



# Study on Modern Energy Absorption Systems in Structures Subjected to Earthquake Forces

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## Abstract

In light of the vast potential for the application of modern energy absorption systems in the structures, the effectiveness of each system should be tested, analyzed, and proved before convincing the structures design companies to use them. In this research, the effectiveness of applying base isolators, viscous and friction dampers and a hybrid system consisted of lead rubber bearing with friction dampers are studied. To quantify the impact of each system, a control structure without any energy absorption system is considered. Base isolators and damper systems are designed according to available international codes. American concrete institute's codes were used to design the concrete structure frames. All of the considered systems therewith hybrid systems including lead rubber base isolation and viscous dampers have been modeled in ETABS 2018 software. The control structure has an intermediate moment resisting frame with high importance located in a high seismic hazard zone. These models were subjected to time history analysis by using Manjil, Loma prieta, and Imperial Valley Earthquakes records. It was observed that the structural design parameters such as base shears and story drifts were significantly reduced by 76–86% and 44–92%, respectively, compared to the structure without any energy absorption system. Also, the total energy dissipated in the structures equipped with modern energy absorption systems was decreased between 32 and 86% compared to the friction dampers. It should be noted that the studied devices may be used either for the design of a new structure or seismic rehabilitation of the existing structures.

**Keywords** Energy dissipation · Seismic base isolator · Friction damper · Viscous fluid damper · Dynamic time history analysis

## Abbreviations

HDRB Rubber isolators with high damping  
LRB Rubber isolators with lead cores

PED-V Passive energy dissipation viscous fluid dampers  
PED-F Passive energy dissipation friction dampers  
Hybrid system Rubber isolators with lead core + Passive energy dissipation viscous fluid damper

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## 1 Introduction

The earthquake affects the structural and non-structural elements directly or indirectly which can lead to human life loss or structural damages (Perrone et al. 2019). It is difficult and expensive to prevent any damage and loss, especially during severe earthquakes. The purpose of the seismic design of buildings is to provide structural safety and comfort by controlling the internal forces and displacements within the defined limits. Conventionally, the seismic design of building structures was based on the concept of increasing the resistance capacity of the structures against earthquakes



# Evaluation Findings For Fip Energy Absorption Systems Lcc Slider Bearings

**Highway Innovative Technology  
Evaluation Center (U.S.)**



## **Evaluation Findings For Fip Energy Absorption Systems Lcc Slider Bearings:**

**Evaluation Findings for Fip-Energy Absorption Systems, L.C.C. Slider Bearings** Highway Innovative Technology Evaluation Center (U.S.), Civil Engineering Research Foundation Staff, 1998 Presents the results of a detailed evaluation for one technology out of eleven that were evaluated The evaluations were designed to test the performance of seismic isolators and dampers produced by several manufacturers Summary of Evaluation Findings for the Testing of Seismic Isolation and Energy Dissipating Devices Highway Innovative Technology Evaluation Center (U.S.), 1999-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Service Center his report summarizes the results of an evaluation that was designed to test the performance of 11 seismic isolators and dampers The devices were tested for stability response during earthquake simulations and fatigue and weathering effects **Evaluation Findings for Earthquake Protection Systems, Inc. Friction Pendulum Bearings** Highway Innovative Technology Evaluation Center (U.S.), 1998-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Service Center This report summarizes the results of a detailed evaluation of Friction Pendulum Bearings manufactured by Earthquake Protection Systems Inc The report is part of a program to test the performance of 11 seismic isolators and dampers produced by several manufacturers The devices were tested for stability response during earthquake simulations and fatigue and weathering effects **Evaluation Findings for Enidine, Inc., Viscous Damper** Highway Innovative Technology Evaluation Center (U.S.), 1999-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Service Center This report summarizes the results of a detailed evaluation of a viscous damper manufactured by Enidine Inc The report is part of a program to test the performance of 11 seismic isolators and dampers produced by several manufacturers The devices were tested for stability response during earthquake simulations and fatigue and weathering effects **Evaluation Findings of the MX 30 Pavement Marking Retroreflectometer** Highway Innovative Technology Evaluation Center (U.S.), 2000-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF service center This report presents the results of a detailed evaluation of the MX 30 pavement marking 30 meter retroreflectometer The evaluation is designed to test the measurement bias repeatability and reproducibility of handheld and mobile retroreflectometers produced by several manufacturers *Guidelines for Testing Large Seismic Isolator and Energy Dissipation Devices* Highway Innovative Technology Evaluation Center (U.S.), 2002-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Innovation Center This report outlines the HITEC Technical Evaluation Plan for large seismic isolator and energy dissipation devices The plan is designed to characterize the fundamental properties and performance characteristics of a wide range of devices produced by U S and overseas manufacturers It describes a program of full scale dynamic tests the results of which should provide guidance to the transportation engineering community regarding the performance of large seismic devices **Summary of Evaluation**

