International Journal of Architecture and Urbanism Vol. 08, No. 03 (2024) 431 – 438

International Journal of Architecture and Urbanism

Journal homepage: https://talenta.usu.ac.id/ijau

Analysis of Roof Displacement in Steel Structures with and without Panel Zone

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ARTICLE INFO

Article history:
Received 18-9-2024
Revised 2-10-2024
Accepted 7-11-2024
Available online 30-11-2024

E-ISSN: 2622-1640
P-ISSN: 2622-0008

How to cite:
Rasuna T.Y, et.al. Analysis of Roof Displacement in Steel Structures with and without Panel Zone. International Journal of Architecture and Urbanism. 2024. 8(3):431-438.

http://doi.org/10.32734/ijau.v8i3.18211

ABSTRACT

This study uses the Indonesian earthquake zone standards SNI 1726:2019 and focuses on seismic design category D to investigate how panel zones affect the seismic behavior of steel structures in Medan City. Soft soils and the special moment-resisting frame (SMRF) system, which has a seismic significance factor of 4, are taken into consideration while designing the structures. The study looks at the story drift ratio and roof displacement of a seven-story steel building that is subjected to seismic pressures with and without panel zones. The findings indicate that compared to the structure without panel zones, the building with panel zones has a roof displacement that is roughly 9.23% higher in the X direction and 10.41% higher in the Y direction. Similarly, the story drift ratio for the structure with panel zones is 9.21% greater in the X direction and 11.55% greater in the Y direction than the structure without panel zones. These findings indicate that incorporating panel zones changes a rigid structure into a semi-rigid one, allowing more rotational movement at the beam-column joints, thereby improving the building's flexibility and overall earthquake resistance.

Keywords: earthquake, panel zone, roof displacement, story drift

1. Introduction

The earthquake that occurred in Aceh with a magnitude of Sembilan Richter Scale claimed at least 230,000 lives spread across various regions, including Aceh, Malaysia, Nias, Sri Lanka, Thailand, and even India [1]. As a result of these earthquakes, buildings with elastic frames are needed in areas prone to earthquakes and moment-bearing frame systems that function as structural restraints for beams, columns, and connections so that they do not collapse when receiving force vibrations caused by earthquakes [2]. The moment-bearing frame structure is a frame technique that very well supports lateral movements given by earthquakes or wind. In the design of multi-storey buildings, SRPM has the advantage of forming a portal structure clearly on a hysteresis curve at a consistent plastic joint, can be a good enough stiffener, has a relatively large vibration period due to high flexibility, and provides freedom to design the room as expected [3][4][5][6][7][8].

One of the moment-resisting frame systems that can be used is the Special Moment Resisting Frame System (SRPMK), a space frame system in which the joints and structural elements resist forces acting through axial, shearing, and bending motions. A system with complete ductility that resists lateral loads, compliance to particular detailed standards, and a response modification factor of R=8.0 must be used while planning the structure [9].

The intersection of beams and columns in steel structures that can withstand shear and bending forces is called the *Panel Zone*.[10]. The *Panel Zone* has deformation that is a function of shear and has a significant impact on the deviation in level [11][12]. The application of Panel Zone at the intersection of beams and columns can assist in the deformation of a structure subjected to vibration [13]. The use of *Panel Zone* without *double plate* or a relatively thin thickness of *Panel Zone* results in melting on the side of *Panel Zone* and produces relatively large stresses[10][14].

The SC-WB concept is one of the structural design innovations by creating a structural system that has a collapse mechanism in accordance with existing regulations. Plastic joints are first allowed to form in the beams and endeavor to avoid plastic joints in the columns during an earthquake.

Based on the above, it can be seen that *Panel Zone* plays a role in *roof dispacement*. In order to determine the influence of Panel Zone use on roof displacement on Strong Column Weak Beam (SCWB), particularly in SRPMK steel structures, this study was carried out to examine the effect of Panel Zone use on SCWB checks. This research is expected to provide insight to structural engineers regarding the importance of panel zone in earthquake resistant building planning.

