
**FLUID DAMPERS FOR APPLICATIONS OF SEISMIC
ENERGY DISSIPATION AND SEISMIC ISOLATION**

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ABSTRACT

Fluid inertial dampers which operate on the principle of fluid flow through orifices have found numerous applications in the shock isolation of military hardware. The adaptation of this hardware and use in civilian applications represents the object of this paper.

The application of these devices as part of seismic energy dissipation systems for buildings and bridges has been experimentally and analytically studied. The study included component testing over a range of temperatures, modeling of devices, shake table testing of 1-story building models, 3-story building models and a bridge model, development of alternate testing methods, analytical prediction of response and development of simplified analysis procedures.

Experimental results demonstrate a significant improvement of the energy dissipation capability of the structures to which the devices are attached. This resulted in substantial drift reductions and under certain conditions in reduction of inertia forces. Within a seismic isolation system, fluid dampers enhanced the system's ability to dissipate energy resulting in substantial reduction of displacement and almost complete insensitivity of the response to the frequency content of the input. Certain devices with nonlinear viscous characteristics and marked insensitivity to temperature variations have been built and tested for application within seismic isolation systems. One such application involving dampers with strokes plus or minus 600mm and an output force of nearly 1,500 kN will be presented, in addition to two other implementations.

Fluid inertial dampers represent a technology which was developed for military applications and has now been shown to be effective in applications of seismic hazard mitigation, either as elements of seismic isolation systems or as elements of seismic energy dissipating systems. The civil engineering profession has readily accepted this technology, resulting in a number of applications.

INTRODUCTION

A fluid damper is a device which dissipates energy by applying a resisting force over a finite displacement. The damper's output force is resistive, therefore it acts in a direction opposite to that of the input motion. Because the damper behaves in accord with the laws of fluid mechanics, the value of the resisting force varies with respect to the translational velocity of the damper at any point in time. The energy dissipated by the damper is equal to:

$$E_D = \int |F| dx$$

Where F is the damper output force function, and x is displacement.

The means of energy dissipation is that of heat transfer, i.e., the mechanical energy dissipated by the damper causes a heating of the damper's fluid and mechanical parts, and this heat energy is harmlessly transferred to the environment by transport mechanisms, usually convection and conduction.

A fluid damper has several inherent and significant advantages compared to other types of energy dissipaters, such as hysteretic (friction), visco-elastic (rubber), tuned masses, and elasto-plastic (yielding metal) types. These advantages are:

1. The output of a fluid damper is essentially out of phase with primary bending and shearing stresses in a structure. This implies that a fluid damper can be used to reduce both internal shear forces *and* deflection in a structure.
2. A fluid damper is self-contained, no auxiliary equipment or power is required.
3. A modern fluid damper operates at a fluid pressure level of significant magnitude, thus making the damper small, compact, and easy to install.
4. Fluid dampers are generally less expensive to purchase, install, and maintain than other types. They can economically reduce the overall cost of a structure, especially when used at high damping ratios in the 15%-40% critical damping range.
5. Fluid dampers have been proven by the test of time, with over 100 years of successful large scale use, in the most severe environments, most notably by the military and aerospace industries.

HISTORY OF FLUID DAMPING

As with many other types of engineered components, the requirements, needs and available funds from the military allowed rapid design evolution of fluid dampers to satisfy the needs of armed forces. Early fluid damping devices operated by viscous effects, where the operating medium was sheared by vanes or plates within the damper. An example is shown in Figure 1.

