International Memorial Symposium
"Protecting Lives from Earthquake and Tsunami Disasters"
Tokyo, Japan, June 27, 2012

International Cooperation on Earthquake Disaster Management for Vrancea Seismic Events

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"Nowhere else in the world is a center of population so exposed to earthquakes originating repeatedly from the same source"

Charles Richter. 15 March 1977,
Letter to the Romanian government

World Map of Natural Hazards prepared by the Münich Re, 1998 indicates for Bucharest: "Large city with Mexico-city effect"

"The unusual nature of the ground motion and the extent and distribution of the structural damage have important bearing on earthquake engineering efforts in the United States."

Jennings & Blume, NRC & EERI Report

Seismicity of Vrancea subcustral source (60-180 km) in Carpathian Mountains

1000 yr catalogue of Vrancea earthquakes

- *Major historical events and major earthquakes in the XX century*

Event	Epicentral intensity I_o	Focus depth. km	Moment magnitude M_w	Obs
1802, October 26 1829, November 20 1838, June 23	> 9 ≥ 8 ≥ 8		7.9	Largest Vrancea event ever occurred
1940, November 10 1977, March 4 1986, August 30	9 8/9 7/8	150 109 133	7.7 7.5 7.2	Largest seismic losses ever experienced

Nov. 10, 1940 earthquake

M_{GR} = 7.4; M_w = 7.7

- At least 350 deaths in Romania
- Collapse of **Carlton Building in Bucharest**
  - 11 storey, h = 47 m
  - RC frame
  - 130 death
- Important damage in Chisinau, R. of Moldova

March 4, 1977 earthquake

M_w = 7.7 ; h = 109 km

Killed 1,578 people (1424 in Bucharest)

Injured 11,221 people (7598 in Bucharest)

- Destroyed or seriously damaged 33,000 housing units and caused lesser damage to 182,000 other dwellings
- Destroyed 11 hospitals and damaged 448 others hospitals, etc.

The World Bank estimation of losses (Report 16.P-2240-RO, 1978):

• Total losses in Romania	**: 2.05 billion USD**	**(100%)**
Construction losses	**: 1.42**	**(70%)**
Building and housing losses	**: 1.02**	**(50%)**

International lessons unlearnt from the 1977 earthquake

1

"A systematic evaluation should be made of all buildings in Bucharest erected prior to the adoption of earthquake design requirements and a hazard abatement plan should be developed."

From:

"Observation on the behaviour of buildings in the Romanian earthquake of March 4, 1977" by G. Fattal, E. Simiu and Ch. Cluver. Edited as the NBS Special Publication 490, US Dept of Commerce, National Bureau of Standards, Sept 1977.

2

"Tentative provisions for consolidation solutions would preferably be developed urgently".

From:

"The Romanian earthquake. Survey report by Survey group of experts and specialists dispatched by the Government of Japan (K. Nakano). Edited by JICA, Japan International Cooperation Agency, June 1977.

3

"Bucharest had been microzoned as part of UNESCO Balkan Project, with microzones denoting three levels of risk. The worst destruction occurred in lowest-risk microzone."

From:

""Earthquake in Romania March 4,1977. An Engineering Report" by G. Berg, B. Bolt, M. Sozen, Ch. Rojahn. Edited by National Academy Press, Washington, D.C. 1980

建築研究資料

Kenchiku Kenkyu Shiryo

No.20 January 1978

ルーマニア地震ディジタル記録

Digitized Data of Strong-Motion Earthquake Accelerograms in Romania (March 4, 1977)

強震観測委員会 by Observational Committee of Strong Motion Earthquake

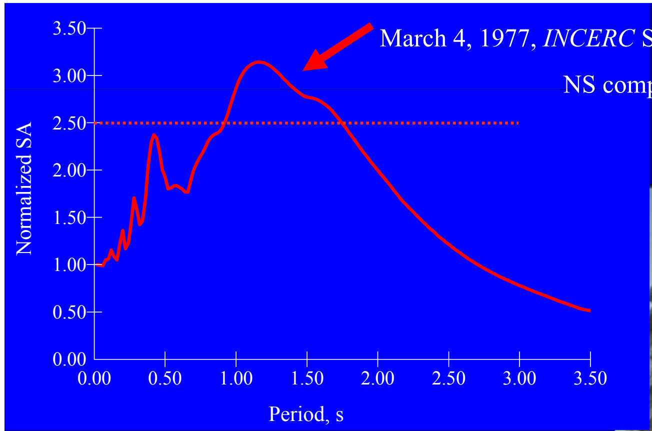
建設省建築研究所

Building Research Institute, Ministry of Construction

March 4, 1977
seismic station INCERC
Bucharest

Station	*Comp.*	*PGA cm/s*	*Tc s*
INCERCO	NS Z EW	194.9 105.8 162.3	1.40s 1.20s 0.89s

First strong ground motion recorded in Romania



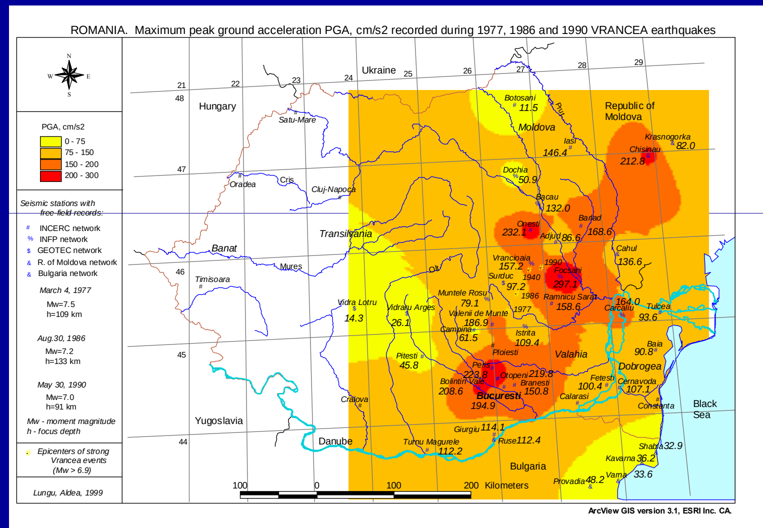
High dynamic amplification at long periods, dangerous for high-rise buildings, that makes Bucharest the most dangerous capital city of Europe

