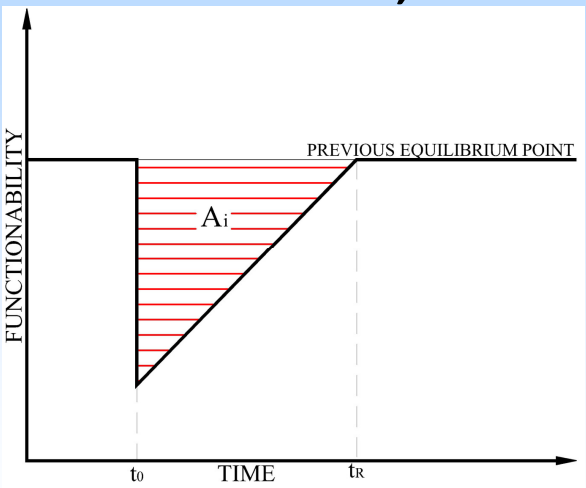
DRR preparedness: Implementing an education and training strategy to achieve earthquake resilience

Stephanos E. Dritsos,
University of Patras, Greece

EARTHQUAKES

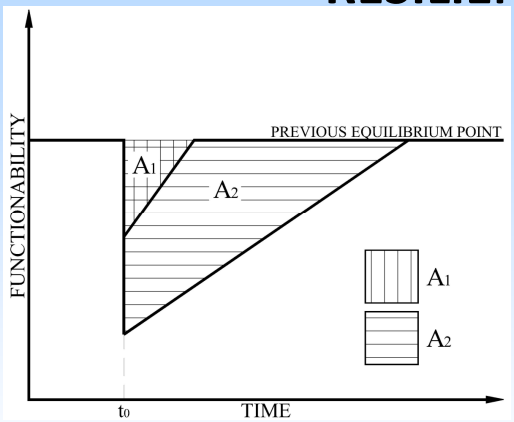
- Are not going to stop happening
- One of the most destructive natural disasters known to humanity
- Occur without warning
- Effects are instantaneous and devastating
- Have the ability to catastrophically destroy the built environment
- Turn back or inhibits development
- Have the ability to change the course of history

RESILIENCE, R



For an event i
maxR_i when minA_i

RESILIENCE



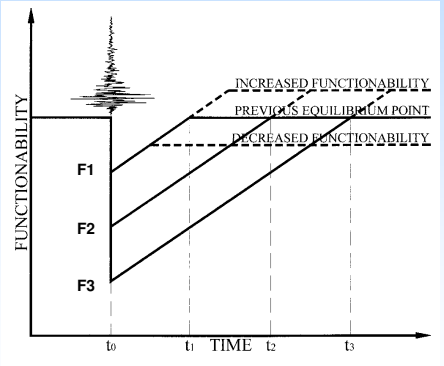
RESILIENCE, R:
For event i, $R_i = f(1/A_i)$
$A_1 < A_2 \rightarrow R_1 > R_2$

A resilient system = little loss + quick recovery

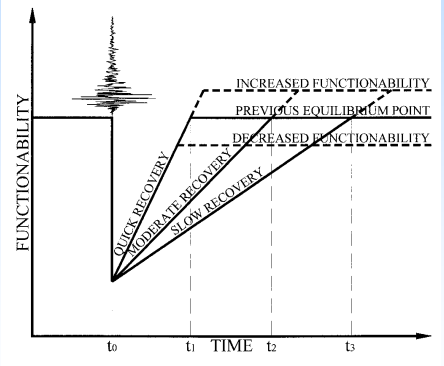
A resilient society would be little affected by and would recover quickly from a disaster

EARTHQUAKE RESILIENCE

RECOVERY AFTER AN EARTHQUAKE



For a constant recovery rate, a more resistant system is least affected F1>F2>F3



A quick and efficient recovery indicates a resilient system
Increased functionability possible

RECOVERY AFTER AN EARTHQUAKE

SOME EXAMPLES OF INCREASED FUNCTIONABILITY

- Volos, Greece, 1955 - devastated by a series of earthquakes - complete redesign of the city - now the third largest port in Greece
- 2008 Sichuan earthquake, China - six and a half million buildings collapsed - the industrial base was rebuilt - now one of the leading manufacturing areas of China
- 1986 Kalamata earthquake, Greece - brought a wind of change - now a modern provincial capital

EARTHQUAKE RESILIENCE

SOME CASES OF NON-RESILIENCE:

- 1755 Lisbon earthquake and tsunami severely affected Portugal's position as a colonial power, changing political, theological and philosophical thinking
- 1908 Messina, Italy earthquake and tsunami considered as Europe's worst earthquake disaster, no anti-seismic design
- 1953 Ionian earthquake, Greece was responsible for the exodus of the population of Kefalonia
- 2010 Haiti earthquake reduced government and essential services to ineffectiveness - law and order broke down

LESSONS HAVE TO BE LEARNED

RESILIENCE

HIGH RESILIENCE

High infrastructure performance (parameter 1)

High peoples' behaviour (parameter 2)

RESILIENCE

Example: A ship sailing

Parameter 1: Infrastructure performance

- **the ship will be strong enough not sink or be affected by storms**
- **the ship will not sink even after capsizing (overturning), no loss of life through drowning, so that the situation can be easily recovered**

Parameter 2: peoples' behaviour

- **the best reaction of the crew and passengers**

DESIGN FOR ALL

A CONCEPT CRITICAL TO DESIGN FOR RESILIENCE

The most vulnerable community groups suffer the most during and after an earthquake

FATALITIES IN PEOPLE WITH DISABILITIES EARTHQUAKES

- **1982 COALINGA CALIFORNIA EARTHQUAKE, 38% OF INJURED PEOPLE CONTACTED AFTER THE EARTHQUAKE WERE DISABLED (ARONI AND DURKIN, 1985)**
- **2011 GREAT EAST JAPAN EARTHQUAKE, MORTALITY RATE FOR REGISTERED PEOPLE WITH DISABILITIES DOUBLE THAT OF THE GENERAL POPULATION (KIYOSHI HARADA, JAPAN DISABILITY FORUM, 2013)**
- **THOSE WITH VISUAL OR MOBILITY LIMITATIONS EXPERIENCE THE MOST DIFFICULTIES (TIERNEY ET AL., 1988)**

TEST RESULTS

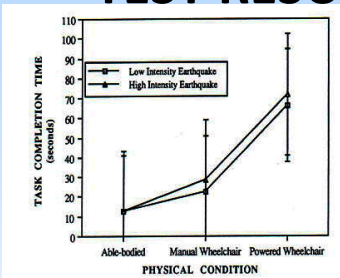


Figure 3. Mean and standard errors for task completion time as a function of physical condition and earthquake intensity

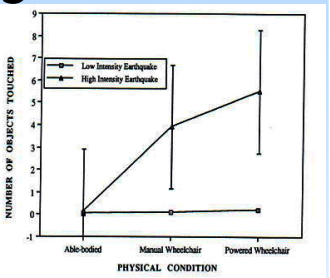


Figure 4. Mean and standard errors for number of objects touched as a function of physical condition and earthquake intensity

- Simulated low and high intensity earthquake disrupted room (fallen furniture, obstacles, etc.).
- Study groups of able-bodied, manual wheelchair and powered wheelchair persons had to pass through the room and carry out simple tasks.
- Measured (1) the time for each group to perform the task (2) the number of objects touched while performing the task and (3) the difficulty of performing the task (answers).

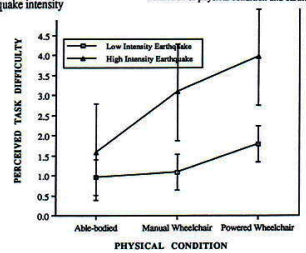


Figure 5. Mean and standard errors for perceived task difficulty rating as a function of physical condition and earthquake intensity

Source: Mansour Rahimi, *"Behavior of Mobility- Disabled People in Earthquakes: A Simulation Experiment"*, Earthquake Spectra, Vol. 10, No.2, p.p. 381-401, 1994

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DESIGN FOR ALL

A CONCEPT CRITICAL TO DESIGN FOR RESILIENCE

- **The most vulnerable community groups suffer the most during and after an earthquake**
- **Society will recover as soon as the functionability of vulnerable groups recovers**
- **Takes into account design for human diversity and social inclusion**
- **At present, ignored by most designers, engineers and architects**

DESIGN FOR ALL

New (?) Concept: Design for all

Consider - Not only the general population

- All possible target groups

↓

Account for the most vulnerable part of the population or the vulnerability characteristics of the target groups

DESIGN FOR ALL

As an example from engineering thinking:

If in a structure there exists a vulnerable element such as a column or a beam, then the vulnerability will affect the integrity of the whole structure

Similarly, if in a community there exists a vulnerable group such as people with disabilities, children, the aged, migrants, etc., then vulnerability will affect the integrity of the whole community. In the ship sailing example, we have in mind the priority "women and children first."

