Seismic fitness

On some features of Earthquake Engineering

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About the author

User:Shustov

Be *simple* but *effective*. Do not pretend you know better. Be better!

Babel:	
ru	Для этого пользователя **русский** язык родной.
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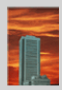
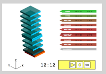
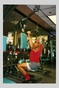


This user is an expert in the field of earthquake engineering.

This user developed and tested earthquake protector.[1]


This user created a number of earthquake control videos. [2]


This user developed the EPETO [3] software.


This user is an expert in fitness training for seniors.


This user has a page on the Russian Wikipedia.

Since 14 January 2011, this User has contributed the following pages:

A

- American Society of Civil Engineers; Architecture; Antifriction and Multi-Step Base Isolation

B

- Base isolation; Bridge structure; Building: Building code; Building elevation control; Category:Buildings [4]; Template:Building structures

C

- California State University; Category:California State University [5]; California State University, Northridge; Civil engineering; Template:Civil engineering; Construction engineering

D

- Dam; Dry-stone walls control

E

- Earthquake; Category:Earthquakes [6]; Template:Earthquakes; Earthquake engineering; Category:Earthquake engineering [7]; Template:Earthquake engineering; Earthquake performance simulation; Earthquake engineering research; EERI; Earthquake protector; EPET; EPETO; Earthquake simulation; Elevated building foundation; Evaluation; Category:Evaluation [8]; Explosion protection

F

- Foundation in construction; Friction pendulum bearing

H

- Highway; Hysteretic damper

I

- Infrastructure

L

- Lead rubber bearing

N

- NEES; National Science Foundation; Category:Natural events [9]

R

- Richter scale; Roads

S

- Seismic damper; Seismic load; Seismic performance; Seismic performance evaluation; Seismic performance analysis; Seismogram; Seismometer; Seismology; Shake-table; Simple roller bearing

T

- Tsunami; Tunnel; Tuned Mass Damper

V

- Vibration control

W

- Wind engineering

ru:Участник:Shustov

References

[1] http://www.structuralpedia.com/index.php?title=Earthquake_protector
[2] http://www.youtube.com/user/vshustov#g/f
[3] http://www.seismicevaluation.org
[4] http://en.wikiversity.org/wiki/Category:Buildings
[5] http://en.wikiversity.org/wiki/Category:California_State_University
[6] http://en.wikiversity.org/wiki/Category:Earthquakes
[7] http://en.wikiversity.org/wiki/Category:Earthquake_engineering
[8] http://en.wikiversity.org/wiki/Category:Evaluation
[9] http://en.wikiversity.org/wiki/Category:Natural_events

Earthquake

Earthquake

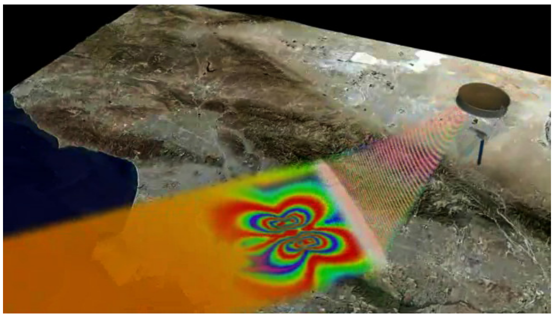
Damaged buildings from the Hanshin-Awaji earthquake of 1995 in Chuo-ku Kobe city.

Earthquake is a violent movement of the rocks in the Earth's crust which creates waves of energy traveling through the Earth. Earthquakes are usually quite brief, but may repeat over a period of time.

There are big earthquakes and small earthquakes. Big earthquakes can take down buildings and cause deaths and injuries. The study of earthquakes is called seismology.[1]

When the earth moves offshore in the ocean, it can cause a tsunami. A tsunami can cause just as much death and destruction as an earthquake. Landslides can happen, too. This is an important part of the Earth's cycle.

Earthquakes are measured using observations from seismometers. The magnitude of an earthquake and the intensity of shaking are measured on a numerical scale. On the scale, 3 or less is scarcely noticeable, and magnitude 7 (or more) causes damage over wide areas.



To predict earthquakes, "InSAR satellite" measures small changes in the earths crust.

Search Wikimedia Commons for images, sounds and other media related to: ***Earthquake damage***

References

[1] *Earth Science*. Austin, Texas 78746-6487: Holt, Rinehart Winston. 2001. ISBN 0-03-055667-8.

Tsunami

Tsunami

A **tsunami** is a chain of fast moving waves in the ocean caused by powerful earthquakes or volcanic eruptions. Tsunami has a very long wave. It can be hundreds of kilometers long. Usually, tsunami starts suddenly. The waves travel at a great speed across an ocean with little energy loss. They can remove sand from beaches, destroy trees, toss and drag vehicles, damage houses and even destroy whole towns.

Tsunami that occurred in 2004 in Thailand. The water of the wave can be seen in the palm trees in the background.

The water will draw back from the coast half of the wave period prior to the wave getting to the coast. If the slope of the coast is not deep, the water may pull back for hundreds of metres. People who do not know of the danger will often remain at the shore.

Tsunamis can not be prevented. However, there are ways to help stop people from dying from a tsunami. Some regions with lots of tsunamis may use warning systems which may warn the population before the big waves reach the land. Because an earthquake that caused the tsunami can be felt before the wave gets to the shore, people can be warned to go somewhere safe.

