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Comparative Study on Influence of Replaceable Links on Seismic Behavior of Multi-Storey Steel Structure having Different Framing Configuration

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***Abstract* - An earthquake is a natural disaster caused by movements of seismic plates inside the Earth which results in the release of energy into the lithosphere called seismic waves. Earthquake poses a great risk to life and properties; hence, to reduce the effect of earthquake, development of devices which will dissipate such kind of energy is necessary. Development and installation of such devices will reduce the damage and increase the serviceability of the structures. The main aim of this study is to compare the seismic behavior of multi-storey steel structure with links and without links by dynamic response spectrum method using STAADPRO having regular plan with different framing arrangements like, Regular frame, X-bracing frames, Chevron bracing frames, Diagonal bracing frames having 8-storey levels with seismic zone V.**

Index Terms – replaceable links, Bracing, response spectrum analysis, bending stress

INTRODUCTION

Earthquake poses a great risk to the life and properties. Brittle elements tend to break and lose strength. It is the challenge commonly faced by several countries especially to those located in the Pacific Ring of fire. In 2007, an earthquake occurred in Szechuan China had more than 87500 fatalities while the one occurred in Japan, in 2011 caused an economic damage of 201 Billion USD. The Indian sub-continent has also suffered from several other greatest earthquakes in the world. In 2001, a massive earthquake stroked Gujarat, India and tremendous loss of life and property took place and reportedly 30,000 people died. All these events with other earthquakes worldwide further fueled the advancements in seismic engineering. The main principle used in seismic design of structure is capacity design [1]. This principle allows the design of dissipative members, where the energy dissipation will be concentrated during seismic event, while the non-dissipative members are protected from failure by providing them with a level of over strength such that they can resist the maximum force developed by the plasticization in the dissipative zone [2] [3].

Hence to overcome all these, replaceable links was introduced at the beams where the stress concentration is more near the support. By designing the links as the weakest points while the other members are designed to remain elastic. By doing so, only the links need to be replaced while the other members continue to be structurally appropriate to function. The use of bolted connections enables the links to be replaceable [4] [5].

This study concludes as the structures provided with replaceable links shows the reduced displacement and bending stress as the provided links will absorb and dissipate the energy and will fail without causing and severe damage to the main structure. Replaceable link in frame is shown in Figure 1. Specifications of links are used according to study [1].

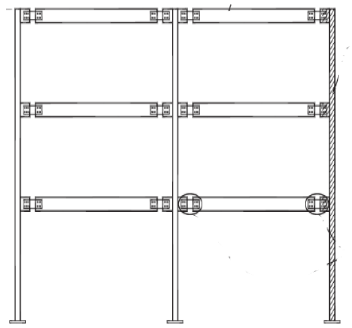

FIGURE 1
FRAME WITH REPLACEABLE LINKS

METHODOLOGY

In this study, 14 different models were considered. 8-storey steel structures of Regular frame without links, X-bracing frames at all the face of the structure without links, X-bracing frames at corner face of the structure without links, Chevron bracing at all the face of the structure without links, Chevron bracing at corner face of the structure without links, Diagonal bracing at all the face of the structure without links, Diagonal bracing at corner face of the structure without links, Regular frame with links, X-bracing frames at all the face of the structure with links, X-bracing frames at corner face of the structure with links, Chevron bracing at all the face of the structure with links, Chevron bracing at corner face of the structure with links, Diagonal bracing at all the face of the structure with links, Diagonal bracing at corner face of the structures are analyzed using STAADPRO Vi8 software. Dynamic Response Spectrum method is used for the analysis of all the structures. After analysis parameters like maximum storey displacement and bending stress were compared between the structures provided with replaceable links and without replaceable links.