DESIGN FOR ALL: New Concept?

Part of a whole culture

Part of a holistic education

Part of a philosophy

In the Greek Language, there are two different words instead of one for "education":

***Εκπαίδευση* (Ekpethefsi) and *Παιδεία* (Petheia)**

EDUCATION

Εκπαίδευση **(Ekpethefsi):**
- **mainly knowledge offered at schools**
- **also sometimes includes training**

Παιδεία **(Petheia):**
- **general way of thinking**
- **philosophical global education**
- **build culture**
- **build behaviour**
- **build character**

More intense for the very young
Παιδεία **(Petheia) = global education**
Παιδί **(Pethi) = child**
And also Παίζω (Pezo) = to play
Μόρφωση **(Morphosi) = to give shape, form (morphology)**

Design for all ⟶ Thinking as a community
Not "me and mine" but "us and ours"

GENERAL FRAMEWORK

Παιδεία **(Petheia): ⟶ Equality in all aspects of life**
Start by focusing on the very young

Note:

"Persons with disabilities have the right to live independently and participate fully in all aspects of life on an equal basis with others in information, communications and other services, including electronic services and emergency services."

(Source: Article 9.1, UN convention on the rights of persons with disabilities)

PEOPLE WITH DISABILITIES IN ANCIENT GREECE

- **ATTAINED HIGH SOCIAL POSITIONS OF RESPONSIBILITY (KINGS, POETS, ETC.)**
- **WERE NOT CONSIDERED AS BEING DISABLED**
- **MADE MAJOR WELL RECOGNISED CONTRIBUTIONS TO SOCIETY**

THEY WERE REPRESENTED BY A GOD (HEPHAESTUS)

ANCIENT GREEK OLYMPIAN GODS

Greek mythology did not involve special revelations or spiritual teachings. It had no formal structure such as a church hierarchy and there was no written code such as a sacred book (Guisepi, 2001). Greek Gods resembled humans and human behaviour. Their most striking features were their human traits such as anger, jealousy, love, wisdom, knowledge, etc. Consequently, it is easy to see that the Ancient Greek Gods reflected Ancient Greek society. In this light, contrary to modern day beliefs depicting the Gods as being at the peak of physical perfection, strength and beauty, it is not surprising to find that one of the twelve Olympian Gods was disabled. **Disabled Greek God Hephaestus** was the inventor God, he married the Goddess of beauty Aphrodite (Venus) making the God Jealous.

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MOBILITY IMPAIRED IN ANCIENT GREECE?

Some Greek Olympian Gods at a cocktail party
Disabled God central stage?

VASE PAINTING
(http://www.crfaster.com.br/Cadeira%20Rodas.htm)

ANCIENT GREEK OLYMPIAN GOD HEPHAESTUS

30 Hephaistos on a winged throne. Cup by the Ambrosios Painter, towards 510. Berlin, Pergamonmuseum F 2273.

Schefold, K., Gods and Heroes in Late Archaic Greek Art. English translation by A. Griffiths. (Cambridge, 1992))

- **POSSIBLE FIRST RECORDED EXAMPLE OF A WINGED WHEELCHAIR OR CHARIOT**
- **INVENTOR: THE GOD HEPHAESTUS!**

PARAMETERS

1: INFRASTRUCTURE PERFORMANCE

2: PEOPLES' BEHAVIOUR

Parameter 1: Infrastructure Performance

GOAL	**Urban planning and the built environment – design the whole city, provide open spaces, escape routes, increased resilience …..** **Earthquake resilient structures** **Design, Construct, Redesign, Retrofit, Reconstruct in order to minimise (attacking) effects of actions from possible disaster sources (earthquakes, floods, fires, windstorms, volcanoes, explosions as well …..)**

Parameter 1: Infrastructure Performance

In General → Focus on increased functionability
Provide **ENOUGH RESISTANCE**
to withstand any possible
disaster actions to an acceptable
minimum level of damage
Ensure quick recovery

In Particular → Depending on the disaster source
→ Type of construction
→ Cost

TOOLS: **EDUCATION** and TRAINING

Parameter 1: Infrastructure Performance
EDUCATION and TRAINING

Obviously it is addressed to:

- Engineers
- Contractors
- Workers

-> University studies
-> Recommendations
-> Technical Divisions
-> Codes
-> Seminars
-> Research

Parameter 2: Peoples' Behaviour

AFTER A DESTRUCTIVE EVENT:

- A WHOLE REGION IS AFFECTED
- EMERGENCY SERVICES WILL BE SEVERELY STRETCHED
- THERE WILL BE MANY OTHER HIGHER PRIORITY LIFE THREATENING SITUATIONS
- IT MAY BE SEVERAL DAYS BEFORE A NORMAL LEVEL OF EMERGENCY SERVICES CAN BE PROVIDED

Parameter 2: Peoples' Behaviour

AFTER A DESTRUCTIVE EVENT:

THE WHOLE POPULATION:

- CANNOT RELY ON ANY EXPECTATION OF ANY IMMEDIATE SPECIAL ASSISTANCE WITH EVACUATION
- SHOULD BE PREPARED TO BE RESPONSIBLE FOR THEIR OWN EMERGENCY PLANNING AND EVACUATION

THEREFORE, MEASURES MUST INCLUDE EDUCATING AND TRAINING THOSE AFFECTED TO BE SELF-RELIANT

Parameter 2: Peoples' Behaviour

GOAL	Educate and train people to minimise losses (mainly fatalities and injuries) from possible disaster sources (earthquakes, floods, fires, windstorms, volcanoes, …..)

Parameter 2: Peoples' Behaviour

In General → Achieve the best effective reaction from people in any disaster

In Particular → Specific measures depending on:
- the disaster source
- the different capabilities of the population

TOOLS: EDUCATION and TRAINING

Parameter 2: Peoples' Behaviour

Specific Actions

ACTION 1: PREPARE A STRATEGY

ACTION 2: STRATEGY IMPLEMENTATION

FEEDBACK

REVISE

Parameter 2: Peoples' Behaviour

EDUCATION AND TRAINING

- GUIDANCE PREPARED FOR THE GENERAL POPULATION IS NOT SUITABLE FOR PEOPLE WITH DISABILITIES OR OTHER VULNERABLE GROUPS

  NECESSARY TO REWRITE CERTAIN MEASURES DEPENDING ON TARGETED DISABILITY OR VULNERABLE GROUP
- MATERIAL IDENTIFIES SPECIFIC MEASURES AND BEHAVIOUR DEPENDING ON THE SPECIFIC CAPABILITIES OF THE TARGET GROUP
- THE SAME PECULIARITIES FOR TRAINING

Parameter 2: Peoples' Behaviour

EDUCATION AND TRAINING

TARGET GROUPS:

1) **GENERAL POPULATION**
2) **VULNERABLE GROUPS:**

People with disabilities, children, the elderly, the infirm, people with injuries, parents with small children, pregnant women, ethnic minorities, migrants, refugees, travellers, tourists, etc.

The vast majority of the population will be physically disabled at sometime or other, as very few people live their whole lives healthy and able bodied (United Nations enable 2014)

TWO MAIN CATEGORIES:

1. **NO PROBLEM WITH UNDERSTANDING**
2. **PROBLEM WITH UNDERSTANDING**

EDUCATION AND TRAINING

Three actions:

- **Protection measures before earthquakes**
  (What you should do from this point onwards)
- **Protection measures during an earthquake**
  (What you should do during the few seconds that an earthquake lasts)
- **Protection measures after an earthquake**
  (Which steps you should follow right after the earthquake finishes)

PREPARING EDUCATIONAL MATERIAL AND TRAINING

PROCEDURE

- **PREPARE FIRST DRAFT**
- **MAKE PILOT APPLICATION on the targeted disability or vulnerable group**
- **OBTAIN FEEDBACK concerning difficulties in implementation and better operation, EVALUATE and ASSESS**
- **REDRAFT ACCORDINGLY**
- **DISSEMINATE, EDUCATE, TRAIN**
- **OBTAIN FEEDBACK (permanent on-line form for comments)**
- **REGULAR REVIEW AND POSSIBLE REVISION**

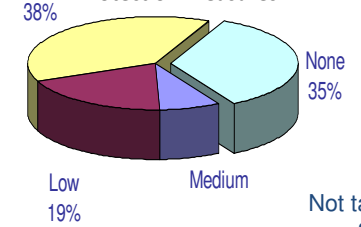
E.P.P.O. – E.C.P.F.E. Actions

PUBLICATIONS

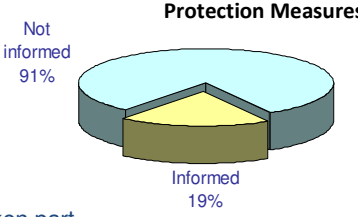
Parameter 2: Peoples' Behaviour – Education
E.P.P.O. – E.C.P.F.E. Actions