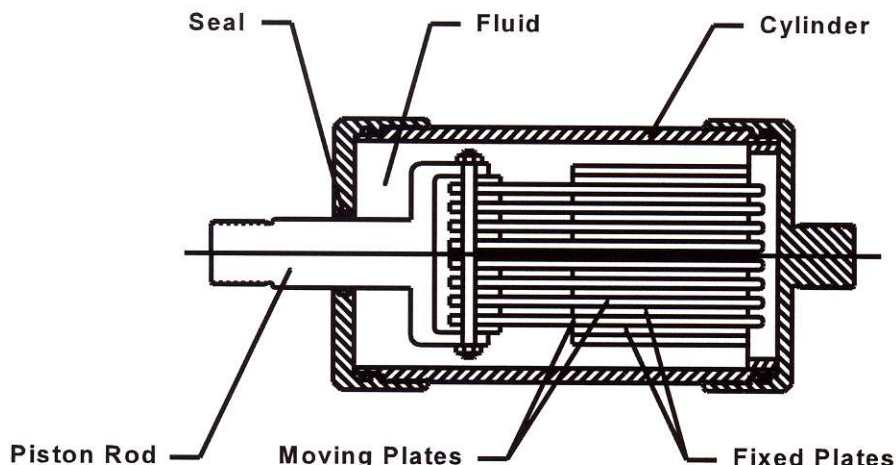


FIGURE 1 - EARLY FLUID VISCOUS EFFECT DAMPER

Designs of this type were mere laboratory curiosities, since the maximum pressure available from shearing a fluid is limited by the onset of cavitation, which generally occurs at between $.06 \text{ N/mm}^2$ and $.1 \text{ N/mm}^2$, depending on the viscosity of the fluid. This operating pressure was so low that for any given output level, a viscous damper was much larger and more costly than other types. In addition, because fluid viscosity changes significantly with temperature, the output from a pure viscous damper changes dramatically with ambient temperature of the damper fluid. By example, even the modern silicone fluids, specifically developed to be thermally stable, will exhibit a viscosity drop of 50% over a temperature range of +20 degrees C to +50 degrees C.

In the late 1800's, applications for dampers arose in the field of artillery, where a high performance device was needed to attenuate the recoil of large cannons. Early artillery, dating back to the middle ages, had used hysteretic damping for recoil control, often by merely dragging a metal spade attached to the gun carriage through the soil behind the weapon. The response of this crude hysteretic device was very irregular. A reliable self-contained damper was needed to allow consistent firing of high powered shells at a high firing rate. After extensive experimentation, the French Army incorporated a unique (and "top-secret") fluid damper into the design of their 75mm gun, Model M1897. The fluid damper design used inertial flows, where oil was forced through small orifices at high speeds (in excess of 200 m/s), in turn generating high damping forces. This allowed the damper to operate at relatively high operating pressures, in the 20 N/mm^2 range. The output of this device was not affected by viscosity changes of the fluid, but rather by the specific mass of the fluid, which changes only slightly with temperature. Thus, not only was this fluid inertial damper extremely compact, but it was also virtually unaffected by temperature. Early production demonstrated an additional important feature, namely that the damper's output could be precisely controlled in mass production by conventional (for that time) machining techniques. Thus, the technology of fluid inertial dampers became widespread within the armies and navies of most countries in the 1900-1945 period, but because of its secretive nature was not widely publicized.

During World War II, the emergence of radar and similar electronic systems required the development of specialized shock isolation techniques so that the equipment could withstand so-called “weapons” grade” shock. During the Cold War period, the guided missile became the weapon of choice for the military, and the fluid inertial damper was again turned to by the military as the most cost effective way of protecting missiles against both conventional and nuclear weapons detonation.

The transient shock from a near miss weapons detonation can contain free field velocities of 3 to 12 m/s, displacements of up to 2000 mm, and accelerations up to 1,000 times gravity. Extremely high damping forces were needed to attenuate these transient pulses on large structures, and fluid inertial dampers became a preferred solution to these problems.

With the end of the Cold War in the late 1980's, much of this fully developed defense technology became available for sale to the general public. Taylor Devices, since 1955, a supplier to the U.S. Government of dampers and shock absorbers to 1,000 tonnes output, teamed with the State University of New York at Buffalo (SUNYAB) to apply these devices to buildings and bridges to improve seismic performance. SUNYAB is the site of the U.S. Multi-Disciplinary Center for Earthquake Engineering Research (MCEER). Experiments began in 1991 using scaled structures and testing on a large seismic shake table.

