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Structural Analysis and Design of a 30-Story Tower with Friction Dampers

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Abstract

In the last few decades the wide of usage of the deformable system or dampers increase significantly. Dampers are the elements that reduce the vibration of the lateral load which are caused by earthquake or wind. Dampers play the vital role to decrease the absorption of the lateral load.[1] this paper have compered the results of technical and economical of the 30-story steel structure with two options including, special moment frames (SMF) plus friction dampers, and special moment frames without using of dampers. This two structure classified with 26-story above the ground and 4-story underground. Shear walls have been implemented its 4-story of basemen. In addition, soil behind the shear walls has been compacted.

Keywords: Friction damper; Steel moment frame; Elastic hinges;

1. INTRODUCTION

Due to the fact that, earthquake cause the structure's elements deformation. Mild earthquakes causes a little deformation and the structure's elements remain in elastic zone. Nevertheless, severe earthquake causes too much structural responses and deformation elements, therefor sudden failure happen. Consequently, using of energy dissipation system reduces the dynamic response of structure as much as possible [1].

This 30-story structure designed by braced bent system five years ago. But just 4-story of the basement constructed. Due to the fact that building code changing every years this structures need to renewed control. Research findings confirm that, this structures need other system to reduce internal load, improve operation and cost of construction.

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2. Situation of 4-story underground its structure

2.1. Columns

2.1.1. Geometric proportions

Table 1 illustrated criteria column width to thickness with two new and previous building code. Research findings confirm that, section A is appropriate compared with two building code. Nonetheless, other sections are not suitable by new building code. 4-story underground's column are made under base level. Therefore, they do not operate in plastic hinge zone. Owing to this recommendation's new building code we can regardless criterion width to thickness for its 4-story underground.

2.1.2. Strength

Structure analysis has shown that, the columns stress ratio of 4-story underground including structure with damper and structure without damper is less than one, As result of which this value is appropriate for forces applied to structure [9].

2.2. Beams

2.2.1. Geometric proportions

Table 1 shows that, B-20 beams are not suitable for criterion width to thickness. Consequently, structures need to further strengthen of mentioned beams. Structure analysis have shown that, although B-23 beams was not suitable in terms of seismic, this won't cause serious problem.

2.2.2. Strength

Result have shown that, some of beams are needed to further strengthening

3. Analysis and design of 30-storey tower

Three-dimensional computer was used, gravity and lateral loads considered by the last edition of building code. Both analysis of sections and structural controls take into account by building frame and friction damper. Structure loud considered by 0.045 base shear compared with previously design that it was 0.035. As a result of which 30 percent structure load increased. The amount of dead load was conservative so it was corrected by new building code, and the Live load increased in new building code.

Seismic hazard analysis and acceleration spectrum used by Iranian 2800 Code.

Table1: The criterion width to thickness in columns

Section	Depth	ThickTop	d/t	d/t Limit-1387	d/t Limit-1392	Status-1387	Status-1392
A	74.50	4.50	16.56	19.22	17.74	O.K	O.K
B	74.50	4.00	18.63	19.22	17.74	O.K	Not O.K
E	50.00	2.50	20.00	19.22	17.74	Not O.K	Not O.K
M	40.00	1.50	26.67	19.22	17.74	Not O.K	Not O.K
N	30.00	1.50	20.00	19.22	17.74	Not O.K	Not O.K

Table2: The criterion width to thickness in beams

SectionName	Depth	WidthTop	ThickTop	WebThick	d/t	d/t Limit	Status	b/2t	b/2t Limit	Status
B-1	57	30	3.5	1.5	33.33	72.4	O.K	4.29	8.87	O.K
B-2	56	30	3	1.5	33.33	72.4	O.K	5.00	8.87	O.K
B-3	56	25	3	1.2	41.67	72.4	O.K	4.17	8.87	O.K
B-7	51	25	3	1.2	37.50	72.4	O.K	4.17	8.87	O.K
B-8	47	20	2	1	43.00	72.4	O.K	5.00	8.87	O.K
B-11	45	25	2.5	1.2	33.33	72.4	O.K	5.00	8.87	O.K
B-12	44	20	2	1	40.00	72.4	O.K	5.00	8.87	O.K
B-14	34	20	2	1	30.00	72.4	O.K	5.00	8.87	O.K
B-15	33	15	1.5	0.8	37.50	72.4	O.K	5.00	8.87	O.K
B-17	55	25	2.5	1.2	41.67	72.4	O.K	5.00	8.87	O.K
B-18	43	25	1.5	1	40.00	72.4	O.K	8.33	8.87	O.K
B-19	43	20	1.5	0.8	50.00	72.4	O.K	6.67	8.87	O.K
B-20	42	20	1	0.8	50.00	72.4	O.K	10.00	8.87	Not O.K
B-21	42	15	1	0.8	50.00	72.4	O.K	7.50	8.87	O.K
B-22	42	20	1.2	0.8	49.50	72.4	O.K	8.33	8.87	O.K
B-23	32	20	1	0.8	37.50	72.4	O.K	10.00	8.87	Not O.K
B-24	32	15	1	0.8	37.50	72.4	O.K	7.50	8.87	O.K