Section dimensions are selected after performing repetitive analysis till optimized sections are obtained. Parameters considered for the study are given in Table I

TABLE I
DETAILS OF PARAMETERS

Parameters	Values
Height of structure	24m
Storey height	3m
Dimension of building	16 × 16m
Beam dimension	ISMB500, ISMB450
Column dimension	ISMB600
Bracings	ISMB200
Earthquake zone	V
Number of storey	8-storey
Soil type	Medium soil
Damping ration	5%
Floor finish	1 KN/m^2
Live load	3 KN/m^2

RESULTS AND DISCUSSION

I. Comparison of Maximum story displacement

Peak story displacement of the structure are compared for all the parameters to known the influence of replaceable links on the seismic behavior of the structure. Peak story displacement variations of all parameters are given in Figure 2 to Figure 5

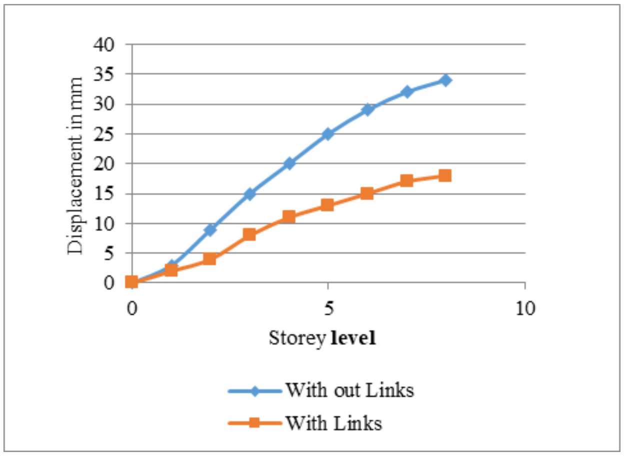

FIGURE 2
DISPLACEMENT VARIATION OF REGULAR FRAME

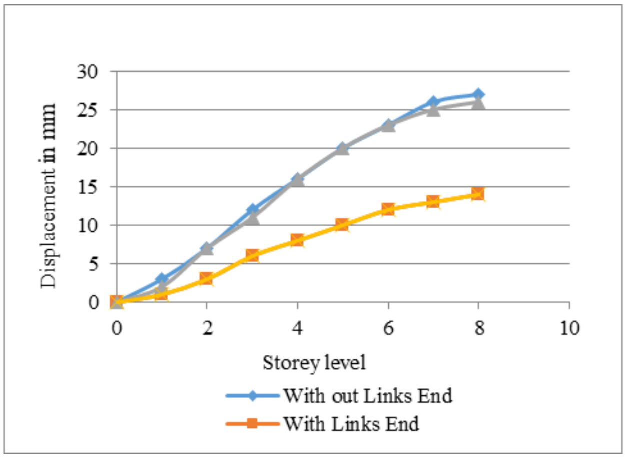

FIGURE 3
DISPLACEMENT VARIATION OF X-BRACED FRAME

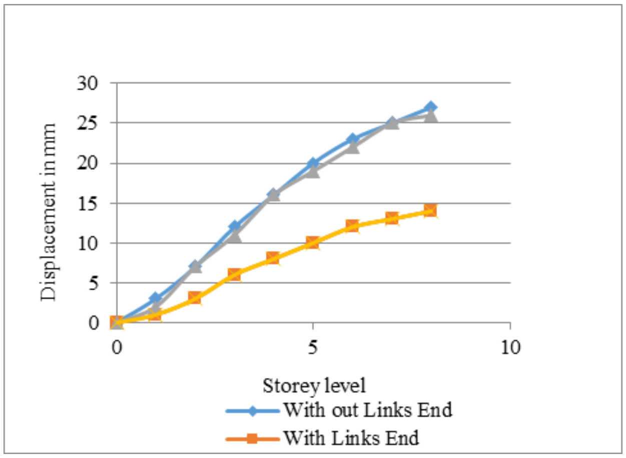

FIGURE 4
DISPLACEMENT VARIATION OF CHEVRON-BRACED FRAME

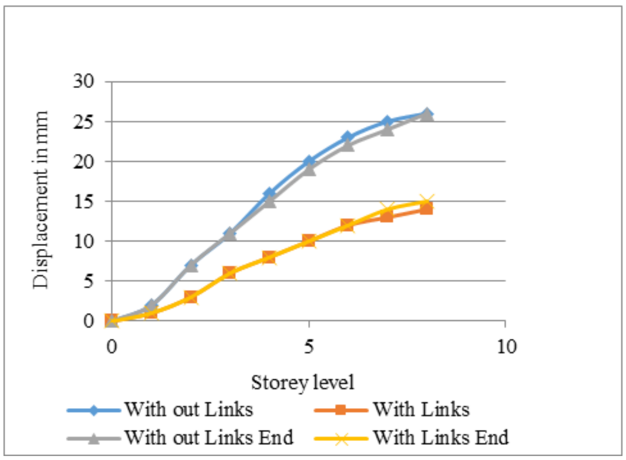

FIGURE 5
DISPLACEMENT VARIATION OF DIAGONAL-BRACED FRAME

From Figure 2 to Figure 5, it can be observed that, structure without replaceable links has undergone more displacement compared to structures with replaceable links, because force transferred to the structure are directly taken by the columns and dissipated through its deformation, this leads to the global displacement of the structure. Thus structures without replaceable links has undergone more displacement than structure with replaceable links. From Figure 2 it is clear that, Presence of replaceable links in regular framed structure reduces