References

Search Wikimedia Commons for images, sounds and other media related to: ***Tsunami***

Field of Earthquake Engineering

Earthquake engineering

Earthquake engineering is the study of the behavior of building structures subject to earthquake impacts.

Building which collapsed at the 2010 Chile earthquake.

Objectives of the earthquake engineering

The main objectives of earthquake engineering are:

- Understand the interaction between buildings and the ground.
- Foresee the potential consequences of strong earthquakes on building structures.
- Design, construct and maintain structures to perform at earthquake exposure up to the expectations and in compliance with building codes[1] .

Tools

A properly engineered structure does not necessarily have to be extremely strong or expensive.

The most powerful and budgetary tools of earthquake engineering are vibration control technologies and, in particular, base isolation.

Concurrent shake table testing of two building models. The right model rests on base isolators, the left one is fixed to the platen[2] .

To verify experimentally the earthquake or seismic performance of a building structure, it is may be put on a *shake-table* that simulates the earth shaking. The earliest shake-table experiments were performed more than a century ago [3]

Tsunami preparedness and protection

Tsunami or a chain of fast moving waves in the ocean caused, mostly, by powerful earthquakes is a very serious challenge for people's safety and for tsunami protection of buildings and civil infrastructure. Those waves can inundate coastal areas, destroy houses and even swipe away whole towns.[4]

Though tsunami can not be prevented, there are Tsunami warning system developed recently[5] which warn the population before the big waves reach the land to let them enough time to rush to safety.

Search Wikimedia Commons for images, sounds and other media related to: ***Earthquake engineering***

External links

- Earthquake engineering [6] at the Open Directory Project
- Earthquake Performance Evaluation Tool Online (EPETO) [7]
- The George E. Brown, Jr. Network for Earthquake Engineering Simulation or NEES [8]
- Vibration control videos [9]

References

[1] Berg, Glen V. (1983). *Seismic Design Codes and Procedures*. EERI. ISBN 0943198259.
[2] Testing of a New Line of Seismic Base Isolators (http://nees.org/data/get/NEES-2006-0283/Public/REPORT.pdf)
[3] Omori, F. (1900). *Seismic Experiments on the Fracturing and Overturning of Columns*. Publ. Earthquake Invest. Comm. In Foreign Languages, N.4, Tokyo.
[4] USGS Poster of the Near the East Coast of Honshu, Japan Earthquake of 11 March 2011 - Magnitude 8.9 (http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0001xgp.php)
[5] Pacific Tsunamy Warning Center (http://ptwc.weather.gov)
[6] http://www.dmoz.org/Science/Technology/Structural_Engineering/Earthquake_Engineering/
[7] http://www.structuralpedia.com/index.php?title=EPETO
[8] http://simple.wikipedia.org/wiki/NEES
[9] http://www.structuralpedia.com/index.php?title=Category:Vibration_control_videos

ru:Сейсмостойкое строительство

Seismic performance

Seismic performance

Seismic performance is an execution of a structure's ability to sustain its due functions, such as safety and serviceability, *at* and *after* a particular earthquake exposure. A structure is, normally, considered *safe* if it does not endanger the lives and wellbeing of those in or around it by partially or completely collapsing. A structure may be considered *serviceable* if it is able to fulfill its operational functions for which it was designed.

A collapsed parking structure at 1994 Northridge earthquake [1]

Basic concepts of the earthquake engineering, implemented in the major building codes, assume that a building should survive The Big One (the most powerful anticipated earthquake) though with partial destruction. Drawing an analogy with a human body, it will have dislocated joints, fractured ribs, traumatized spine and knocked out teeth but be alive and, therefore, quite O.K. according to the prescriptive building codes. This situation is a major barrier to implementation of any structural innovations in the earthquake engineering technologies employing the seismic vibration control and, particularly, the most effective brands of base isolation.

However, alternative performance-based design approaches already exist and are implemented at earthquake engineering research. Some of them, for assessment or comparison of the anticipated seismic performance or for seismic performance analysis, use the *Story Performance Rating* **R** as a major criterion [2] while the *Seismic Performance Ratio* (**SPR**) is used for a rather accurate prediction of seismic performance of a building up to the point of its state of *severe damage* [3] .

Anyway, replacement of the present prescriptive design standards with the future codes of performance is not an easy task: most of the designers would be reluctant to accept any additional legal obligations.

References

[1] http://en.wikipedia.org/wiki/1994_Northridge_earthquake
[2] A NEW CONCEPT OF DESIGN CODE FOR SEISMIC PERFORMANCE (http://www.ecs.csun.edu/~shustov/Topic7.htm)
[3] SGER: Testing of a New Line of Seismic Base Isolators (https://central.nees.org/data/get/NEES-2006-0283/Public/REPORT.pdf)

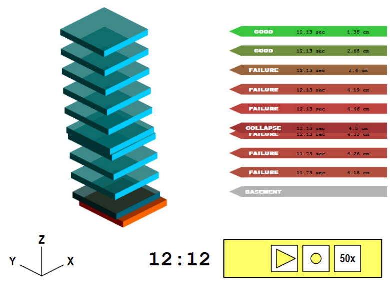
Earthquake (seismic) performance simulation

Earthquake performance simulation

Earthquake performance simulation is meant to study effect of earthquakes on building structures and is a practical way of seeing a thing to happen without it actually taking place in the same way. There are research institutions just devoted to earthquake performance simulations, like, e.g., *The George E. Brown, Jr. Network for Earthquake Engineering Simulation* or NEES.