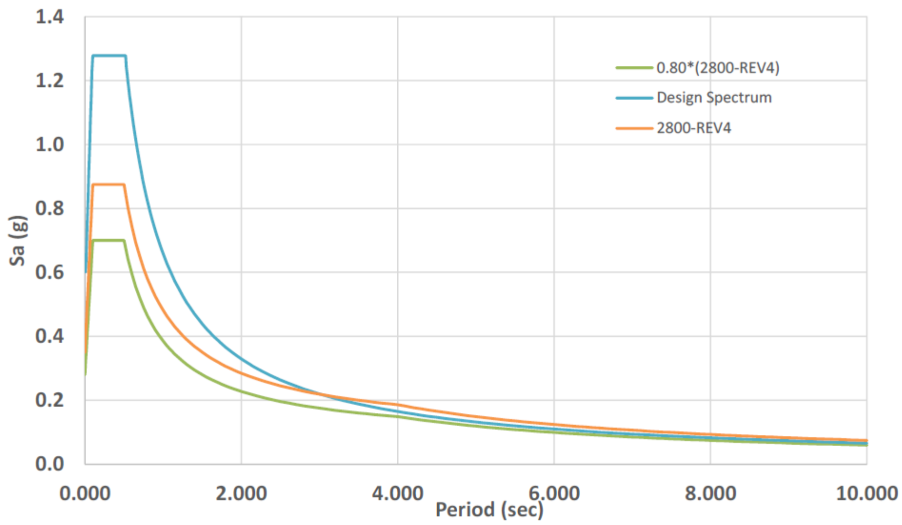

Fig.1 The horizontal acceleration spectrum, 475-year return period

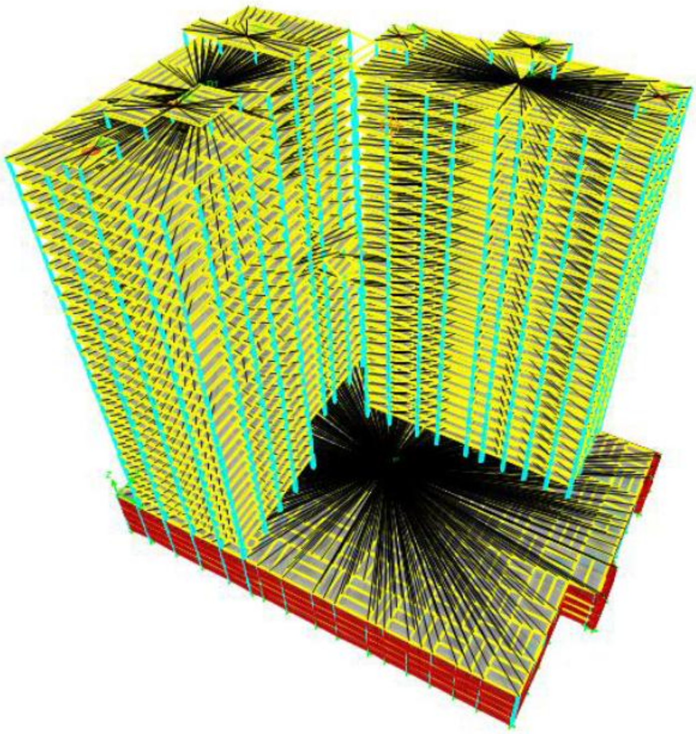

Fig.2 Three-dimensional of tower

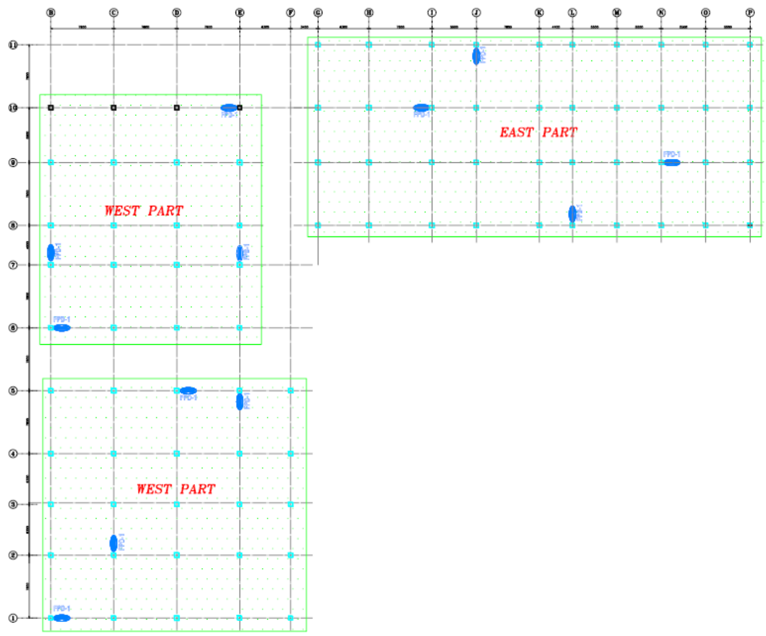

Fig.3 Plan and location of dampers

3.1. Geometric characteristic of 30-story tower

Figure below shows Three-dimensional of tower, plan and location of damper. Structure of steel for 4-story underground is ST-37 with ultimate strength F_u=3700 kg/cm^{2}and minimum yield stress F_y=2400 kg/cm^{2}another column 26-story above ground are steel type ST-52 with ultimate strength F_u=5200 kg/cm^2 and minimum yield stress F_y=3600 kg/cm^2.

