted framed connections along with their ability given by codes. The reason for such institutionalized associations is to speed up the plan.

Fig 1 Bolted Framed Connections

II. Objectives of the research

It is proposed to carryout analysis of multistory multi bay steel structure considering ideally rigid, ideally pinned & semi-rigid beam end conditions in STAAD Pro using IS 800:2007. The following are the objectives of the proposed work.

- To determine the stability of structure with rigid and semi rigid joints
- To determine the utilization of analysis tool etabs in analysis of a high rise steel structure under seismic loading.
- To determine the variations in forces and stresses in both the cases in comparison.
- To determine the stability of structure with x type bracing at the corner.

III. LITERATURE REVIEW

Alfredo Reyes-Salazar et al (2014) research paper investigated nonlinear seismic responses of 3D steel buildings with perimeter moment resisting frames (PMRF) and interior gravity frames (IGF), explicitly considering the contribution of the IGF. The effect on the structural response of the stiffness of the beam-to-column connections of the IGF, which is usually neglected, was further studied. It is commonly believed that the flexibility of shear connections is negligible and that 2D models can be used to properly represent 3D real structures.

Results stated that the moments developed on columns of IGF can be considerable and that modelling buildings as plane frames may result in very conservative designs. The contribution of IGF to the lateral structural resistance may be significant. The contribution increases when their connections are assumed to be partially restrained (PR). The incremented participation of IGF when the stiffness of their connections is considered helps to counteract the no conservative effect that results in practice when lateral seismic loads are not considered in IGF while designing steel buildings with PMRF. Thus, if the structural system under consideration is used, the three-dimensional model should be used in seismic analysis and the IGF and the stiffness of their connections should be considered as part of the lateral resistance system.

Harsh Rana et al (2020) research paper introduced the effect of static and dynamic loading on high rise steel structure of G+15 story with 4m, 6m and 8m three bay span length. Structure is analyzed under two different condition of partial release of semi-rigid connections which is derived by fixity factor of values 0.5 and 0.75 (as per AISC) in this study. The analysis was done commercially available software-STAAD.Pro. From the non-linear analysis, the story displacement and story drift was obtained. The overall performance of the structure from the analysis, semi-rigid joints display more story displacement and story drift compared to rigid joints. To overcome the results, bracing system was introduced at different location of periphery of structure. These brace frame structure consist of X- bracing and diagonal bracing. Comparative analysis was performed in STAAD.Pro on these three-bay span lengths. It is found that braced semi-rigid frame structure perform quite well as compared to unbraced frame structure.

Results stated that lateral displacement in semi-rigid connection is more than rigid connections as well as increasing in bay length. Reduction in results with increasing the flexibility of connection about fixity factor '0.75' as compare to fixity factor '0.5'. As span increase the more lateral displacement observed. To overcome this effect the bracing system is used to improve the lateral stability of structure. The analysis results of X-braced frame have indicated more lateral stability than diagonal braced frame. In the overall seismic analysis of high-rise structure, corner and full perimeter braced frame enhance to give least lateral displacement and drift comparing with middle braced frame.

IV. METHODOLOGY

Step 1- The first step in general is to review research papers from different authors or to identify the problem statement and the remedies adopted from different researchers. The review of the papers were summarized in section two.

Step 2- The grid system are defined from the predefined template or even provides the option to customize it as per the stature of the desired structure. The model is designed as per model initialization to define the unit and IS codes.

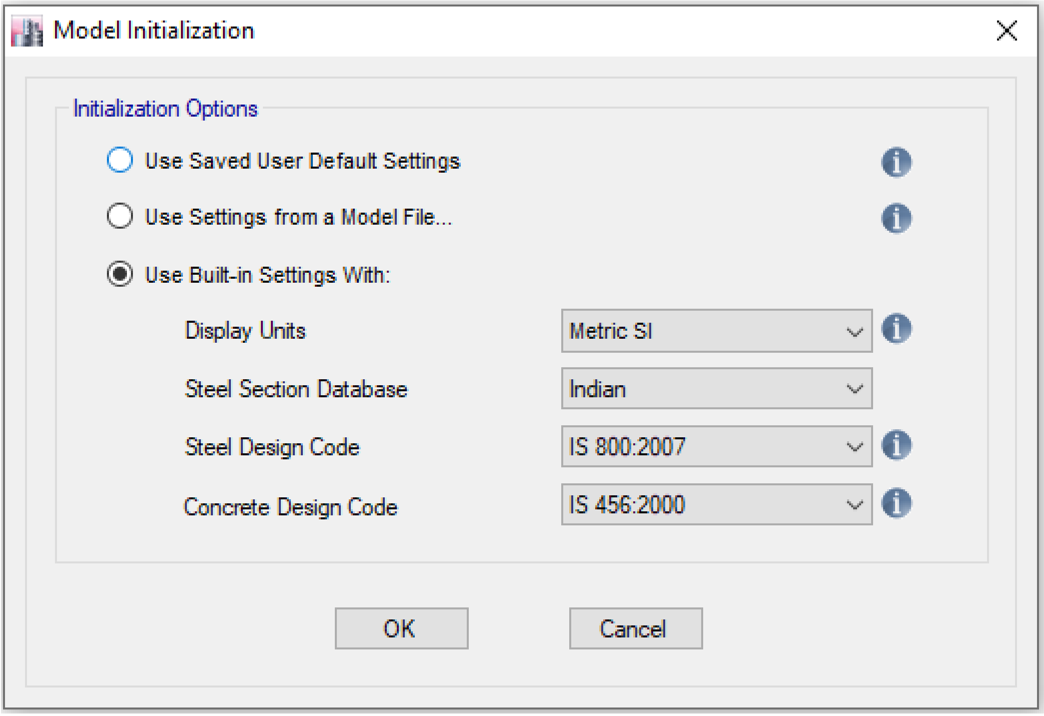

Fig 2 Model Initialization

Step 3- the grip matrix for the structure is designed as per the quick template available in analytical application ETABS. The grid is defined in X and Y direction whereas the storey height is defined in Z direction.