the peak story displacement by 51.01%. Presence of replaceable links provided in the beams of frame take the energy observed by the structure and dissipate through its deformation. Deformation of the structure is concentrated only for the replaceable links, thus reduces the stress on column, this leads to the reduction in global displacement of the structure. Presence of replaceable links has reduced peak displacement on an average by 40% in all configuration that can be seen in Figure 2 to Figure 5.

II. Comparison of Time Period

Time period of any structure is dependent on the mass and stiffness of the structure. Mode shape of the building swaying with the time period of the structure, mode shape of structure is depending on the geometry and material properties of the building. In current work time period of first mode has been used for comparison. Time period of all configurations of the structures for the first mode are given in Figure 6 and Figure 7. Presence of the replaceable links induce the ductility to the structure thus leads to the increase in time period of the structure. Increase in the time period leads to the reduction in the stresses over the members of the structure.

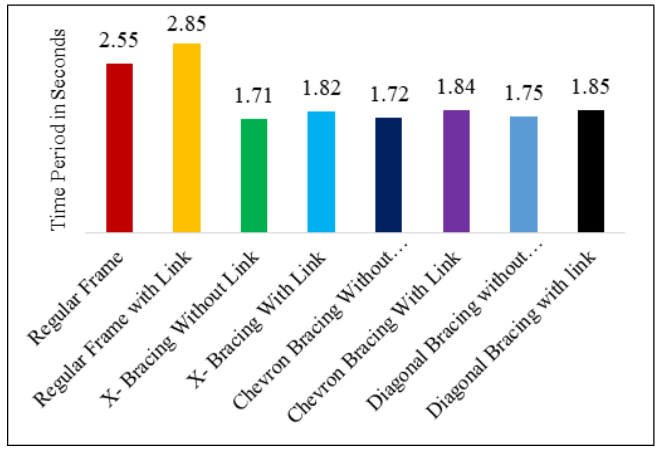

FIGURE 6
TIME PERIOD COMPARISON OF STRUCTURES WITH BRACING IN SURFACE FRAME

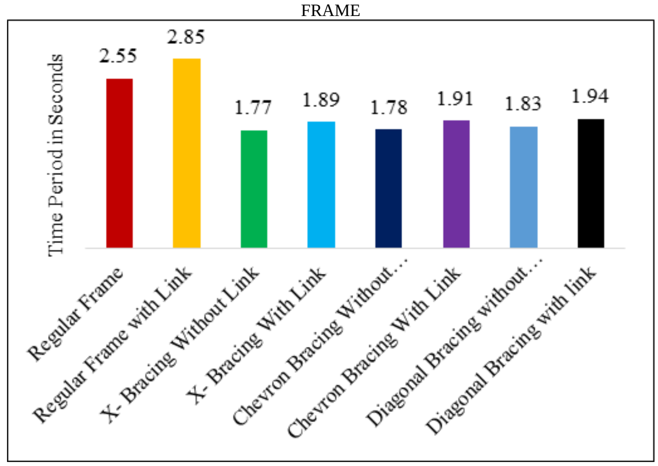

FIGURE 7
TIME PERIOD COMPARISON OF STRUCTURES WITH BRACING AT CORNER FRAME

Presence of replaceable link in regular framed structure has increased the time period by 11.7%, where as in case of braced struucture time period has increased by 5% to 7%. There is a less than 1% variation in the time period of X-braced and Chevron braced structure in all the configurations.