Physical simulation of earthquake performance of two building models.

Physical earthquake performance simulation



Print-screen of a computational earthquake performance simulation.

The best way to do it is to put the structure on a shake-table that simulates the seismic loads and watch what may happen next (if you have no time to stand out in the field and wait for a real earthquake to strike, of course). The earliest experiments like this were performed more than a century ago[1]

Computational earthquake performance simulation

Another way is to evaluate the earthquake performance analytically. The very first earthquake simulations were performed by statically applying some *horizontal inertia forces*, based on scaled peak ground accelerations, to a mathematical model of a building [2] . With the further development of computational technologies, statics approaches began to give way to dynamics ones [3] .

References

	Search Wikimedia Commons for images, sounds and other media related to: ***Earthquake performance simulation***

[1] Omori, F. (1900). *Seismic Experiments on the Fracturing and Overturning of Columns*. Publ. Earthquake Invest. Comm. In Foreign Languages, N.4, Tokyo.

[2] Lindeburg, Michael R.; Baradar, Majid (2001). *Seismic Design of Building Structures*. Professional Publications. ISBN 1888577525.

[3] Clough, Ray W.; Penzien, Joseph (1993). *Dynamics of Structures*. McGraw-Hill. ISBN 0070113947.

Other websites

- Network for Earthquake Engineering Simulation (NEES) (http://www.nsf.gov/news/special_reports/nees/about.jsp)
- AEM Earthquake Simulation (http://www.appliedelementmethod.com/StructuralVulnerabilityAssessment.aspx)

Seismic load

Seismic load

Seismic load is one of the basic concepts of earthquake engineering which means application of an earthquake-generated agitation to a building structure.

It happens at contact surfaces of a structure either with the ground, see The Geotechnical Earthquake Engineering Portal [1], or with adjacent structures, see Seismic Pounding between Adjacent Building Structures [1], or with gravity waves from tsunami, see Tsunami wave propagation [2].


The last Day of Pompeii by Karl Briullov, The State Russian Museum.

Seismic load depends, primarily, on:

- Anticipated earthquake's parameters at the site
- Geotechnical parameters of the site
- Structure's parameters
- Characteristics of the anticipated gravity waves from tsunami (if applicable).

Sometimes, seismic load exceeds ability of a structure to resist it without being broken, partially or completely. Due to their mutual interaction, seismic loading and seismic performance of a structure are intimately related.

References

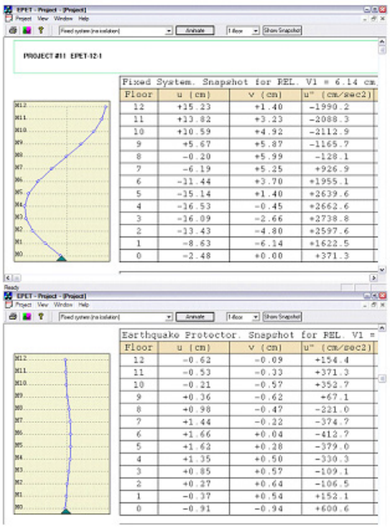
[1] http://earthquake.geoengineer.org/
[2] http://www.youtube.com/watch?v=w9ygYqj4rVM&feature=Pl/

Seismic performance evaluation

Seismic performance evaluation

Seismic performance evaluation is a formal procedure to quantify the level of actual or anticipated seismic performance associated with the direct damage to an individual building subject to a specified ground shaking.

Snapshot from a shake-table destructive testing in Japan [1]



Concurrent computational testing of two models [2].

The best way to do it is to put a model that simulates the building structure on a shake-table that simulates the earth shaking and to watch what may happen next (if you have no time to stand out in the field and wait for a real earthquake to strike, which is called a *field testing*). Such kinds of experiments were performed still more than a century ago. Another way is to evaluate the earthquake performance analytically.

The very first earthquake simulations were performed by statically applying some *horizontal inertia forces*, based on scaled peak ground accelerations, to a mathematical model of a building. With the further development of computational technologies, static approaches began to give way to dynamic ones.

Traditionally, numerical simulation and physical tests have been uncoupled and performed separately. So-called *hybrid testing* systems employ rapid, parallel analysis using both physical and computational tests [3] .

References

[1] http://www.youtube.com/watch?v=3z4YLUqOysI&feature=related
[2] http://www.epet.space3d.biz
[3] Valentin Shustov (2011), "Earthquake Performance Evaluation Tool Online,". (https://nees.org/resources/epeto)

Seismic performance analysis

Seismic performance analysis

Seismic performance analysis is an intellectual tool of earthquake engineering which breaks the complex topic into smaller parts to gain a better understanding of seismic performance of building and non-building structures. The technique as a formal concept is a relatively recent development.

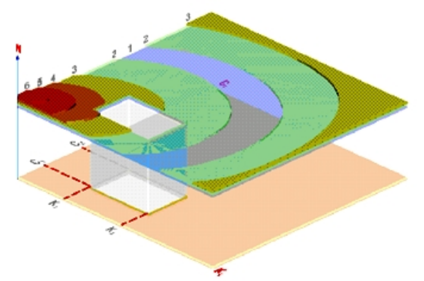


Chart of seismic performance

In general, seismic analysis is based on the methods of structural dynamics. For decades, the most prominent instrument of seismic analysis has been the earthquake *response spectrum* method which, also, contributed to the proposed building code's concept of today [1].

