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CONTROL OF TORSION EFFECTS IN BUILDINGS WITH EXTREME TORSIONAL IRREGULARITY THROUGH THE USE OF HYSTERICAL DISSIPATORS-SLB

KONTROLA TORZIONIH EFEKATA U ZGRADAMA SA EKSTREMNOM TORZIJSKOM NEPRAVILNOŠĆU KORIŠĆENJEM HISTERIČNIH DISIPATORA-SLB

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- *Seismic analysis*
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Abstract

Torsional irregularities are one of the main causes of failure in structures during seismic events, which must be considered because they can cause them to collapse. This type of irregularity is included in many seismic codes in the world. In this study, the behavior of a 7-story building is evaluated; for which 2 types of analysis are carried out separately, one of the methods defined by the Peruvian code-2018 (E.030-2018) and for the other it was proposed to incorporate a seismic protection system, based on SLB hysterical dissipators, using a modal spectral analysis and non-linear time history. Iterations were carried out to achieve the most effective location of the devices, thus strategically proposing 3 lines of resistance with SLB heatsinks. In this way, only in certain parts of the building that have been provided with the use of the devices, will energy absorption and non-linear behavior occur. The results of the response history showed that with the incorporation of the dissipators the damping was increased, and drifts of the floors were reduced by 60% and displacements by 70%. It is concluded that the incorporation of these devices controls the effect of the extreme torsional behavior of the structure.

Ključne reči

- Seizmička analiza
- torziona nepravilnost
- vremensko-istorijska analiza

Izvod

Torzione nepravilnosti su jedan od glavnih uzroka kvara u konstrukcijama tokom seizmičkih događaja, što se mora uzeti u obzir jer mogu izazvati njihovo urušavanje. Ova vrsta nepravilnosti je uključena u mnoge seizmičke kodove u svetu. U ovoj studiji se ocenjuje ponašanje zgrade od 7 spratova; za koje se 2 tipa analize vrše odvojeno, jedna od metoda definisanih Peruanskim kodeksom-2018 (E.030-2018), a za drugu je predloženo da se ugradi sistem seizmičke zaštite, zasnovan na SLB histereztičkim odvodnicima, korišćenjem modalnu spektralnu analizu i nelinearnu vremensku istoriju. Iteracije su sprovedene da bi se postigla najefikasnija lokacija uređaja, čime su strateški predložene 3 linije otpora sa SLB rashladnim elementima. Na ovaj način će samo u pojedinim delovima zgrade koji su obezbeđeni upotrebom uređaja doći do apsorpcije energije i nelinearnog ponašanja. Rezultati istorije odziva su pokazali da je ugradnjom disipatora prigušenje povećano, a nanosi podova su smanjeni za 60%, a pomaci za 70%. Zaključeno je da se ugradnjom ovih uređaja kontroliše efekat ekstremnog torzionog ponašanja konstrukcije.

1. INTRODUCTION

The most severe earthquakes leave great lessons. Over time, during strong seismic events it has been observed that structures with torsional irregularity can suffer serious damage, leading to their collapse [1]. This is because the center of mass and the center of rigidity are not in the same place. For this reason, an excessive increase in lateral movements occurs when dynamic loads excite buildings, becoming one of the most severe causes of vulnerabilities [2].

Current seismic codes, such as the European code EC-8, ASCE 7-16, Peruvian standard E.030-2018, among others, to ensure the performance of structures with torsional irregularity, incorporate special requirements that vary according to a series of factors that they include the geometry of the plan, the dimensions and positions of the structural elements and the floor numbers [3]. In addition to a procedure based on the calculation through torque equations on each floor and changing the center of mass to eliminate eccentricity, placing masses or additional structural components.

However, the lack of consensus between design regulations, and the results of recent earthquakes have shown that concrete structures with extreme torsion problems are very difficult and even impossible to repair. Such as the earthquake that occurred in the city of Pisco on August 15, 2007, of moment magnitude MW=8.0, which left at least 519 dead. The damages were considerable, which were magnified when the structures were also irregular [4].

This suggests the need to consider the advantages of modern seismic design methods and incorporate energy dissipation systems to control the responses to the demands of a seismic event.

