3rd Euro Congress on Steel and Structural Engineering
conferenceseries.com
Steel Congress 2017
November 16-17, 2017 London , UK

MODAL DAMPING RATIOS OF LOW RISE STEEL FRAMES WITH SEESAW SYSTEM

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1. Introduction

The seesaw system, originally proposed by Kang and Tagawa [1-3], consists of a pin-supported seesaw, two spiral strand ropes with turnbuckles that intersect from the edges of the seesaw and a couple of dampers installed vertically on the seesaw (Fig.1). Variations of this system regarding its installation type as well as the kind of dampers used (fluid, viscoelastic, slit) can be also found in the literature. For seismic response/design purposes of steel frames with the seesaw system, modal damping ratios have to be computed in order to be applied in the context of the spectrum analysis of seismic codes. This work provides modal damping ratios for some low-rise steel frames equipped with a seesaw system with linear fluid (viscous) dampers.

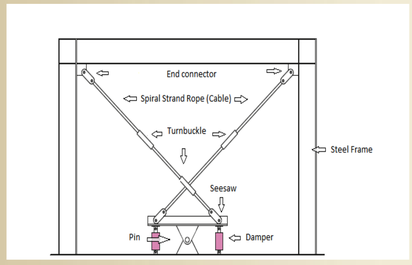


Figure 1 : The seesaw system

2. Methodology

The set of low-rise (one-, three- and six-storey) steel frames studied herein is shown in Fig.2. Each bay has 6.0m span and each storey has 3.0m height. The steel frames have been designed according to Eurocodes 3 and 8 using standard HEA and IPE sections for columns and beams, respectively, and S275 steel grade. The design of spiral strand ropes has been performed according to Eurocode 3-Part 1-11.

The seesaw system has been considered to be in the middle bay (either at the bottom storey or at every storey), whereas the spiral strand ropes (shown with green lines) can be anchored in different beams but at the same floor level. In the steel frames of Fig.2, all columns can be oriented either along their major or along their minor axis. Moreover, the damping coefficient C of the dampers can be 250, 500, 750, 1000 and 1500 kNsec/m. The computation of modal damping ratios is performed employing the numerical damping identification model presented in [4].

3. Results and Conclusions

The modal damping ratios for all cases of steel frames with seesaw system examined herein have been tabulated in Tables 1-3. In these tables NE means that the corresponding mode has not been excited and, thus, damping ratio is not provided for it. From the results of Tables 1-3, it can be concluded that when the seesaw system is installed at the bottom storey of the steel frame and the spiral strand ropes are anchored to the upper left- and right-side of the outer beams, the highest modal damping ratios are attained. Furthermore, the effect of increased damping coefficient is also more pronounced for the aforementioned configuration of the seesaw system.

From the damping results presented in this work as well as from other response results in terms of interstorey drift ratios, residual interstorey drift ratios, peak floor accelerations, column rotations etc. (not shown herein due to space limitations), it can be said that the seesaw system with linear viscous dampers can effectively control the dynamic behavior of low-rise steel frames and significantly reduce their inelastic seismic response.

Nevertheless, this seismic response reduction depends on the properties of the spiral strand ropes (including their prestressing), the type of their end connection (anchorage), the type of viscous dampers used (linear or non-linear) and the height and width of the seesaw. The latter dimensions of the seesaw are directly associated with both the stroke of the damper and the inclination angle of the spiral strand rope.

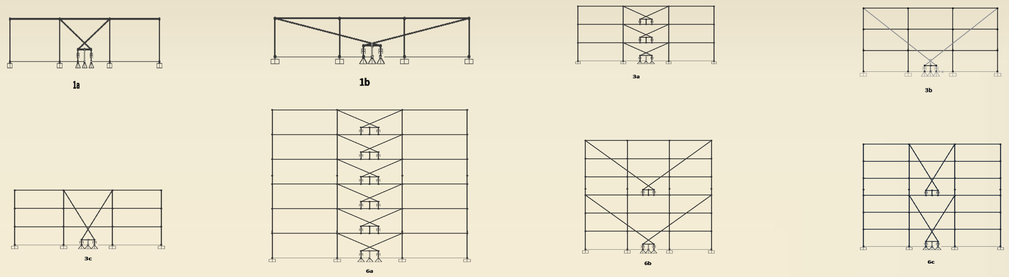


Figure 2 : Steel frames with various configurations of the seesaw system

Frame – Column orientation	Mode 1 – % Damping ratio	
	C = 250 kNsec/m	C = 500 kNsec/m
1a - major	29.10	52.60
1a - minor	38.84	70.32
1b - major	43.53	78.87
1b - minor	58.13	86.80

