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Seismic Behavior of Steel Buildings with Double Telescoping Self-Centering Energy-Dissipative Brace (DT-SCED)

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1. Introduction

Telescopic Self-Centering braces are of the very successful examples of Self-Centering braces which perform well in seismic loading. In this study, a new example of Telescopic Self-Centering brace is introduced, which has superior features over other telescopic braces. These include: high axial load capacity, use of shorter cables in brace construction, simplicity of construction, use of separate cables for compressive and traction modes, less fatigue in cyclic loads and, allowing for more dynamic loading cycles. In this paper, a sample building with the double telescoping Self-Centering Energy-Dissipative Brace (DT-SCED) was subjected to 60 earthquakes of different scales and the results are compared with the sample buildings with the Self-Centering Energy-Dissipative Bracing (SCED) and the Telescoping Self-Centering Energy-Dissipative Bracing (T-SCED). The results of the analysis and the comparison with other samples confirm the seismic superiority of performance of the DT-SCED brace over other samples. Comparison parameters were: period, initial building stiffness, post activation stiffness, maximum acceleration (g), peak drift (%), peak residual drift (%) and maximum base shear (kn).

2. Introducing Double Telescoping Self-Centering Energy-Dissipative Brace (DT-SCED)

After reviewing all previous centrifugal brackets, considering the available material and manufacturing facilities in Iran, a Double Telescoping Self-Centering Energy- issipative Brace (DT-SCED) was proposed. The previous proposed braces all had several disadvantages, including difficulty in manufacturing, high cost, low energy dissipation, and low axial force capacity. The brace has four series cables, two of which are activated in tension and the other two in compression. Figure 1 schematically shows the brace behavior. The advantage of this type of brace over the previous models is the use of fewer cables and halved fatigue in the cables due to the separate tension and compression cables. Simplicity of construction and ease of installation are other advantages of this brace compared to previous models, which makes it easy to manufacture in Iran. The important parameters of the proposed brace are briefly described as high axial load capacity, use of shorter brace cables, simplicity of construction, use of separate cables for compression and tension modes, less fatigue in cyclic loads and allowing for more dynamic loading cycles.

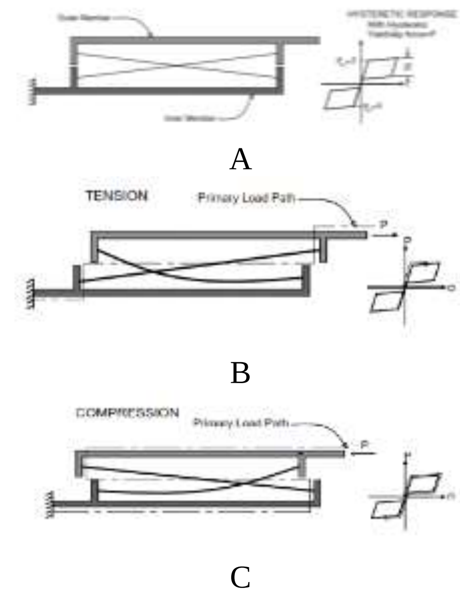

Figure 1. Schematic shape of the DT-SCED: A) no-load mode B) tensile loading C) compressive loading

3. Sample Six-Storey Building Design

In this study, a six-storey prototype frame with a (DT-SCED) was used to investigate seismic behavior in real structures. The results were compared with two other research samples. It should be noted that ASCE7-05 was used to design this structure. This prototype building was designed for normal occupancy on class D soil in downtown Los Angeles, California. The design was done using the modal response spectrum analysis procedure. The SCED braces themselves were designed using the same response modification coefficient R=7, overstrength factor $\Omega_0 = 2$, and deflection amplification factor C_d=5.5, the same as those prescribed for buckling-restrained braced frames in ASCE 7-05. All columns and beams were steel W-Sections. Concrete floor slabs acted as rigid diaphragms at every storey. The total effective seismic weight of the structure W was 32 100kN. The plan and elevation of the six-storey building are shown in Figure 2. The building lateral force resisting system consisted of SCED-braced frames in the north-south direction and special moment-resisting frames (SMRFs) in the east-west direction. For the current study, only the SCED frame response will be considered, meaning that the SCED frames have been analyzed in 2D and the contribution of the orthogonal SMRFs has been neglected. To model the DT-SCED, the hysteresis diagrams of each storey were calculated in the first step. The amount of lateral force was applied in each storey and the DT-SCED details were calculated according to the maximum axial force.

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4. Individual Record Response and Hystereses

In this study, after analyzing sample frames at all three earthquake risk levels, the behavior of first-storey brace hysteresis was compared. The plots in Figure 3 shows the effect of varying seismic hazard on selected designs.

