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ORIGINAL ARTICLE

Comparison of Dual System of Steel Moment frame and Thin steel Plate shear walls with Dual system of Steel moment frame and cross Bracing or Chevron with a Design Method based on Performance levels

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ABSTRACT
Various systems are applied to counteract lateral forces and especially the earthquake force, including: dual systems that include combined system of moment frame and other resistant systems. In 2800 code system, dual systems of steel moment frame include moment frame and the variety of braces and steel shear wall 4 is not mentioned. Only in the code system of the law of Canada (CAS, 1994) a part is explicitly assigned to this element bearing. Recently, among the methods for designing structures against earthquakes, method of "design based on performance levels" is taken into consideration, due to taking the inelastic behaviour of structures in the instruction of FEMA274, FEMA273, and ATC40 into account. In this paper, dual systems including intermediate moment frames and thin steel moment frame and intermediate moment frame and convergent braces are used in different frames and performance point of them is obtained using Capacity spectrum method and is compared to each other. Also coefficient of thin steel shear walls and the rate of energy loss of the dual systems are investigated. Soft-waresSAP2000 and ANSYS are used for modeling and analysis.
Keywords: Thin steel plate shear wall, Design based on performance levels, Capacity spectrum method, Convergent braces.

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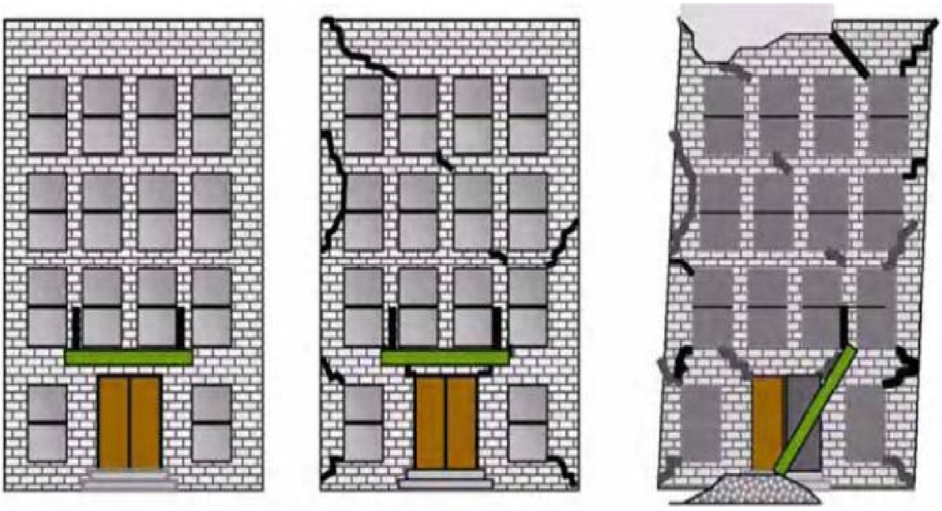
INTRODUCTION

Iran is among the countries that have seen so many lives and the financial losses in the earthquake, therefore noticing seismic resistant systems seem essential. In the steel buildings, moment frame system seems an appropriate system due to good ductility and possibility of high dissipation of earthquake energy. The main problem of this system is in lateral displacement and in other words in lack of sufficient hardness. To solve this problem, idea of using dual systems including steel moment frame and another resistant system that actually is the complementary of this resolute system of the problem of replacement of moment frame came to mind. Complementary system of moment frame in dual systems in Iran is converging and non-converging braces. Converged braces generally include cross and chevron (vestibule) braces. In recent years, in many countries another new system called thin steel moment frame shear walls is also used as complementary of moment frame in dual systems. This new system is been well-received due to the speed of implementation and economic cost, but in our country it's been rarely used because of lack of knowledge and lack of adequate regulations of the country rather than other countries. In this paper, we try to compare a design method based on performance levels, which is a new and efficient way about the non-linear behavior of structures, between complementary systems for intermediate moment frames, i.e. the thin steel shear walls and converging braces. For comparison, 5 frames of different spans and heights have been considered and the performance point of these frames is calculated using capacity spectrums, also the rate of energy dissipation and coefficient of behavior of intermediate steel moment frame dual system and thin steel plate shear wall is calculated.

Design method based on performance levels

Design method based on resistance doesn't make an appropriate response in many cases because of the structural elements of the resistivity parameter. In this method possibility of accurate assessment of structures based on their expected performance doesn't occur. For this reason, in recent years performance-based design approach and focus on the issue of performance instead of issue of resistance has been considered. This new design method, specifies three main levels of performance for structural members (figure (1))[2]. In this method, due to the expected performance level, point of performance is determined. To determine the performance point, different methods have been mentioned in regulations that the most important methods among them are capacity spectrum and methods and displacement coefficients. Capacity spectrum method that is been used in this paper, is provided by ATC institution of America in magazine number 40 [3]. In this method collision point of structural capacity spectrum and decreased seismic demand spectrum is presented as performance point of the structure.