DESCRIPTION OF DAMPER USED FOR EXPERIMENTS

The damper type selected for testing was a production fluid inertial damper based upon a military device used on the U.S. Air Force’s B-2 “Stealth” Bomber. The construction of the tested device is shown in Figure 2. It consists of a stainless steel piston, with a bronze orifice head, and a self-contained piston displacement accumulator. The damper is filled with silicone oil, normally used by the cosmetics industry in lotions and hand creams. This fluid is non-flammable, non-toxic, environmentally safe, and thermally stable. The damper had been previously tested by the military at temperatures from –50 degrees C to +90 degrees C, frequencies of 0 to 2,000 Hz., and had passed a 10 million cycle life test. Thus, this device includes performance characteristics considered as state of the art in fluid, sealing, and manufacturing technology.

The fluid inertial damper as tested produced a linear damping output, where output force is proportional to velocity of displacement. Other versions of this damper have been produced which provide non-linear damping, where force is proportional to velocity raised to a power, i.e.:

$$F \propto V^K$$

Thus, $F = CV^K$

Where K has a value in the range of .1 to 1.2, as specified for a given application.

OPERATION OF DAMPERS

The force that is generated by the fluid inertial damper is due to a pressure differential across the piston head. Consider that the piston moves from left to right in Figure 2 (device subjected to compression force). Fluid flows from chamber 2 towards chamber 1. Accordingly, the damping force is proportional to the pressure differential in these two chambers. However, the fluid volume is reduced by the product of travel and piston rod area. Since the fluid is compressible, this reduction in fluid volume is accompanied by the development of a restoring (spring-like) force. This is prevented by the use of the accumulator. The tested device showed no measurable stiffness for piston motions with frequency less than about 4 Hz. In general, this cutoff frequency depends on the design of the accumulator and may be specified in the design. If desired, this type of damper can be manufactured without a specified cut-off frequency and the damper will then respond over the range of 0-2,000 Hz.

The existence of the aforementioned cutoff frequency is a desirable property. The devices may provide additional viscous type damping to the fundamental mode of the structure (typically with a frequency less than the cutoff frequency) and additional damping and stiffness to the higher modes. This may, in effect, completely suppress the contribution of the higher modes of vibration.