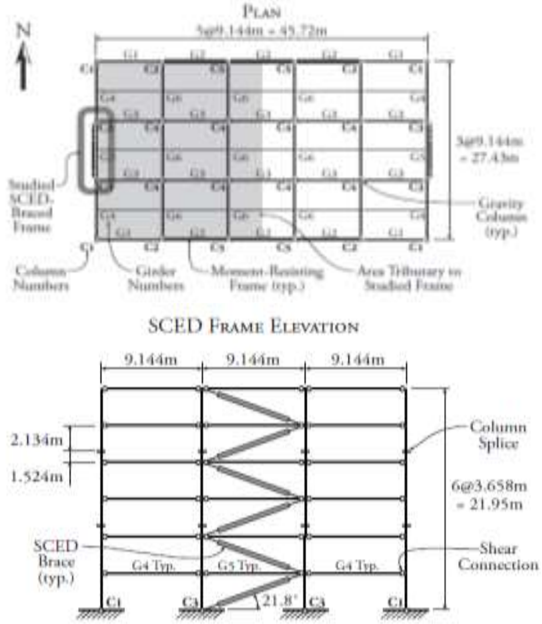

Figure 2. Six-storey SCED building design

(A): At the FOE hazard level, all three braces are flagged. The initial stiffness of all three braces is approximately the same. The area below the SCED chart is higher than the other two. The secondary stiffness of DT-SCED in the tensile state is less than that of the other samples. The residual displacement in the DT-SCED bracket is less than the other two specimens. The reason for this may be the use of shorter and longer separation cables in compression and tension modes. Generally, the seismic performance of the DT-SCED is appropriate at this level of earthquake.

(B): At the DBE hazard level, all three brace also have flagging behavior. The initial stiffness of the DT-SCED is higher than the other two. Also the area below the DT-SCED chart is higher than the other two and the residual displacement in the DT-SCED bracket is less than the other two specimens.

(C): At the MCE hazard level, unlike the two previous hazard levels, the SCED is not fully flagged and the hysteresis behavior of the SCED brace is not Self-Centering. One of the important points presented in this study is the stability of T-SCED and DT-SCED hysteresis behavior in MCE hazard level earthquakes. Other major point is the higher number of cycles of the DT-SCED hysteresis chart than the T-SCED. This stability or fatigue of the hysteresis diagram cycles can be due to the separate cable.

The most desirable performance of Self-Centering braces can be expressed as its ability to create flagging behavior in the building. It is observed that the Residual-Drift in buildings with T-SCED and DT-SCED braces is close to zero.

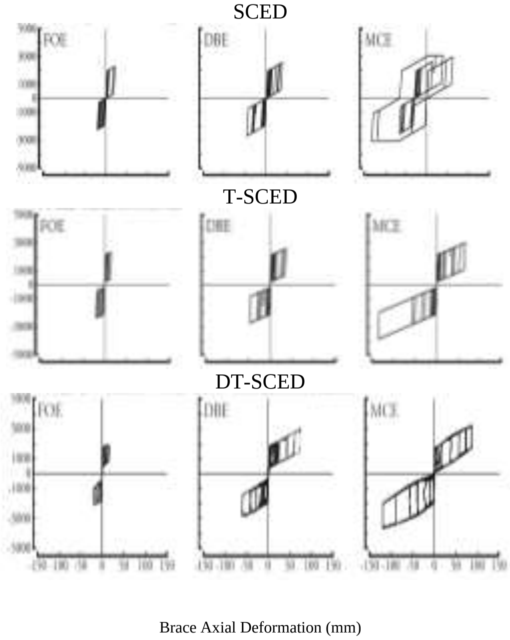

Figure 3. Hysteretic response comparison for first storey brace (MCE Earthquake LA21)

5. Conclusion

In this study, the DT-SCED was introduced. Details of the design and assembly of the brace have been provided in a detailed manner for real dimensions. In this research, after modeling and analyzing the sample frames, their seismic behavior was compared with each other. The performance of the DT-SCED showed superior characteristics. Comparison parameters were: period, initial building stiffness, the post activation stiffness, maximum acceleration (g), peak drift (%), peak residual drift (%) and maximum base shear (kN). Design dimensions of DT-SCED braces are executable and manufactured in Iran. These members were more economical than SCED and T-SCED braces in terms of outer, internal and cabling cross-sectional area. The seismic performance of the DT-SCED brace is far better than the SCED brace in the prototype building. Unlike the SCED brace, in earthquakes with an MCE hazard level the DT-SCED brace behaves completely self-centering and the Residual-DRIFT of the building is approximately zero.

The seismic performance of the DT-SCED brace is similar to the T-SCED brace. DT-SCED brace displacement is lower than the T-SCED brace, which can be due to the use of separate cables in compression and traction modes. As a result, it can be concluded that the use of DT-SCED brace improves the seismic performance of the building. Moreover, due to the ease of construction and assembly of these braces (DT-SCED), they can easily create a self-centering behavior in buildings.