Uninterrupted use Johnny safety and Verge of collapse

Figure 1- structural performance levels

To obtain the capacity spectrum, that is in fact curve of load - displacement structures, some analysis are performed. The mathematical model of the structure in each stage is modified in such a way that reduction of resistances due to plastic hinge formation is considered. This process will continue till the time that structure reaches a predetermined limit. The demand spectrum is the very same design spectrum of regulation that its value decreases in the non-linear area due to the increase in the effective damping of the structure. Accordingly ATC-40 magazine presents, depending on the amount of entrance of the structure in non-linear area, the reduction coefficients for areas of constant acceleration and velocity spectra as follows:

$$SR_A = \frac{3.21 - .68Ln(\beta_{eff})}{2.12}$$

$$SR_V = \frac{2.31 - .41Ln(\beta_{eff})}{1.65}$$

$$\beta_{eff} = \beta_0 + 5$$

$\beta_{eff}\beta_{eff}$ =Effective damping

β_0 =Equivalent viscous damping due to hysteretic behavior of structures

It should be noted that in this method both demand and capacity spectrum should turn into graph S_a against (ADRS)S_d. Considering that the effective damping capacity of points on the spectrum is different, therefore reduction factor of demand spectrum for different points would also be different, for this reason obtaining the performance point of structure is an iterative procedure and is combined with trial and error. In the case that this method is used to obtain seismic parameters, performance point is specific and is in fact the very same point of demolition point of structure with maintaining the margin of safety. In ATC-40 the maximum allowable lateral displacement to meet life safety codes that are the same as the buildings of average importance in 2008 regulations, 0.02 is the height of the structure.

Thin steel plate shear wall

Steel plate shear walls are an innovative system resistant to wind and seismic lateral loads. As shown in Figure (2), the system includes a series of panels, Each panel is surrounded by the two beams and columns and a steel plate attached to the environmental elements. This type of establishment, makes the steel plate shear walls similar to a beam of tress sheet that columns are supposed to be its wings, beams its vertical stiffening and the sheet its life or spirit [4]. (Figure (3))

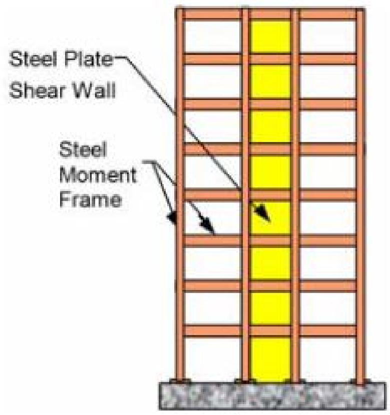


Figure 2- Environmental shear walls and steel moment frame

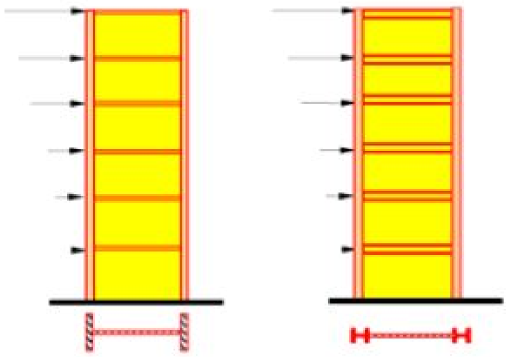


Figure 3- Steel shear wall on the right hand side and beam sheets on the left hand side

The basis of the idea of thin shear walls that has been seriously considered in the last 15 years, is using diagonal tension field that is created after buckling of the steel plate. This meta-buckling strength of thin steel sheets applied to dissipation of a lot of seismic energy. However, condition of the creation of this tension field is that the plate should be reinforced well enough in boundaries that in this case post-buckling strength would be several times more than buckling strength [5].

Introducing case study frames

In this paper, as shown in Figures (4),(5) and (6), 15 frames with dual intermediate moment frame system and cross bracing or chevron or thin steel shear walls have been investigated. An equal element among complementary systems is weight, in other words, cross and chevron braces and the steel shear walls are in the same weight.