Table 1 : Modal damping ratios for the one-storey steel frame

Frame – Column orientation	Mode 1 / 2 / 3 – % Damping ratio			
	C = 250 kNsec/m	C = 500 kNsec/m	C =750 kNsec/m	C = 1000 kNsec/m
3a - major	6.80 / 8.14 / NE	10.37 / 13.28 / NE	13.93 / 18.43 / NE	17.55 / NE / NE
3a - minor	8.01 / 8.84 / 8.06	12.99 / 14.60 / NE	18.02 / NE / NE	22.99 / NE / NE
3b - major	25.82 / 5.62 / 5.77	47.86 / 8.53 / 5.89	68.98 / 11.90 / 5.83	89.86 / 15.48 / 5.58
3b - minor	29.28 / 6.92 / 5.10	54.39 / 11.50 / 5.32	79.07 / 16.41 / 5.03	97.02 / NE / 6.64
3c - major	11.11 / 3.86 / 5.63	19.21 / 4.84 / 5.72	27.18 / 5.83 / 5.80	35.06 / 6.84 / 5.85
3c - minor	12.39 / 4.29 / 4.82	21.71 / 5.72 / 4.99	30.88 / 7.20 / 5.13	39.90 / 8.75 / 5.23

Table 2 : Modal damping ratios for the three-storey steel frame

Frame - Column orientation	Mode 1 / 2 / 3 / 4 / 5 – % Damping ratio				
	C = 250 kNsec/m	C = 500 kNsec/m	C =750 kNsec/m	C = 1000 kNsec/m	C = 1500 kNsec/m
6a - major	3.44 / 4.11 / 6.21 / NE / NE	3.84 / 5.20 / 7.85 / NE / NE	4.24 / 6.28 / 9.47 / NE / NE	4.64 / 7.36 / 11.09 / NE / NE	5.44 / 9.50 14.15 / NE / NE
6a - minor	4.49 / 5.50 / 7.19 / 12.9 / NE	5.97 / 8.24 / 9.77 / 17.00 / NE	7.45 / 11.20 / NE / NE / NE	8.92 / 14.06 / NE / NE / NE	11.87 / 19.63 / NE / NE / NE
6b - major	9.49 / 4.51 / 3.79 / 7.14 / NE	15.93 / 6.44 / 3.83 / 8.43 / NE	22.26 / 8.32 / 3.85 / 9.77 / NE	28.70 / NE / 4.16 / NE / NE	41.15 / NE / 4.31 / NE / NE
6b - minor	12.83 / 3.85 / 6.77 / 6.54 / 5.96	22.41 / 4.87 7.56 / 8.42 / 6.00	31.75 / 5.89 / 8.98 / NE / 6.77	40.79 / 6.99 / 9.57 / NE / 6.92	58.71 / 12.53 / 8.04 / NE / NE
6c - major	5.03 / 3.90 / 4.33 / 7.68 / NE	7.06 / 5.11 / 4.36 / 8.21 / NE	9.10 / 6.32 / 4.39 / 8.73 / NE	11.13 / 7.53 / 4.42 / 9.25 / NE	15.15 / 9.97 / 4.48 / 10.33 / NE
6c - minor	6.22 / 3.82 / 3.71 / 11.16 / 10.22	9.44 / 4.91 / 3.77 / 12.73 / 9.91	12.61 / 6.00 / 3.82 / 14.32 / 9.70	15.77 / 7.07 / 3.88 / 15.89 / 9.51	22.04 / 9.21 / 3.97 / 19.06 / 9.28

Table 3 : Modal damping ratios for the six-storey steel frame

4. References

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[4] Papagiannopoulos G.A. and Beskos D.E., *On a modal damping identification model for non-classically damped linear building structures subjected to earthquakes*, Soil Dynamics and Earthquake Engineering, 2009, Vol. 29, pp. 583-589.