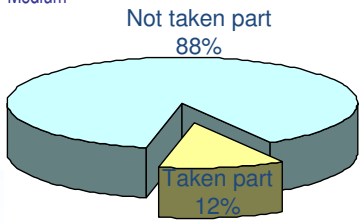
SURVEY OF PEOPLE WITH DISABILITIES

Level of Knowledge of People with Disabilities for Earthquakes and Protection Measures



People with Disabilities who have been informed about Earthquake Protection Measures





People with Disabilities who have taken part in Earthquake Drills

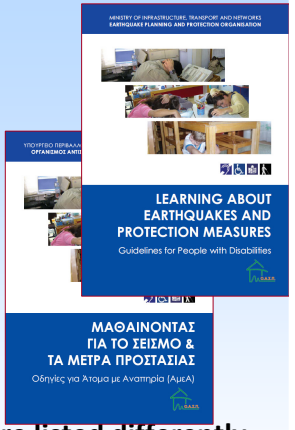
According to a SURVEY* carried out by E.P.P.O, in the Framework of the Project POLITEIA, (March 2008)

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education
E.P.P.O. – E.C.P.F.E. Actions

TEXTBOOKS FOR PEOPLE WITH DISABILITIES

- addresses People with Disabilities
  - Mobility impairments
  - Visual impairments/Blindness
  - Hearing impairments/Deafness
  - Cognitive impairments – Speech Communication impairments
- is divided into two parts:
  - information about earthquakes
  - earthquake protection measures
- specific guidelines for each type of disability are listed differently



The textbook :

- has been translated into Braille by E.P.P.O. and the Organization: "Lighthouse for the Blind of Greece"

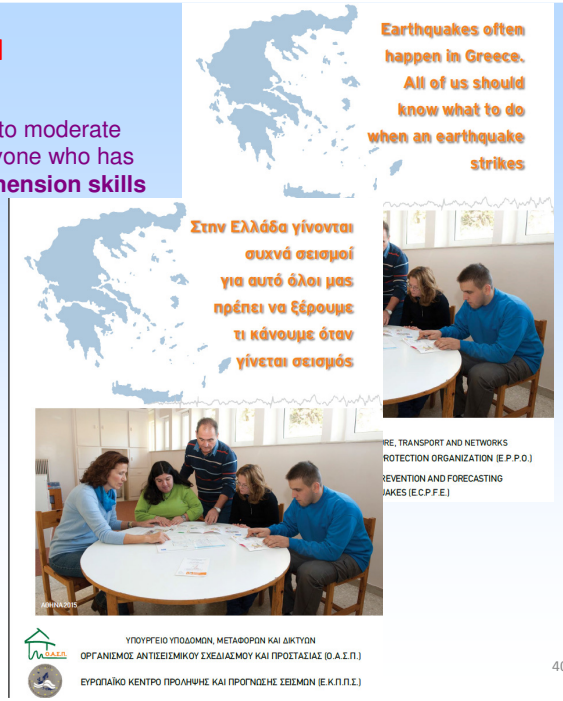
Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education
E.P.P.O. – E.C.P.F.E. Actions

LEAFLETS

Booklet
"easy-to-read" method

Addresses people with mild to moderate intellectual disability and anyone who has **minimum reading comprehension skills**



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Booklet
"easy-to-read" method

Booklet
MAKATON language

Addresses people with moderate to severe intellectual disability with or without autism and anyone who has minimum **pre-reading skills**

Booklet
MAKATON language

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

An e-learning platform was designed to host this educational material

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

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Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

ECPFE website – ON LINE QUESTIONNAIRE FOR INDIVIDUALS WITH DISABILITIES

A questionnaire for an e-learning application in Greek and English languages has been created, so as to educate and inform People with Disabilities

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Earthquake Seminars and Drills

- Organise seminars – workshops and training courses for students, teachers and educators in special schools
- is planning to create specific leaflets for each disability

Many earthquake drills have to be held, for each type of disability, in order to:

- act correctly and instinctively in case of a real earthquake
- identify gaps and challenges
- create a culture of earthquake behaviour
- further earthquake-disaster reductio

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training- Earthquake Drills

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training - Earthquake Drills

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

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Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training- Earthquake Drills

Very young and multi-disability cases

After: Evacuate the building with the aid of the caregivers

During: Cover your head & neck with your hands and if this is not possible with the aid of the caregivers

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training - Earthquake Drills

Cognitive Impairment

During: Cover your body under sturdy furniture, holding its leg with your hands

After: evacuate the building, avoid using the elevators

Source: C. Gountromixou, L. Pelli, E. Lekkas and S. Dritsos, "Earthquake Protection Policy for People with Disabilities" Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, European Council, Paris, 2013.

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training - Earthquake Drills

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training - Earthquake Drills

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Parameter 2: Peoples' Behaviour – Education

E.P.P.P. – E.C.P.F.E. Actions

Training - Earthquake Drills

Parameter 2: Peoples' Behaviour – Education

E.P.P.O. – E.C.P.F.E. Actions

Training - Earthquake Drills

PARAMETER 1: INFRASTRUCTURE PERFORMANCE

Parameter 1: Infrastructure Performance

Design for All

- GLOBAL APPROACH
- INVOLVES THE CONCEPTS OF ACCESSIBILITY, RESILIENCE, UNIVERSAL DESIGN AND INCLUSIVE DESIGN
- INCLUDES EVERYBODY REGARDLESS OF RESTRICTIONS
- NOT ONLY GENERAL POPULATION
  - INCLUDES PEOPLE WITH DISABILITIES
  - INCLUDES THE AGED AND CHILDREN
  - CROSSES LANGUAGE BARRIERS:

    ETHNIC MINORITIES, MIGRANTS, REFUGEES, ASYLUM SEEKERS, TRAVELERS, TOURISTS, ETC.
- AT THE PRESENT MOMENT, MOST DESIGNERS, ENGINEERS AND ARCHITECTS IGNORE THE CONCEPT

Parameter 1: Infrastructure Performance

EARTHQUAKES

PRIMARY DESIGN RULES FOR LIFE SAFETY AND RESILIENCE

- **ROBUSTNESS - REDUNDANCY**
  Alternative load-paths
- **LIMITED DAMAGE ACCEPTABLE – FAILURE UNACCEPTABLE**
- **PROVIDE SPECIFIC AREAS FOR SAFE REFUGE (overdesigned)**
  Earthquake proof shelters and rescue rooms accessible for all
- **DESIGN EVACUATION MEASURES FOR ALL**
  Emergency lifts, emergency doors, fire doors, specific evacuation tools for people with disabilities and other vulnerable groups (in general terms)
- **CONSIDER FUNCTIONALITY DURING AND AFTER AN EARTHQUAKE**
  Design earthquake resistant furniture depending on specific disabilities

EARTHQUAKES FATALITIES

MOST FATALITIES NOT FROM STRUCTURAL DAMAGE

It has been reported (Jones et al., 1990 for the Loma Prieta earthquake and Barque et al., 1991 for Whittier Narrows earthquake) that the majority of fatalities and injuries were mostly affected by how people behaved during or immediately after the earthquake and the fatalities and injuries were caused by people failing down or being hit by non structural elements and building contents.

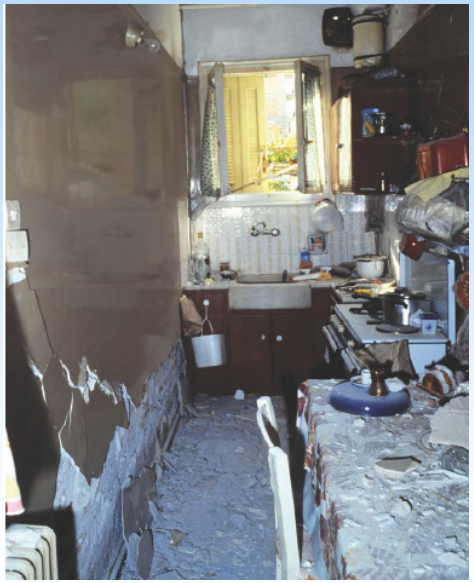
Parameter 1: Infrastructure Performance

Parameter 1: Infrastructure Performance

Parameter 1: Infrastructure Performance

Fatalities can also occur without serious damage to the building

Parameter 1: Infrastructure Performance



Fatalities can also occur without damage to the building

Parameter 1: Infrastructure Performance

Fatalities can also occur without damage to the building

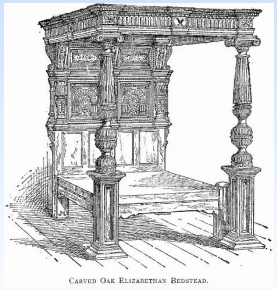
Parameter 1: Infrastructure Performance

Fatalities can also occur without damage to the building
Mind to get under the table when you feel shaking from an earthquake

EXAMPLE: EARTHQUAKE RESISTANT BED

Recommended for people with mobility impairments but also for other cases

Enclosed beds with a strong roof



Four poster bed

(http://inhabitat.com/)