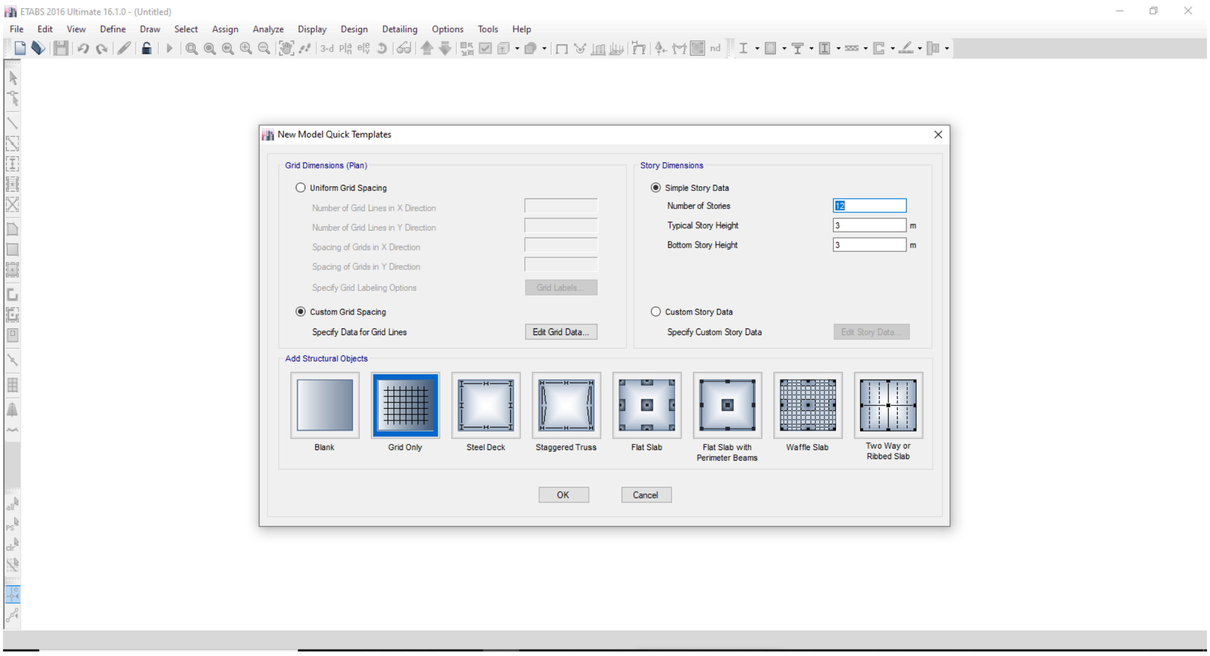

Fig 3 New Model Quick Template

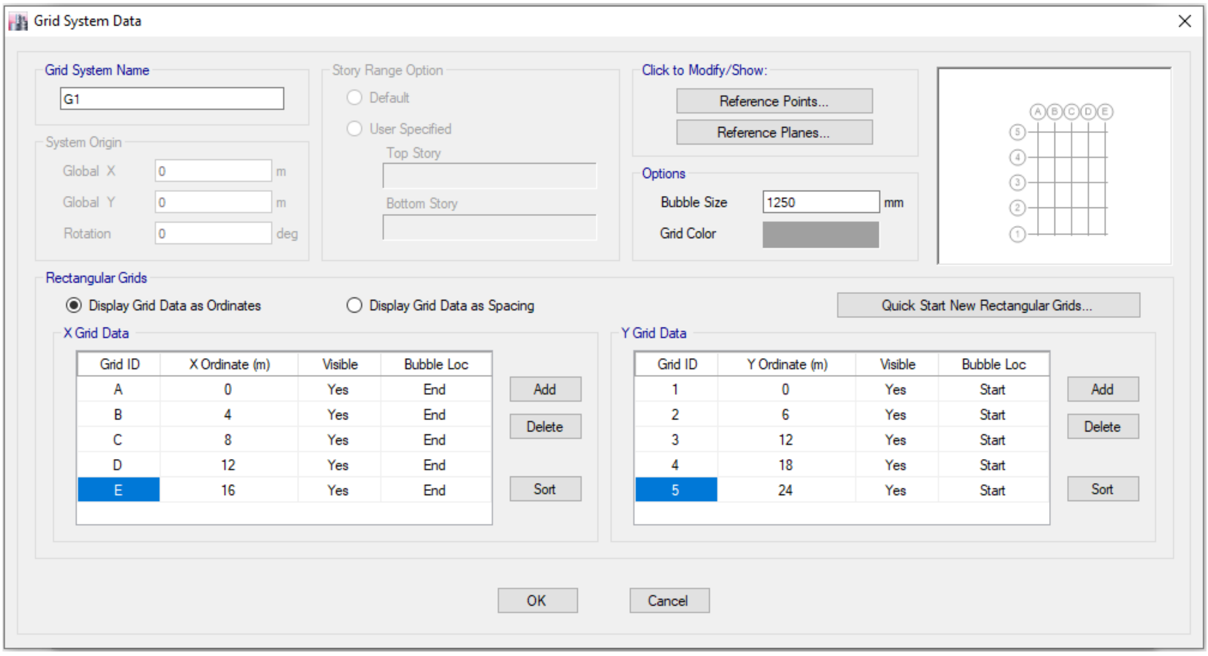

Fig 4 Grid System Data.

Step 4- this step involves the properties of material as here in this case, a steel structure is considered and the properties of steel is defined.

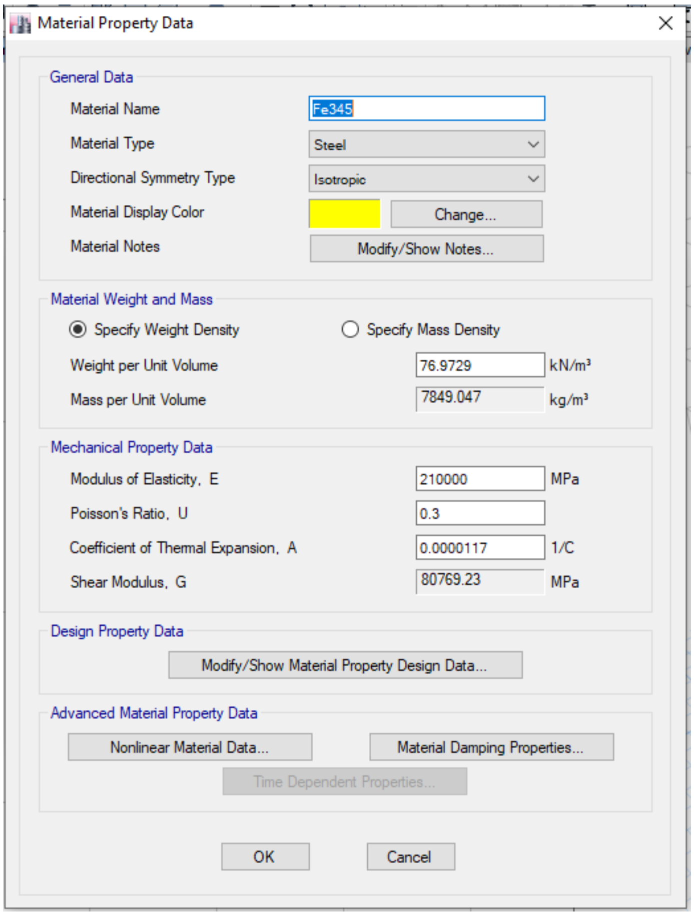

Fig 5 Properties of Steel

Step 5- Defining section properties for the steel frame and steel slab where the sections are defined for steel beams and columns.

