SELF-CENTERING CAPABILITY OF SHAPE MEMORY ALLOY (SMA)-BASED SUPERELASTICITY-ASSISTED SLIDER (SSS)

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The self-centering capability (Berton et al., 2007; Katsaras et al., 2008; Cardone, 2012), emphasized in design codes as a fundamental feature of aseismic isolation systems, is investigated for the shape memory alloy -based superelasticity-assisted slider (Narjabadifam and Eradat, 2013). Restoring forces in the Shape memory alloy (SMA)-based Superelasticity-assisted Slider (SSS) are associated with austenitic SMA wires in order to properly re-center flat sliders allow isolation displacements. Energy considerations are examined first to provide insight into the problem, revealing also the governing parameters. The self-centering capability is then investigated through an extensive parametric study of the isolated structures idealized as single-degree-of-freedom systems subjected to a large group of recorded earthquakes. The results of the analyses show the dependence of the residual displacement after the earthquake and the cumulative build-up of displacements after a series of successive earthquakes on the governing parameters. SSS exhibits an acceptable self-centering capability, satisfying code provisions.

Capability of SSS to re-center itself depends on two counteracting components. This capability is increased by the SMA-based superelastic restoring forces that always act towards the origin, being decreased by friction forces that can act away from the origin. The behavior of SSS in terms of self-centering capability may be more clearly interpreted by dividing the seismic motion into two successive time stages. The first part is the strong-motion stage, in which the system absorbs energy from the seismic ground motion, and the second part is the free-vibration stage, in which seismic energy input can be considered insignificant compared with the variation in the kinetic and potential energies of the system. The reason for considering these two distinct stages is the fact that the free-vibration stage is mainly affected by the system properties and analytical considerations are possible, whereas the strong-motion stage is also strongly affected by the details of the ground motion which can only be investigated in a statistical manner. The restoring capability is examined for each of these stages based on energy concepts. As a result of these examinations, the residual displacements (d_{res}) can be estimated by equation 1.

$$d_{res} = d_r[1+(1-\frac{(m+1)\alpha(\alpha+2\beta)}{2m}+\frac{\alpha\beta}{m})\frac{d_y}{d_r}-\frac{\beta}{m}(\frac{d_{FV0}}{d_r}-1)] \qquad (1)$$

where d_r is the static residual displacement, d_y is the yield displacement, m is the order of force-displacement curve after yielding, d_{FV0} is the displacement corresponding to the beginning of free-vibration stage can be in general any displacement less than or equal to d_{max}. α and β are internal parameters defined by Figure 1, showing the force-displacement behavior of SSS with the austenitic SMA re-centering wires (wire ropes) arranged in vertical configuration, which is considered in this study.

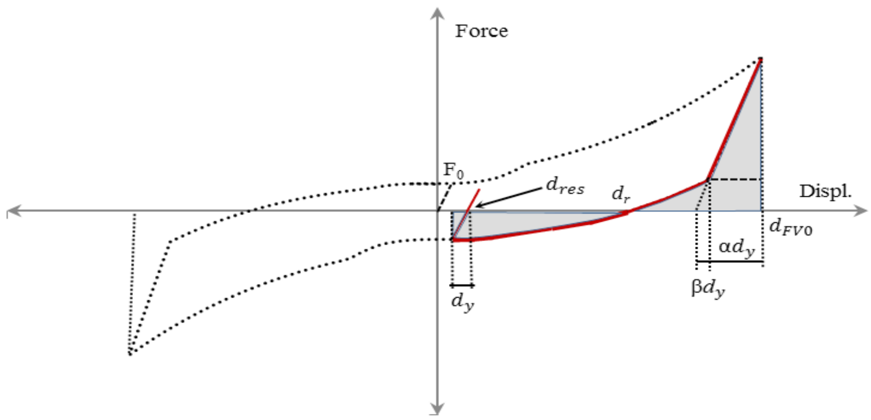

Figure 1. The force-displacement behavior of SSS in terms of self-centering capability

A database of 222 ground motions, which corresponds to historic records of 24 different seismic events and includes a number of records with near-fault effects is used to evaluate self-centering capability of SSS subjected to seismic actions. The residual displacements of the system are evaluated through nonlinear time history analyses. The results obtained from this parametric study coincide acceptably with those estimated by energy considerations. Eurocode 8 (2005) and AASHTO (2000) provisions are also checked out. EC8 requires that the force at the design displacement minus the force at half the design displacement is greater than 0.025W multiplied by the ratio of static residual displacement to design displacement. AASHTO requires that the ratio between the restoring force at the design displacement and the restoring force at half the design displacement shall be greater than unity. When EC8 is mostly satisfied, the requirement by AASHTO is perfectly satisfied.

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