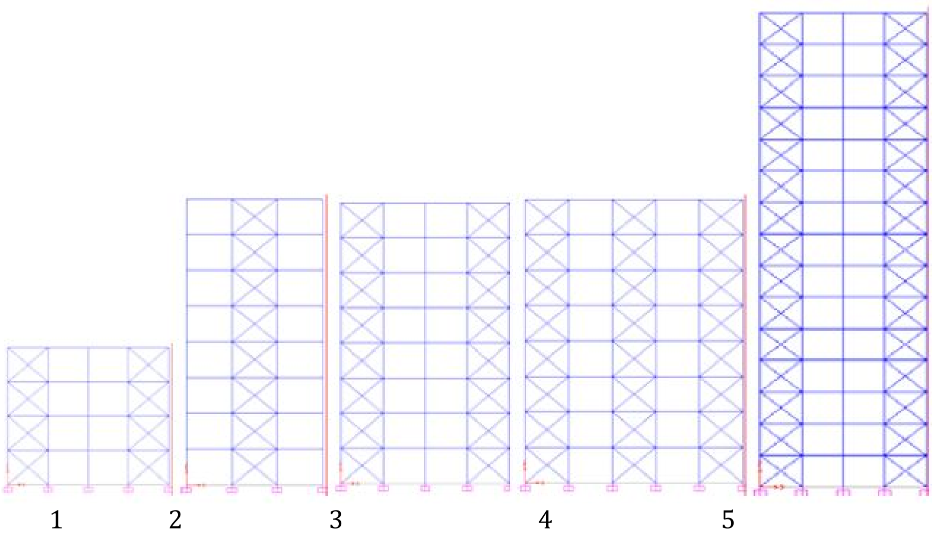


Figure 4- Frames with dual systems with intermediate moment frame and cross bracing

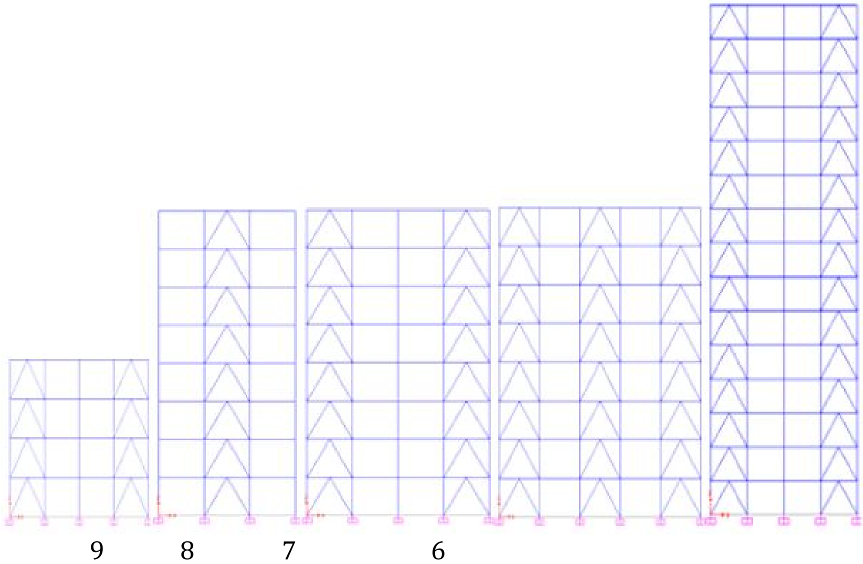


Figure 5- Frames with dual systems with intermediate moment frame and chevron bracing

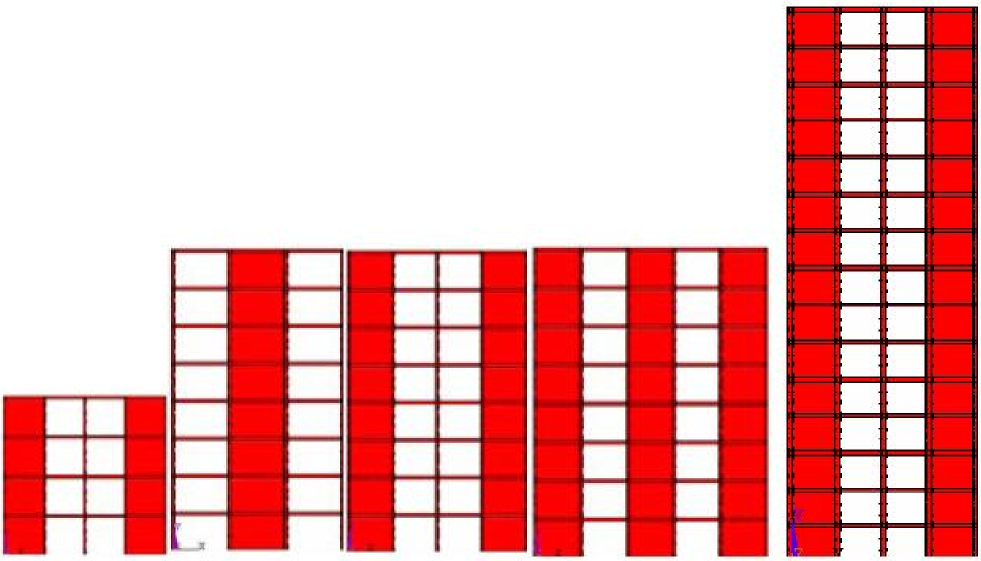


Figure 6- Frames with dual systems with intermediate moment frame and thin steel shear wall