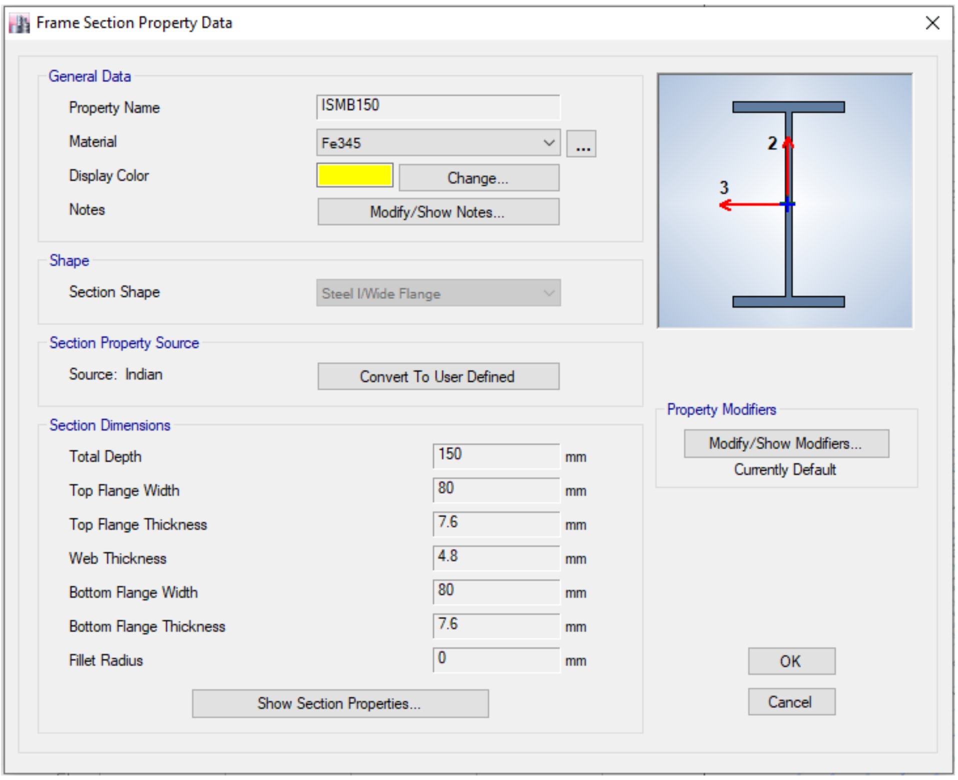

Fig 6: Frame Section Property Data for Wide Flange

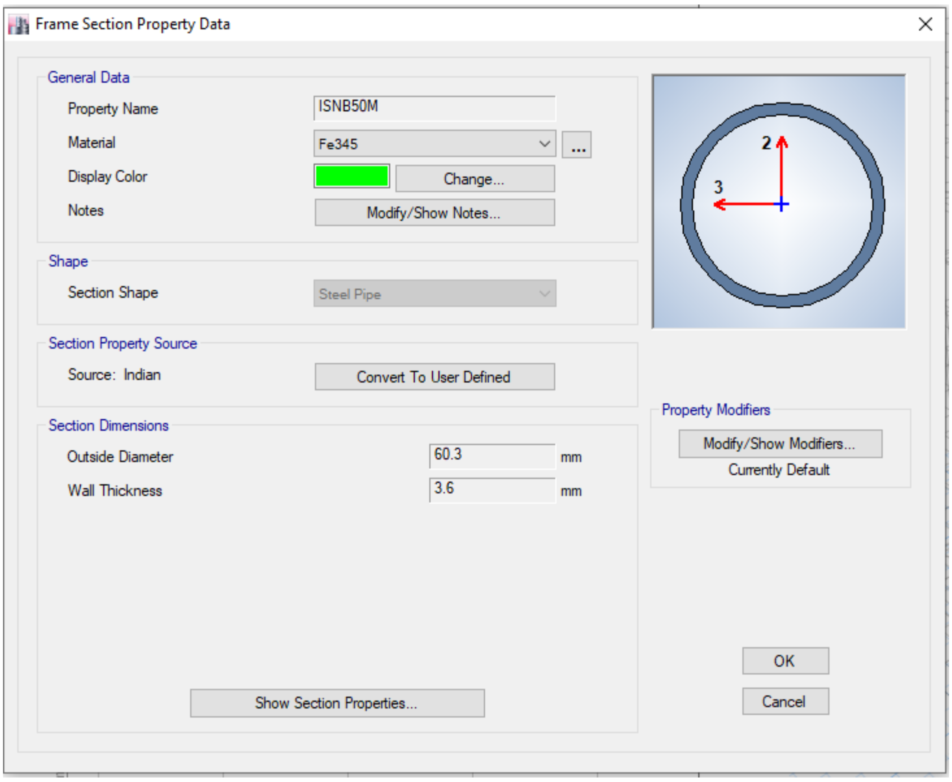

Fig 7: Bracing Frame Section

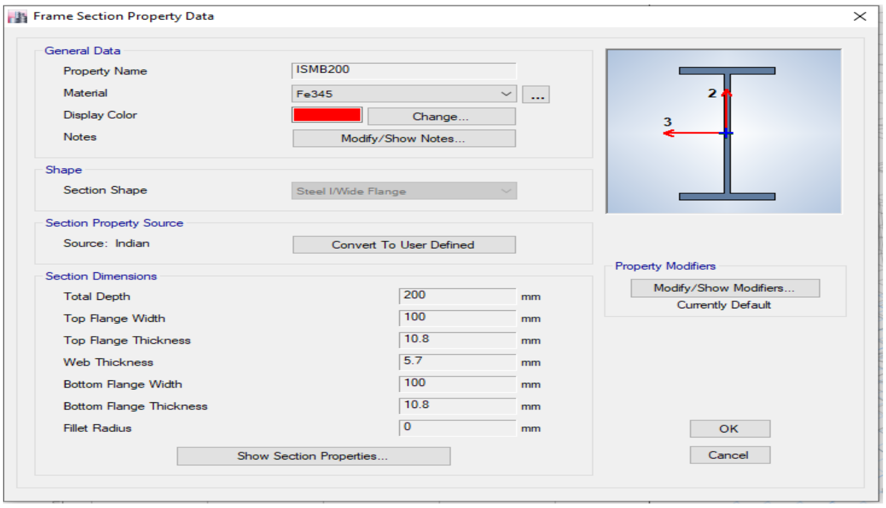

Fig 8: Frame Section Property Data for Wide Flange (ISMB 200)