Current investigations such as: Procedure to optimize the structural design for buildings equipped with hysteretic SLB devices by Riccardo Chianese, conclude that these devices represent a good solution for the seismic protection of buildings because they provide a significant contribution to the reduction of drift between floors and a great energy dissipation capacity due to its hysteretic behavior [5]. In the article Modeling, analysis and seismic design of structures using energy dissipators SLB , it is explained that these devices can dissipate the energy introduced by an earthquake in the structure, protecting other structural elements from being damaged [6].Guillermo Bozzo proposes a new type of heatsink that manages to extend the deformation limits of current SLB devices and, in addition, meets similar requirements to those of restricted buckling arms in the AISC standard in terms of their cyclic load protocols. and essays [7].

Many devices have been proposed in the literature so far, characterized by different shapes, constituent material, and energy dissipation principle. However, the idea of using a passive control system, which does not need an external power source to work, and which, combined with reinforced concrete frames and uncoupled walls with heat sinks, increases rigidity and ductility [8]. It offers a viable alternative that in practical terms reduces possible structural damage by reducing design forces below the elastic limit.

Therefore, current research in order to improve the seismic response to extreme torsion problems and ensure its continued functionality, proposes the incorporation of Bozzo Shear Link Heatsinks (SLB) into the structure.

2. MATERIALS AND METHODS

Two types of structures are proposed, which are modeled and analyzed using ETABS software (CSI 2018.1). These models include a 7-level structure, a type A and type B model. The heatsinks are incorporated in the type B.

As shown in Figure 1, the type A model is observed, a 7-story building that presents a conventional structure made up of a Dual system, structural walls and reinforced concrete porticos. Where the seismic response was evaluated by means of a spectral modal analysis presenting extreme torsional irregularity. If the coefficient of torsional irregularity, which determines the amount of torsion in the building, is greater than 1.5 in either direction, the building is assumed to have extreme torsional irregularity [9].

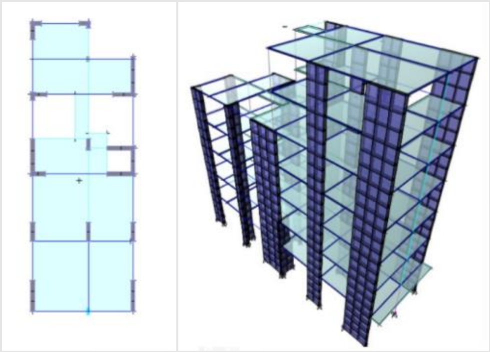


FIGURE 1: TYPE A MODEL

The second model is type B, in this model SLB heatsinks are incorporated to control extreme torsional irregularity. The location of these devices were raised in 3 additional lines of resistance, these are lines of defense that represent structural redundancy that are resistant to lateral loads and that cause a high degree of hyperstaticity [10]. Figure 2 shows the floors from the second to the fifth level, this level being a typical floor up to the seventh level, where these devices are located.

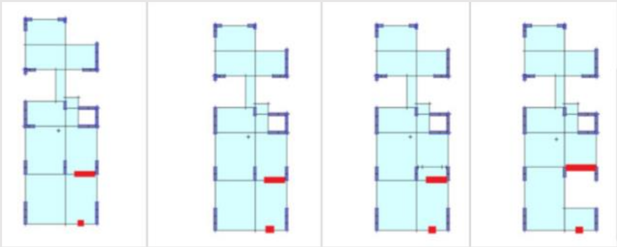
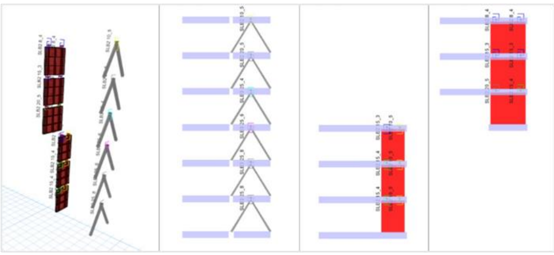


FIGURE 2: TYPE B MODEL, FLOORS FROM THE SECOND TO THE FIFTH LEVEL

Figure 3a shows the 3D model in which 2 types of heatsinks are represented: uncoupled walls and chevron diagonals considered at the level of the entire structure. Figure 3b shows the first line of resistance formed by Chevron diagonals that go from the second to the seventh level on the façade, in figure 3c 3 dissipators were proposed on uncoupled walls that go from the second to the fifth level, and finally, in figure 3d, a third resistance line was added with 3 more heatsinks on uncoupled walls, from the fifth level to the seventh level.