2. Method

This research is an analytical study conducted on a pattern with a Special Truss System (SRPMK). The building will be designed using *Panel Zone* and without *Panel Zone* by using Indonesia Earthquake Zone. The data used in this analysis consists of the function of the building is a school which is included in the Resio IV category[15]. The structure, which is situated in Medan City, is made up of two types of seven-story buildings: one without a panel zone and the other with one. It has a seismic design category D, an earthquake primacy factor of 1.5, a response modification coefficient (R) of 8, a system overpower factor Ω0 of 3, a deflection magnification factor (Cd) of 5.5, yield stress (fy) of 240 MPa, and tensile stress (fu) of 400 MPa.

The response spectrum approach was applied in the investigation. The Program for Calculating Building Structure Analysis is one of the software support tools utilized in this investigation.

3. Result and Discussion

3.1 Roof Dispacement Analysis

Roof displacement under seismic loading was assessed for steel structures with and without panel zones based on the simulation findings. The outcomes unequivocally show how the panel zone affects how the structure reacts to lateral stresses from the earthquake. The findings demonstrate that, in general, the roof displacement of the structure with panel zones is greater than that of the one without. The structure without panel zones has a maximum displacement of 52,782 mm in the X direction; with panel zones, this displacement rises to 58,148 mm. Table 1 shows the outcomes on each floor.

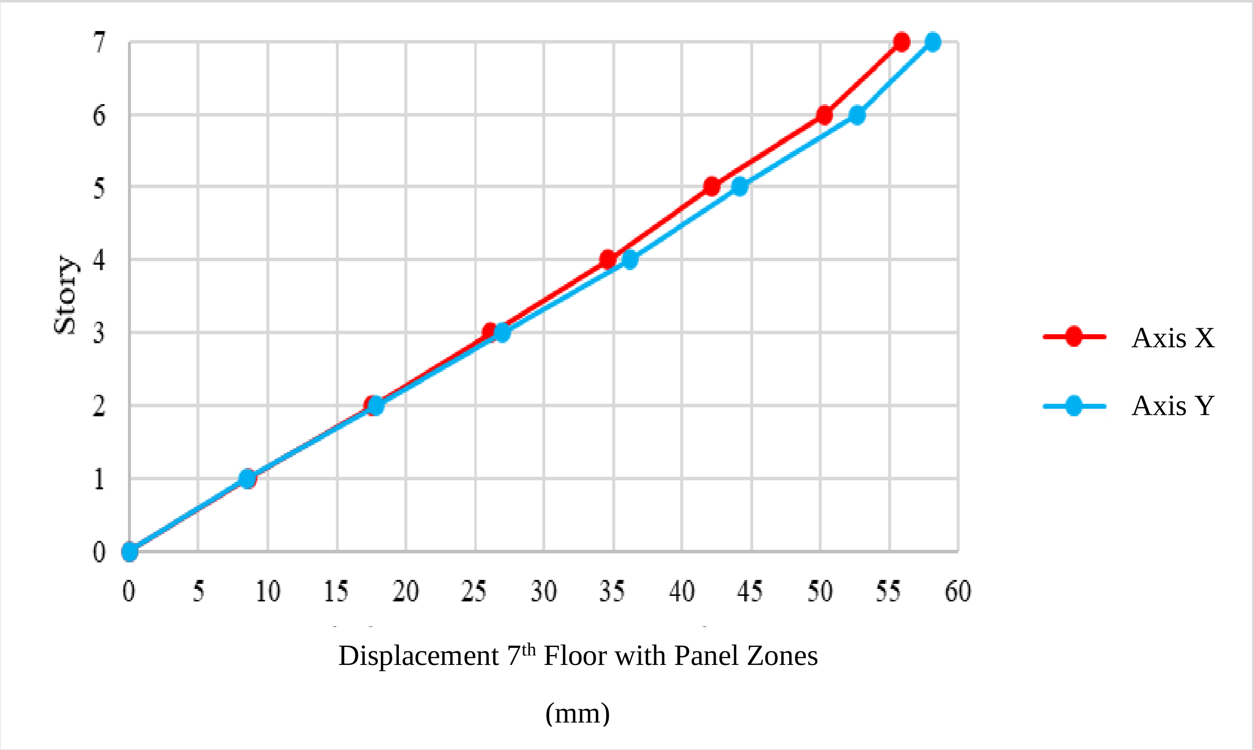
A similar trend is seen in the Y direction, where the building with panel zones shows greater roof displacement than the one without. When panel zones are included in the construction, the maximum roof displacement in the Y direction is 62,444 mm, as opposed to 55,946 mm when they are not. Table 2 shows the outcomes on each floor. Figure 1 compares the roof displacement in the X and Y directions with Panel Zone, and Figure 2 compares the roof displacement in the X and Y directions without Panel Zone.