(http://www.lifeguardstructures.com/order/index.php?dispatch=products.view&product_id=48)

IN CONCLUSION

TWO MAIN APPROACHES FOR EARTHQUAKE DESIGN:

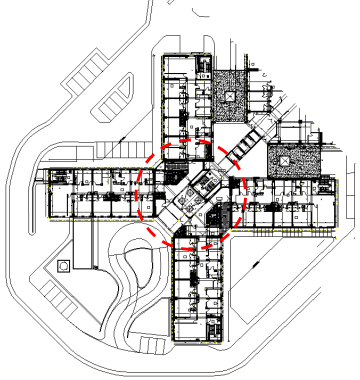
1. CONVENTIONAL DESIGN
Trying to follow (as much as possible) the "Design for All" and "Resilience" Concepts

2. INNOVATIVE DESIGN
Design for resilience

EARTHQUAKES

CONVENTIONAL DESIGN: STRUCTURAL DESIGN FOR ALL

CASE STUDY – HOSPITAL KIFISIA, ATHENS

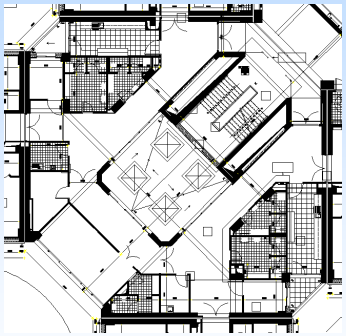


- **NO DEAD ENDS**
- **SHORT TRAVEL DISTANCES**

(DESIGN OFFICE http://www.koumoulos.com, PATRAS, GREECE)

EARTHQUAKES

CONVENTIONAL DESIGN: STRUCTURAL DESIGN FOR ALL



- **INDEPENDENT STRONG RESILIENT CENTRAL CORE**
- **SEISMIC GAP, SEPARATION OF BUILDINGS' STRUCTURES**
- **LARGE AREA FOR SAFE REFUGE**

"AGIOI ANARGYROI" GENERAL ONCOLOGY HOSPITAL KIFISIA (DESIGN OFFICE http://www.koumoulos.com, PATRAS, GREECE)

S. E. DRITSOS

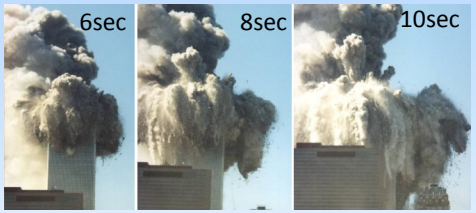
DESIGN FOR RESILIENCE

Three examples of innovative design:

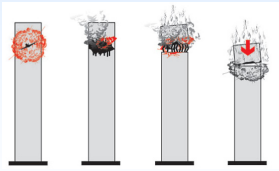
- **Design for loss of column(s) due to unidentified accidental actions**
- **Seismic isolation as a design solution**
- **Rocking isolation as a design solution**

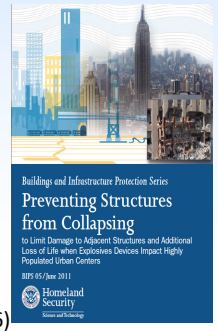
A. Design for loss of column(s) due to unidentified accidental actions

Ronan Point (London 1968)
Gas explosion on 18th floor



World Trade Centre (2001)





Guidelines publication

(Bousias, 22nd Students' Conference, Patras, 2016)

EN 1990-1 (Basis of Structural Design)

(4)P A structure shall be designed and executed in such a way that it will not be damaged by events such as :
– explosion,
– impact, and
– the consequences of human errors,
to an extent disproportionate to the original cause.

Further information is given in EN 1991-1-7 (Accidental Actions)

EN 1991-1-7 (Accidental Actions)

The adoption of strategies for limiting the extent of localised failure may provide adequate robustness against those accidental actions identified in the code or any other action resulting from an unspecified cause

Resistance of reinforced concrete elements to explosions

For explosions with devastating effects, the damage:

•Develops in a few critical building elements

•The building collapses due to an inability to carry the vertical loads

Objective: To reduce the impact on critical elements

(Seible et al., 2011)

(Bousias, 22nd Students' Conference, Patras, 2016)

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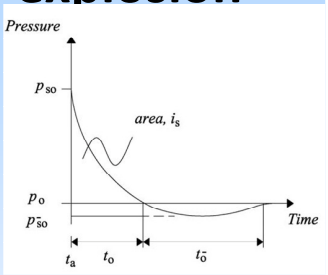
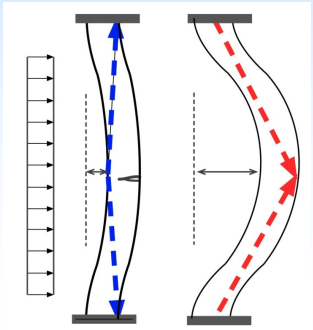
Loss of support due to explosion

- Time - pressure change
- High energy (velocity) impact
- High localised energy consumption requirement
- Unknown load bearing capacity



Examine:

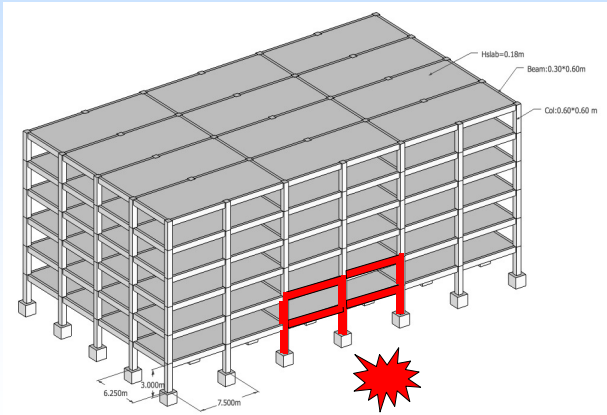
- Damage
- Change of axis
- Effectiveness of resistance techniques adopted in antiseismic design



(Bousias, 22nd Students' Conference, Patras, 2016)

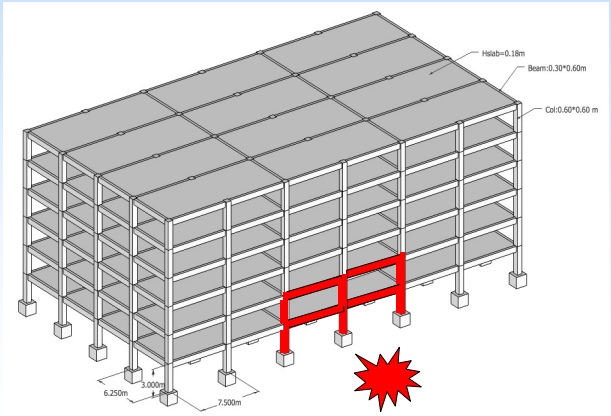
Effects of explosions

- Loss of column(s) → load redistribution
- Possible progressive collapse



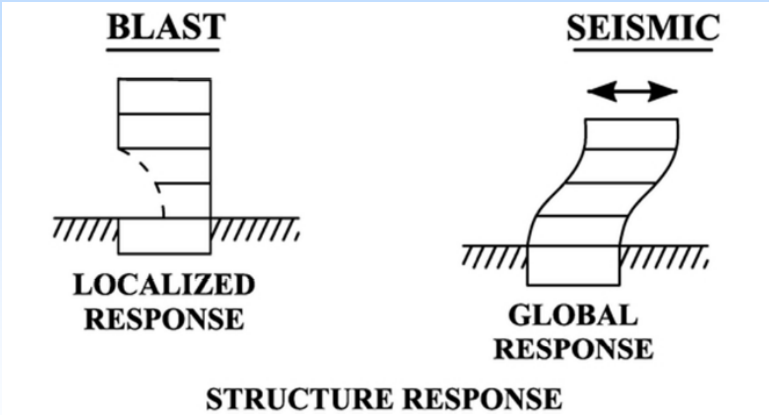
(Bousias, 22nd Students' Conference, Patras, 2016)

Contribution of seismic design to resist explosions



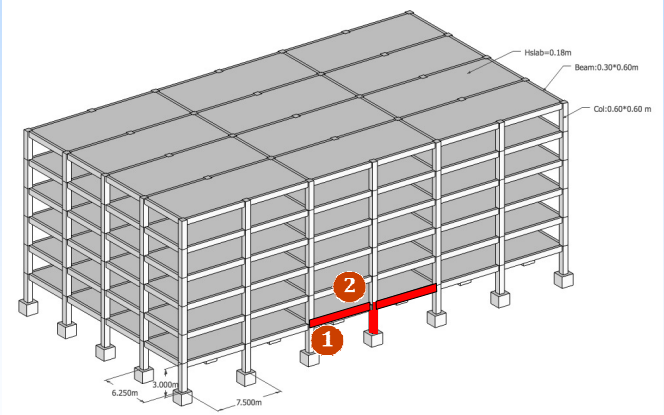
(Bousias, 22nd Students' Conference, Patras, 2016)

Drakatos, I-S and Dritsos, S. E., 2014. Contribution of earthquake resistant design for reinforced concrete buildings when coping with external explosions. Journal of Earthquake Engineering, 18(4), pp. 502-527.



