Parametric investigation of the cyclic response of hysteretic steel dampers in braced buildings

Emanuele Gandelli (✉ emanuele.gandelli@polimi.it)

Politecnico di Milano <https://orcid.org/0000-0003-2717-6113>

Dario De Domenico

University of Messina: Università degli Studi di Messina

Virginio Quaglini

Politecnico di Milano

Original Article

Keywords: supplemental energy dissipation, braced frames, code requirements, parametric study, number of effective cycles, hysteretic steel dampers.

Posted Date: February 15th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-194100/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Hysteretic steel dampers have been effectively used to improve the seismic performance of framed buildings by confining the dissipation of seismic energy into sacrificial, replaceable devices which are not part of the gravity framing system. The number of cycles sustained by the dampers during the earthquake is a primary design parameter, since it can be associated to low-cycle fatigue, with ensuing degradation of the mechanical properties and potential failure of the system. Current standards, like e.g. the European code EN 15129, indeed prescribe, for the initial qualification and the production control of hysteretic steel dampers, cyclic tests in which the devices are assessed over ten cycles with amplitude equal to the seismic design displacement d_{bd} . This paper presents a parametric study focused on the number of effective cycles of the damper during a design earthquake in order to assess the reliability of the testing procedure proposed by the standards. The study considers typical applications of hysteretic steel dampers in low- and medium rise steel and reinforced concrete framed buildings and different ductility requirements. The results point out that the cyclic engagement of the damper is primarily affected by the fundamental period of the braced building and the design spectrum, and that, depending on these parameters, the actual number of cycles can be substantially smaller or larger than that recommended by the standards. A more refined criterion for establishing the number of cycles to be implemented in testing protocols is eventually formulated.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the latest manuscript can be downloaded and [accessed as a PDF](#).

Figures

Figure 1

Theoretical hysteresis loops of hysteretic dampers: (a) with elastic-ideally plastic behavior; (b) with hardening behavior.

Figure 2

Displacement history prescribed by EN 15129 for qualification and factory production control tests.

Figure 3

Steel frames case-studies

Figure 4

RC frames case-studies

Figure 5

Determination of equivalent elastic-perfectly plastic SDOF system according to EC8 (CEN, 2004)

Figure 6

Comparison between the target spectrum and the average spectrum obtained for each suite of fourteen ground motion records for: (a) ULS-soilA; (b) ULS-soilC; (c) SLS-soilA; (d) SLS-soilC

Figure 7

Adopted design method for the hysteretic damper: rheological model (left) and iterative response spectrum analyses (right)

Figure 8

Identification of the actual performance point through the ADRS representation of the “sA” response spectrum and “st2” capacity curve

Figure 9

Structural models adopted in NLTH analyses: (a) MDOF braced frame (with a scheme of the calculation method for the number of effective cycles of the damper); (b) equivalent SDOF system

Figure 10

(a) Comparison between peak displacement calculated through spectral, MDOF, and equivalent SDOF NLTH analyses; (b) accuracy of spectral analyses; (c) accuracy of equivalent SDOF NLTH analyses.

Figure 11

Comparison between the number of effective cycles sustained by hysteretic dampers (N_{cycles}) calculated in NLTH analyses using either MDOF models or equivalent SDOF-NLTH models (left), and relative deviation (right).

Figure 12

Comparison between the 90th percentile of number of effective cycles sustained by hysteretic dampers ($N_{cycles,90\%}$) calculated in NLTH analyses using either MDOF models or equivalent SDOF models (left), and relative deviation (right).

Figure 13

Please see the Manuscript PDF file for the complete figure caption.

Figure 14

Comparison between the displacement time-histories of the “ $F^* + D^*$ ” systems with a large (a) and a small (b) hysteretic engagement

Figure 15

Damper cyclic engagement (N_{cycles}) at ULS as a function of the equivalent viscous damping ($\xi_{eq,F+D}^*$) of the braced frames

Figure 16

Damper cyclic engagement (N_{cycles}) at ULS (left) and SLS (right)

Figure 17

90th percentile of the number of effective cycles ($N_{cycles,90\%}$) at ULS (left) and SLS (right) seismic events