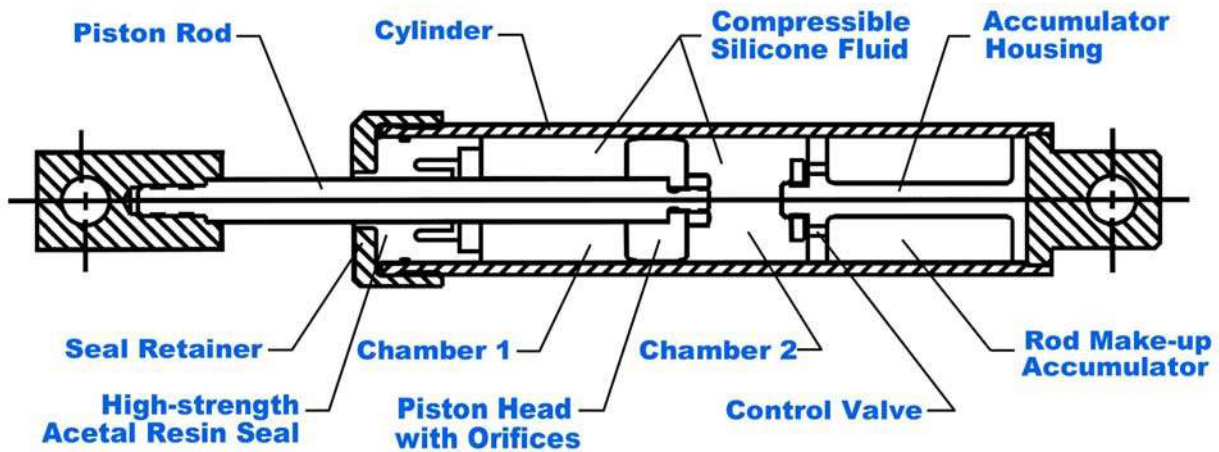


FIGURE 2 - FLUID INERTIAL DAMPER

TEST RESULTS

Various structural models were submitted to shake table testing at SUNYAB in the 1991-1995 period, with and without the fluid inertial dampers. These models included 1 and 3-story steel frame building models, of 2,800 kg. mass, by Constantinou and Symans (1992). A bridge model was tested, this being of 16,000 kg. mass, by Tsopelas and Constantinou (1994), and Tsopelas, et al (1994). A building floor model was also tested, of 2,818 kg. mass, by Lambrou and Constantinou (1994). Lastly, tests were performed by Reinhorn, Li, and Constantinou (1995) on a 3-story reinforced concrete frame of 12,000 kg. mass. More than 200 individual shake table tests are documented by the research reports noted.

The various models were subjected to numerous earthquake transients, including El Centro, Taft, and Pacoima Dam from the U.S., and the Japanese Hachinohe and Miyagiken records. Overall damping levels tested ranged from 20% to 60% critical. In all cases, the addition of fluid inertial dampers greatly reduced structural deflections, and in many cases, stresses decreased also, even at very high damping levels. High damping values without stress increases are possible only because of the out-of-phase response of the fluid inertial dampers, as compared to all other types. Figure 3 provides typical results on a 1-story steel frame building model. In this case, the addition of the dampers alone allowed the transient to be increased from 33% El Centro to 100% El Centro, without increasing stress or deflection from that of the undamped structure subjected to the lesser transient. The structure remained elastic at all times.

The seismic improvements possible with fluid inertial dampers, verified by testing and combined with their previous long years of military service, allowed this technology to be quickly implemented. Advantages of the damper will vary from application to application, depending on specific project requirements. In all of the projects to date, the incorporation of fluid inertial dampers reduced the overall cost of the project, compared to conventional seismic designs, or other types of damping devices.

IMPLEMENTATION EXPERIENCE

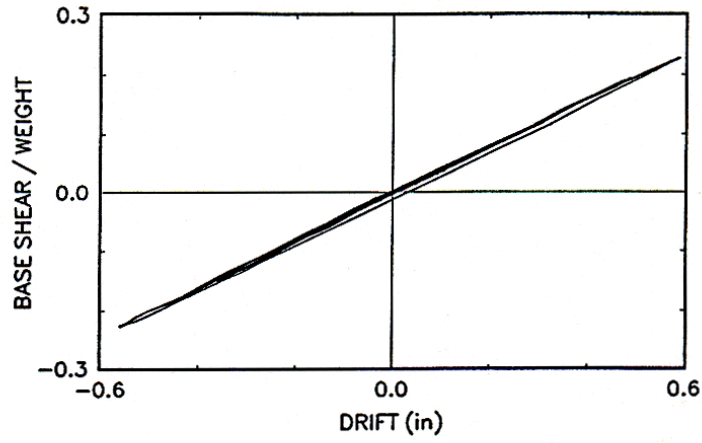
Use of fluid inertial dampers for seismic energy dissipation on full size civil engineering structures began in 1993. The first application was on five buildings of the San Bernardino County Medical Center Replacement Project, totaling 84,000 m² floor area. Located in a high seismic zone east of Los Angeles, California, the buildings were being designed to remain occupied and in service during and after seismic transients of up to 152 cm/s peak translational velocity. All buildings were intended to be base isolated on high damping rubber bearings, but deflection was unacceptably large, in the range of plus or minus 1500 mm. Using the test results from SUNYAB, the design group evaluated the improvements possible from adding dampers in parallel with base isolation bearings. A fluid inertial damper with nonlinear damping of $F = CV^4$ was selected for use in the project. It was determined by analysis that fluid damping levels in the 45% to 50% critical range were possible before shear stress increases occurred on this application. The resulting building base displacements were reduced to plus or minus 560 mm. An additional advantage of the fluid inertial dampers was that the long period rubber bearings and fluid dampers would be able to fully reset the building after a seismic event with no permanent offset. Other types of dampers that were hysteretic or of yielding material type would cause a large offset due to their essentially hysteretic response.

