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Seismic Rehabilitation By Steel Jacketing Method Affected By Different Base Support Conditions Using Pushover Analysis

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ABSTRACT: *Rehabilitation of vulnerable existing structures against earthquakes is essential. Structures need to be retrofitted for a variety of reasons, such as change of use, structural elements corrosion, design code changes, and the lack of match between the computational results and construction. One of the most common and economical ways of retrofitting structures in developing countries such as Iran is the steel jacketing method which increases the stiffness and strength of structural elements. In this paper, first the seismic vulnerability of a three-dimensional four-story residential building was proved and then the effect of base support conditions on structural retrofitting by steel jacketing method was studied using pushover analysis. It was observed that the behavior of the retrofitted structures depends on their base support conditions. According to pushover curves, the retrofitted structures with pinned and fixed base support conditions showed similar behavior in the linear zone and presented a different behavior in terms of stiffness and ductility in the nonlinear region.*

KEYWORDS: *pushover analysis, seismic rehabilitation, steel structures*

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I INTRODUCTION

Alcocer and Jirsa (1993) stated that seismic rehabilitation is a suitable way to increase people's safety and to protect their investments in vulnerable structures [1]. To obtain this goal, various investigations have been carried out by researchers, but most of them are focused on retrofitting reinforced concrete structures. Sheykh (1994) studied a method for obtaining the amount of confined steel for rectangular columns [2]. Migliacci et al. (1983) studied a way to increase the strength and energy absorption of retrofitted connections by a closed steel frame at the corners of the column by pre-stressed straps [3]. A model was provided by Corazao and Durrani (1989) to increase the stiffness, strength, and ductility of the beam-to-column connections by confined concrete jacketing surrounded by steel plates [4]. Hoffschild et al. (1993) studied another method which was using a grouted circular steel jacket to increase the cross-sectional moment capacity [5].

Pushover analysis was utilized to rehabilitate considered structure by steel jacketing method. In the pushover analysis, the structure is subjected to a specific lateral load pattern. In this type of analysis, the criterion is the amount of displacement of the structure, so the force increases to a point that the desired displacement is provided. Although nonlinear time history analysis is more accurate than the pushover analysis and Ali Vatanshenas's (2017) study showed that by time history analysis it is possible to determine the directivity effect of the earthquake on the structure [6], pushover analysis was used. The pushover analysis has various merits such that the pushover analysis provides the nonlinear responses quickly with low computational complexity and also there is no response dispersion in this analysis and no complicated interpretation in this type of analysis. In the pushover analysis by applying a predetermined displacement all structural responses to different displacements are analyzed within that range. Krawinkler and Seneviratna (1997) mentioned that with pushover analysis it is possible to estimate the deformation demands for the components that do not have a brittle behavior and should absorb energy by plastic deformation [7], moreover forcing a structure to apply the desired behavior by the lateral load pattern is a unique feature that can be accomplished through the pushover analysis.

II STRUCTURAL VULNERABILITY ASSESSMENT

The considered structure in this study should provide the life safety level of performance under the influence of the design base earthquake so that the failure occurs in the structure due to the earthquake but the extent of the failure should not menace the life safety of occupants. Skokan and Hart (2000) mentioned that considering the seismic demand assessment of low and medium height structures has a higher accuracy [8]. in this paper a three-dimensional four-story steel structure with a concentrically braced frame system that has residential use is considered. Before starting the rehabilitation by steel jacketing method, structural vulnerability must be proven. The main components of the studied structure i.e. the elements that resist the earthquake force in order to achieve the desired level of performance are braces and columns beside the braces in which the axial compressive and tensile forces were created. As shown in Fig.1 a hypothetical lateral static force was applied to the structure to determine these main components of the structure.