However, those response spectra are good, mostly, for single-degree-of-freedom structural systems. Numerical *step-by-step integration*, applied with the *charts of seismic performance* [2], proved to be a more effective method of performance analysis for the multi-degree-of-freedom structural systems with severe non-linearity and under a substantially transient process of earthquake type kinematic excitation or earthquake simulation [3] [4] .

Search Wikimedia Commons for images, sounds and other media related to: ***Earthquake engineering***

References

[1] http://www.ecs.csun.edu/~shustov/Topic7.htm
[2] http://www.ecs.csun.edu/~shustov/Topic6.htm
[3] Valentin Shustov (2010), "Testing of a New Line of Seismic Base Isolators," https://nees.org/resources/770.
[4] Valentin Shustov (2011), "Earthquake Performance Evaluation Tool One," https://nees.org/resources/epet1

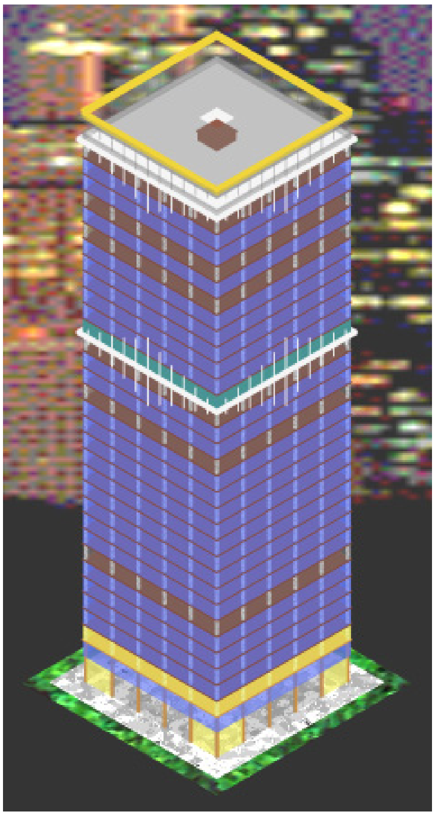
Vibration control

Vibration control

Vibration control in earthquake engineering is a set of technical means aimed to mitigate seismic impacts in building and non-building structures. All seismic vibration control devices may be classified as *passive*, *active* or *hybrid* [1] where:

- *passive control devices* have no feedback capability between them, structural elements and the ground;
- *active control devices* incorporate real-time recoding instrumentation on the ground integrated with earthquake input processing equipment and actuators within the structure;
- *hybrid control devices* have combined features of active and passive control systems.

When ground seismic waves reach up and start to penetrate a base of a building, their energy flow density, due to reflections, reduces dramatically: usually, up to 90%. However, the remaining portions of the incident waves during a major earthquake still bear a huge devastating potential.



High-rise with Multi-Frequency Quieting Building System [2]

Ways of control

After the seismic waves enter a superstructure, there is a number of ways to control them in order to sooth their damaging effect and improve the building's seismic performance, for instance:

- to *dissipate* the wave energy inside a superstructure with properly engineered seismic dampers [3];
- to *disperse* the wave energy between a wider range of frequencies [4], [5];
- to *reflect*, *diffract*, and *dissipate* seismic waves in a process of their vertical propagation with the help of elevated building foundation [6];
- to *absorb* the resonant portions of the whole wave frequencies band with the help of so called tuned mass dampers [7].

Devices of the last kind, abbreviated correspondingly as TMD for the tuned (*passive*), as AMD for the *active*, and as HMD for the *hybrid mass dampers*, have been studied and installed in high-rise buildings, predominantly in Japan, for a quarter of a century [8].

To increase the shielded range of forcing frequencies, the concept of Multi-Frequency Quieting Building System (MFQBS) was developed [2].

However, there is quite another approach: partial suppression of the seismic energy flow into the superstructure known as seismic or base isolation.

For this, some pads are inserted into or under all major load-carrying elements in the base of the building which should substantially decouple a superstructure from its substructure resting on a shaking ground. The first evidence of earthquake protection by using the principle of base isolation was discovered in Pasargadae, a city in ancient

Persia, now Iran: it goes back to VI century BC [9].

References

[1] http://physics-animations.com/Physics/English/spri_txt.htm
[2] http://www.ecs.csun.edu/~shustov/Topic9.htm
[3] http://www.structuralpedia.com/index.php?title=Hysteretic_damper
[4] http://www.ecs.csun.edu/~shustov/Topic5.htm
[5] http://www.youtube.com/watch?v=Hexb8EILj6A
[6] https://central.nees.org/data/get/NEES-2006-0283/Public/EBF%20and%20EP.pdf
[7] http://ffden-2.phys.uaf.edu/211_fall2002.web.dir/Eva_Burk/Eva's%201st%20page.htm
[8] http://www.takenaka.co.jp/takenaka_e/quake_e/seishin/seishin.htm
[9] http://en.wikipedia.org/wiki/Pasargadae

Structural control technics

Base isolation

Base isolation or **seismic isolation** is a collection of special units in a building resting on its foundation to provide separation of the building from the shaking ground thus improving its seismic performance [2] .