32 tall buildings completely collapsed

1977 earthquake in Bucharest

1977 earthquake in Bucharest

The recorded maximum peak ground acceleration in Romania during 1977, 1986 and 1990 Vrancea earthquakes



World Bank report

"Preventable Losses: Saving Lives and Property through Hazard Risk Management"

Strategic Framework for reducing the Social and Economic Impact of Earthquake, Flood and Landslide Hazards in the Europe and Central Asia Region

Draft, May 2004

- ***Romania*** *is regarded as one the most seismically active countries in Europe*
- ***Bucharest*** *is one of the 10 most vulnerable cities in the world.*

Recommendations for Romania:

- ***Upgrade the legal framework*** *for hazard specific management;*
- ***Review the existing buildings code*** *for the retrofitting of vulnerable buildings;*
- *Conduct a* ***comprehensive public awareness campaign*** *for the earthquake risk;*

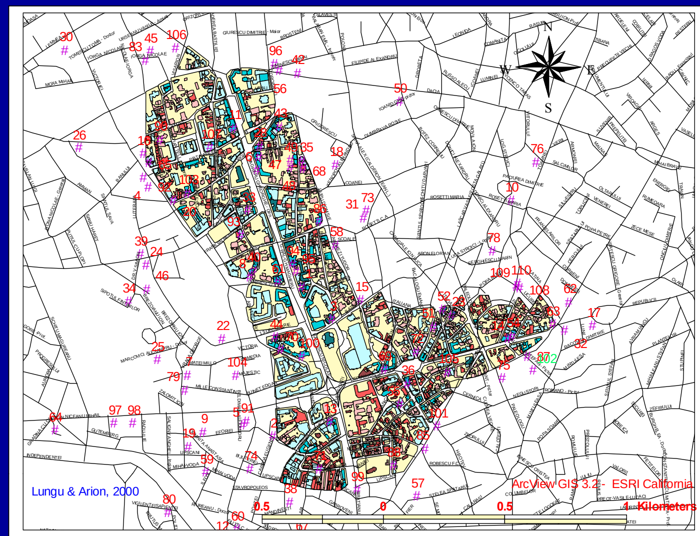
- ***Invest in hazard mitigation*** *activities in order to reduce the risks caused by earthquakes;*
- ***Develop financing strategy*** *for catastrophic events.*

National programs for seismic risk mitigation in Romania

Objectives:

- *Strengthening of "seismic risk class I" buildings:*
  Legislation + Construction work
- *Upgrading of the code for seismic design of buildings and structures*
- *Seismic instrumentation*

Central Bucharest: 129 buildings built prior to 1945 and listed as having seismic risk class 1 in case of a strong earthquake, *Mw*≥7.5



Strengthening of 9 storey residential building in central Bucharest

June 2012, ***after ≈ 15 yr of actions:***

26 buildings are fully retrofitted out of which

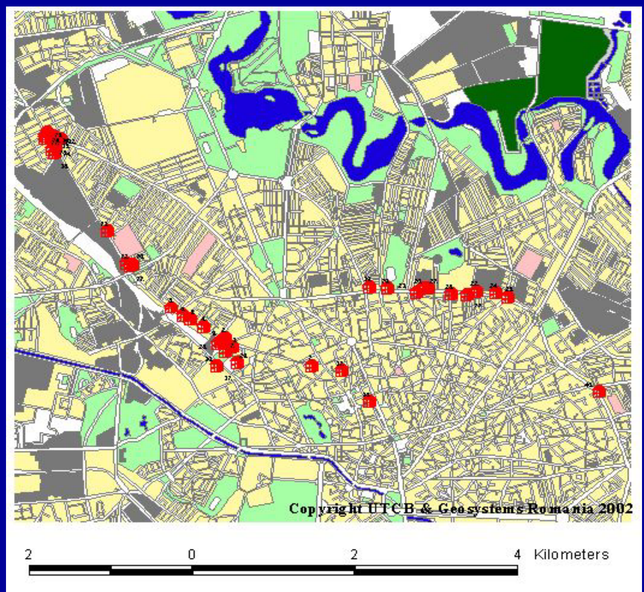
11 were seismic risk class I

Strengthening of residential buildings in Bucharest

Catogory	No. of. buildings	No. of apartments	Total floor area, m^2
1	26	716	79648
2	111	3189	395738
3	263	2668	366228
4	299	10732	946944
5	69	1590	182622
6	6	86	12530
7	1658	5037	753706
8	147	1522	92122
TOTAL	2579	25540	2829538

1. Retrofitted buildings
2. Seismic risk class I buildings that represent public danger
3. Seismic risk class I buildings
4. Seismic risk class II buildings
5. Seismic risk class III buildings
6. Seismic risk class IV buildings
7. Buildings seismically evaluated according to P100-92
8. Buildings seismically evaluated but not ranked within a seismic risk class.