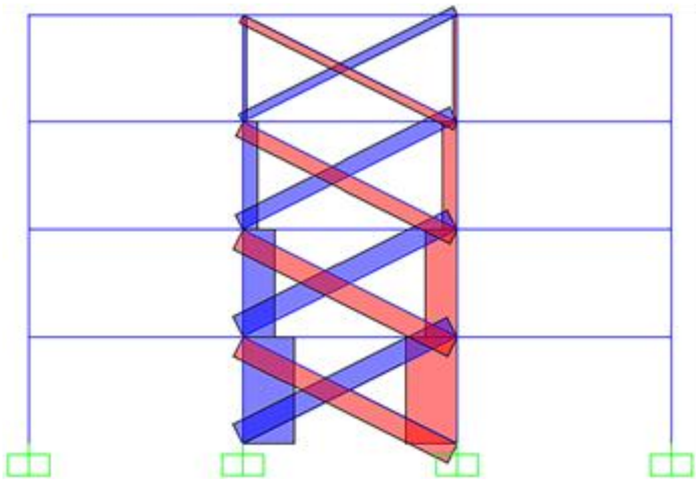

Fig. 1: The main components of considered structure was determined by a hypothetical lateral static force

For investigating the vulnerability of the considered structure following assumptions were considered: the monitor point was selected as the center of the mass of the roof, the lateral load pattern was determined according to the first mode of the structure. The amount of target displacement is obtained by Equation (1) based on Fema (2005) [9] where C_0 is the correction coefficient for the spectral displacement of one degree of freedom system to the roof displacement of several degrees of freedom, C_1 is the correction coefficient to apply system's inelastic displacement, C_2 is the correction coefficient for the effects of reduction of stiffness and structural members strength, C_3 is the correction coefficient to show the displacement of the P-Δ effect, S_a is the spectral acceleration and T_e is the effective period obtained by Equation (2) based on Fema (2005) [9] Where Ki and K_e are obtained by the pushover diagram shown in Fig.2 and T_i is the initial period. After investigating the analysis results of the studied structure, it was illustrated in Fig.3 that the structure in both directions of X and Y needs to be retrofitted.