Shake-table testing of two building models at CSUN. The right one is equipped with a base isolation device [1].

Basic parts of base isolation system

Base isolation system consists of *isolation units* with or without *isolation components*, where:

1. *Isolation units* are the basic elements of *base isolation system* which provide the mentioned separation effect to a building structure.

2. *Isolation components* are the connections between *isolation units* and other parts of the building having no separation effect of their own.

Famous base-isolated buildings


Pasadena City Hall, California, U.S.


San Francisco City Hall, California, U.S.


Salt Lake City/County Building, Utah, U.S.

History

From the very beginning, the theory of base isolation rested on two pillars: *heavy damping* and *frequency separation*. Unfortunately, nobody paid any attention that the heavy damping was a sort of a strong connection between a *substructure* and *superstructure*, and that the idea of decoupling them with the help of such connections was of no good [3] . Anyway, to virtually test-drive any design concept of base isolation, some online help is available now [4] .

Other websites

	Search Wikimedia Commons for images, sounds and other media related to: ***Base isolation***

- Vibration control
- Vibration control videos [5]

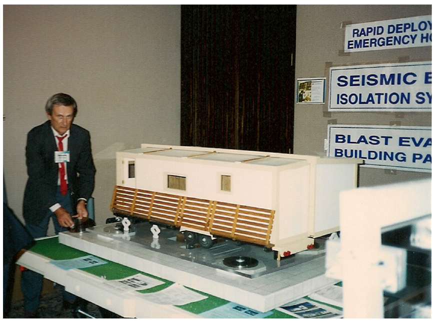
References

[1] http://www.youtube.com/watch?v=ZqlXp3czrrM
[2] Benchmark for structural vibration control (http://www.youtube.com/user/vshustov#g/f)
[3] Base Isolation: Promise, Design & Performance (http://www.ecs.csun.edu/~shustov/Topic4.htm)
[4] Earthquake Performance Evaluation Tool Online (http://www.seismicevaluation.org)
[5] http://structuralpedia.com/index.php?title=Category:Vibration_control_videos

es:Aislamiento sísmico fr:Isolement bas it:Isolatori sismici ru:Сейсмическая изоляция uk:Сейсмічна ізоляція

Antifriction and Multi-Step Base Isolation

Antifriction and Multi-Step Base Isolation (**AF&MS BI**), also called **Shock Evader**, is relatively recent type of seismic vibration control. In spite of the fact that the first attempts to isolate buildings from potentially shaky ground were made thousands years ago, the modern concept of seismic isolation (flexible mounting + damping) is foreign for earthquake engineering: it has not been inherited, it has been borrowed from mechanical engineering [1].



Building model on *Shock Evaders* at FEMA conference, Alexandria. [2]

Though the concept is working perfectly in all sorts of vehicles, in seismic isolation everything is not so smooth because the conditions in both cases are quite different.

In a car, for instance, the working stresses in auto parts are far below their ultimate bearing capacity. Therefore, some overloads associated with heavy damping are of no practical importance here. Another matter is a building structure: during a strong earthquake, it is intended to perform at the near-to-collapse level and, therefore, any extras can become crucial for its safety.

However, there is an alternative to the contradictory damping mechanism of those base isolators. It can be found in the utmost lessening the damping and substituting its positive, mitigating quality with any sort of tuning-out mechanism which satisfies the following requirements:

- Let the earth move its way.
- Prevent resonant amplifications.
- Restore the structure in its pre-earthquake position on the foundation.

It is not the building, it is the earth that should be vibrating if the building is supported on the ideal isolation system. Any attempt to reduce a relative displacement of the superstructure with respect to the base will inevitably result in additional transmission of earthquake energy into the building.

Shock Evader in action at a museum shake-table, Los Angeles. [3]

This new concept has been embodied in **Shock Evader** or, which is the same, in the **Antifriction and Multi-Step Base Isolation** (**AF&MS BI**) that incorporated the merits of the traditional flexible mounting but without its drawback - a compulsory damping mechanism [4].

Search Wikimedia Commons for images, sounds and other media related to: ***Base isolation***

References

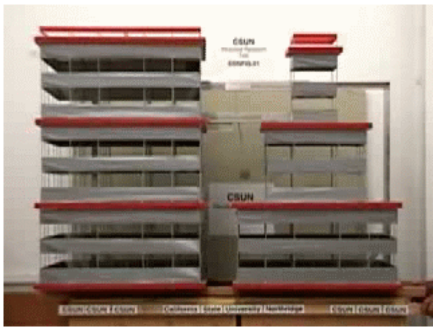
[1] http://en.wikipedia.org/wiki/Mechanical_engineering
[2] http://en.wikipedia.org/wiki/Alexandria,_Virginia
[3] http://en.wikipedia.org/wiki/Los_Angeles
[4] http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=38E6C029A1E36535B1E68A6B61CC1CC5?purl=/10181073-rbd7LK/

Building elevation control

Transamerica Pyramid building in San Francisco, California

Building elevation control is a valuable source of vibration control of seismic loading. Thus, pyramid-shaped skyscrapers, continue to attract attention of architects and engineers because such structures promise a better stability against earthquakes and winds.

Besides, the elevation configuration can prevent buildings' resonant amplifications due to the fact that a properly configured building disperses the shear wave energy between a wide range of frequencies.