(a) (b) (c) (d)

FIGURE 3: ELEVATION OF SLB HEATSINKS, USED IN THE TYPE B MODEL

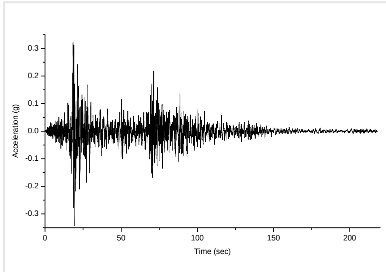
For the seismic analysis of the Type B model, the modal overlap (MS) method and the non-linear time history analysis (THNL) method were used. For the MS, a building importance factor of 1 and seismic zone 4 are considered. For the THNL analysis, two sets of ground acceleration records are used, each of which includes two components in orthogonal directions [11] .

PISCO:

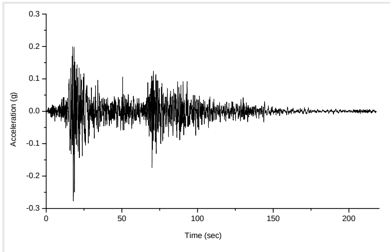
- Earthquake of August 15, 2007 - EW Component, (dt=0.01 sec and Duration 218.06 sec) 0.2771g- (Figure 4a)
- Earthquake of August 15, 2007 - NS Component, (dt=0.01 sec and Duration 218.06 sec) 0.3425g- (Figure 4b)

MOQUEGUA:

- Earthquake of June 23, 2001 - EW Component, (dt=0.01 sec and Duration 198.91 sec) 0.3014g- (Figure 5a)
- Earthquake of June 23, 2001 - NS Component, (dt=0.01 sec and Duration 198.91 sec) 0.2239g- (Figure 5b)

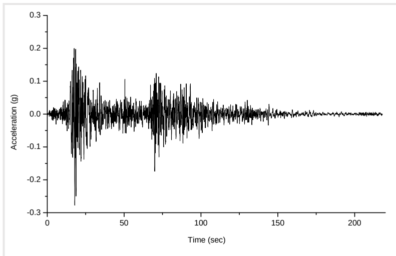


(a)

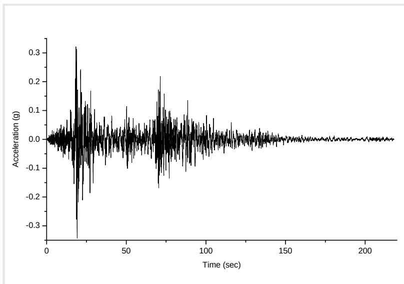


(b)

FIGURE 4: RECORD OF THE PISCO - CISMID EARTHQUAKE



(a)



(b)

FIGURE 5: RECORD OF THE MOQUEGUA- CISMID EARTHQUAKE

The design of the SLB heatsinks has been carried out using the ETABS 18.1 Software with the capacity to evaluate the non-linearity of these heatsinks. The model has 18 devices, of which 6 dissipators are Diagonal Chevron and 12 have been located between walls and uncoupled beams. For its design, it is necessary to verify the level of displacement requested in each device, for which it is necessary to obtain the hysteretic time-history curve, verifying that the displacement values are less than 30mm, which is the limit established by the SLB heatsink standards. As well as the verification of the control of the demand vs. capacity by cut [12].
For uncoupled wall dissipators, the stresses in the connection areas are verified to provide adequate confinement. This to absorb the tension forces generated by the rotation of the connection plate. In the case of the Chevron diagonals, a crenellated connection is left in the upper part, consequently, they do not transfer axial load and only work in shear for horizontal forces, thus they will not suffer significant degradation after several load cycles, demonstrating be a stable and secure connection [13].

3. RESULTS AND DISCUSSION

- As a result of the analysis, in the type A model, the mezzanine drifts exceed the limit proposed by the E.030-2018 standard [9], 0.0165>0.007, showing great flexibility of the structure in the short direction. In the type B model, the interstory drifts are 0.0068.
  It can be seen in Figure 6, that with the incorporation of these devices in the type B model, the damping was increased and the interstory drifts were reduced by 60%.