**Findings for 30-meter Handheld and Mobile Pavement Marking Retroreflectometers** Highway Innovative Technology Evaluation Center (U.S.),2001-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Innovation Center This report summarizes the results of detailed evaluations performed on four handheld and two mobile pavement marking retroreflectometers The evaluations were designed to test the measurement bias repeatability and reproducibility of handheld and mobile retroreflectometers produced by several manufacturers      **Evaluation of the**

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**Retained Soil Wall System** Highway Innovative Technology Evaluation Center (U.S.),2002-01-01 Prepared by the Highway Innovative Technology Evaluation Center a CERF IIEC Innovation Center This report describes a HITEC evaluation designed to determine the basic capabilities and limitations of the Tricon System for use as a technically viable precast mechanically stabilized earth retaining wall system The evaluation considered material design construction performance and quality assurance information outlined in the HITEC Protocol      **Environmental Technology Verification Report for**

**Installation of Silt Fence Using the Tommy Static Slicing Method** Environmental Technology Evaluation Center (U.S.),2001-01-01 Prepared by the Environmental Technology Evaluation Center EvTEC a CERF Innovation Center This verification report describes a field evaluation of the installation of a silt fence using the Tommy Silt Fence Static Slicing Method and compares this method to traditional trenching methods The slicing method has been used extensively over the past few years but has not undergone a true field application test by a third party State Departments of Transportation and federal state and local environmental regulatory agencies have expressed a desire and in some cases a need for baseline environmental data providing a general picture of performance and feasibility of the Tommy Slicing Method for silt fence installation and erosion control      **Evaluation of the Geo-Con VERT Wall System** Highway Innovative Technology

Evaluation Center (U.S.),2002-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF IIEC Innovation Center This report describes a HITEC evaluation designed to determine the basic capabilities and limitations of the Geo Con VERT Wall for use as a technically viable permanent excavation support retaining wall system The evaluation was conducted based on design construction performance and quality assurance information outlined in the HITEC Protocol

The Geo Con VERT Wall System is an in situ retaining wall system intended as an alternative to other types of cut walls such as soldier pile and anchored retaining walls. The Geo Con VERT Wall System is comprised of deep soil mix columns consisting of overlapping or tangent soil cement columns along the front face backed up by tangent rows of overlapping soil cement columns. A soil cement relieving platform overtop the columns. Steel beams embedded in the front face soil cement columns for support of the permanent facing and permanent facing consisting of precast reinforced concrete panels or reinforced cast in place concrete. The relieving platform is intended to provide internal stability by tying the soil mix columns together and transferring the load to the bottom of the columns.

#### **Evaluation of Thermocoax Piezoelectric Weigh-in-Motion**

**Sensors** Highway Innovative Technology Evaluation Center (U.S.), 2001-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Innovation Center. This report describes a program of installation testing and evaluation designed to determine the capabilities and limitations of Thermocoax's weigh in motion sensor.

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**Environmental Technology Verification Report for the Plasma Enhanced Melter**, 2003-01-01 Prepared by the Environmental Technology Evaluation Center EvTEC a service center of CERF IIEC. This Technology Verification report describes the nature and scope of the environmental evaluation of the performance of the Plasma Enhanced Melter PEM system for waste treatment. The evaluation was conducted through a cooperative program established in 1998 between the Washington State Department of Ecology Integrated Environmental Technology Inc Allied Technology Group and the Civil Engineering Research Foundation. The goal of this report is to provide potential users and purchasers of the PEM system with information they need to make more informed decisions regarding the performance of PEM as an equivalent or alternative to incineration for treating hazardous waste.