3.2. Technical specification of dampers and calculation of effective attenuation

Friction damper was used for this structure figure 4. In terms of complexity of structure's architectural style, damper used by gateway's figure. Damper by 600KN capacity used for first 10-storey and 500KN capacity used for other stories of structure.

The amount of damping including, inherent damping, hysteretic damping and damping of damper system. Inherent damping is 5 percent .Effective damping in mth mode of vibration in the desired direction, calculated by the following equation: [2]

$$\beta_{mD} = \beta_1 + \beta_{Vm}\sqrt{\mu_D} + \beta_{HD} \qquad (1)$$

β_1:Inherent damping, β_{Vm}:Viscous damping of the dampers, μ_D:Domain of effective ductility of force-resistance system, β_{HD}:Hysteretic damping of structure.

3.2.1. Hysteretic damping

Hysteretic damping based on testes or analysis, obtain by below relation: [2]

$$\beta_{HD} = q_H(0.64 - \beta_1)\left[1 - \frac{1}{\mu_D}\right] \qquad (2)$$

q_H:Adjustment factor of hysteresis loop, calculate by below relation: [2]

$$0.5 \le q_H = 0.67\frac{T_S}{T_1} \le 1.0 \qquad (3)$$

Ts:Is natural period of vibration that defined by S_{D1}/S_{DS}, T1:The main mode period in the desired direction.

3.2.2. Viscose damping

Viscose damping in mth mode of vibration in the desired direction calculated by: [2]

$$\beta_{Vm} = \frac{\sum_j W_{mj}}{4\pi W_m} \qquad (4)$$

W_{mj}:Related work of jth damper in modal displacement δ_{im}, W_m: maximum strain energy in modal displacement δ_{im} calculated by: [2]

$$W_m = \frac{1}{2}\sum_j F_{im}\,\delta_{im} \qquad (5)$$

Table3: The Capacity and number of dampers in structure

Story	East Part		West Part	
	Number of Dampers	Capacity of Dampers (KN)	Number of Dampers	Capacity of Dampers (KN)
25	4	500	4	500
24	4	500	4	500
23	4	500	4	500
22	4	500	4	500
21	4	500	4	500
20	4	500	4	500
19	4	500	4	500
18	4	500	8	500
17	4	500	8	500
16	4	500	8	500
15	4	500	8	500
14	4	500	8	500
13	4	500	8	500
12	4	500	8	500
11	4	500	8	500
10	4	600	8	600
9	4	600	8	600
8	4	600	8	600
7	4	600	8	600
6	4	600	8	600
5	4	600	8	600
4	4	600	8	600
3	4	600	8	600
2	4	600	8	600
1	4	600	8	600
GR	6	600	8	600

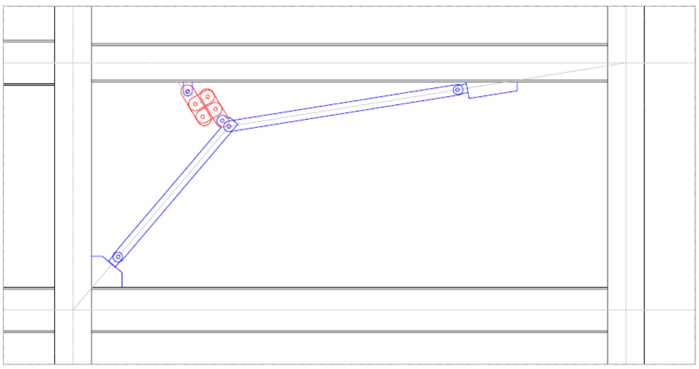

Fig.4 Connecting dampers

Table4: The weight of steel used in the structure

Part	Type	Amount of Steel (TON)	Amount of Steel (Kg/m2)
East Part	SMF	3410	103
	SMF+FD	2867	78
West Part	SMF	4872	116
	SMF+FD	4389	105

SMF: Special Moment Frame

FD: Friction Damper

4. Conclusion

Dampers are the elements that reduce the vibration of the lateral load which are caused by earthquake or wind. In addition, dampers have direct proportion to the reduction of structural response and increase softness and plasticity.

In table 4 compared weight of steel used in the structure for two eastern and western blocks:

It is observed that the used of friction dampers in addition to the optimization of structural design in terms of seismic performance, leads to reduction of structural sections and weight of the structure.

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