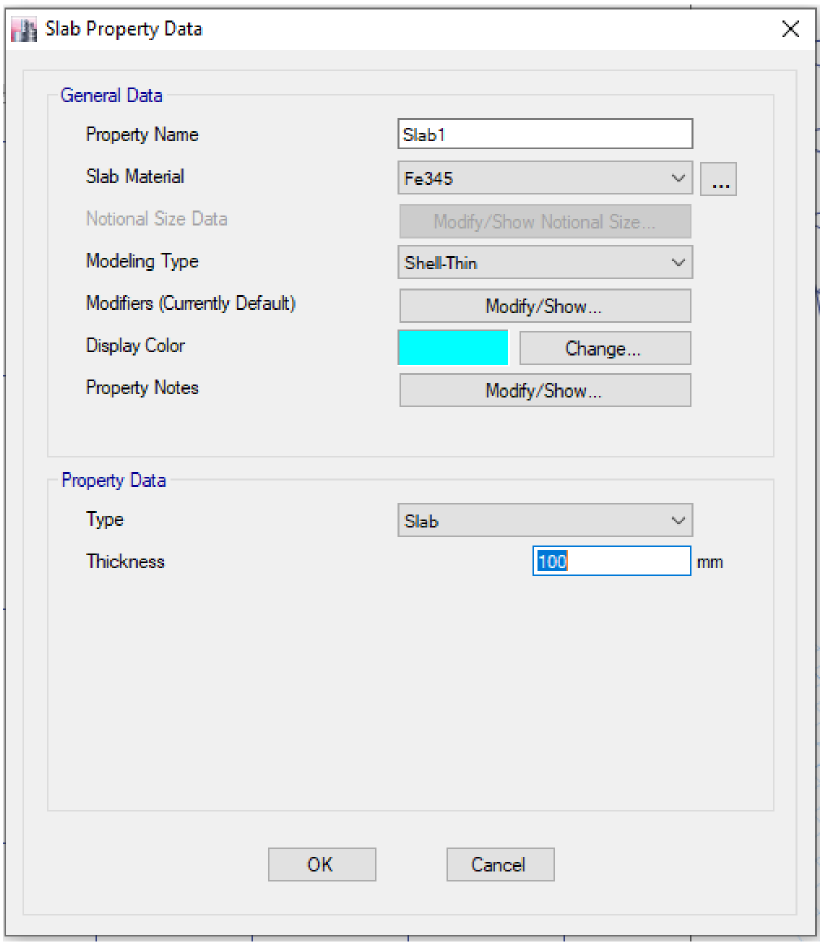

Fig 9: Slab Property Data

Step 6 Defining properties for Rigid Joints and Semi RIgid Joints for the steel structure