**Evaluation of the ISOGRID Retaining Wall System** Highway Innovative Technology Evaluation Center (U.S.), 1999-01-01 Prepared by the Highway Innovative Technology Evaluation Center a CERF service center. This report presents the results of a HITEC evaluation of the Isogrid Retaining Wall System designed and developed by the Neel Company. The report describes the basic capabilities and limitations of the Isogrid System for use as a technically viable precast mechanically stabilized earth retaining wall system. The evaluation was conducted based on material design construction performance and quality assurance information outlined in the HITEC Protocol. The Isogrid System features a

diamond shaped segmental precast concrete facing panel with weep holes where four panels intersect and welded wire grid type soil reinforcement attached to the center of each facing panel      *Evaluation of the SSL MSE Plus Retaining Wall System* Highway Innovative Technology Evaluation Center (U.S.),2001-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF service center This report describes a HITEC evaluation designed to determine the basic capabilities and limitations of the MSE Plus System manufactured by SSL LLC for use as a mechanically stabilized earth retaining system The evaluation was conducted based on material design construction performance and quality assurance information outlined in the HITEC Protocol The MSE Plus System features rectangular segmental precast concrete facing panels and galvanized welded wire grid type soil reinforcement      *Evaluation of the Keysystem I Retaining Wall* Highway Innovative Technology Evaluation Center (U.S.),2000-01-01 Prepared by the Highway Innovative Technology Evaluation Center HITEC a CERF Innovation Center This report describes an evaluation to determine the capabilities and limitations of the KeySystem I Retaining Wall System a mechanically stabilized earth structure developed designed and supplied by Keystone Retaining Wall Systems Inc The evaluation was conducted based on design construction performance and quality assurance information outlined in the HITEC Protocol KeySystem I features modular block facing to which KeyStrips are attached KeyStrips are structural welded wire grid type reinforcement produced from high strength steel

Evaluation of the CON/SPAN Wingwall System Highway Innovative Technology Evaluation Center (U.S.),2001-01-01 This report describes a HITEC evaluation designed to determine the basic capabilities and limitations of CON SPAN Wingwalls for use as a precast retaining wall system The evaluation was conducted based on design construction performances and quality assurance information outlined in the HITEC Protocol      Evaluation of SSET: The Sewer Scanner and Evaluation Technology Civil Engineering Research Foundation,2001-01-01 Prepared by CEITEC a CERF innovation center serving the engineering and construction industries This report describes an evaluation of Sewer Scanner and Evaluation Technology SSET designed to determine the basic capabilities and limitations of SSET for use as a technically viable technology for inspecting sewer pipes The evaluation focused on the performance and in service demonstration of SSET The technology involves digital scanning to obtain a flat unfolded image of the pipeline s interior This evaluation includes field demonstrations performed at 13 municipal public works agencies throughout North America Subsequent to this evaluation SSET was modified to include a fisheye lens camera and fiber optic gyroscope which replaced the rotating mechanical scanner and mechanical gyroscope The evaluation confirmed the operability of SSET and its viability in data presentation A degree of enhancement was recognized with additional features most notably the ability to produce a digital report of the sewer pipe to identify vertical deflection in pipes and to deliver easily comprehensible and manageable results The evaluation also revealed that SSET cannot reproduce all the features typically available from closed circuit television CCTV inspection Such features include the ability to clearly see corrosion infiltration rates and ovality The limitations in applicability were

determined and an economic comparison of SSET and CCTV is provided      Environmental Technical Verification Report for Ammonia Recovery Process Environmental Technology Evaluation Center (U.S.),2000-01-01 Prepared by the Environmental Technology Evaluation Center EvTEC a CERF Service Center This report describes the nature and scope of an environmental evaluation of ThermoEnergy Corporation s Ammonia Recovery Process ARP System a method for recycling ammonia in wastewater The data in this report were collected over a three month pilot study Tests found that the ARP system is capable of removing 75 99% of the ammonia in the waste stream in a domestic wastewater treatment plant The ARP System uses a series of absorption evaporation and crystallization steps to convert ammonia in wastewater into a commercial fertilizer ammonium sulfate The evaluation results clearly indicate that the ARP process is capable of achieving significant ammonia reduction under a range of environmental conditions

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