The detail design of the fluid inertial dampers was taken directly from a previous U.S. Military program. This prior application was that of a 2000 kN, 1000 mm deflection Taylor Devices' damping device used to attenuate weapons' ground attack motions on the MX Intercontinental Ballistic Missile. In this form, the damper dissipated the energy of a transient having more than 12 m/s velocity. A proprietary element incorporated into this design allowed the damper to fully and properly respond even to step function inputs, where peak transient speeds are reached in less than 1 millisecond. This design feature was incorporated into the San Bernardino fluid inertial dampers. Subsequent concerns by the structural engineering community about step function transients was generated from earthquake records of the 1994 Northridge, California and 1995 Kobe, Japan earthquakes. Interest was such that Taylor Devices, Inc. now incorporates this feature into all fluid inertial dampers produced for structural use.

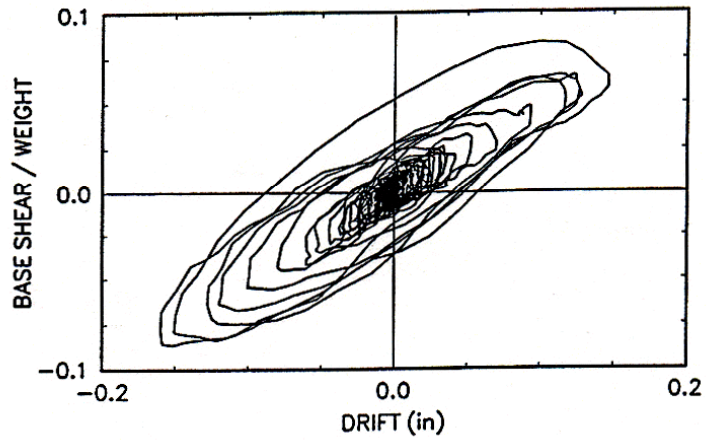
A total of 186 dampers were fabricated for the San Bernardino project, each having an output force of 1456 kN, and a maximum energy dissipation rate per damper of 2.17 megawatts. Table 1 provides parametric data on the dampers, and Figure 4 is a photograph of the completed device. Due to the large size and high capacity of these devices, testing of the production dampers presented difficulty, in that no suitable sine wave cycling testing machine was available. After extensive evaluation and demonstration, the time honored military method of drop testing was adapted for this project. A drop test consists of impacting the vertically mounted damper with a large free falling weight. By dropping the weight at varying heights, the dampers force-velocity function can be determined, even at very high force levels. For the San Bernardino project, validation testing was performed on a 1/6 force scaled damper with both a hydraulic actuator located at SUNYAB and with a drop tester. Sine wave cyclic test output from the actuator was compared to a series of drop tests from different free fall heights. Comparison of measured force and velocity from both test methods showed virtually no discernable differences in results, thus validating the test method. The results also verified that the damper's measured force-velocity relationship was the same with either test technique, and was virtually unaffected by extreme testing temperatures. Each of the full size production dampers were then drop tested at various velocities up to the maximum of 1456 kN force at 1.5 m/s velocity. Taylor and Constantinou (1995) report on testing of the production dampers. Drop testing has since been used on numerous other seismic projects, as listed in Table 2.

A second significant project was an emergency communication services building in Sacramento, California, owned by Pacific Bell. The building was of braced steel frame construction with a fixed base, 3 stories in height, and of 15,000 m² floor area. The dampers were installed into chevron braces throughout the structure. A total of 62 fluid inertial dampers were used, each of 130 kN output force. Damping level was of sufficient magnitude to keep the frame fully elastic under a maximum level earthquake. This allows for immediate occupancy after a seismic event, assuring minimum loss of emergency services. The damper design utilized for the Pacific Bell project originated on the U.S. Navy Standard Surface to Air Missile Program.