GENERAL CONCLUSION: Seismic design of buildings improves their resistance to explosions
(The paper only concerns the case of external explosions)

Resistance to loss of support Alternative load paths?



(Bousias, 22nd Students' Conference, Patras, 2016)

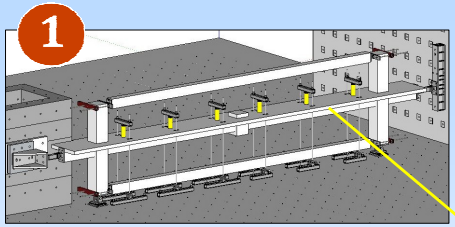
PRESCIENT University of Patras project

Paradigm for **Res**ilient **C**oncrete **I**nfrastructures to **E**xtreme **N**atural and **M**an-made **T**hreats

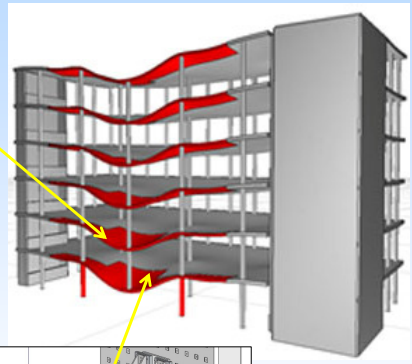
Co-ordinator: Prof. M. Fardis

www.prescient.upatras.gr

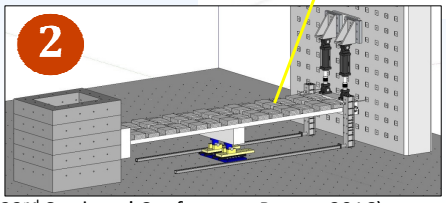
Column failure



How does the frame take the load?



Can the slab and the internal beam transfer the load to the external beams?

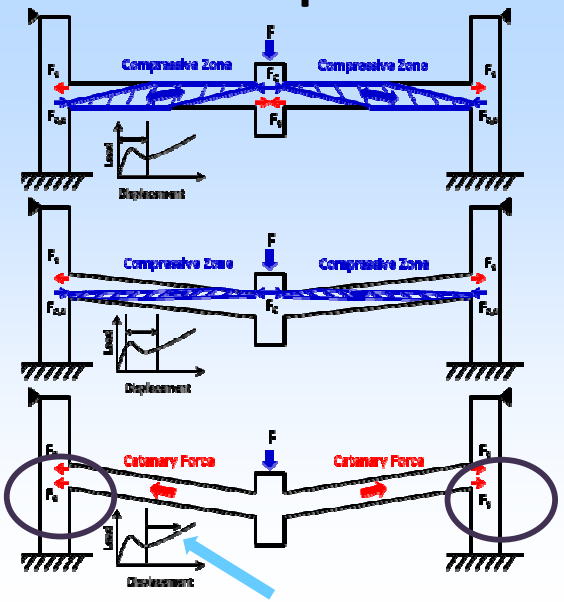


(Bousias, 22nd Students' Conference, Patras, 2016)

Alternative load path

"Frame" action

"Catenery" action



(Bousias, 22nd Students' Conference, Patras, 2016)

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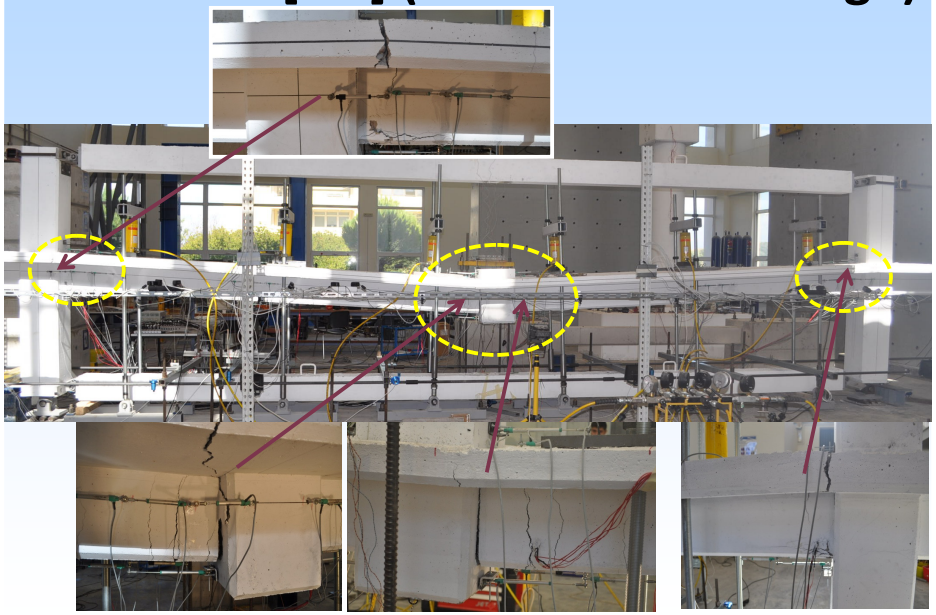
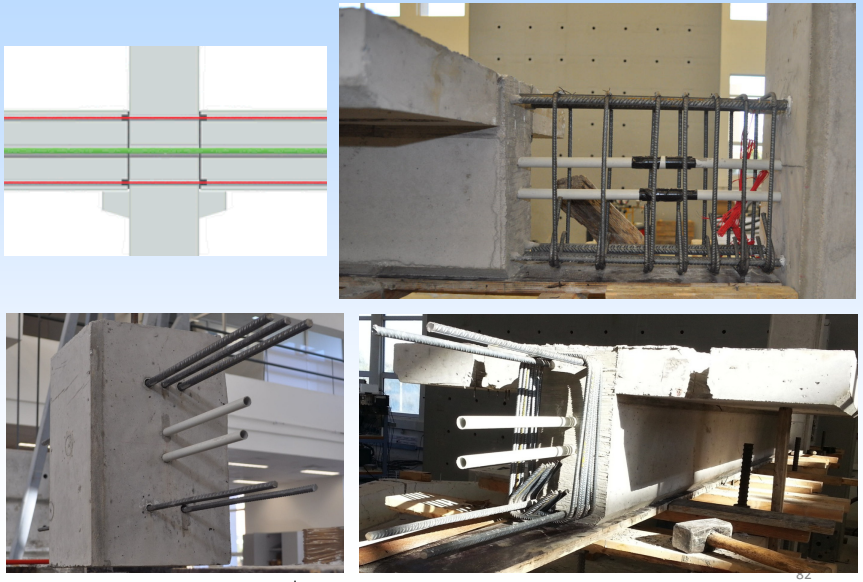
Frame test [B1] (Conventional Design)



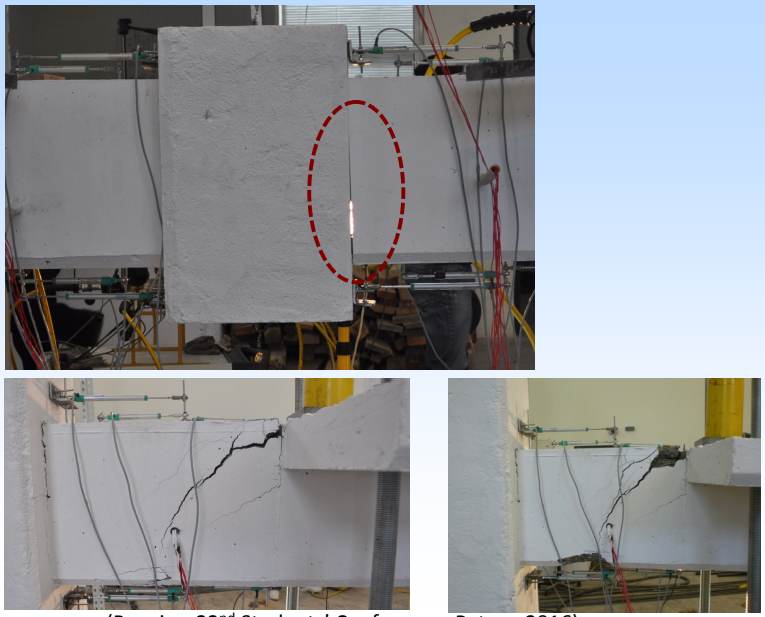
(Bousias, 22nd Students' Conference, Patras, 2016)

Frame test [B2] (Dry Joint Construction)