Fragile tall RC buildings with soft and weak groundfloor, built in Bucharest, 1960-1977



Fragile 7-story RC frame building with soft and weak groundfloor, built in '60s, Stefan cel Mare Boulevard

Fragile 7-story RC frame building with soft and weak groundfloor, after 1977 seismic event, Stefan cel Mare Boulevard

Upgrading the code for seismic design of buildings and structures

*The code for earthquake resistance of **new** buildings,*

P100/1-2006, following EN 1998-1 format, was enforced (Jan 2007)

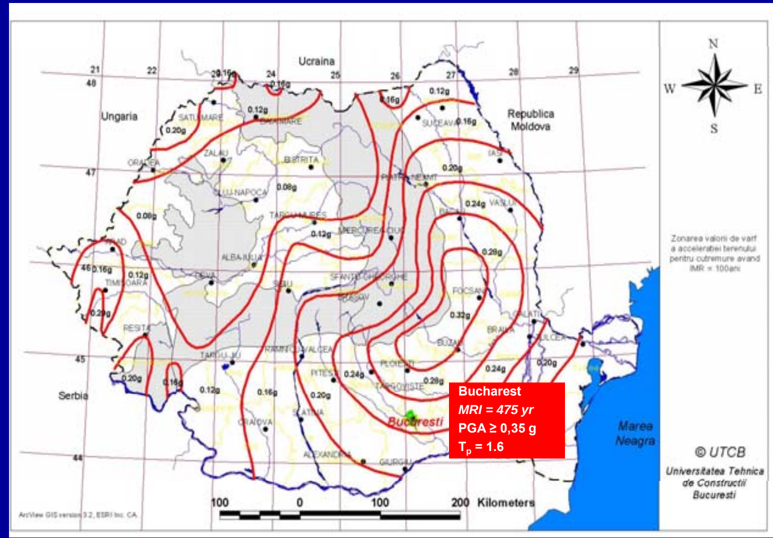
*The code for seismic evaluation and retrofit of **existing** buildings,*

P100/3-2008, following EN 1998-3 format, was enforced (2008)

*The code for earthquake resistance of **new** buildings,*

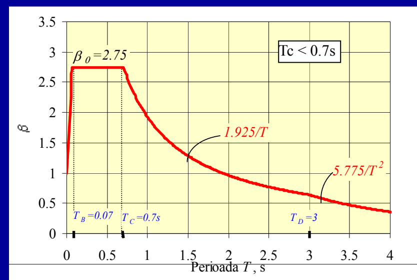
P100/1-2006, is under revision

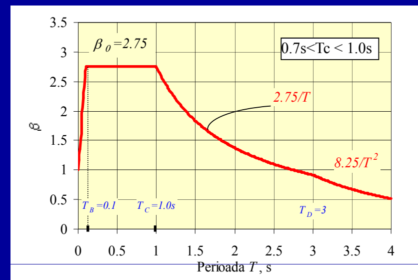
Probabilistic zonation of peak ground acceleration for design P100/1-2006 Code: *MRI =100 yr*

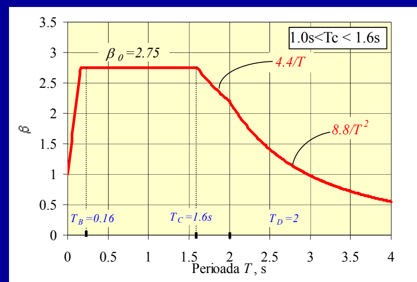


Zonation of control period of response spectrum, T_C P100/1-2006 Code

Normalised Response Spectra in *EC8* format *P100-1/2006*







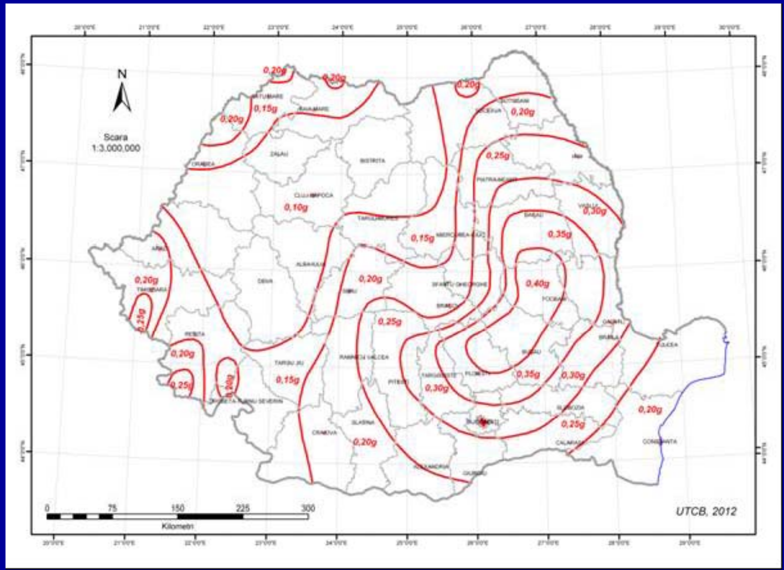
$T < T_B$ $\quad \beta = 1 + \dfrac{(\beta_0 - 1)}{T_B} T$

