Adaptive Passive Stiffness Shaping and Apparent Weakening for Seismic Protection

Andrei M Reinhorn, PhD, PE
Professor Emeritus (former Clifford C. Furnas Eminent Professor)
University at Buffalo - the State University of New York - USA

Contributors: *S. Nagarajaiah, DTR Pasala and SV Vemuru , Rice University, Houston; M. C. Constantinou, AA Sarlis and T. Ray , University at Buffalo, Buffalo; M. Symans and N. Attari, RPI, Troy; D. Taylor, J. Metzger and D Lee, Taylor Devices, Buffalo; J. Zhang and Z Shu, UCLA, Los Angeles;*

Abstract

Traditionally engineers have focused on use of supplemental damping systems for earthquake protection. An engineering team has developed a supplemental adaptive stiffness device for stiffness shaping in structures along with apparent weakening for seismic protection. This lecture presents various stages of development of the concept of adaptive-passive stiffness shaping achieved through the introduction of supplemental negative and positive tangential stiffness, and the design procedure for implementing it in various structures. The teams of engineers from Rice University, University at Buffalo, Rensselaer Polytechnic Institute and University of California at Los Angeles, funded through the US-NSF Network for Earthquake Engineering Simulations (NEES) program, have developed a practical and true negative stiffness system. The aim of the project was to prove the concept, develop, verify and validate the a true negative stiffness system that mimic "yielding" of the structure while retaining the main structure either in the elastic range or in the mildly inelastic range with reduced inelastic excursions-leading to a new concept called "apparent weakening." The lecture presents the invention of the *Negative Stiffness Device* (NSD) and process that lead to the innovation of the NSD by the teams of researchers. Detailed analytical and shake table test results are presented to show the effectiveness of the new and innovative concept of adaptive negative-positive tangential stiffness which allows stiffness shaping in structures and apparent weakening for earthquake protection. Effectiveness of NSD in base isolated structures, inelastic single and multistory buildings, and based isolated bridges is demonstrated using experimental and analytical results obtained in the “NEES-Adapt-Struct” project. The four years project resulted in two US patents (final approval pending), two computational approaches (incorporated in platforms), design guidelines, and numerous scientific publications

Andrei M. Reinhorn *is a retired professor (emeritus) at University at Buffalo and was involved in education, research and consulting in structural dynamics with applications to earthquake engineering, wind effects and extreme loads engineering. He is a graduate of the Technion – Israel Institute of Technology (BS 1968, PhD 1978) followed by an academic career at University at Buffalo - State University of New York - for over thirty years. Prof Reinhorn conducted research in evaluation and design of building structures experiencing inelastic deformations near collapse. He also developed modeling and solution techniques for structural control and base-isolated structures. Computational platforms 3D-BASIS and IDARC developed by him and his coworkers are widely used by academics and design professionals around the world. He pioneered experimental structural control that brought the experimentation from small scale laboratory implementations to the full scale real-life realization of controlled structures using active tendon systems in Japan. He was one of the pioneers in defining the disaster resilience of communities and its quantification, using basic principles of process control. Most recently he developed new approaches to analysis of structures using State Space Approach (SSA) and Mixed Lagrangian Formulation (MLF). He developed integrated computing and experimentation methods, which are in the forefront of hybrid simulation techniques. As one of its designers and founders, he directed one of the largest laboratories in the US for structural engineering and earthquake simulations (SEESL) located at University at Buffalo.*

Professor Reinhorn was awarded the 2011 ASCE-Nathan M. Newmark Medal. He has received numerous other awards including 2007 SUNY Chancellor’s Award for Excellence in Scholarship and Creative Activity, 2006 UB – University at Buffalo “Exceptional Scholar” Sustained Achievement Award, 2005 ASCE/CERF Charles Pankow Award for Innovation, and 1998 AGC-Build San Diego Award., for work related to applications of structural control. More information can be found at [*http://civivl.eng.buffalo. edu/~reinhorn/*](http://civivl.eng.buffalo.edu/~reinhorn/)