Shake-table testing of a regular building model (left) and a model with the vertical control (right) [1]

Earthquake or wind quieting ability of the elevation configuration is provided by a specific pattern of multiple reflections and transmissions of vertically propagating shear waves, which are generated by breakdowns into homogeneity of story layers, and a taper. Any abrupt changes of the propagating waves velocity result in a considerable dispersion of the wave energy between a wide ranges of frequencies thus preventing the resonant displacement amplifications in the building.

Tapered profile of a building is not a compulsory feature of this method of structural control. A similar resonance preventing effect can be also obtained by a proper *tapering* of other characteristics of a building structure, namely, its mass and stiffness [4]. As a result, the building elevation configuration techniques permit an architectural design that may be both attractive and functional.

Search Wikimedia Commons for images, sounds and other media related to: ***Structural control***

References

[1] http://www.ecs.csun.edu/~shustov/001-Config-02.html

Dry-stone walls control

People of Inca civilization were masters of the polished **dry-stone walls**, called *ashlar*, where blocks of stone were cut to fit together tightly without any mortar. The Incas were among the best stone masons the world has ever seen [1], and many junctions in their masonry were so perfect that even blades of grass could not fit between the stones.


Dry-stone walls of Machu Picchu Temple of the Sun, Peru

Peru is a highly seismic land, and for centuries the mortar-free construction proved to be apparently more earthquake-resistant than using mortar. The stones of the dry-stone walls built by the Incas could move slightly and resettle without the walls collapsing which should be recognized as an ingenious passive vibration control technique employing both the principle of energy dissipation and that of suppressing resonant amplifications [2].

References

[1] http://www.pbs.org/wgbh/nova/inca1/qanda.html
[2] http://www.pbs.org/wgbh/nova/easter/civilization/first.html

Earthquake protector

Earthquake protector is a type of base isolation intended for protection of building and non-building structures against potentially damaging lateral impact of strong earthquakes [1] .

Heavy damping mechanism sometimes incorporated in vibration control technologies and, particularly, in base isolation devices, may be considered a valuable source of suppressing vibrations thus enhancing a building's seismic performance. However, for the very pliant systems such as base isolated structures, with a relatively low bearing stiffness but with an high damping, the so-called "damping force" may turn out the main pushing force at a strong earthquake [2]. This finding created a theoretical ground in earthquake engineering for a damping-disengaged base isolation technology called Earthquake protector [3].

18-story model on earthquake protectors: shake-table test at UCSD outdoor facility.

A shake-table video of concurrent shake-table experiments with two identical and kinematically equivalent to their 12-story prototype building models is presented at [4]. The right model is resting on Earthquake Protectors, while the left one, caught at the time of its crash, is fixed to the shake-table platen.

Analytical software

Analytical software called *EPET or Earthquake Performance Evaluation Tool* [5] enables concurrent virtual experiments on the same building models with any sliding type of base isolation, including Earthquake protector, and without.

References

[1] Valentin Shustov (2010), "Testing of a New Line of Seismic Base Isolators," https://nees.org/resources/770
[2] http://www.ecs.csun.edu/~shustov/Topic4.htm
[3] https://nees.org/data/get/NEES-2006-0283/Public/REPORT.pdf
[4] http://www.youtube.com/watch?v=kzVvd4Dk6sw
[5] http://www.structuralpedia.com/index.php?title=EPET

Elevated building foundation

Elevated building foundation (EBF) is a kind of seismic base isolation technology which is made a major part of a building superstructure [2] . It is made to protect the building's superstructure against damage from the shaking caused by an earthquake.

Bottom view of the Municipal Services Building [1] sitting on abutments of its elevated building foundation, Glendale, CA

Seismically retrofitted Municipal Services Building in Glendale, CA

This goal can be met with the right building materials, size, and setup of EBF for the building site and local soil conditions.

As a result of multiple wave reflections and diffractions, as well as energy dissipation of the seismic waves as they move up through the EBF, any movement of seismic wave energy into the building superstructure will be decreased, which will lower seismic loads and improve seismic performance of the structure [3] .

In other words, the building does not shake as much because it is sitting on the elevated building foundation, and will probably take less damage from the earthquake.

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Notes

[1] Municipal Services Building of Glendale (http://www.ci.glendale.ca.us/planning/MSB EIR/AppendixB.pdf)
[2] Elevated Foundation for Earthquake Protection of Building Structures (http://www.ecs.csun.edu/~shustov/CME-C19.html)
[3] Elevated Building Foundation and Earthquake protector: new features in passive structural control. (https://central.nees.org/data/get/NEES-2006-0283/Public/EBF and EP.pdf)

Friction pendulum bearing

Friction Pendulum Bearing (FPB) is another name of **Friction Pendulum System** (FPS). It is based on three pillars[2] :

- articulated friction slider;
- spherical concave sliding surface;
- enclosing cylinder for lateral displacement restraint.

Snapshot with the link to video clip of a shake-table testing of FPB system supporting a rigid building model is presented at the right.

FPB [1] shake-table testing, Berkeley, CA.

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Refereces

[1] http://www.youtube.com/watch?v=cfl-VueWTGE&feature=PlayList&p=660C7AFD70E81C12&index=27
[2] Zayas, Victor A. et al. (1990). *A Simple Pendulum Technique for Achieving Seismic Isolation*. Earthquake Spectra. pp. 317, Vol.6, No.2. ISBN 0087552930.