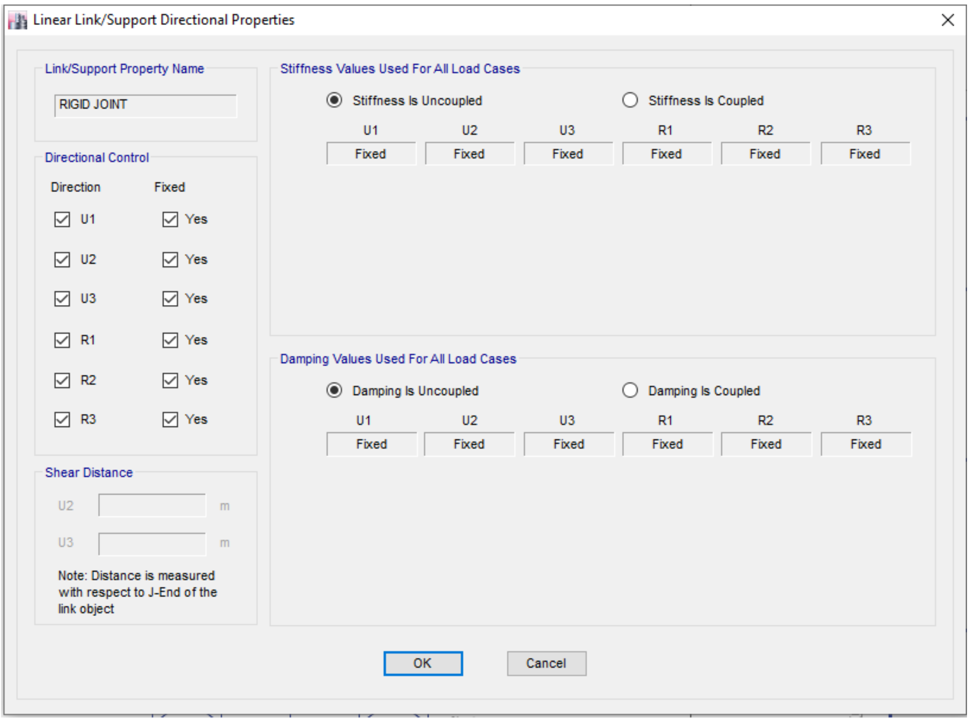

Fig 10: Rigid Joints

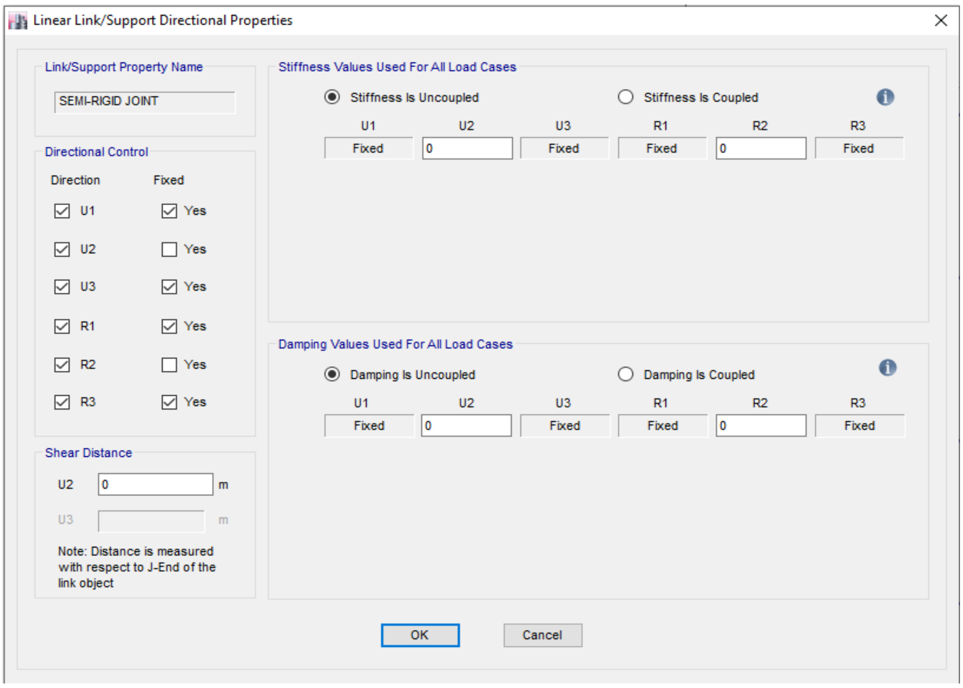

Fig 11: Semi Rigid Joints

Step 6 Defining loading conditions and load patterns assigned to the frame of the structure.