Frames belong to the buildings with residential use and the same spans of 4 meters and 3 meters in the height of floors. The position of the area's buildings is of high risk and with Type 2 soil. Type of the roof, considered beam block and the floors dead and live loads are respectively calculated 600 and 200 Kilogram per Meter Square. For columns IPB sections and for beams IPE and for braces the double studs sections are used. All of the columns and beams and braces of the one floor are a type; in addition each 3 floors in height are a type (except for the frames of four floors, that each two floors are type).

Determination of the performance point of the frames

Frames with dual intermediate moment frame system and thin steel plate shear wall with the finite element software ANSYS 5.4 and frames with dual intermediate moment frame system and converged bracings with SAP2000 software are molded and analyzed and the base shear curve is obtained according to roof displacement then using program written in EXELL performance point is calculated. For example the performance point that is the confluence of capacity spectrum and demand spectrum in ADRS format, for frames 5, 10 and 15 are shown in Figure (7).

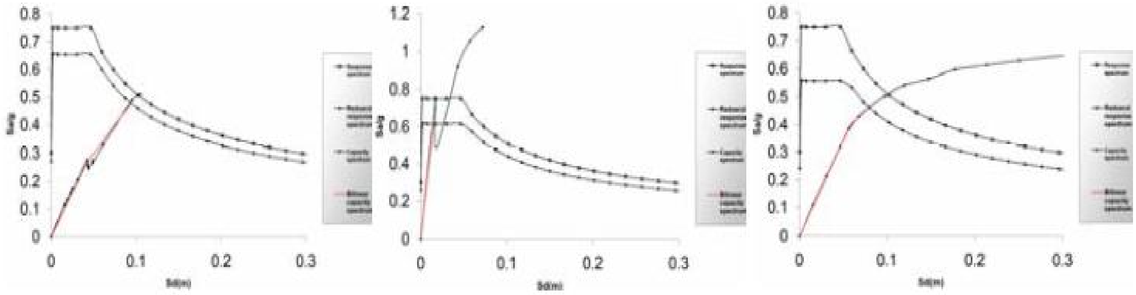


Figure 7- performance point of frame 15 (in the right hand side), frame 10 (in the middle) and frame 5 (in the left hand side)

Displacement and base shear like performance point for the studied frames are in the table (1):

Table 1- Displacement and base shear like performance point for the studied frames (displacement is per cm and base shear is per ton)

Number of the frame	Displacement of roof	Base shear	Number of the frame	Displacement of roof	Base shear	Number of the frame	Displacement of roof	Base shear
1	-	-	6	-	-	11	37.04	115.81
2	-	-	7	-	-	12	17.54	128.36
3	13.17	124.4	8	10.1	100.9	13	19.11	97.47
4	19.4	85.25	9	13.3	72.6	14	22.13	61.48
5	2.62	69.1	10	2.18	78.5	15	8.9	57.05

Spaces in the table indicate that curve of capacity spectrum and demand spectrum is not cut. As it can be observed, frames 1, 2, 6 and 7 are not suitable dual systems. All numbers relating to the lateral displacement, satisfy the condition of .02H corresponding to ATC-40 in the case of residential buildings.

The rate of energy dissipation

As we know work or energy is equal to the area under the graph of load-displacement. In designing of the buildings against earthquake if the building prior to demolition dissipated more energy, it would be structurally more ductile and more popular. Steel moment frame alone is one of good systems for dissipation of seismic energy. In this study, by investigating the capacity curve of the studied frames, we calculate the rate of energy dissipation of these frames and determine the complementary system that dissipates more energy. For better comparison between dual systems as it can be seen in Figure (8), column chart is used.

