Structures Congress 2018

Buildings and Disaster Management

Proceedings of the Structures Congress 2018

- Fort Worth, Texas
- April 19–21, 2018

ASCE

EDITED BY

James Gregory Soules, P.E., S.E., P.Eng.

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SELECTED PAPERS FROM THE STRUCTURES CONGRESS 2018

April 19–21, 2018
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SPONSORED BY
The Structural Engineering Institute (SEI)
of the American Society of Civil Engineers

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Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

***Errata:* Errata, if any, can be found at https://doi.org/10.1061/9780784481325**

ISBN 978-0-7844-8132-5 (PDF)
Manufactured in the United States of America.

Preface

The Structures Congress has a robust technical program focusing on topics important to Structural Engineers.

The papers in the proceeding are on the following topics

- Advances in Structural Engineering Research
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- Natural Disasters - Moving Toward Improved Resilience
- Nonbuilding Structures and Nonstructural Components
- Special Topics in Structures
- Transformation in SE Education

Acknowledgments

Preparation for the Structures Congress required significant time and effort from the members of the National Technical Program Committee, the Local Planning Committee and staff. Much of the success of the conference reflects the dedication and hard work by these volunteers.

The National Technical Program Committee, the Local Planning Committee and staff would like to acknowledge the critical support of the sponsors, exhibitors, presenters, and moderators who contributed to the success of the conference through their participation.

Thank you for spending your valuable time attending the Structures Congress. It is our hope that you and your colleagues will benefit greatly from the information provided, learn things you can implement and make professional connections that last for years.

Sincerely,

J. G. (Greg) Soules, P.E., S.E., P.Eng, SECB, F.SEI, F.ASCE
CB&I, LLC
Chair, National Technical Program Committee

Contents

Design of Structures with Dampers per ASCE 7-16 and Performance for Large Earthquakes

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ABSTRACT

An impediment to the use of seismic protection devices has been the difficulty for practicing engineers to design buildings with isolation system or damping devices. ASCE/SEI task committees charged with development of new generation of codes for seismic design and retrofit of buildings have updated the relevant code sections with one goal being to encourage the use of such devices. An effort was undertaken to develop a step-by-step design guideline for such design. Following the preparation of guideline, incremental analysis of four steel SMF building models was undertaken. The benchmark model was designed using the strength and drift requirements of ASCE 7-16. The other models were based on provisions of Chapter 18 of ASCE 7-16. For one model the lower base shear value was used, and for a third model, the drift ratios were further limited to obtain enhanced performance. Lower- and upper-bound analyses as required by ASCE 7-16 were conducted to size the dampers. The models were then subjected to incremental nonlinear analysis and key response parameters were evaluated. In all cases, the use of dampers resulted in reduction in the hinging of SMF members. It was notes that the best performing model was the model designed for 100% of nominal base shear and above minimum effective damping had superior performance, remaining elastic at design earthquake, and having almost no residual displacement at very large earthquakes.

INTRODUCTION

Overview: Fluid viscous dampers (FVDs) were originally developed as shock absorbers for the defense and aerospace industries. FVDs consist of a cylinder and a stainless steel piston. The cylinder is filled with incompressible silicone fluid. The damper is activated by the flow of silicone fluid between chambers at opposite ends of the unit, through small orifices. Figure 1 shows the damper cross section. In recent years, they have been used extensively for seismic application for both new and retrofit construction. During seismic events, the devices become active and the seismic input energy is used to heat the fluid and is thusly dissipated. Subsequent to installation, the dampers require minimal maintenance. They have been shown to possess stable and dependable properties for design earthquakes. Figure 2 shows the diagonal dampers placed in a reinforced concrete moment frame building.

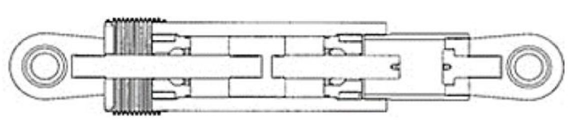

Figure 1. FVD cross section (Taylor 2017)

Figure 2. Diagonal FVD in a building

The combination of fluid viscous dampers and steel or reinforced concrete special moment resisting frames (SMF) provide an attractive option for the design of new buildings in the regions of high seismicity. The resulting building is a highly damped, low-frequency building that limits seismic demand on structural and nonstructural components. FVDs can be incorporated into new construction to produce large equivalent viscous damping thus reduce the demand on the structural system.

The main advantage of this design is the reduction in the steel or concrete tonnage. Since the design of SMF is generally governed by the story drift ratios (SDRs), larger steel or concrete sizes would be required to meet this requirement. However, since in this design, FVDs are used to control SDR, smaller member sizes can be used, and this saving in material would compensate for the cost of the dampers.

ASCE 7-16 design procedure: The general approach is to design the SMF members for the strength requirements of the building code only. Such building would then meet all the relevant requirements of ASCE (2016) except the limitations for the SDRs. FVDs are then added to design to reduce the SDRs and provide compliance with all the code requirements. Since the force in FVDs is primarily out-of-phase with the inertial forces, the demand on the existing members of foundation is not significantly increased. However, a second design check for the model with the dampers in necessary to assure that the design is still satisfactory.

The provisions in the ASCE 7 (2016) provide information on the bounding analysis. For viscous dampers it is anticipated that the property modification factors (λ factors) to be in the range of +/-15%. The upper bound analysis would govern the requirement for the damper force, whereas the lower bound analysis will determine the damper constant necessary to meet the SDR requirements.

When a building is designed according to the Chapter 18 of ASCE 7-16, it is permissible to reduce the base shear demand to as low as 75% of the computed demand to account for the beneficial effect of supplementary damping. The effect of this reduction in strength on the response of the structure to large earthquakes is not well known.

Additionally, currently there are no provisions on the minimum effective damping to be added as part of the design process. Research (Miyamoto and Gilani 2015) has shown that enhanced performance with a reduced SDR can be archived for the design by using larger dampers. While the larger (or more) dampers will add slightly to the initial cost, both the seismic performance and the life-cycle cost are significantly improved.

In this paper, analytical investigation of an example steel SMF with dampers is presented. The models were designed per ASCE 7-16 for the design earthquake (DE) and then subjected to larger earthquake and key responses and level of expected damage (assumed correlated to the plastic hinging and plastic hinge rotations) was investigated. Table 1 summarizes the ley