Hysteretic damper

Hysteretic damper is intended to provide better and more reliable seismic performance than that of a conventional structure at the expense of the seismic load energy dissipation.[1] There are four major groups of hysteretic dampers used for the purpose, namely:

- Fluid viscous dampers (FVDs)
- Metallic yielding dampers (MYDs)
- Viscoelastic dampers (VEDs)
- Friction dampers (FDs)

Each group of dampers has specific characteristics, advantages and disadvantages for structural applications.

Fluid viscous damper installed in a building structure

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References

[1] http://www.structuremag.org/OldArchives/2004/july/Structural%20Practices.pdf

Lead rubber bearing

Lead Rubber Bearing or LRB is a type of base isolation employing a heavy damping. It was invented by William Robinson, a New Zealander.[1] Heavy damping mechanism incorporated in vibration control technologies and, particularly, in base isolation devices, is often considered a valuable source of suppressing vibrations thus enhancing a building's seismic performance. However, for the rather pliant systems such as base isolated structures, with a relatively low bearing stiffness but with a high damping, the so-called "damping force" may turn out the main pushing force at a strong earthquake. The video [2] shows a Lead Rubber Bearing being tested at the UCSD Caltrans-SRMD facility. The bearing is made of rubber with a lead core. It was a uniaxial test in which the bearing was also under a full structure load. Many buildings and bridges, both in New Zealand and elsewhere, are protected with lead dampers and lead and rubber bearings.[1]

LRB being tested at the UCSD Caltrans-SRMD facility, San Diego, CA

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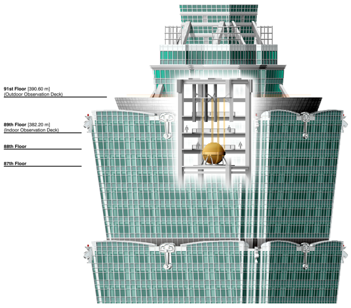
References

[1] http://www.teara.govt.nz/en/earthquakes/4
[2] http://www.youtube.com/watch?v=2yXgu4aS8HE

Seismic damper

When seismic waves start to penetrate a base of building structure, **seismic dampers** can decrease their damaging effect and improve the building's seismic performance [1] . Some samples of seismic dampers design and implementation are presented in the images below:

Heavy damping Lead-Rubber Bearing being tested at the UCSD facility.



Tuned mass damper in Taipei 101, the world's second tallest skyscraper.

Pyramid-shaped skyscraper to prevent buildings' resonant amplifications.

Other pages

Search Wikimedia Commons for images, sounds and other media related to: ***Structural control***

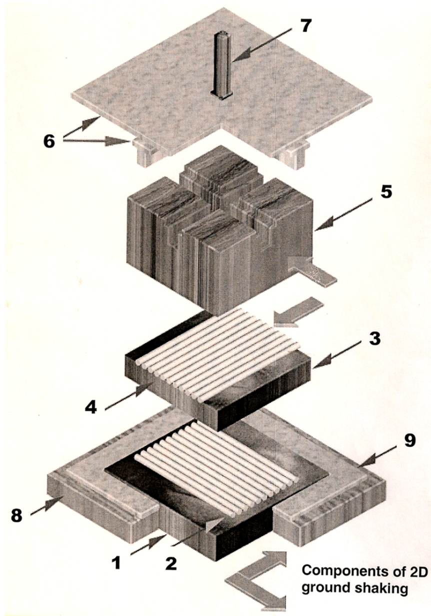
- Seismic Dampers [2]
- Seismic vibration control [3]

Notes

[1] Chu, S.Y.; Soong, T.T.; Reinhorn, A.M. (2005). *Active, Hybrid and Semi-Active Structural Control*. John Wiley & Sons. ISBN 0470013524.
[2] http://www.structuremag.org/OldArchives/2004/july/Structural%20Practices.pdf
[3] http://www.structuralpedia.com/index.php?title=Vibration_control

Simple roller bearing

Simple roller bearing or *Earthquake-protective building buffer* [3] is a simplified version of a base isolation device called earthquake protector which is intended for protection of various building and non-building structures against potentially damaging lateral impacts of strong earthquakes.



Earthquake-protective building buffer - exploded view, Video [1]

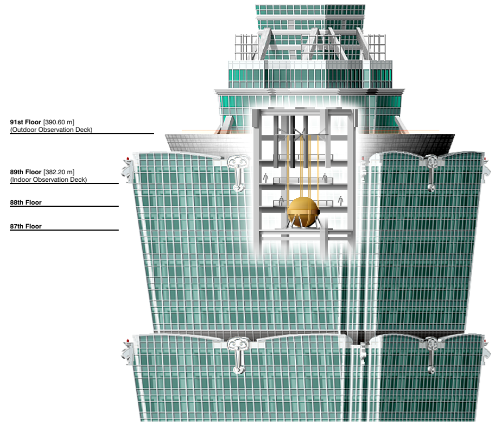
The metallic bearing support shown on the right may be adapted, with certain precautions, as a seismic isolator to skyscrapers and buildings on soft ground. Recently, it has been employed for a housing complex (17 stories) in Tokyo, Japan.

Housing complex mounted on *roller bearings* [2].