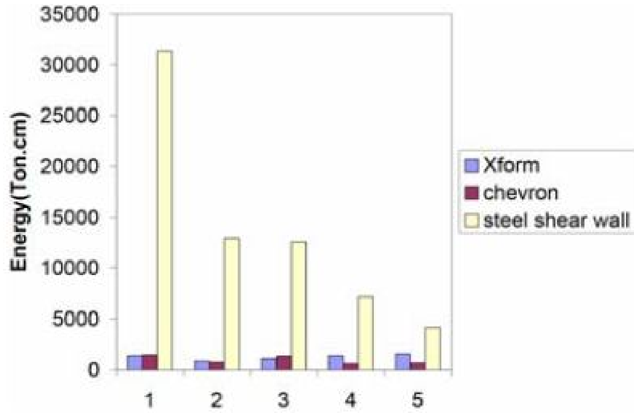


Figure 8-The rate of energy dissipation (1: frames 1, 6, 11- 2: frames 2, 7, 12- 3: frames 3, 8, 13- 4: frames 4, 9, and 14- 5: frames 5, 10, 15)

Coefficient of intermediate moment frame system and thin steel shear wall

Closest type of analysis to the actual behavior of structures in earthquake is the nonlinear dynamic analysis, but because it is time consuming, designers usually try to use simpler methods to analyze. One of these methods is linear static analysis and considering coefficient of behavior. Coefficient of behavior somehow equivalents the nonlinear behavior of the structure [6].There are two methods for determining the coefficient of behavior: 1- Ductility coefficient of Yang method [7] 2- capacity spectrum method of Freeman. That the first method is used in this paper.

Ductility coefficient of Yang method

The general behavior of a structure is shown in the form of horizontal curve base shear and displacement in Figure (9).

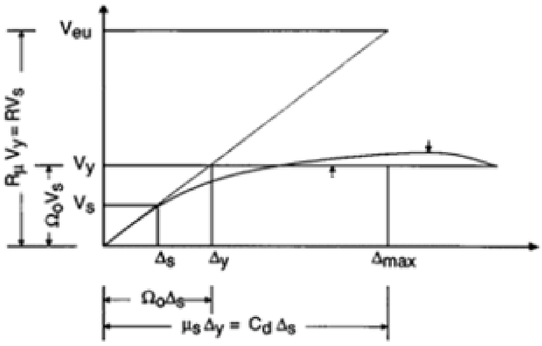


Figure 9- curve of the real and ideal capacity.

In this Figure, the curve is clear by actual behaviour and the two ideal linear behaviours. Vertical and horizontal axes in this Figure, respectively, represent that base shear and displacement of structure is total or partial of structure's floors. To determine the coefficients of the equations we use the following:

$$R = R\mu \times \Omega_0 \times \gamma$$

$$\Omega_0 = \frac{Y_y}{Y_s}$$

$$\mu_s = \frac{\Delta_{max}}{\Delta_y}$$

In equation (4), R_μ is called reduction coefficient due to ductility and is calculated by μ_s that is called coefficient of structural ductility. γ (coefficient of allowable stress) in most of regulations is proposed to be 1.4 and Ω_0 is the reduction coefficient due to the added resistance. For obtaining $R_\mu$by μ_s, and according to equation (7) that is recommended for sedimentary lands, we use the method of Miranda [8].

$$R_\mu = \frac{\mu_s - 1}{\varphi} + 1 \leq \mu_s$$

$$\varphi = 1 + \frac{1}{12T - \mu T} - \frac{2}{5T} \exp\left[-2(lnT - 0.2)^2\right]$$

In the equations above considering T that is the main period of construction, answers closer to the reality are expected. According to capacity curve and above formulas obtained coefficient of behavior for dual intermediate moment frame system and thin steel shear wall is calculated and mentioned in Table (2).

Table 2- behavior coefficient of dual intermediate moment frame system and thin steel shear wall

Number of frame	11	12	13	14	15
Behavior coefficient	8.88	8.29	9.53	10.52	6.53

CONCLUSION

Acceding to performance point, using dual system of moment frame and thin steel shear wall for medium and high buildings is more suitable than dual system of moment frame and converging bracings.

Using dual system of moment frame and cross bracings seems more suitable than dual system of moment frame and chevron bracings, because chevron bracings increase the possibility of making plastic hinge in the column and consequently the possibility of brittle fracture.

Rate of energy dissipation in dual system of moment frame and thin steel shear wall is more than in dual system of moment frame and converging bracings. So this relates to extension of plastic hinge area in steel shear wall and in other words its high uncertainty towards the converging bracings.

The obtained behavior coefficient of intermediate dual system of moment frame and steel shear wall for short buildings is less than behavior coefficient contained in 2800 regulation for intermediate dual system of moment frame and cross bracings (7) but for the high and medium buildings this coefficient is obtained with a larger number than the behavior coefficient of 2800 regulation for intermediate dual system of moment frame and cross bracings (7).

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