論文 / 著書情報
Article / Book Information

題目(和文)	水平2方向入力を受ける免震構造に設置されたU型鋼材ダンパーの信頼性
Title(English)	Reliability of U-shaped steel dampers as seismic isolation devices for base-isolated structures subjected to biaxial excitation
著者(和文)	Ene Diana
Author(English)	Diana Ene
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第10201号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:山田 哲,坂田 弘安,山中 浩明,寒野 善博,吉敷 祥一
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第10201号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	環境理工学創造 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（工学）
学生氏名： Student's Name	Ene Diana	指導教員（主）： Academic Advisor(main)		山田 哲
		指導教員（副）： Academic Advisor(sub)		坂田 弘安

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Earthquake resilient structures, *i.e.* structures that suffer little or no damage under strong seismic excitation, represent the ultimate objective of earthquake engineering. One particular type of such structures is represented by seismic isolated buildings that reduce the earthquake-induced damage by introducing an isolation layer between the foundation and the upper-structure. The behavior of the isolation layer – generally composed of isolators and dampers – is of essential importance to the structural integrity of the whole building during a seismic event. Therefore, to ensure a proper performance of the structure, first it is necessary to investigate the reliability of the seismic isolation devices.

U-shaped steel dampers are hysteretic devices widely used in Japan for seismic isolated structures. Based on their basic behavior under simple one- and bidirectional loading patterns, a methodology for estimating their damage and ultimate inelastic deformation capacity was proposed in previous studies. In the present study, the first objective is to investigate the fidelity of this method for the case of biaxial seismic excitation. This goal is achieved by conducting a set of dynamic tests on full-scale specimens using realistic bidirectional displacement histories. The latter are established by running nonlinear dynamic time-history analyses on a single mass system with two degrees of freedom conferred by adopting a Multiple Shear Spring (MSS) element. The test results confirmed that the methodology proposed in previous studies is suitable for estimating the damage of U-shaped steel dampers subjected to realistic bidirectional loading histories. Moreover, it was verified that the dampers can resist a considerable number of strong ground motions without reaching fracture. This important observation proves that even if strong aftershocks occur right after the main shock, the dampers will perform as intended, successfully dissipating the earthquake energy.

Based on various test results, the hysteretic behavior of the dampers is modeled as bilinear, and, in combination with an MSS element, this model is employed to simulate the force – deformation relations under bidirectional loading. To validate the model, the analytical data are compared to the experimental data obtained during the dynamic test. The correlation coefficient between the analytical and the experimental forces is derived and its values confirm that the two sets of data agree well.

Having confirmed the suitability of both the damage evaluation methodology and the analytical model, the second objective of this research is to assess the reliability of the dampers under various seismic intensity levels. For this purpose, a probabilistic method – incremental dynamic analysis (IDA) – is employed using a set of 17 strong motions for which both horizontal components are simultaneously applied to compute the nonlinear response of the considered system. Further on, the bidirectional damage of the dampers is obtained. A set of limit states that divide the performance of the dampers into 5 levels is proposed, and the corresponding fragility curves are derived. The latter are expressed using PGV_{gm} as intensity measure, the peak ground velocity computed as the geometric mean of the horizontal components by taking into consideration different sensor orientations. In addition, median curves that relate the damage of the dampers to the seismic intensity are derived based on the obtained IDA curves. These results enable the structural engineer to estimate the bidirectional damage of the dampers without having to conduct any analysis.

The third goal of the present research is to quantitatively assess the difference between the typical damage evaluation method currently adopted in design practices in Japan (in-plane frame analysis) and the bidirectional approach. The main cause for this difference is the fact that the ultimate inelastic deformation capacity of the dampers under bidirectional loading proved to be considerably reduced when compared to that corresponding to one-directional loading. Other causes are: (1) neglecting the damage induced by the other horizontal seismic component, (2) assuming that the response is one-directional (neglect the interaction between the displacement components). Therefore, by adopting a one-directional damage evaluation approach, the safety margin against fracture of the dampers is overestimated, which can lead to

dangerous situations. To avoid such situations, in the present study a set of equations estimating the values of the bidirectional damage indicators based on one-directional ones is proposed. These equations are derived based on a probabilistic approach and provide satisfactory results for the seismic intensity range of interest. The advantage of the proposed set of equations is that they eliminate the threat of potentially dangerous situations without requiring to conduct bidirectional response analyses which are not common in design practices.

The main conclusions are: (1) under realistic large-amplitude displacement histories, U-shaped steel dampers have a stable behavior and are reliable even when subjected to several such loadings, (2) fragility curves that relate the damage level to the seismic intensity were derived, allowing the prediction of the bidirectional performance, (3) the damage evaluation approach adopted in typical design practices provides unconservative estimations, thus a set of equations deriving the bidirectional damage indicators using the one-directional ones was proposed.