$$\delta_t = C_0 C_1 C_2 C_3 S_a (T_e^2/4\Pi^2)\, g \quad (1)$$

$$T_e = \sqrt{(K_i/K_e)}\, T_i \quad (2)$$

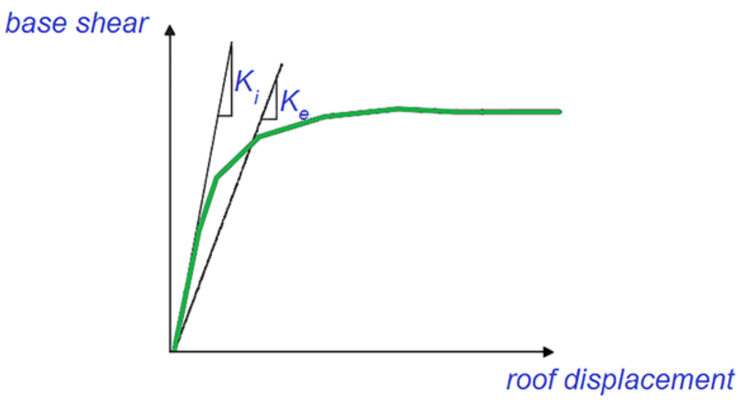

Fig. 2: The K_i and K_e parameters in the pushover diagram

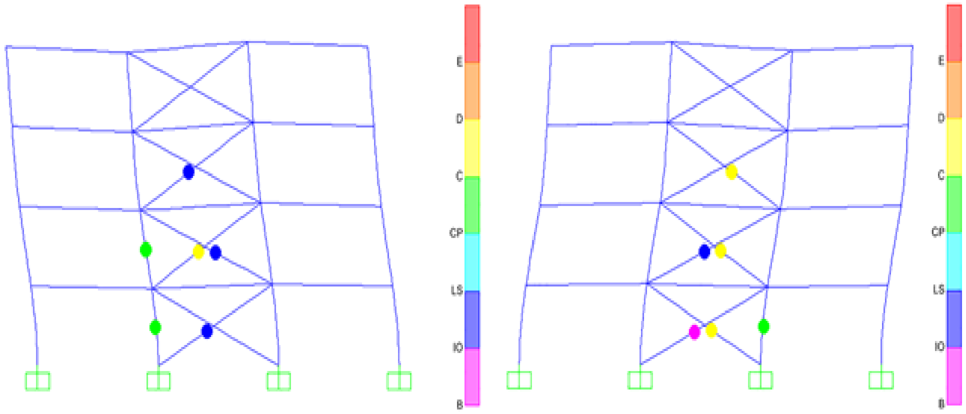

Fig. 3: The structure in both X and Y directions needs to be retrofitted

III SEISMIC REHABILITATION BY STEEL JACKETING METHOD

Seismic rehabilitation goal is balancing the structure's demand and capacity; therefore, the structure's demand should be reduced or its capacity should be increased for rehabilitation. When rehabilitation is carried out by increasing the structural capacity, it is referred to as retrofitting. As shown in Fig.4 one of the most common methods of retrofitting is the use of steel jacketing method in which the vulnerable section is retrofitted by increasing strength and stiffness. After retrofitting the vulnerable columns by steel jacketing method no plastic hinge was created in any column even though the hinges created in the braces went beyond the life safety performance level. However, in the case of the concentrically braced frame, the strip colors that are shown in Fig.5 and Fig.6 are not a valid criterion for the acceptability of the braces and their acceptable displacements should be checked based on their acceptance criteria at the life safety performance level for all created hinges. It was observed that all hinges created in braces provided the desired performance level.

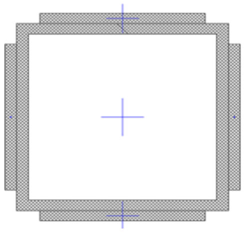

Fig. 4: A retrofitted element with added steel plates surround it

The impact of the steel jacketing method was considered in two modes. The first mode is shown in Fig.5 when the structure connection to the foundation is assumed to be completely rigid and the other case is shown in Fig.6 when the structure connection to the foundation is assumed to be pinned. The created hinges, in the last step of pushover analysis of the retrofitted structures were dependent on the base supporting conditions and in the retrofitted structure with pinned support conditions, the hinges created on the first floor had a more critical condition than the second floor while the opposite was observed in the structure with rigid support conditions.

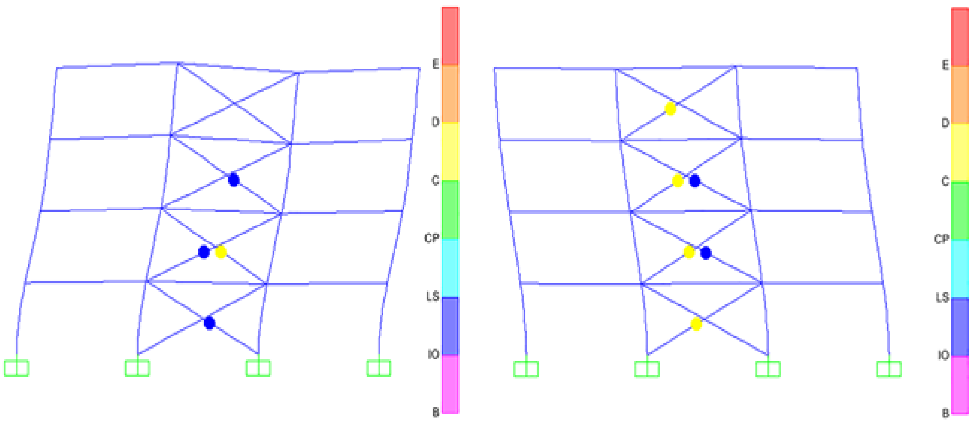

Fig. 5: Hinges created in the structure with rigid support after rehabilitation by steel jacketing method