III. Comparison of Combined Bending and Axial Stress

Combined bending and axial Stress is the normal stress induced in the sections due to the applied load. This section presents the variation of combined bending and axial stress in the column of the selected frame after providing the replaceable link for same configuration. Frame highlighted in Figure 8 of the structure been considered for the comparison of stresses for all parameters. Variation of combined bending and axial stress for all configurations are given in Figure 9.

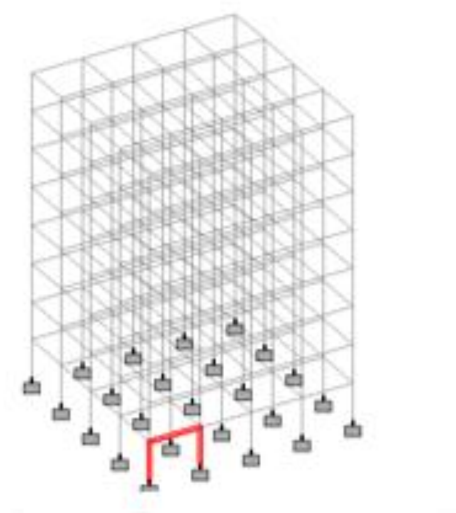

FIGURE 8
FRAME SELECTED FOR COMPARIOSN OF STRESS

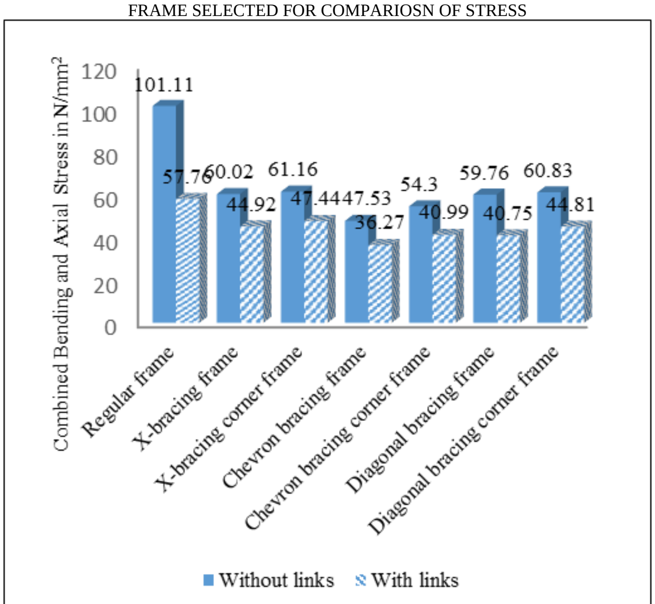

FIGURE 9
VARIATION OF COMBINED BENDING AND AXIAL STRESS IN COLUMN OF SELECTED FRAME

Figure 9 give the details of variation of combined bending and axial Stress developed in column of the selected frames of all structures with and without replaceable links. Steel structure with replaceable links shows the minimum stress compared to the structure without links because replaceable link acts as weak zone in the structure, stress will get concentrated at the weaker zone and relieves the other components from the stress.

From Figure 9 it can be observed that, Presence of replaceable links in regular framed structure reduces the stress in column maximum by 42.8%. Presence of replaceable link in X-braced frame reduced the column stress by 25%. Whereas in other configurations column stress is reduced by 20% to 25%. Maximum reduction in the column stress has been observed in case of regular frame.

CONCLUSIONS

Presence of replaceable link has improved the seismic performance of framed structure. In case of regular framed steel structure peak displacement has reduced by 51.01% after providing replaceable links in the beams of framed structure. Presence of replaceable links in regular framed structure reduces the combined axial and bending stress by 42.8%. On providing replaceable links in the braces of structure, peak displacement has been reduced by 40% and combined stress in column by 20% to 25%. Replaceable links have induced flexibility to the structure thus leads to increase in time period of the structure.

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