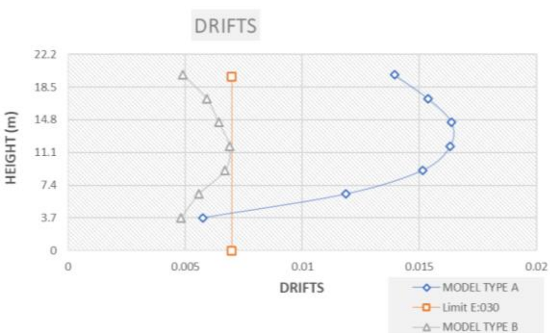


FIGURE 6: DRIFTS FROM MEASUREMENT OF THE TYPE A AND B MODELS

- Table 1 shows the coefficients of torsional irregularity that for the type A model are greater than for the type B model, the latter presents ratios in the short direction (X-X) less than 1.5, values that are within the range they are considered acceptable for a type 4 zone in the E0.30-2018 standard.

Table 1: COEFFICIENTS OF TORSIONAL IRREGULARITY

Type A model torsion degree			
Story	Output Case	Item	Ratio
Story7	DESP X-X	Diaph D7 X	1.254
Story6	DESP X-X	Diaph D6 X	1.314
Story5	DESP X-X	Diaph D5 X	1.691
Story4	DESP X-X	Diaph D4 X	1.638
Story3	DESP X-X	Diaph D3 X	1.597
Story2	DESP X-X	Diaph D2 X	1.548
Story1	DESP X-X	Diaph D1 X	1.512
Type B model torsion degree			
Story	Output Case	Item	Ratio
Story7	DESP X-X	Diaph D7 X	1.096
Story6	DESP X-X	Diaph D6 X	1.149
Story5	DESP X-X	Diaph D5 X	1.413
Story4	DESP X-X	Diaph D4 X	1.346
Story3	DESP X-X	Diaph D3 X	1.294
Story2	DESP X-X	Diaph D2 X	1.243
Story1	DESP X-X	Diaph D1 X	1.398

- It was found that the interstory displacements for the type A model in the last level is >25 cm, exceeding the maximum displacement for 7 levels, which is usually approximately 1 cm per level, for this type of structural system. In the Type B model, reductions in lateral displacements were obtained by increasing the damping level in the structure. Figure 7 shows the different displacement values obtained, noting that the structure with SLB achieves the reduction of lateral displacements by up to 70%.

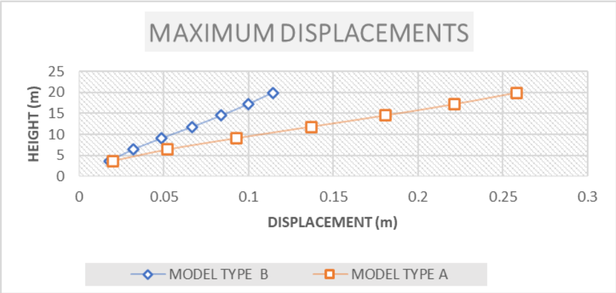


FIGURE 7: MAXIMUM DISPLACEMENTS OF TYPE A AND B MODELS

- The type A model has a maximum mezzanine acceleration of 0.65g at the last level, with the type B model it was possible to obtain reductions in these accelerations of up to 20% as shown in figure 8.

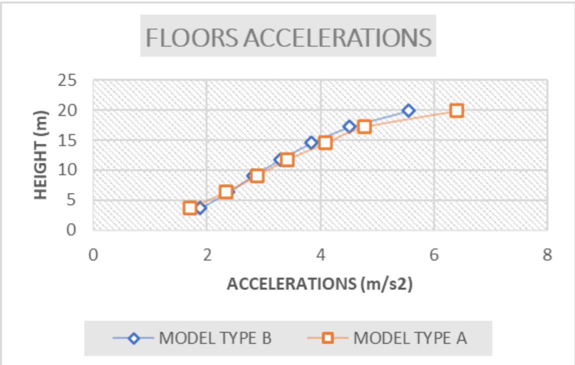


FIGURE 8: FLOOR ACCELERATIONS OF TYPE A AND B MODELS

- The results of the analysis for the type A model show inter-story stiffness at the first level of 33685.241 tonf/m. For the type B model at the same level, it is 46398.331 tonf/m, observing in figure 9 that the values of lateral rigidity were increased by 40%, qualifying as a rigid structure against lateral loads.