Table 1 Roof Displacement Comparison in X Direction

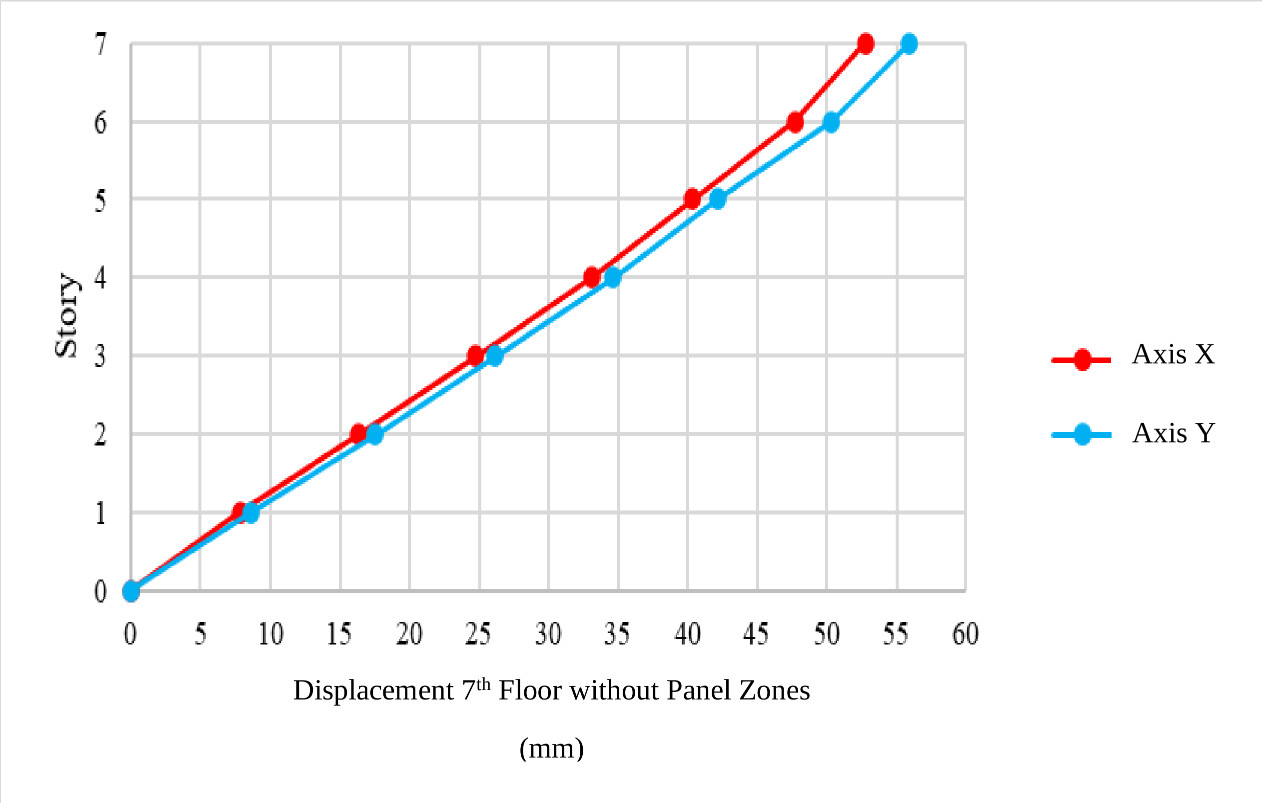
Story	Without Panel Zone (mm)	With Panel Zone (mm)
7	52,782	58,148
6	47,697	52,701
5	40,316	44,172
4	33,069	36,217
3	24,730	26,984
2	16,295	17,833
1	7,840	8,520

Table 2 Roof Displacement Comparison in Y Direction

Story	Without Panel Zone (mm)	With Panel Zone (mm)
7	55,946	62,444
6	50,353	56,241
5	42,089	46,210
4	34,630	38,078
3	26,151	28,676
2	17,526	18,750
1	8,654	9,597