$T_B < T \leq T_C$ $\quad \beta = \beta_0$

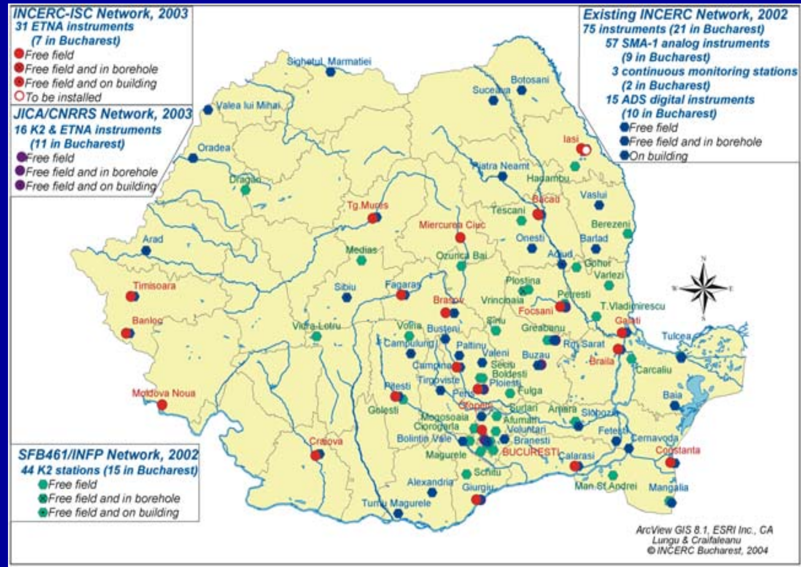
$T_C < T \leq T_D$ $\quad \beta = \beta_0 \dfrac{T_C}{T}$

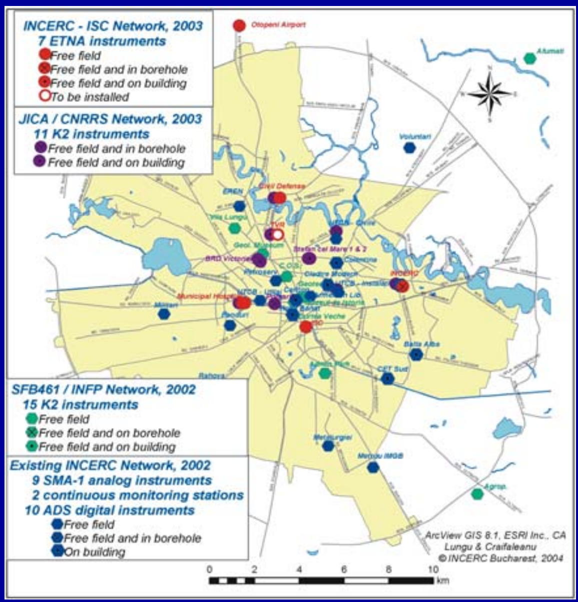
$T > T_D$ $\quad \beta = \beta_0 \dfrac{T_C \cdot T_D}{T^2}$

Zonation map of Romania in terms of ground acceleration a_g for seismic events with MRI = 225 yr



Romania
Seismic networks





Bucharest
Seismic networks

2. International projects for seismic risk mitigation in Romania

- *JICA Project - Reduction of seismic risk for buildings and structures in Romania*
- *CRC 461 Project – Vrancea Earthquakes. Tectonics, Hazard and Risk Mitigation*
- *RISK-UE - An advanced approach to earthquake risk scenarios with applications to different European town*
- *PROHITECH - Earthquake Protection of Historical Buildings by Reversible Mixed Technologies*
- *World Bank Hazard and risk mitigation in Romania*
  - Component B: *Earthquake Risk Reduction*
- *NATO Project- Harmonization of Seismic Hazard Risk and Reduction in Countries Influenced by Vrancea Earthquakes*

JICA PROJECT - *Reduction of seismic risk for buildings and structures in Romania*

• *Project signed in 2002, when 100 years of diplomatic relations between Japan and Romania were celebrated*

Partnership of 3 institutions:

NCSRR, National Center for Seismic Risk Reduction

UTCB, Technical University of Civil Engineering Bucharest

INCERC, National Institute for Building Research, Bucharest

under the authority of:

MDLPL, Ministry of Development, Public Works and Housing

• Project duration: 5.5 yr

Total cost of the project

7 mil. USD – Donation from *JICA*

- Equipment cost 3 mil. USD:
  - Soil testing laboratory
  - Structure testing laboratory
  - Seismic instrumentation network in Bucharest and Romania (free field, borehole, buildings)

- 29 Romanian young students/engineer trained in Japan
- 46 Japanese short term and long term experts in Romania

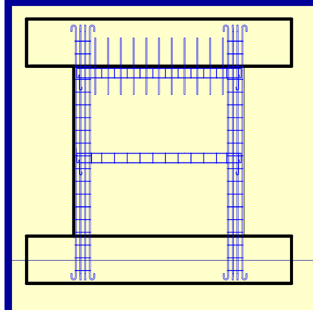
Structural testing equipment - Reaction frame

✓Maximum weight of tested specimens - 7t

✓Maximum dimensions of the tested specimens - 2.5m by 3 m

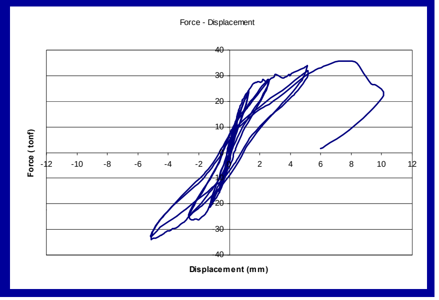
✓Reaction frame 9.7m x 7.6m

JICA Project – structural testing

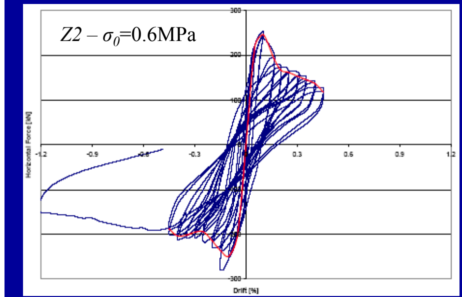


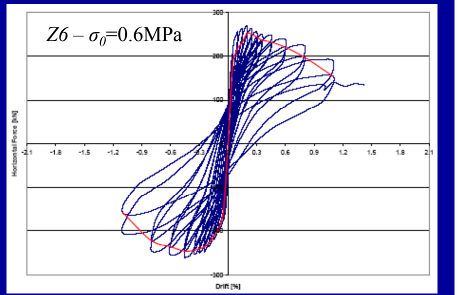
Specimen	σ_0	Armare “grinda”	Armare “stalp”	Armare inima	Mod de cedare
W1	0.13	da	sporita	-	Forta taietoare
W2	0.26	da	sporita	-	Forta taietoare
W3	0.13	-	sporita	-	Forta taietoare
W4	0.13	da	normala	-	Incovoiere
W5	0.13	da	normala	da	Incovoiere