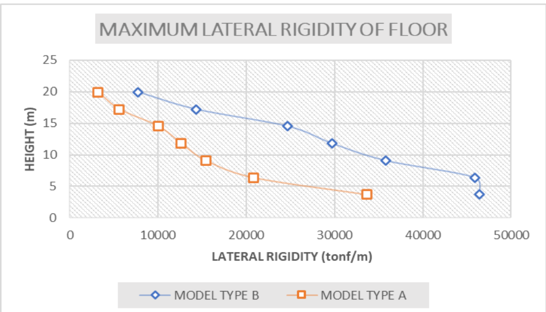


FIGURE 9: MAXIMUM LATERAL RIGIDITY OF FLOOR of model type A and B

- The maximum period of the structure for the type A model is 0.7 s. in mode 1, and 0.476 in the same mode for the type B model.
- As part of the processing of the results obtained, the design is presented as an example of the 2 types of heatsinks used in this study:
  - In Figure 10, it can be seen that the Diagonal Chevron located on the second level on the façade of the structure, for the MOQUEGUA EW accelerogram, presents a demand of 552.64 kN, being the maximum shear value that the device supports (SLB3-25- 8) is 776.40 kN.

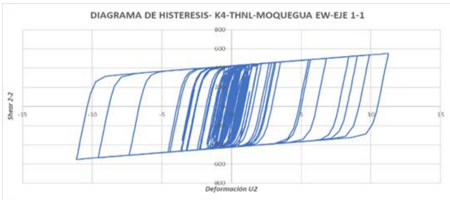


FIGURE 10: Hysteresis Diagram- K1-THNL-Axis 1-1- Moquegua EW

  - In Figure 11, the uncoupled wall located on the fifth level, for the MOQUEGUA EW accelerogram, presents a demand of 269.13 kN, with the maximum shear value supported by the device (SLB2 20-5) being 395.71 kN.

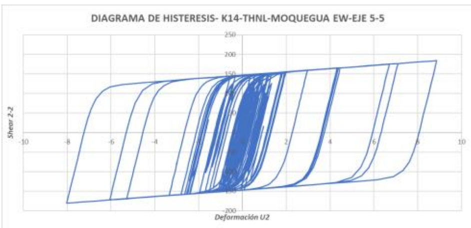


FIGURE 11: Hysteresis Diagram- K14-THNL-Axis 5-5- Moquegua EW

Table 2 shows a summary table with the proposed SLB devices for the structure and their respective capacity demand.

Table 2: HEATSINKS USED IN THE TYPE B MODEL

FORCE (KN)	HEATSINK	TYPE	RESISTANCE	d/c
160.42	SLB2-15-3	DECOUPLED WALL	240.45	0.66717
160.25	SLB2-15-3		240.45	0.66646
82.42	SLB2-8-4		120.87	0.68189
82.45	SLB2-8-4		120.87	0.68214
115.86	SLB2-15-4		276.57	0.41892
269.13	SLB2-20-5		395.71	0.68012
126.32	SLB2-10-5	DECOUPLED WALL	182.26	0.69308
160.94	SLB2-15-4		276.57	0.58191
127.3	SLB2-10-5		182.26	0.69845
164.46	SLB2-15-3		240.45	0.68397
124.42	SLB2-10-5		182.26	0.68265
184.23	SLB2-15-4		276.57	0.66612
128.31	SLB2-10-5	CHEVRON	182.26	0.70399
287.21	SLB2-20-5		395.71	0.72581
552.64	SLB3-25-8		776.4	0.71180
576.36	SLB3-25-8		776.4	0.74235
496.6	SLB3-25-6		655.36	0.75775
387.75	SLB3-25-4		526.49	0.73648

4. CONCLUSIONS

- The results show that it is feasible to control the extreme torsion in a dual building, incorporating SLB heatsinks, estimating the location and number of these devices, in order to balance the center of rigidity to the center of mass of the entire structure and without the need to carry them. to the base.
- The uses of the dissipators in flexible structures, also allow to control, interstory drifts, the maximum displacements and increase the lateral rigidity of the structure while reducing the seismic accelerations.
- Faced with a non-linear time-History analysis, the structures with sinks satisfactorily comply with the mezzanine drifts.
- These devices concentrate the ductility demands on industrially manufactured connections with defined mechanical properties, thus representing an advance to the classical design of structures based on ductility and hyperstaticity.
- From the results obtained from the analysis, they show that the incorporation of the SLB heatsinks to the structure and the effect they have on it, controlling extreme torsion, makes it important to include this heatsink system in the Peruvian standard E.030- 2018, considering the characteristics of the Peruvian seismic records.

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