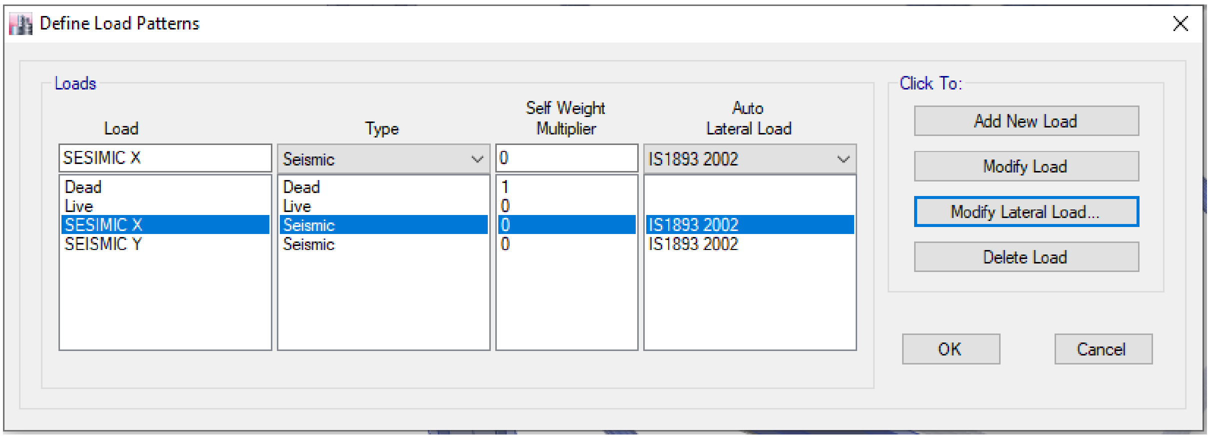

Fig 12: Defining Load Pattern

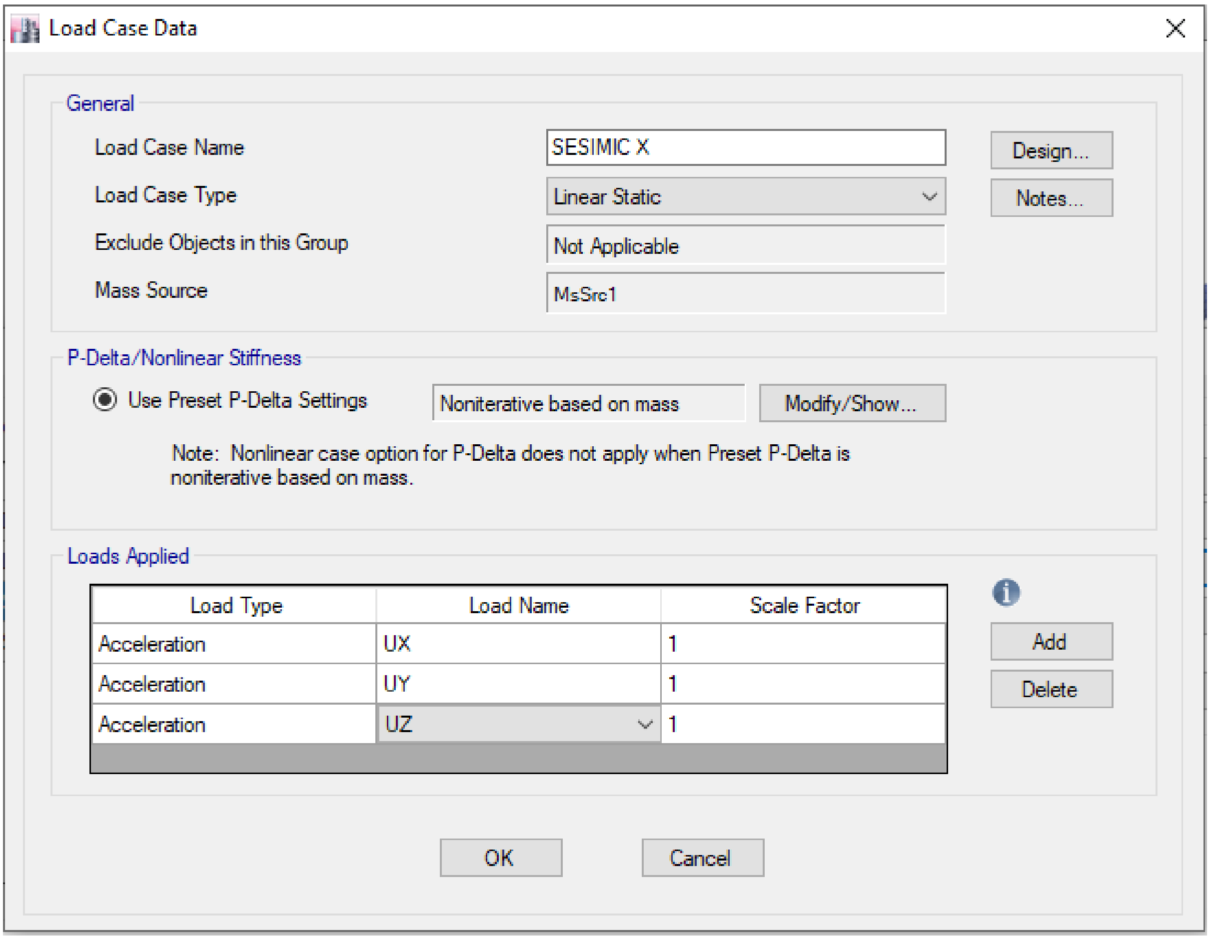

Fig 13: Load Case Data

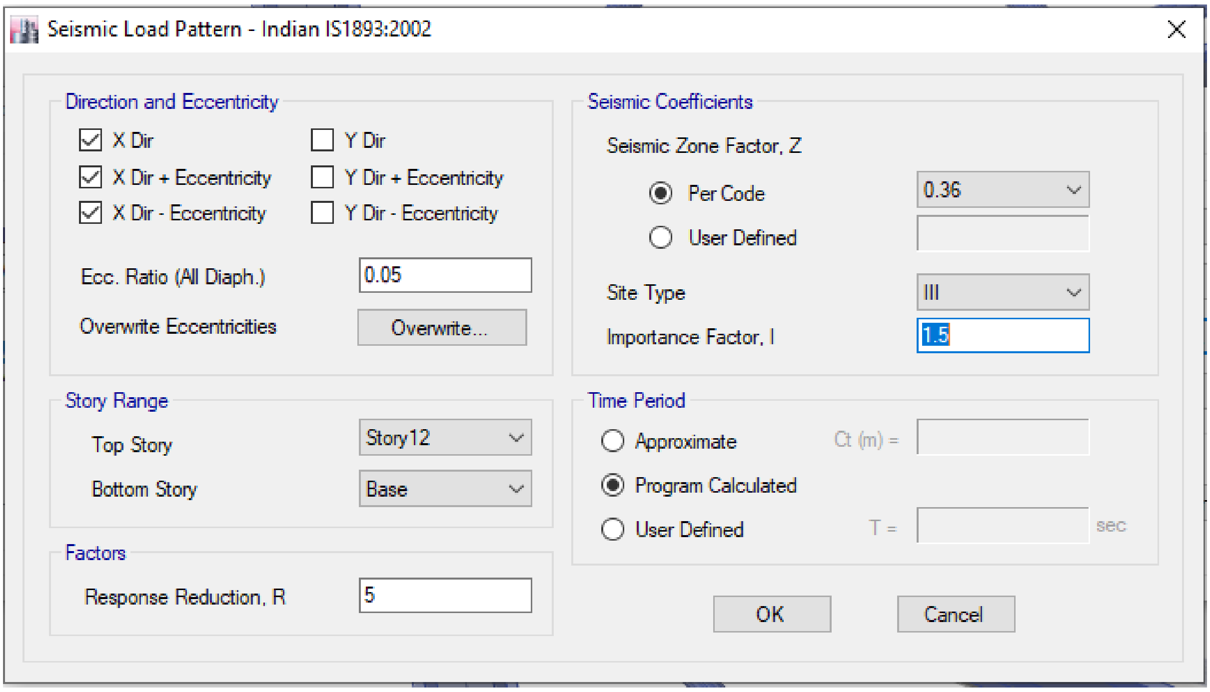

Fig 14: Seismic Load Patterns as per IS 1893:2002.

Step 8- Analyzing the model on parameters of displacement, shear force, bending moment and Joint Analysis.