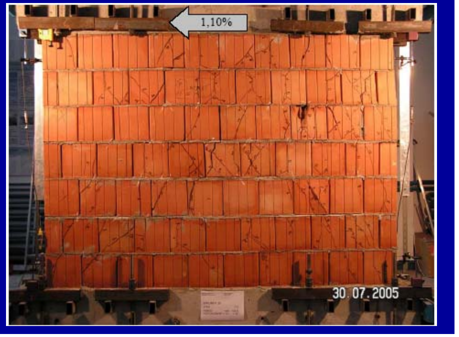
W1



JICA Project – structural testing

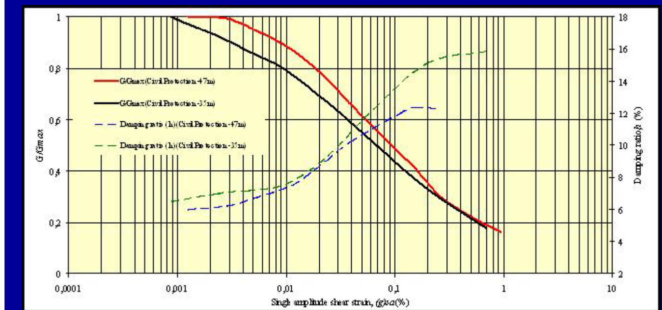




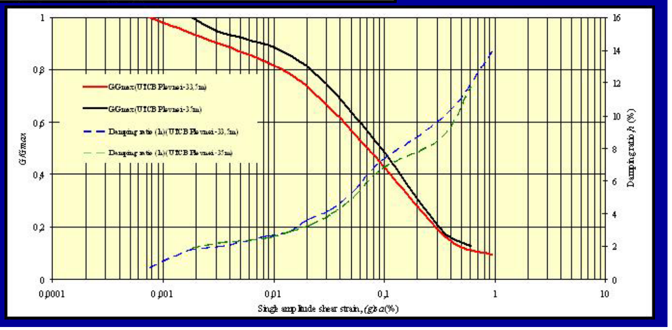


Equipments for soil investigation
Triaxial testing equipment

JICA Project – soil investigation



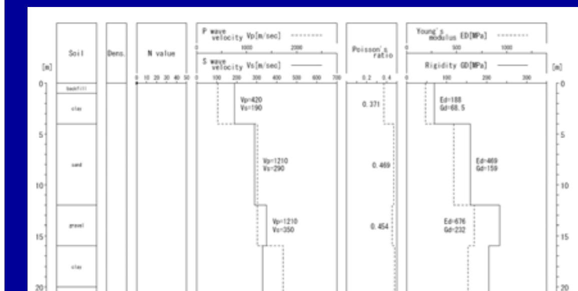
Results from triaxial testing equipment for *Civil Protection* site



Results from triaxial testing equipment for *UTCB Plevnei* site

PS logging, downhole method results

Adancime foraj, m	Site	$V_{s,30}$	T_g	$V_{s,51}$	T_g
140	INCERC	271	0.449	301	0.677
69	SPITAL	246	0.495	279	0.731
110	Victoriei	285	0.427	309	0.660
78	UTCB	310	0.393	325	0.627
66	INSTALATII	289	0.421	317	0.643
68	PRC	294	0.414	308	0.662
51	Primarie	224	0.544	264	0.772



JICA Project – seismic network

✓*ETNA-Kinematrics* and *Geosig* accelerometers (3 channels) - placed in free field outside Bucharest

✓*ALTUS K2-Kinematrics* and *Geosig* accelerometers (12 channels) – installed in boreholes and buildings inside Bucharest

Seismic network

Free field outside Bucharest	Borehole Bucharest	Building Bucharest
ETNA & Geo	*K2&Geo*	*K2&Geo*
8 sites	8 sites	5 sites
6 - JICA	7 - JICA	4 - JICA
2 - MTCT	1 - MTCT	1 - MTCT

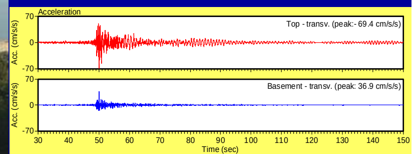
Typical RC frame structure residential Buildings
1 - after 1977 (11 storeys)
2 - before 1977 (7 storeys)

National Romanian Television. RC frame structure built before 1977 earthquake (14 storeys)

BRD - Société Générale bank headquarters

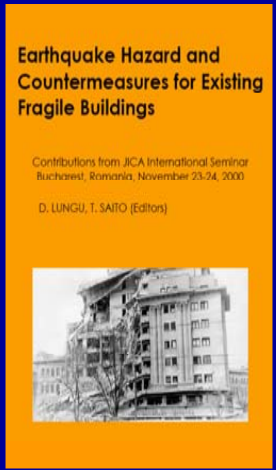
RC structure, 2002

19 storeys



27 October, 2004 seismic event

JICA Project for Seismic Risk Reduction in Romania



JICA International Seminar, Bucharest, Nov. 23-24, 2000

International Symposium on Seismic Risk Reduction – The JICA Technical Cooperation Project, Bucharest, April 26-27, 2007

JICA Project for Seismic Risk Reduction in Romania

Even the *NCSRR* was created for building a capacity to last even after the termination of *JICA* Project in Romania, in August 2010 the Romanian authorities decided to dismantle the *Center* and to relocate the equipments to the former partner, *INCERC*. The whole staff of *NCSRR* from *UTCB* (almost 90% of the staff of *NCSRR*) stayed with the University.