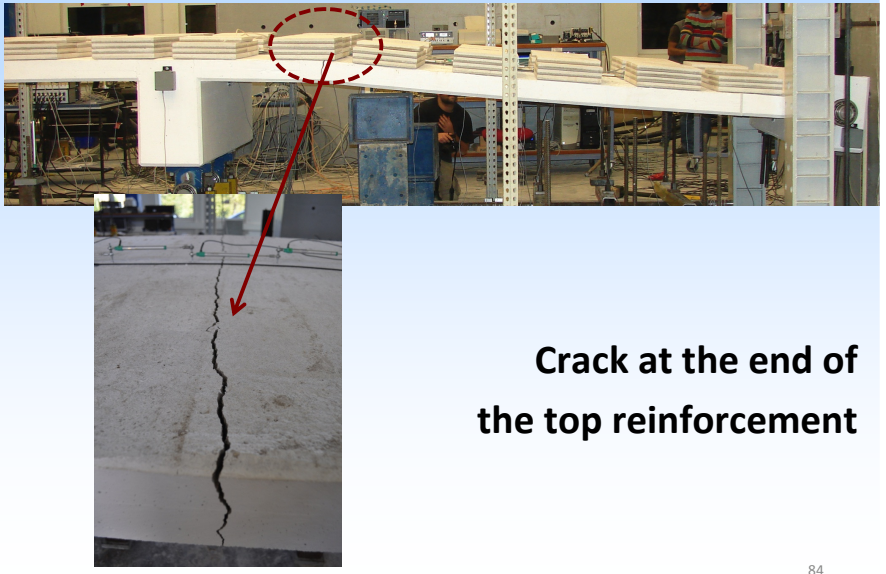
(Bousias, 22nd Students' Conference, Patras, 2016)

Frame test [B2] (Dry Joint Construction)



(Bousias, 22nd Students' Conference, Patras, 2016)

Slab test [S1]

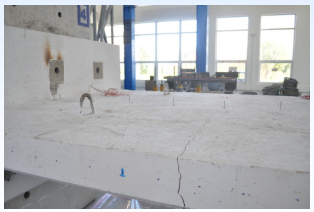


Crack at the end of the top reinforcement

(Bousias, 22nd Students' Conference, Patras, 2016)

Slab test [S2]

Development of plastic hinges on both sides of intermediate support



(Bousias, 22nd Students' Conference, Patras, 2016)

Earthquake damage
Column loss

Beneficial role of infill walls in the upper floor to resist progressive collapse following the loss of column(s)

(Bousias, 22nd Students' Conference, Patras, 2016)

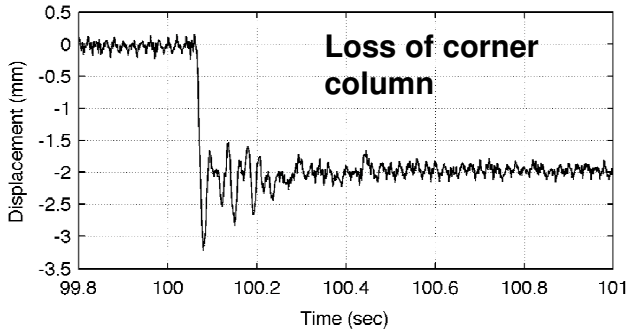
Testing a building for loss of column

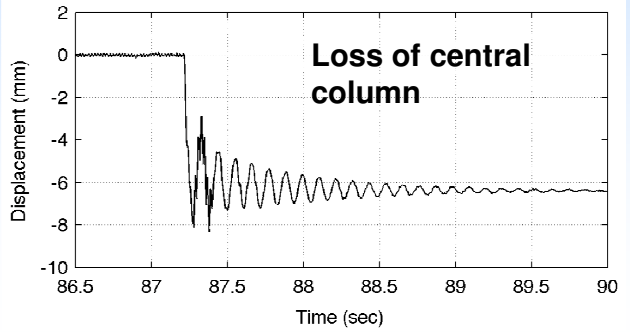
Investigate building behaviour designed to withstand earthquakes (according to Eurocode 8) with/without infill walls on the first floor during the instantaneous removal of:

- **Perimeter column**
- **Corner column**
- **Central column**

(Bousias, 22nd Students' Conference, Patras, 2016)

(Bousias, 22nd Students' Conference, Patras, 2016)





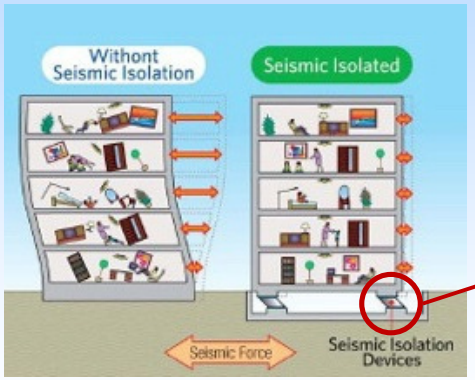
(Bousias, 22nd Students' Conference, Patras, 2016)

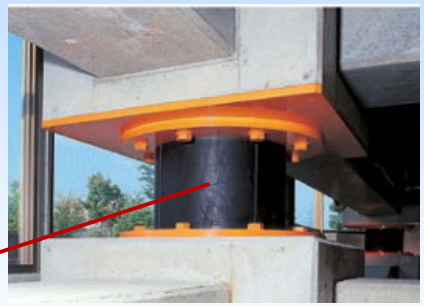
The final test under way

- Remove infill walls
- Increase load (37 ton/floor → 70 ton/floor)
- Remove perimeter column

(Bousias, 22nd Students' Conference, Patras, 2016)

B. SEISMIC ISOLATION





(https://mathspig.wordpress.com/category/topics/differentiation/)

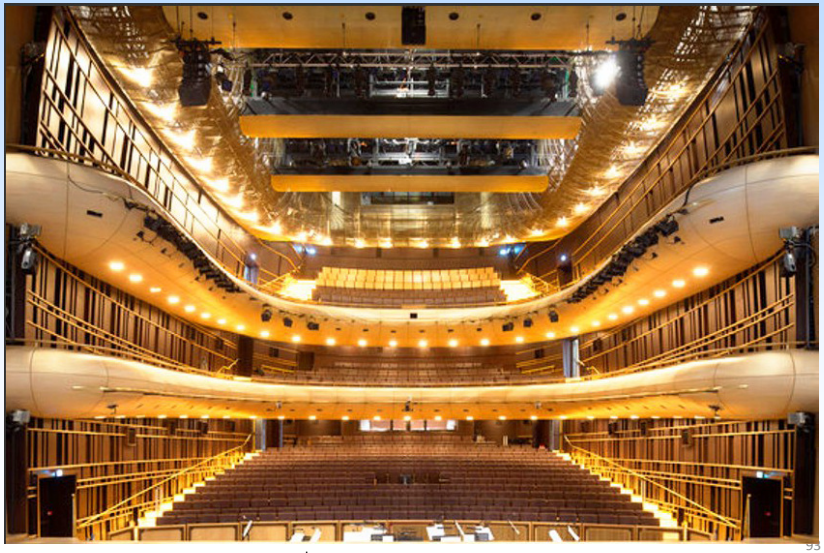
DESIGN OF TWO SEISMIC ISOLATED BUILDINGS

Onassis Cultural Centre

Stavros Niarchos Foundation Cultural Centre

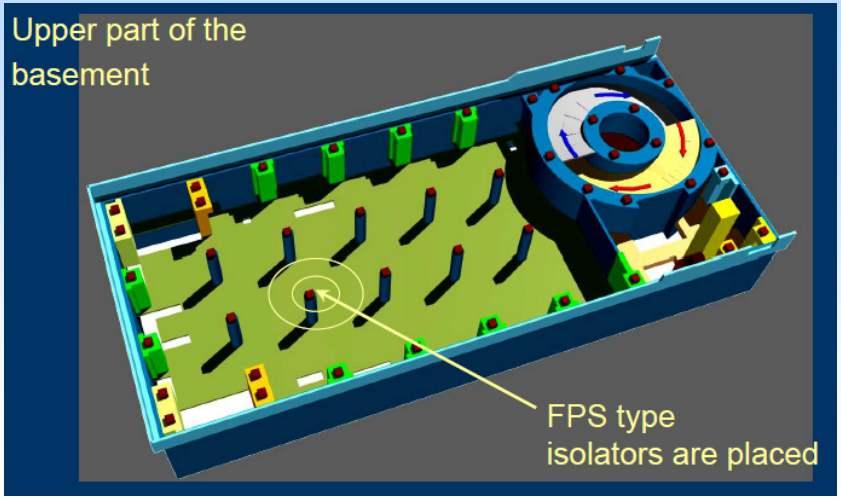
(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

ONASSIS CULTURAL CENTRE



(Giarlelis, 22nd Students' Conference, Patras, 2016)