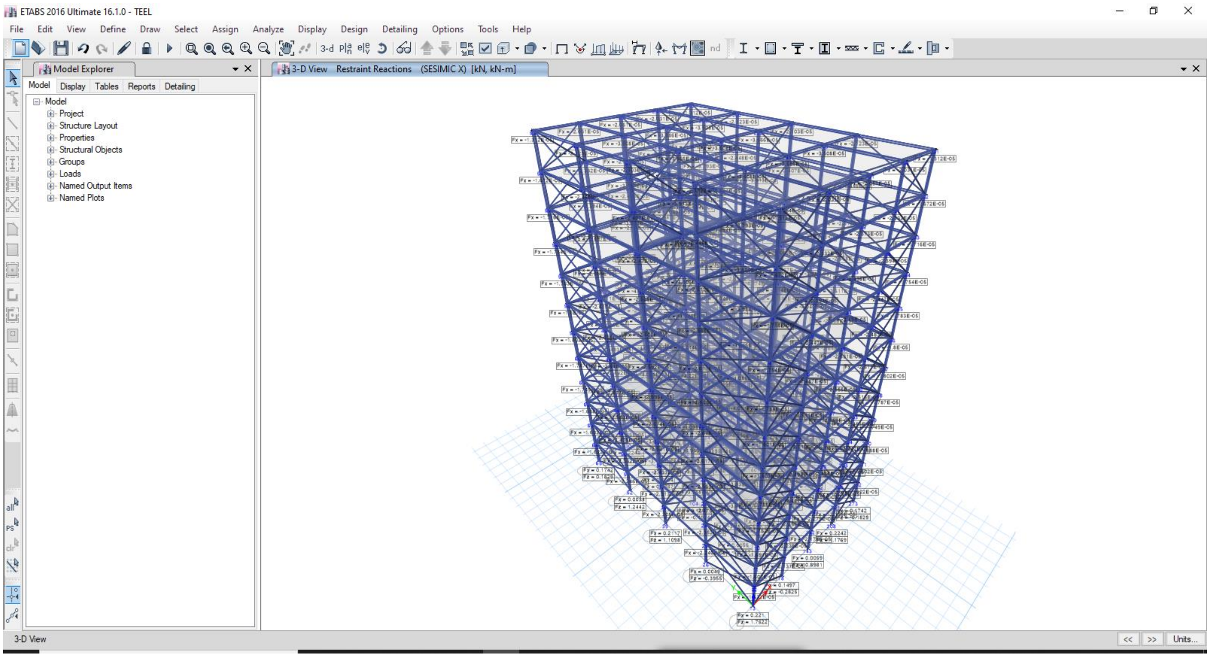

Fig 15: Joint Output

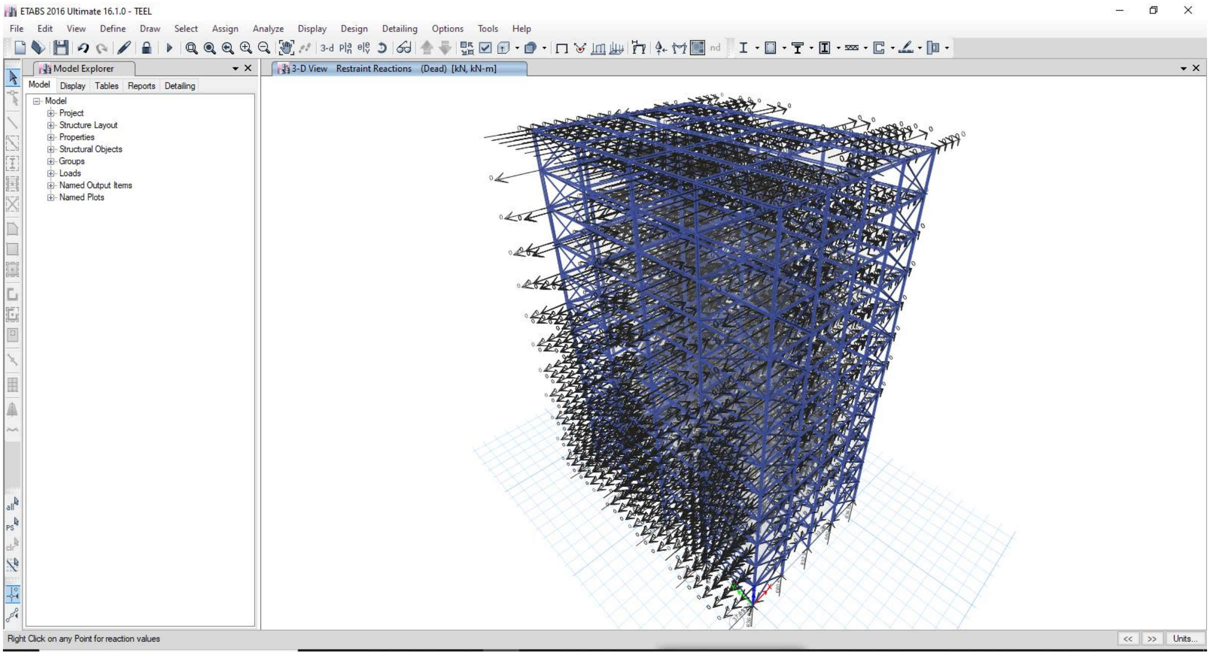

Fig 16:Joint Analysis

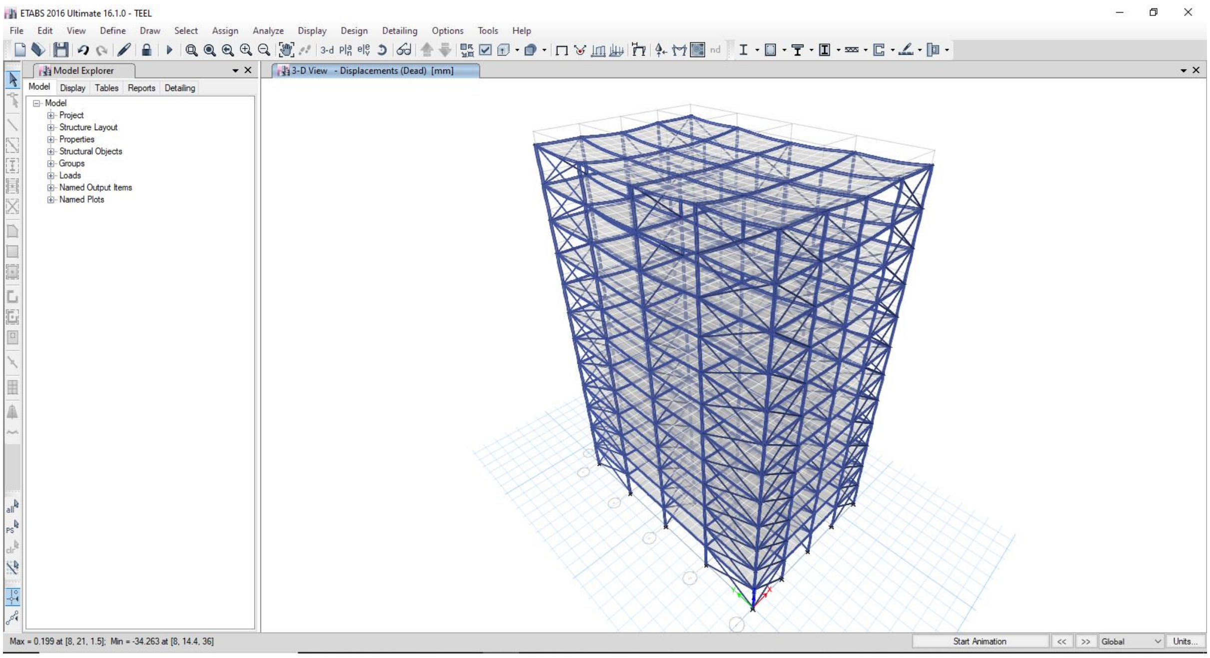

Fig 17: Displacement

Step 9- This last step is to present the comparative analysis of steel structure with two different joints namely rigid and semi rigid joints. The results will be tabulated and presented graphically in section 5.

Table 1: Parameters of developed steel frame models

Structural type	Commercial
Total stories	12 (G+11)
Total height of building	42 m

Size of column	ISWB 600 @ 145.1 kg/m
Size of beam	ISWB 300 @ 48.1kg/m, ISMB 400 @ 61.6 kg/m and ISMB 600 @ 122.6 kg/m
Thickness of slab	150 mm
Floor height	3.5 m
Grade of slab concrete	M25
Live load	4 kN/m2
Dead load	1.5 kN/m2
Seismic zone	V
Soil Type	Medium
Importance factor	1
Response reduction factor	5
Damping ratio	5%