References

[1] http://www.ecs.csun.edu/~shustov/001-EPF-03.html
[2] http://www.okumuragumi.co.jp/en/technology/building.html
[3] http://www.ecs.csun.edu/~shustov/CME-C5.htm

Tuned Mass Damper



Tuned mass damper in Taipei 101, the world's tallest skyscraper

Typically, the **tuned mass dampers**, a kind of seismic vibration control technology [1] , are huge concrete blocks mounted in skyscrapers or other structures and moved in opposition to the resonance frequency oscillations of the structures by means of some sort of spring mechanism.

Taipei 101 skyscraper [2] depicted on the left needs to withstand typhoon winds and earthquake tremors common in its area of the Asia-Pacific. For this purpose, a steel pendulum weighing 660 metric tons that serves as a tuned mass damper was designed and installed atop the structure. Suspended from the 92nd to the 88th floor, the pendulum sways to decrease resonant amplifications of lateral displacements in the building caused by earthquakes and strong gusts.

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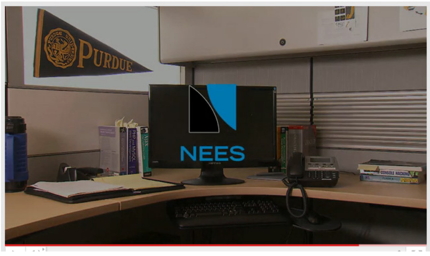
References

[1] Tuned mass damper (http://en.wikipedia.org/wiki/Tuned_mass_damper)
[2] Taipei World Financial Center (http://en.wikipedia.org/wiki/Taipei_101)

Earthquake engineering research

Earthquake engineering research

Earthquake engineering research means both field and analytical investigation or experimentation intended for discovery and scientific explanation of earthquake engineering related facts, revision of conventional concepts in the light of new findings, and practical application of the developed theories.



NEEShub presentation snapshot [1].

The National Science Foundation (NSF) is the main United States government agency that supports fundamental research and education in all fields of earthquake engineering. In particular, it focuses on experimental, analytical, and computational research on design and performance enhancement of structural systems. The Earthquake Engineering Research Institute (EERI) is a leader in dissemination of earthquake engineering research related information both in the U.S. and globally.

All earthquake engineering research activities worldwide are mostly associated with the following centers:

- Earthquake Engineering Research Institute (EERI) [2]
- Earthquake Engineering Research Center [3]
- Pacific Earthquake Engineering Research Center (PEER) [4]
- John A. Blume Earthquake Engineering Center [5]
- Consortium of Universities for Research in Earthquake Engineering (CUREE) [6]
- Multidisciplinary Center for Earthquake Engineering Research (MCEER) [7]
- Earthquake Engineering Research Projects of CSUN [8]
- George E. Brown, Jr. Network for Earthquake Engineering Simulation ([[NEES [9]])]
- USGS Earthquake Hazards Program [10]
- Office of Earthquake Engineering at Caltrans [11]
- Earthquake Engineering Research Centre of Iceland [12]
- Earthquake Engineering New Zealand [13]
- Earthquake Engineering Research - [[Earthquake engineering research|research program [14]] by U.S. Army]
- Canadian Research Centers and Research Groups on Earthquake Engineering [15]
- Hyogo Earthquake Engineering Research Center [16]
- Laboratory for Earthquake Engineering of NTUA [17]
- Earthquakes and Earthquake Engineering in The Library of Congress [18]
- International Institute of Earthquake Engineering and Seismology [19]
- National Center for Research on Earthquake Engineering [20]

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[1] http://www.youtube.com/user/vshustov#p/f/0/aZb3uSynpWg
[2] http://www.eeri.org/site/
[3] http://eerc.berkeley.edu/
[4] http://peer.berkeley.edu/news/2008/peer_transition_announcement.html
[5] http://blume.stanford.edu/
[6] http://www.curee.org/
[7] http://mceer.buffalo.edu/About_MCEER/default.asp
[8] http://www.ecs.csun.edu/~shustov/CME_research.htm
[9] http://www.nees.org/
[10] http://earthquake.usgs.gov/learning/topics/index.php?topicID=52&topic=Engineering,+Earthquake
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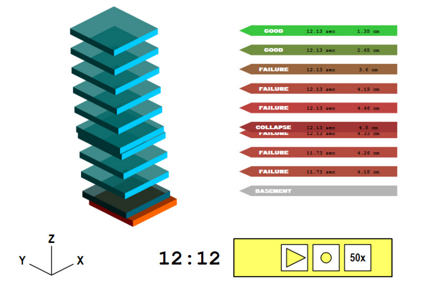
[19] http://en.wikipedia.org/wiki/International_Institute_of_Earthquake_Engineering_and_Seismology
[20] http://en.wikipedia.org/wiki/National_Center_for_Research_on_Earthquake_Engineering

Earthquake Performance Evaluation Tool Online

EPETO



EPETO [1] animation PrintScreen.

EPETO or **Earthquake Performance Evaluation Tool Online** [2] is the educational earthquake engineering internet site developed to facilitate potential users' performance and to expand variety of buildings, earthquake exposure and types of seismic control devices. It has been successfully tested during July-August 2010 and is ready for public use without restrictions. The project may be accessed by clicking on EPETO: Operational scenarios [3].

This site is a continuation of the recent research (NSF Award No: CMS-0618183) [4] which gave rise to a non-commercial release of the innovative software called **Earthquake Performance Evaluation Tool** or **EPET** [5].

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[4] http://nees.org/data/get/NEES-2006-0283/Public/REPORT.pdf
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