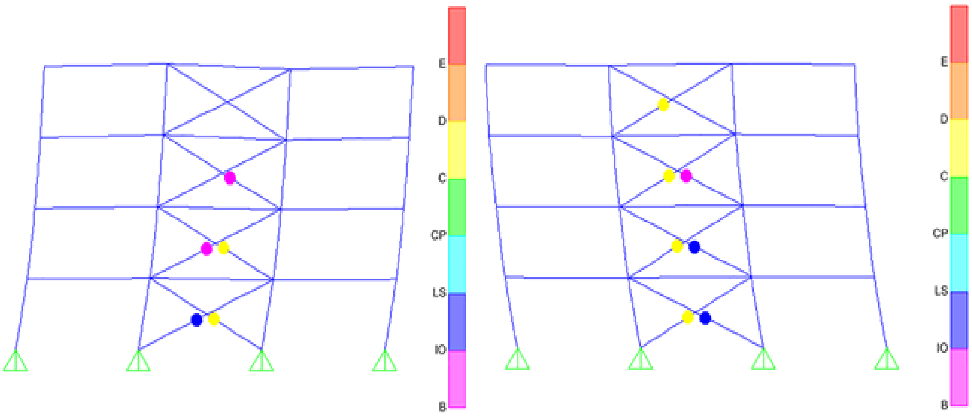

Fig. 6: Hinges created in the structure with pinned support after rehabilitation by steel jacketing method

IV COMPARISON OF OBTAINED PUSHOVER DIAGRAMS

The total capacity of the structure was indicated by the base shear-roof displacement diagrams. The results obtained from the pushover diagrams of the non-retrofitted and retrofitted structures by steel jacketing method with rigid and pinned support conditions were compared according to the Fema (2005) [9]. As shown in Fig.7 and Fig.8 It was observed that the retrofitted structures by steel jacketing method had higher slope in the linear region which means that the retrofitted structures by steel jacketing method were stiffer than the non-retrofitted structure and the slope of the linear region in the case that the retrofitted structure had the rigid support conditions was not different with the case that the support conditions were pinned thus they have equal stiffness. In the obtained diagrams, retrofitted structures showed more brittle behavior than the base structure and the non-retrofitted structures showed more ductile behavior because of the greater distance between their yield and final displacements. It was observed that along Y direction which structures had less stiffness than the X direction, the retrofitted structure with pinned support conditions showed better ductility. It was also observed that in the nonlinear region the stiffness of the retrofitted structure with rigid support conditions was more than the structure with pinned support conditions.