ANALYSIS RESULT

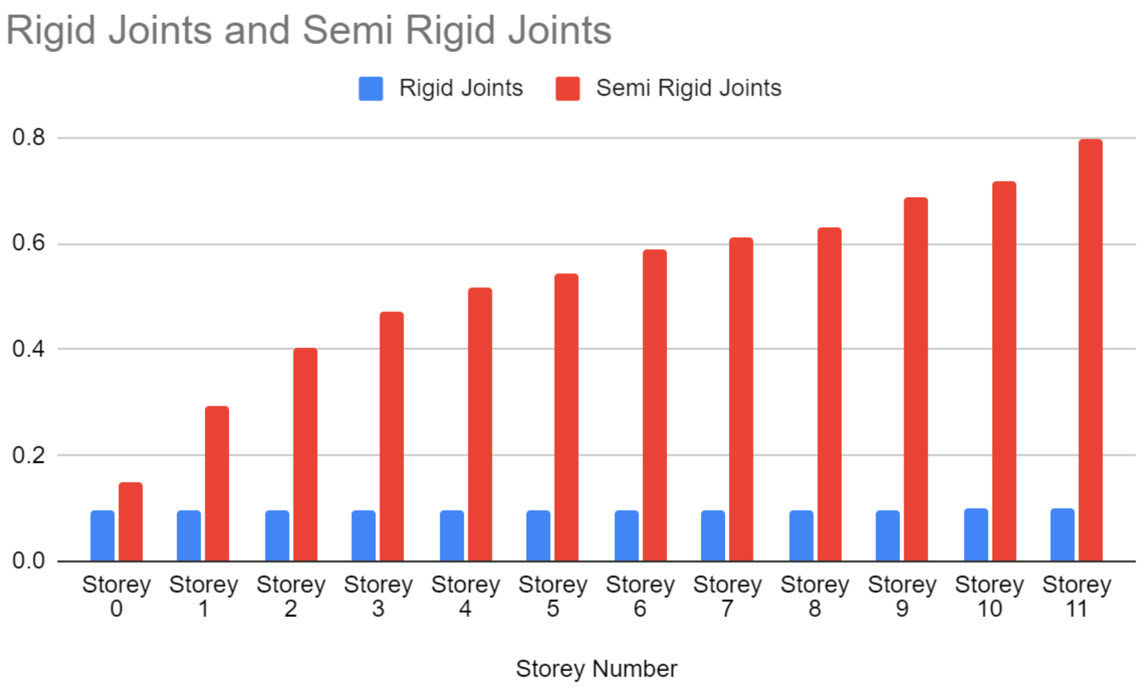

Table 2: Shearforce

Shear Force in kN		
Storey Number	Rigid Joints	Semi Rigid Joints
Storey 0	11.98	11.02
Storey 1	12.34	11.41
Storey 2	12.96	11.77
Storey 3	13.55	12.31
Storey 4	11.03	11.33
Storey 5	10.13	10.24
Storey 6	8.49	8.79
Storey 7	7.99	8.05
Storey 8	6.67	6.75
Storey 9	5.98	6.02
Storey 10	5.21	5.28
Storey 11	4.76	4.81

Table 3: axial force

Shear Force in kN		
Storey Number	Rigid Joints	Semi Rigid Joints
Storey 0	11.98	11.02
Storey 1	12.34	11.41
Storey 2	12.96	11.77
Storey 3	13.55	12.31
Storey 4	11.03	11.33
Storey 5	10.13	10.24
Storey 6	8.49	8.79
Storey 7	7.99	8.05
Storey 8	6.67	6.75
Storey 9	5.98	6.02
Storey 10	5.21	5.28
Storey 11	4.76	4.81

V. CONCLUSION

An Effort was made to evaluate the behavior of rigid and semi rigid connection. The performance point, storey drift and time period of the G+11 storied structure was evaluated with respect to rigid and semi rigid connection. Based on Analytical results, following conclusion can be drawn.

- Semi rigid connections show enhanced performance to the number of steps, 16% higher displacement, at a considerably greater base shear which helps to prove analytically that semi rigid connections are better replacement for hinged and fixed connections which are down by 2% and 16% respectively.
- It also indicates the collapse point of the various models analytically and it is shown that the collapse point for semi rigid structures are 2% higher than the hinged structures and more than 20% higher than fixed structures.
- from the performance point for hinged connection is seen to be higher than the performance point for fixed and semi rigid connections, but as the loading proceeds towards the collapse point, the semi rigid connections show a greater yield for base shear than the hinged and fixed connections.
- It shows us significant readings in terms of base shear and displacement. The base shear in fixed frames are the highest followed by the semi rigid model frames and the hinged frames. The following observation thus implying that fixed frames collapse after reaching the particular saturation point.
- From the modal analysis the time period is increased for the semi rigid by 36% whereas it is decreased by 34% for hinged models and very less for fixed models by 17%
- Table 3 gives us the drift ratio for the various models and shows us that the drift ratio is 1.5% for the hinged models while it comes up to 3% for semi rigid models and it take only 1% for rigid models.

VI. REFERENCES

[1]. Alfredo Alfredo Reyes-Salazar, Edén Bojórquez, Achintya Haldar, Arturo López-Barraza, and J. Luz Rivera-Salas, [Seismic Response of 3D Steel Buildings considering the Effect of PR Connections and Gravity Frames], Hindawi Publishing Corporation e Scientific World Journal Volume 2014, Article ID 346156, 13 pages.

[2]. M. Ghassemieh and A.R. Bahadori, [Seismic Evaluation of a Steel Moment Frame with Cover Plate Connection Considering Flexibility by Component Method], Advances in Structure Engineering and Mechanics, August 2015.

[3]. Dr B. A. Shah, [Seismic Performance Evaluation of RC Frames with Semirigid Joints using Storey Drift as a Criterion], International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 5 Issue 05, May-2016.

[4]. Iman Faridmehr, Mahmood Md. Tahir, Tom Lahmer, and Mohd Hanim Osman, [Seismic Performance of Steel Frames with Semirigid Connections], Hindawi Journal of Engineering Volume 2017, Article ID 5284247, 10 pages.

[5]. A. Moghadam, H.E. Estekanchi, and M. Yekrangnia, [Evaluation of PR steel frame connection with torsional plate and its optimal placement], Scientia Iranica A (2018) 25(3), 1025{1038.

[6]. Hardik M Paghadal, Dr. Darshana R. Bhatt and Dr. Snehal V. Mevada, [Ductility evaluation of steel frames using semi-rigid connections, Journal of Emerging

Technologies and Innovative Research (JETIR), November 2018, Volume 5, Issue 11.
[7]. Neema B.R., Shreyas S.C. and Dr. Chidananda G, [EFFECT OF CONNECTION RIGIDITY ON SEISMIC PERFORMANCE OF MULTI STOREY STEEL FRAMES], International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 07 | July 2018.
[8]. Harsh Rana, Dr. Darshana R. Bhatt and Dr. Snehal V. Mevada, [High Rise Long Span Steel Structure with Semi-Rigid Connection using Bracing System], International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 9 Issue 03, March-2020.
[9]. Cinitha A, Umesha P. K and Nagesh R. Iyer, [Evaluation of Seismic Performance of Existing Steel Buildings], American Journal of Civil and Structural Engineering (2014) 23-33.

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