1-Story, No Dampers, El Centro 33.3%



1-Story, 2 Dampers, El Centro 33.3%



1-Story, 2 Dampers, El Centro 100%

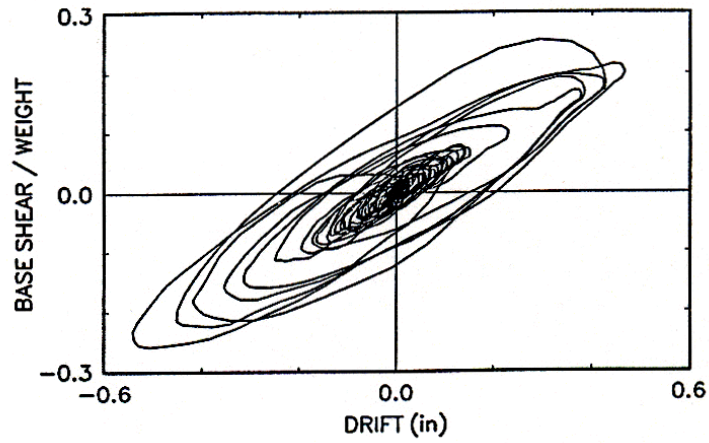


FIGURE 3 -TEST RESULTS

A third significant application was the Woodland Hotel, located in the city of Woodland, California. This historic 4-story structure dates to 1927, and is of non-ductile concrete construction with a so-called “soft” first story. The owner wished to improve the earthquake resistance of the building, while maintaining its historic appearance. Fluid inertial dampers proved to be the most cost effective retrofit strategy, as compared to conventional shear walls or braces. In addition, the fluid inertial dampers did not alter or obscure the historic appearance of the building. An arrangement of 16 fluid inertial dampers, each of 450 kN force output, were utilized in this construction. The dampers were installed into the walls of the structure with chevron braces. Miyamoto and Scholl (1995) provide an extensive report on the project effort. Similar to the other two projects, the detail design of the Woodland Hotel fluid inertial damper again originated with the military, with a damper used to attenuate underwater mine explosions on ships and submarines of the U.S. Navy.

TABLE 1
DAMPER SPECIFICATIONS
SAN BERNARDINO COUNTY MEDICAL CENTER

DISPLACEMENT	=	1.2 METERS
MAXIMUM DAMPING FORCE	=	1,456,000 NT.
MAXIMUM OPERATING VELOCITY	=	1.5 M/SEC.
POWER DISSIPATION (EACH DAMPER)	=	2,170,000 WATTS
LENGTH	=	4.37 METERS EXTENDED
DIAMETER	=	36 CM
WEIGHT (EACH DAMPER)	=	13,400 NT.
QUANTITY REQUIRED	=	186 UNITS



FIGURE 4 - FLUID INERTIAL DAMPER, 1456 kN OUTPUT

CONCLUSIONS

Fluid inertial dampers, used extensively in military applications, have direct applications on civil engineering structures. These products can be used for the purpose of dissipating seismic energy or wind energy as a primary element of design.

Comprehensive shake table testing at the University level has demonstrated that fluid inertial dampers have a response that is essentially out of phase with structural shear stresses. Thus, they have the capability to reduce both shear stresses and deflections in a structure. Extensive shake table testing has demonstrated the benefits of the out of phase damper response. The benefits of damping levels of up to 60% critical have also been demonstrated by test, and these levels are now achievable in a compact device, proven by the test of time in applications dating to 1897.

Large structures are now utilizing fluid inertial dampers for seismic and wind energy dissipation. Many of these applications utilize fluid inertial dampers that have been taken directly from military production designs of the Cold War period. Benefits obtained in these constructions from fluid inertial dampers include reduced project cost, lower column stresses and deflections, reduced construction materials, and preservation of architectural attributes and enhancements. To date, more than 300 civil engineering structures are now utilizing this technology. Table 2 provides a select list of representative projects.