ONASSIS CULTURAL CENTRE



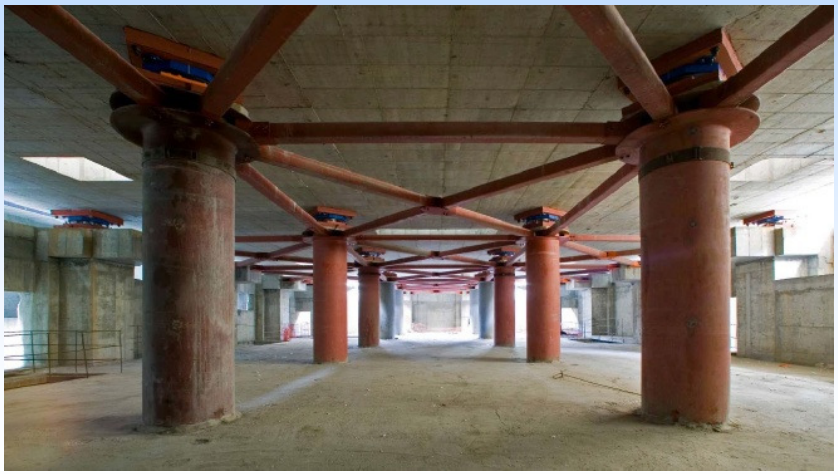
(FPS = friction pendulum system)

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

ONASSIS CULTURAL CENTRE

(Giarlelis, 22nd Students' Conference, Patras, 2016)

ONASSIS CULTURAL CENTRE



(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

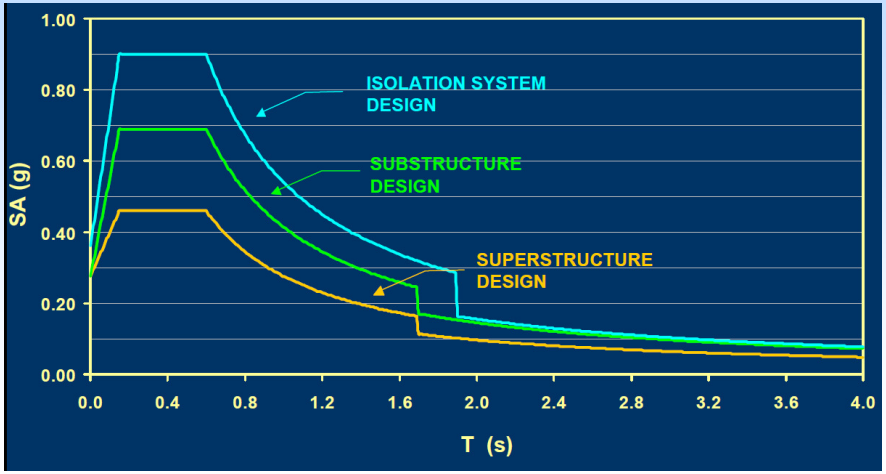
ONASSIS CULTURAL CENTRE

Onassis Cultural Center		Typical Building in Athens
α = 0.24	= 4 X	α = 0.16
γ_I = 1.15		γ_I = 1.0
q = 1.5		q = 3.5

more than **4** times greater demand
(in terms of spectral acceleration)

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

DESIGN SPECTRA



(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

STAVROS NIARCHOS FOUNDATION CULTURAL CENTRE

(Giarlelis, 22nd Students' Conference, Patras, 2016)

STAVROS NIARCHOS FOUNDATION CULTURAL CENTRE

- **Very poor soil conditions (piles required)**
- **High seismic performance requirement – no damage at all after occurrence of design earthquake**
- **Extreme architectural demands concept that could not be met through conventional design**
- **Choice of seismic isolation liberated the architectural concept from the limitations of seismic design**

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

STAVROS NIARCHOS FOUNDATION CULTURAL CENTRE

SNFCC Opera & Library		Typical Building in Athens
α = 0.27	= 5 X	α = 0.16
γ_I = 1.4		γ_I = 1.0
q = 1.5		q = 3.5
SA amp = 3.0		*SA amp*=2.5

more than **5** times greater demand
(in terms of spectral acceleration)

101

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

FRICTION PENDULUM SYSTEM

102

(Giarlelis, 22nd Students' Conference, Patras, 2016)

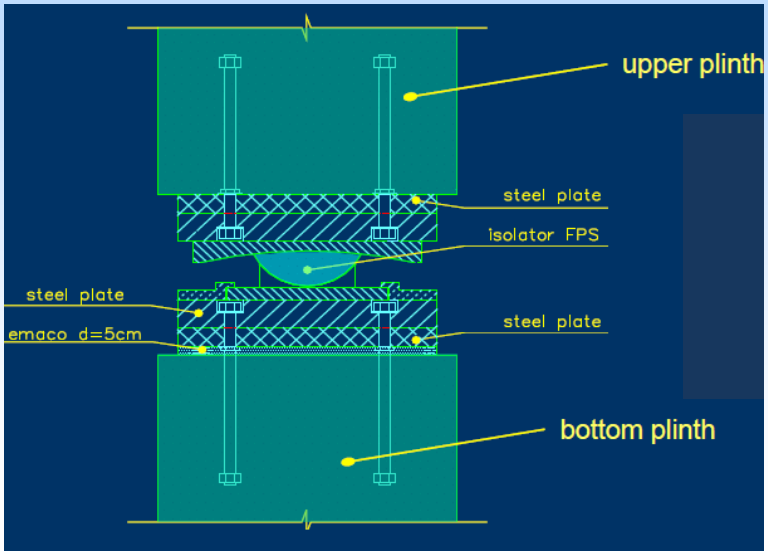
FRICTION PENDULUM SYSTEM

Isolator and seismic joint

103

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

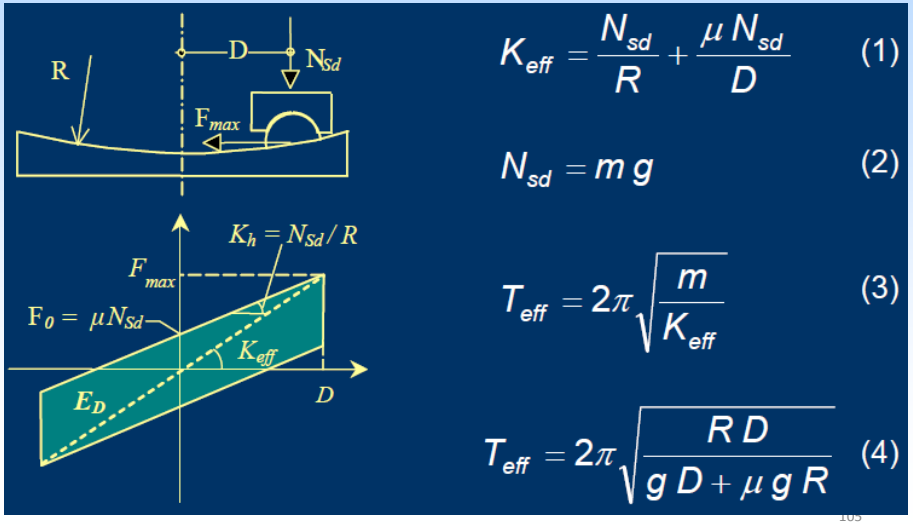
FRICTION PENDULUM SYSTEM



104

(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

FRICTION PENDULUM SYSTEM



$$K_{eff} = \frac{N_{sd}}{R} + \frac{\mu N_{sd}}{D} \quad (1)$$

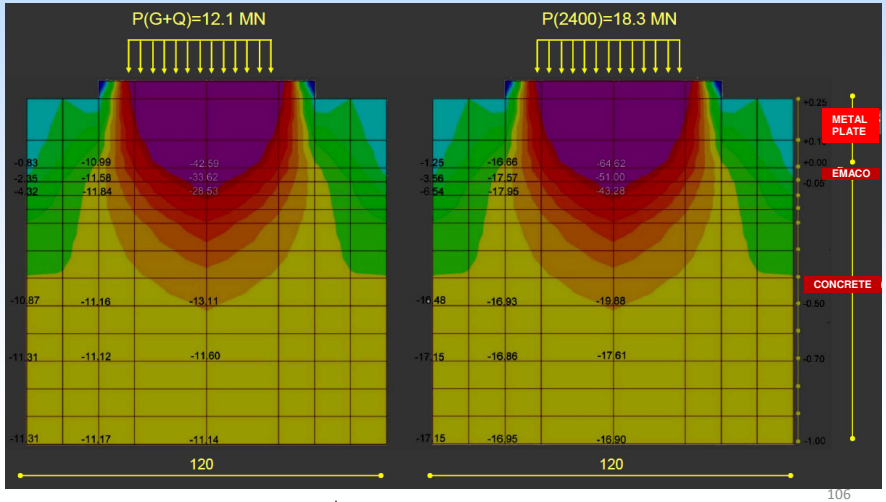
$$N_{sd} = m\,g \quad (2)$$

$$T_{eff} = 2\pi\sqrt{\frac{m}{K_{eff}}} \quad (3)$$

$$T_{eff} = 2\pi\sqrt{\frac{R\,D}{g\,D + \mu\,g\,R}} \quad (4)$$

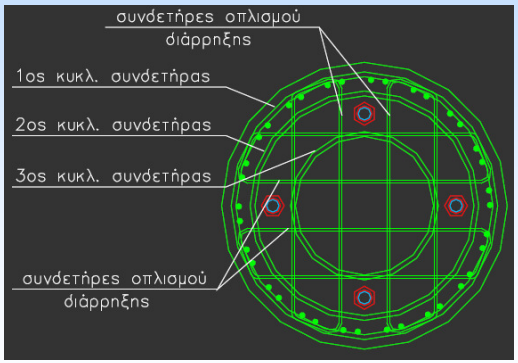
(Giarlelis, IABSE WG7 Geneva Workshop, 2015)