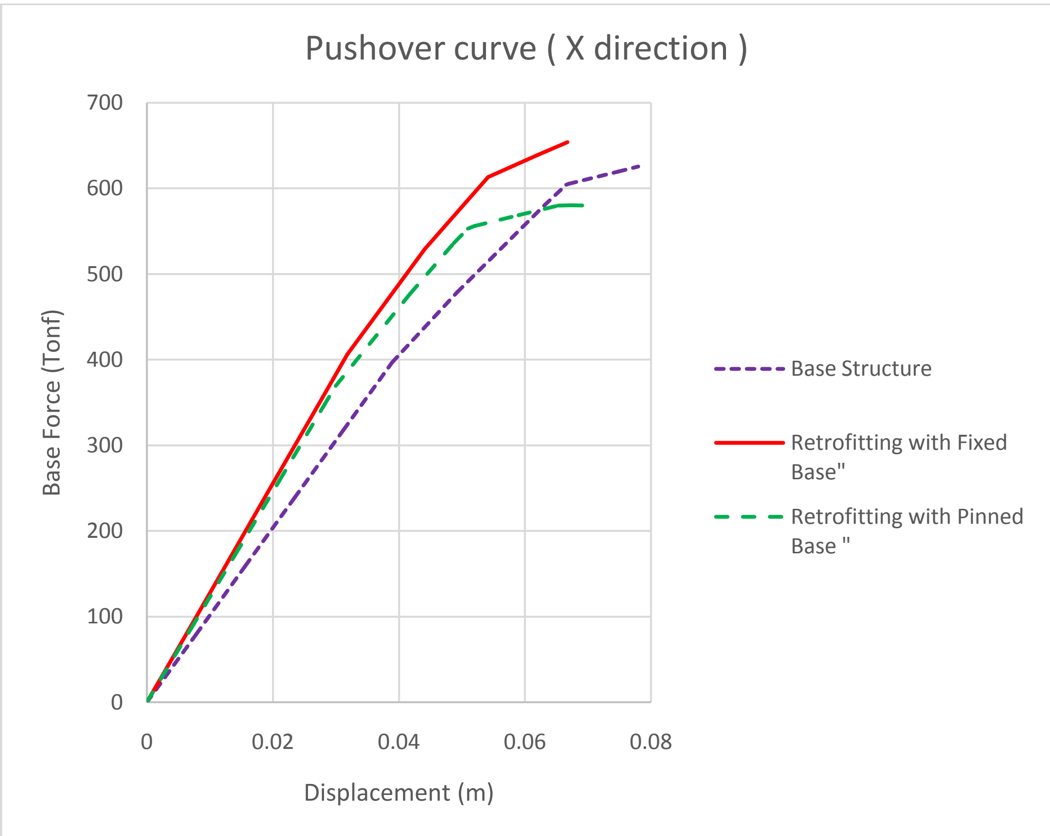

Fig. 7: Pushover diagrams of the base and retrofitted structures in X direction

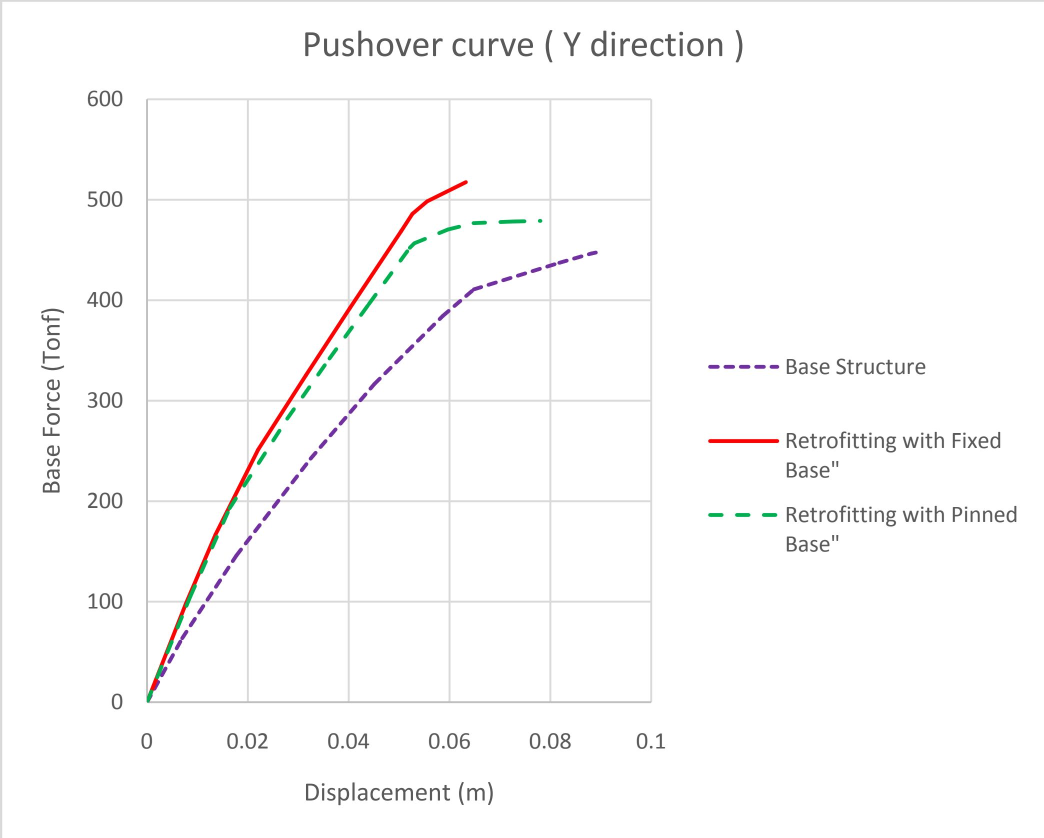

Fig. 8: Pushover diagrams of the base and retrofitted structures in Y direction

V CONCLUSION

It was observed that in the case that the structure had pinned support conditions, the hinges created on the first floor were more critical than the second floor while the opposite was observed in the structure with the rigid support conditions. After reviewing the pushover diagrams it was observed that the retrofitted structures behaved stiffer than the base structure and there was no significant difference between the stiffness of the two retrofitted structures in the linear region but in the nonlinear region the structure retrofitted with the rigid support conditions behaved stiffer than the one retrofitted with the pinned support conditions.

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