TABLE 2
STRUCTURAL APPLICATIONS OF FLUID VISCOUS DAMPERS

NAME AND TYPE OF STRUCTURE	COUNTRY/CITY	TYPE AND NUMBER OF DAMPERS	DATE	LOAD	ADDITIONAL INFORMATION
Barwon Heads Bridge	Australia/Victoria	Taylor Fluid Dampers Total: 10 405kN ± 50mm stroke	2010	Seismic	Lock-up devices used to limit bridge deck displacements for a new highway bridge with timber piers.
Meguro Gajoen Extension Project	Japan/Tokyo	Taylor Fluid Dampers Total: 72 1000kN ± 50mm stroke 1500kN ± 50mm stroke 2000kN ± 50mm stroke	2010	Seismic	New construction, 16-story steel and concrete frame office/hotel/parking structure uses dampers to dissipate earthquake energy.
Kasumigaseki 3 Chome Project	Japan/Tokyo	Taylor Fluid Dampers Total: 64 1000kN ± 50mm stroke 1500kN ± 50mm stroke	2010	Seismic	New construction, 17-story steel frame office/parking structure uses dampers to dissipate earthquake energy.
250 West 55th Street	USA/New York, NY	Taylor Fluid Dampers Total: 7 1690 kN ± 100 mm stroke	2009	Wind	Custom high capacity metal bellows dampers used as part of an outrigger system in a new 39- story all glass exterior office building to reduce wind motion.
WRCT Project	USA/Boone County, KY	Taylor Fluid Dampers Total: 2 750 kN ± 100 mm stroke	2009	Seismic	Devices used to provide dynamic force transfer across thermal expansion joint of the supporting structure for this elevated Western Regional Conveyance Tunnel.
US Dept. of Interior Bureau of Reclamation - Utah Projects Office Complex	USA/Provo, UT	Taylor Fluid Dampers Total: 9 445kN ± 100mm stroke 245kN ± 75mm stroke	2009	Seismic	Retrofit of an office complex. Dampers and lock-up devices used in diagonal braces to dissipate earthquake energy and reduce displacement.
LAX Theme Building	USA/Los Angeles, CA	Taylor Fluid Dampers Total 8 555 kN ± 15mm stroke	2009	Seismic	Retrofit of an elevated restaurant supported by four curved legs. Dampers used as part of a mass damper system to control movement of the mass block during an earthquake.
100 International Drive - Steel warehouse	USA/East Hartford, CT	Taylor Fluid Dampers Total: 2 330 kN ± 100 mm stroke	2009	Seismic	Single-story steel framed warehouse building with plan dimensions of 676' x 450'. Dampers transfer loads across expansion joint at diaphragm chord trusses.
T.F. Green Airport Parking Garage	USA/Providence, RI	Taylor Fluid Dampers Total: 64 135 kN ± 32 mm stroke 270 kN ± 75 mm stroke	2009	Seismic	Located in Warwick, near Providence, RI, this airport parking garage uses dampers to transfer loads across expansion joints, thereby reducing the large seismic expansion joint/gap requirements.

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NAME AND TYPE OF STRUCTURE	COUNTRY/CITY	TYPE AND NUMBER OF DAMPERS	DATE	LOAD	ADDITIONAL INFORMATION
Aircraft Hanger	USA/Hawthorne, CA	Taylor Fluid Dampers Total: 160 900 kN ± 100 mm stroke	2009	Seismic	Voluntary seismic upgrade of an aircraft hangar building using dampers in double-diagonal braces to provide seismic energy dissipation.
865 Market Street - San Francisco Centre	USA/San Francisco, CA	Taylor Fluid Dampers Total: 50 2000 kN ± 125 mm stroke 2000 kN ± 165 mm stroke	2009	Seismic	Voluntary Seismic upgrade of existing multi-story Nordstrom Store in a San Francisco downtown shopping center mall. Dampers in diagonal braces provide seismic energy dissipation.
3300 Hyland Ave – Abraxis Biosciences	USA/Costa Mesa, CA	Taylor Fluid Dampers Total: 44 1000 kN ± 100 mm stroke	2009	Seismic	Seismic upgrade of 3-story existing structure containing offices on the first and third floors and a state-of-the-art upgraded laboratory on the second floor. Dampers in double-diagonals provide seismic energy dissipation.
IETMC	USA/Fontana, CA	Taylor Fluid Dampers Total: 8 1500 kN ± 610 mm stroke	2009	Seismic	New Caltrans District 8 Inland Empire Transportation Management Center with 24/7 Emergency traffic response and management facilities uses rubber isolators and Taylor dampers to meet immediate occupancy criteria in this 2-story steel structure
Dubai Racetrack Stadium	United Arab Emirates/Dubai	Taylor Fluid Dampers Total: 108 885 kN ± 50 mm stroke 1280 kN ± 50 mm stroke 1370 kN ± 50 mm stroke	2009	Wind	New stadium utilizing 36 Tuned Mass Dampers for the reduction of wind vibrations in large cantilevered roof truss sections.
Meixihe Bridge	China/ Chongqing	Taylor Fluid Dampers Total: 4 1750kN ± 250mm stroke	2009	Seismic	Retrofit of a 1990 vintage suspension bridge with a 222m main span. Dampers used to reduce displacements caused by earthquakes.
Nanping Mingjian Bridge	China/Fujian	Taylor Fluid Dampers Total: 4 1400kN ± 500mm stroke	2009	Seismic	Cable-stayed bridge uses dampers between bridge deck and piers to control movements caused by earthquakes.
Ningbo Yongjiang Bridge	China/Ningbo	Taylor Fluid Dampers Total: 8 1800kN ± 550mm stroke	2009	Seismic	Cable-stayed bridge uses dampers between bridge deck and piers to control movements caused by earthquakes.
Xinjiang Guozili Bridge	China/Xinjiang	Taylor Fluid Dampers Total: 8 1100kN ± 400mm stroke 1200kN ± 500mm stroke	2009	Seismic	Cable-stayed bridge uses dampers between bridge deck and piers to control movements caused by earthquakes.