It is like a computer with the software (highly trained engineers) in one place and the hardware (equipment) in some other place – not operational.

CRC 461, Collaborative Research Center **- Strong Earthquakes: A Challenge for Geosciences and Civil Engineering**

University of Karlsruhe, Germany

Starting Date: 1996
Ending Date: 2007

Future
Extension of seismic cooperation
?

Participants

- *Collaborative Research Center (CRC) 461*: “Strong Earthquakes: A Challenge for Geosciences and Civil Engineering”, University of Karlsruhe, Germany

and

- *Romanian Group for Strong Vrancea Earthquakes (RGVE)*
  - ***INFP,*** *National Institute for Earth Physics*
  - ***UTCB,*** *Technical University of Civil Engineering*
  - ***INCERC****, National Institute for Building Research*
  - ***University of Bucharest,*** *Faculty of Geology and Geophysics*
  - ***GEOTEC,*** *Institute for Geotechnical and Geophysical Studies*

  and others

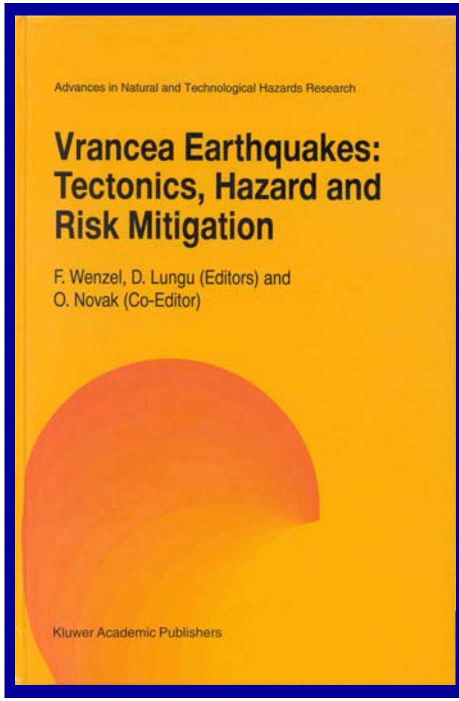
Project planning

A I:	*Deep Seismic Sounding of the Vrancea Zone*
A 6:	*Stress Field and Geodynamics*
A 7:	*Strong Ground Motion Assessment*
B 1:	*Three-Dimensional Plate Kinematics in Romania*
B 3:	*Seismogenic Potential of the Vrancea Subduction Zone - Quantification of Source- and Site-Effects from Strong Earthquakes*
B 4:	*Non-Linear Wave Phenomena in Fine and Soft Soils*
B 6:	*Geotechnical and Seismic Microzoning of Bucharest*
B 7:	*Hydrogeology and Site Effects by Earthquakes in Bucharest*
C 2:	*Methods for the Retrofitting of Damaged Buildings*
C 3:	*Disaster Management - Models and Simulation*
C 5:	*Image Analysis in Geosciences and Civil Engineering*
C 6:	*Knowledge Representation for Disasters with a Technical Information System*
C 7:	*Novel Rescue and Restoration Technologies*
C 9:	*Vulnerability Analysis of Existing Structures*
Z 1:	*Central Geographical Information System (GIS)*
Z 2:	*SFB Management*

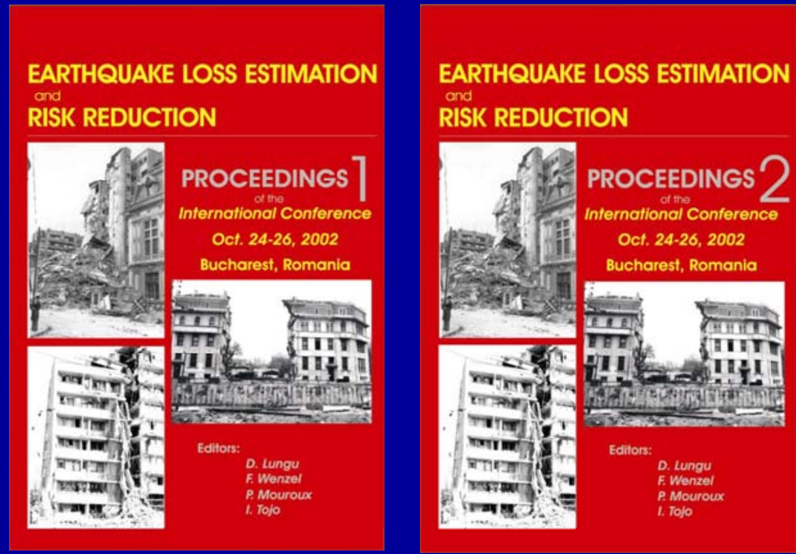
The contribution of engineers from RC departments in both UTCB & Univ. of Karlsruhe to the CRC461 seismic instrumentation project in Romania was focusing on conversion of the original pattern of CRC461 instrumentation initially planned outside Bucharest into finally dense seismic instrumentation inside Bucharest.

That new pattern of the CRC461 network in Bucharest was the basis for the future microzonation studies as well as for dynamic characterization of site conditions in the capital city of Romania.