Figures 1 Roof Displacement in X Direction for Structure with Panel Zones



Figures 2 Roof Displacement in X Direction for Structure (a) with and (b) without Panel Zones

3.2 Comparison of Roof Displacement

The findings show that adding panel zones considerably raises the roof displacement in both the X and Y dimensions. The structure with panel zones has a roof displacement that is roughly 9,23% larger in the X direction than the one without panel zones. When panel zones are used instead of not, there is a 10,41% increase in displacement in the Y direction. Table 3 displays the outcomes of the percentage increase in Roof Displacement.

Table 3 Percentage Increase in Roof Displacement

Direction	Without Panel Zone (mm)	With Panel Zone (mm)	Percentage Increase (%)
X	52,782	58,148	9,23
Y	55,946	62,444	10,41

3.3 Story Drift Analysis

Story drift, another critical measure of a building's performance under seismic loads, was also evaluated. The results showed that the structure with panel zones had a higher story drift ratio than the one without, indicating that the panel zone's presence increases lateral flexibility. The results can be seen in Table 4 and Table 5 as well as Fig. 3 and Fig. 4.

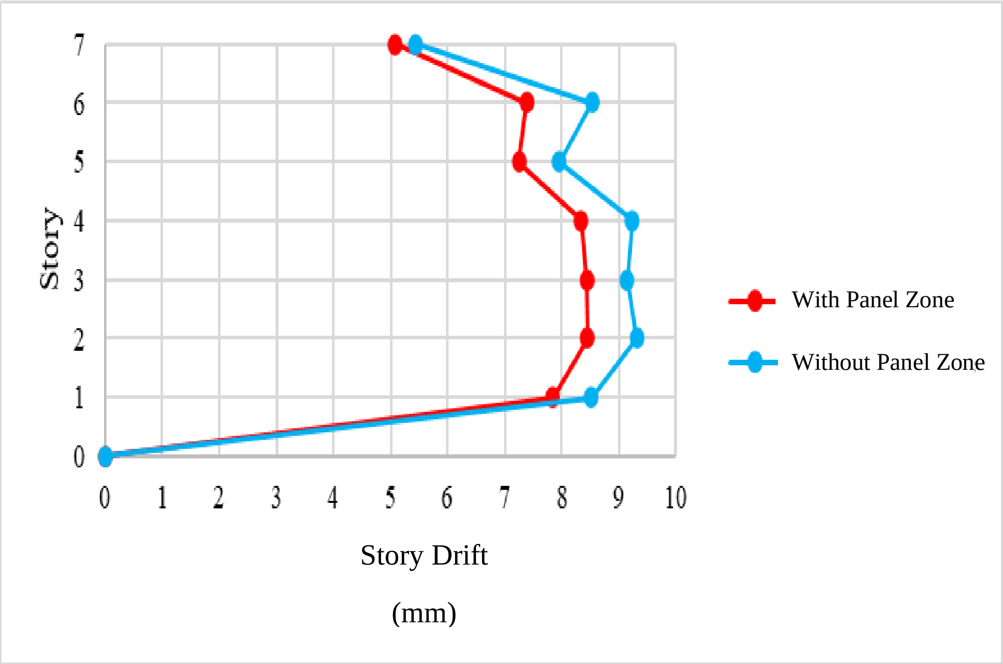
Table 4 Story Drift Comparison in X Direction

Story	Without Panel Zone (mm)	With Panel Zone (mm)
7	5,085	5,447
6	7,381	8,529
5	7,247	7,955
4	8,339	9,233
3	8,435	9,151
2	8,455	9,313
1	7,840	8,520