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NAME AND TYPE OF STRUCTURE	COUNTRY/CITY	TYPE AND NUMBER OF DAMPERS	DATE	LOAD	ADDITIONAL INFORMATION
Nihonbashi Nomura Project	Japan/Tokyo	Taylor Fluid Dampers Total: 52 1000kN ± 50mm stroke 1500kN ± 50mm stroke 2000kN ± 50mm stroke	2009	Seismic	New construction, 21-story steel frame office/commerce facility/parking uses dampers to dissipate earthquake energy.
Hydra Waves	Mexico/Mazatlan	Taylor Fluid Dampers Total: 18 680kN ± 50mm stroke	2009	Seismic	New structure use dampers to absorb earthquake energy and reduce deflection and stress.
Tauranga Harbour Link Bridge	New Zealand/Tauranga	Taylor Fluid Dampers Total: 21 980kN ± 175mm stroke 1470kN ± 175mm stroke 1750kN ± 225mm stroke	2009	Seismic	New four lane highway bridge use Lock-Up Devices with force limiting devices to control bridge deck movement during seismic events.
ASE I – Mihai Eminescu Project	Romania/Bucharest	Taylor Fluid Dampers Total: 142 1000 kN ± 100 mm stroke 100 kN ± 100 mm stroke	2009	Seismic	Retrofit of a historic building with dampers in diagonal braces to provide seismic energy dissipation.
TSMC Fab #12 P5	Taiwan/Hsin Chu City	Taylor Fluid Dampers Total: 6 2000 kN ± 75 mm stroke	2009	Seismic	Retrofit of a semiconductor processing plant uses dampers to dissipate seismic energy and micro-vibrations.
Uni-President B8 Project	Taiwan/Taipei	Taylor Fluid Dampers Total: 336 600 kN ± 75 mm stroke	2009	Seismic	Known as Taipei Hsin-Yi Project, this new 22-story reinforced concrete building uses dampers in chevron braces to dissipate seismic energy.
FDS Project	Taiwan/Taipei	Taylor Fluid Dampers Total: 6 500 kN ± 75 mm stroke	2009	Seismic	Dampers installed in RC supporting wall in a new reinforced concrete building.
Farglory H61 Project	Taiwan/Taipei	Taylor Fluid Dampers Total: 12 500kN ± 75mm stroke	2009	Seismic	Dampers installed in RC supporting wall in a new reinforced concrete building.
Farglory H63 Project	Taiwan/Taipei	Taylor Fluid Dampers Total: 52 500kN ± 75mm stroke	2009	Seismic	Dampers used in chevron bracing elements in a new 15-story reinforced concrete building.

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