Test building at INCERC site and
ALGA rubber bearings HDRB 250x164.5



First International Workshop on Vrancea Earthquakes, Bucharest, Nov. 1-4, 1997



RISK-UE - An advanced approach to earthquake risk scenarios with applications to different European towns

Contract n° EVK4-CT-2000-00014 with European Commission, Research Directorate General

Amount: 2 477 643 €
Funding: EC : 66 %
participants: 34 %
Starting Date: 2001
Ending Date: 2004

Project planning

WP 1: *Evaluation of European distinctive features*

WP 2: *Earthquake hazard assessment*

WP 3: *Urban system analysis*

WP 4: *Vulnerability assessment of current buildings*

WP 5: *Vulnerability assessment of historical and monumental buildings*

WP 6: *Vulnerability assessment of lifelines and essential structures*

WP 7: *Earthquake risk scenarios*

Participants

Name Participants	Responsible person
Bureau de Recherches Géologiques et Minières, BRGM, France	P. Mouroux Project Co-ordinator
Géologie tectonique environnement et risques, France	C. Martin
Politecnico di Milano, POLIMI, Italy	E. Faccioli
University of Genoa, UNIGE, Italy	S. Lagomarsino
Technical University of Civil Engineering, UTCB, Romania	D. Lungu
Institut Cartografic de Catalunya, ICC, Spain	A. Roca
Aristotle University of Thessaloniki, AUTH, Greece	K. Pitilakis
Institute of Earthquake Engineering and Engineering Seismology, IZIIS, FYROM Macedonia	Z. Milutinovic
Central Laboratory for Seismic Mechanics and Earthquake Engineering, CLSMEE, Bulgaria	M. Kostov

Workpackage 1 of **RISK-UE**

European distinctive features, inventory database and typology

Objective 1 - Distinctive features of European towns

- Town identity
- Population characteristics
- Urbanised area and elements at risk
- Impact of past earthquakes on elements at risk
- Strong motion data in the city and seismic hazard
- Geological, geophysical and geotechnical information
- Evolution of earthquake resistant design codes
- Earthquake risk management efforts

References

Objective 2 - Europe inventory database and typology

Classification of buildings occupancy

Code	Occupancy category	Importance & exposure category		
		1	2	3
B	***GENERAL BUILDING STOCK***			
B1	***Residential***			
1.1	Single family dwelling (house)			x
1.2	Multi family dwelling (apartment bldg.)			
1.3	Low-rise (1-2)			x
1.4	Mid-rise (3-7)			x
1.5	High-rise (8+)		x1)	x
1.6	Institutional dormitory		x1)	x
B2	***Commercial***			
2.1	Supermarkets, Malls		x2)	x
2.2	Offices		x2)	x
2.3	Services			x
2.4	Hotels, Motels		x2)	x
2.5	Restaurants, Bars			x
2.6	Parking			x
2.7	Warehouse			x
B3	***Cultural***			
3.1	Museums		x3)	x
3.2	Theatres, Cinemas		x2)	x
3.3	Public event buildings		x2)	x
3.4	Stadiums		x2)	x

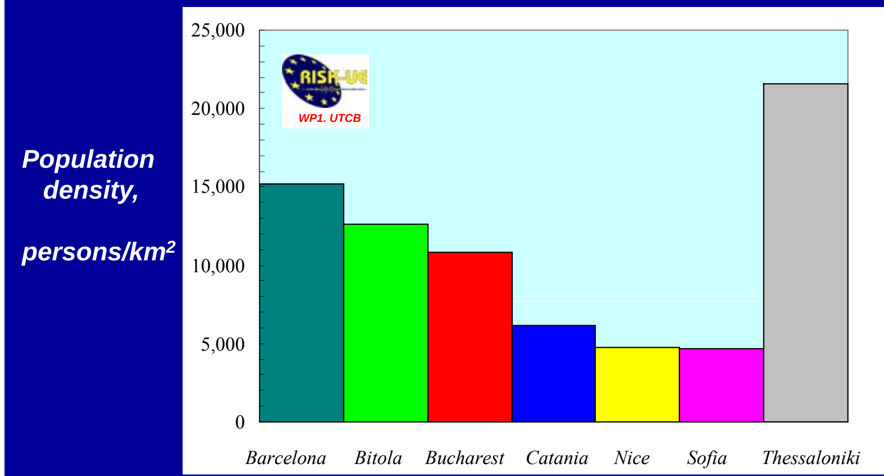
1) Buildings with capacity greater than 150 people
2) Buildings with capacity greater than 300 people or where more than 300 people congregate in one area

Building typology matrix, *BTM*

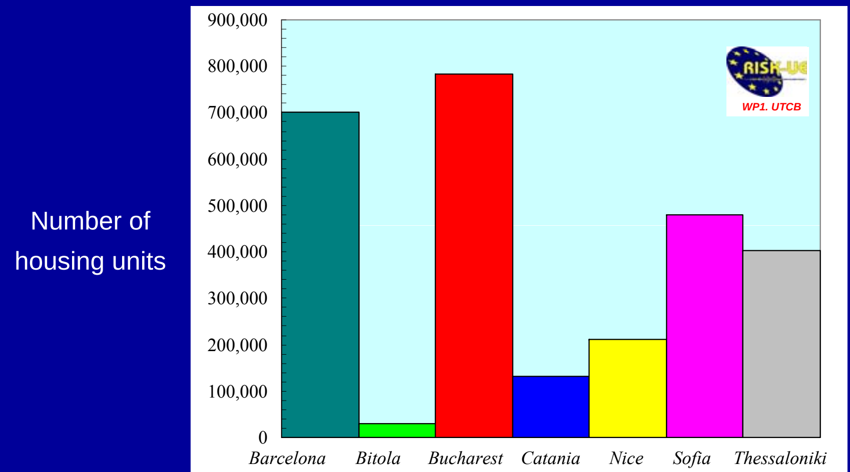
Label	Building type description	Height description			Code level*			
		Name	No. of stories	Height h, m	N	L	M	H
RC	***Reinforced concrete structures***							
RC1	Concrete moment frames	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
RC2	Concrete shear walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
RC3	Concrete frames with unreinforced masonry infill walls							
3.1	Regularly infilled frames	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
3.2	Irregularly frames (i.e., irregular structural system, irregular infills, soft/weak story)	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
RC4	RC Dual systems (RC frames and walls)	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
RC5	Precast Concrete Tilt-Up Walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				
RC6	Precast Concrete Frames with Concrete shear walls	Low-rise Mid-rise High-rise	1 - 3 4 - 7 8+	$h \le 9$ $9 < h \le 21$ $h > 21$				