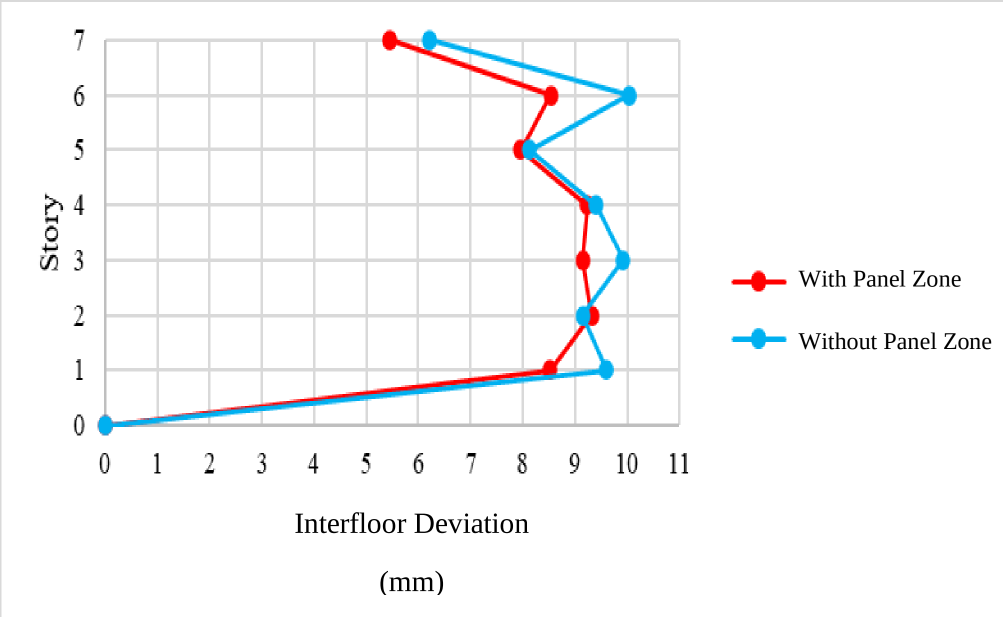
Table 5 Story Drift Comparison in Y Direction

Story	Without Panel Zone (mm)	With Panel Zone (mm)
7	5,593	6,203
6	8,264	10,031
5	7,459	8,132
4	8,479	9,402
3	8,625	9,926
2	8,872	9,153
1	8,654	9,597

The higher drift values in the structure with panel zones suggest a more ductile response, which can be benefical in certain seismic design strategies.



Figures 3 Comparison Chart of X-Direction Interfloor Deviation Without *Panel Zone* and With *Panel Zone*



Figures 4 Comparison Chart of Y-Direction Interfloor Deviation Without *Panel Zone* and With *Panel Zone*

3.4 Analysis

The analysis shows that adding panel zones to steel structures significantly affects roof displacement and story drift. While the increased displacement and drift may initially seem like drawbacks, they indicate a more ductile behavior, which can help prevent sudden failure during seismic events. Therefore, incorporating panel zones should be carefully considered in seismic design strategies, depending on the performance requirements and safety standards of the structure.

4. Conclusion

The examination of roof displacement in steel structures under seismic loading, comparing those with and without panel zones, has revealed that the presence of panel zones significantly impacts the structural response. Specifically, structures with panel zones experience greater roof displacement compared to those without, with an increase of around 9.23% in the X direction and 10.41% in the Y direction for the 7-story building, and similar increases for the 10-story building. This indicates that panel zones not only allow for greater displacement but also offer improved ductility and flexibility, which can be beneficial in seismic design by enabling the structure to absorb more energy without collapsing.

Furthermore, the story drift ratio for structures with panel zones exceeds that of those without, suggesting that the existence of panel zones allows for more rotational movement at beam-column joints, resulting in a semi-rigid rather than rigid structure. This semi-rigid behavior aids in more effective distribution of seismic forces, potentially averting sudden failure during an earthquake.

In summary, the incorporation of panel zones leads to increased roof displacement and story drift, while also enhancing the overall durability and seismic performance of steel structures. It is recommended that future studies delve into more detailed economic analysis and optimize beam-column dimensions, as well as validate these findings with real-world seismic data to further refine seismic-resistant building designs.

5. Acknowledgements

Three people did a study that resulted to this research. The purpose of this study is to ascertain, in compliance with Indonesian rules, whether zone panels should be used in earthquake-resistant buildings located inside the Indonesian seismic.

6. Conflict of Interest References

The authors of this work, whose names are stated below, attest to the absence of conflicts of interest.

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If there are more than ten writers, a photocopy of this form may be used. This statement is signed by all of the foregoing information being accurate and correct:

Author's name	Author's signature
T Yuan Rasuna	

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