COLUMN SUPPORT
Stress Distribution



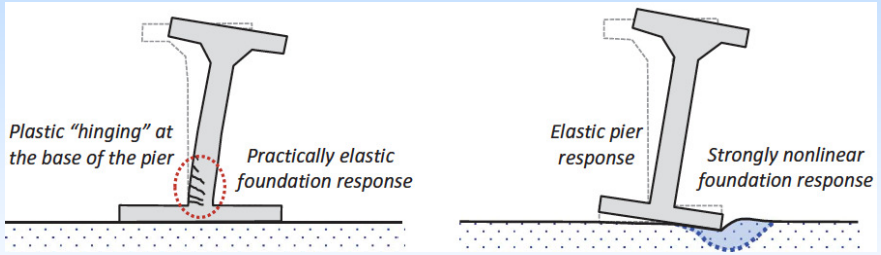
(Giarlelis, 22nd Students' Conference, Patras, 2016)

COLUMN SUPPORT
Detailing



(Giarlelis, 22nd Students' Conference, Patras, 2016)

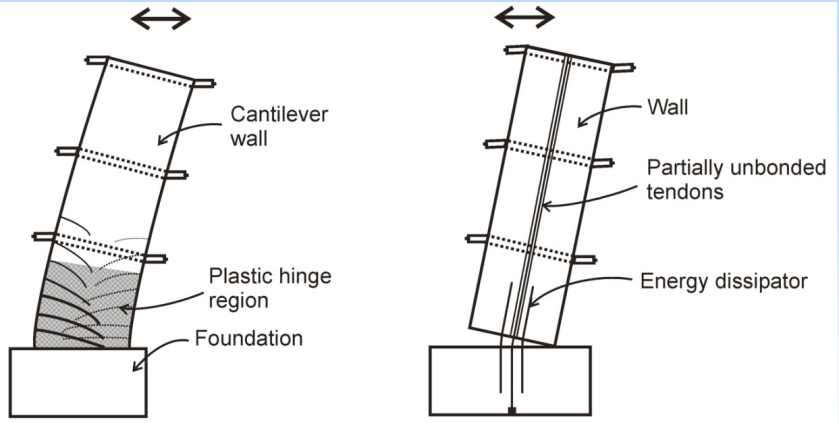
C. ROCKING ISOLATION



When columns are fixed on the ground, damage is expected through plastic hinge formation at the base while' if the ground allows rocking, an elastic response of the column is expected.

(Bousias, 22nd Students' Conference, Patras, 2016)

ROCKING ISOLATION



An innovative design could be to allow rocking and expect an elastic response of the column.

→ **Minimum damage (losses)**

→ **Recovery to original** → **RESILIENCE**

(Bousias, 22nd Students' Conference, Patras, 2016)

ROCKING ISOLATION

Seismic table tests

Dept. of Civil Engineering, Patras University

(Bousias, 22nd Students' Conference, Patras, 2016)

ROCKING ISOLATION

Pseudodynamic Tests

Structural Lab, Dept. of Civil Engineering, Patras University

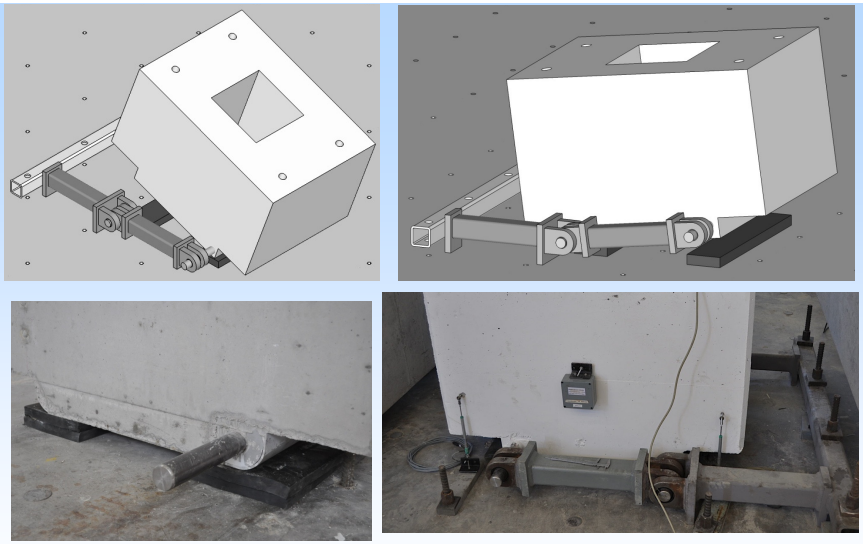
(Bousias, 22nd Students' Conference, Patras, 2016)

SIMULATION OF ROCKING ISOLATION

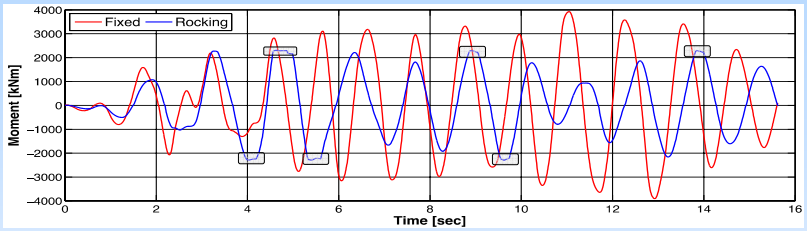
Pseudodynamic Tests

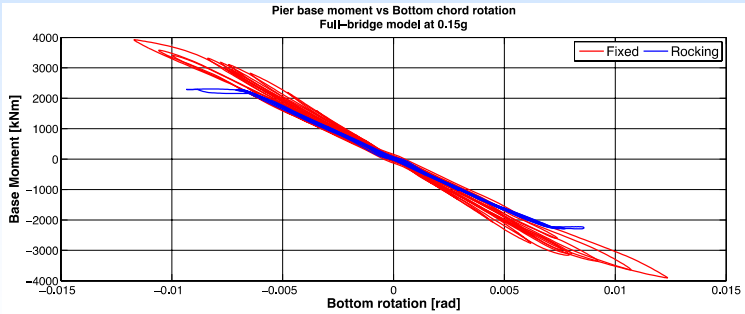
Structural Lab, Dept. of Civil Engineering, Patras University

(Bousias, 22nd Students' Conference, Patras, 2016)



SIMULATION OF ROCKING ISOLATION
Pseudodynamic Tests
Structural Lab, Dept. of Civil Engineering, Patras University
(Bousias, 22nd Students' Conference, Patras, 2016)



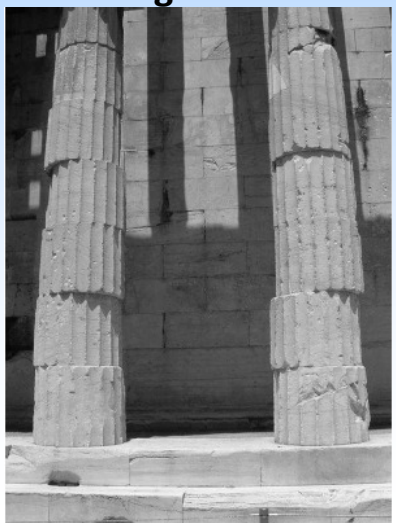


ROCKING ISOLATION COMPARISONS

(Bousias, 22nd Students' Conference, Patras, 2016)

LEARNING FROM ANCIENT GREECE

Resilience through unbonded sliding and rocking segmented columns



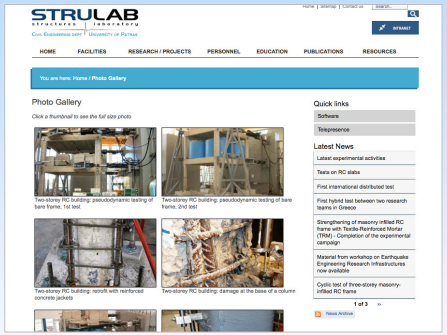
Still standing after 2500 years

(Galanopoulos, 1956)

A GREEK MYTH

The ancient Greeks symbolised the earthquake as the chief of the Giants named Egelados, who was attacking and punishing the people. Goddess Athena beat Egelados in a battle and imprisoned him in Mount Etna in Sicily. This is the reason why Etna erupts from time to time, as Egelados tries to escape. As Athena was the goddess of wisdom and knowledge, the myth's message is that people should not be afraid. Wisdom and knowledge will win the battle with the earthquake.

Find more .....



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