*Code level
N - no code;
L - low-code (designed with unique arbitrary base shear seismic coefficient);
M - moderate-code;
H - high-code (code comparable with Eurocode 8)

Population density in the 7 towns



Number of housing units for 7 towns



Vulnerability and typology of European buildings stock

Building stock age in the 7 towns versus Seismic codes inter-benchmark periods

Town	Seismic codes inter-benchmark periods		
	Pre-code	Low-code	Moderate code
Barcelona	*79%*	*21%*	--
Bitola	*48%*	*29%*	*23%*
Bucharest	*30%*	*30%*	*40%*
Catania	*92%*	-	*8%*
Nice	*75%*		*25%*
Sofia	*Data not available*		
Thessaloniki	*20%*	*50%*	*30%*

PROHITECH - Earthquake Protection of Historical Buildings by Reversible Mixed Technologies

Contract n° INCO – CT-2004 - 509119 with European Commission, Research Directorate General

Amount: 2 400 000€
Funding: EC: 88 %,
participants : 12 %
Starting Date: 2004
Ending Date: 2007

Project planning

WP 1: *Overview of existing techniques*
WP 2: *Damage assessment*
WP 3: *Risk Analysis*
WP 4: *Intervention strategies*
WP 5: *Innovative materials and techniques*
WP 6: *Reversible mixed technologies*
WP 7: *Experimental analysis*
WP 8: *Numerical analyses*
WP 9: *Calculation models*
WP 10: *Validation of innovative solutions and procedures*
WP 11: *Study cases*
WP 12: *Design guidelines*

Participants

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World Bank Project in Romania

Component A:

Strengthening of disaster management capacity

Component B:

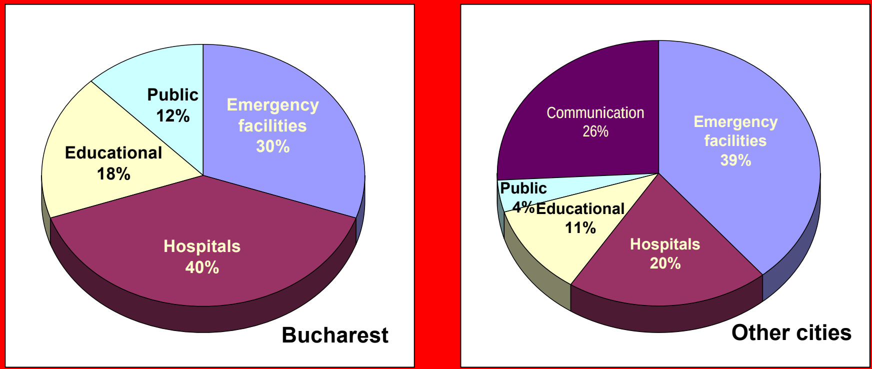
Earthquake Risk Reduction - 71.2 million US$

Subcomponents:

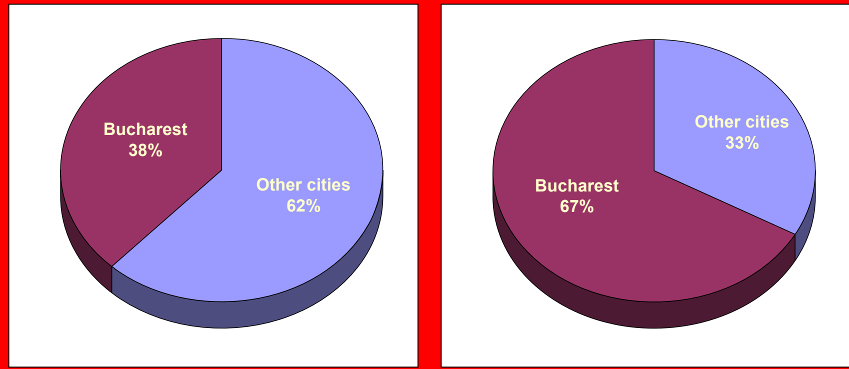
- ***Strengthening of high priority buildings and lifelines***
- ***Design & supervision***
- ***Building code review and study of code enforcement***
- ***Professional training in cost effective retrofitting***

Components C, D&E: ***Flood, Pollution & Project Management***

Distribution of buildings with occupancy



Distribution of number of buildings to be retrofitted / Distribution of cost for buildings to be retrofitted



Conclusions

Impediments in Earthquake Disaster Management

1. Weak political support – results pay off later
2. Low public awareness – time between earthquakes longer than the vivid memories of the public – as consequences:
   - Disaster relief – OK
   - Preparedness – low
3. Retrofitting of residential buildings – hard process because of social issues: multiple owners, lack of awareness, poverty, juridical issues on property
4. International financing bodies of retrofitting programs – focus on public buildings and structures

Conclusions

Further actions

1. Prepare and endorse a manual for post-earthquake investigation to be used within IPRED missions; manual shall include very clear rules and very precise criteria for making the decision on the damage state of the buildings
2. The post-earthquake investigation information on the damage on buildings, structures and lifelines shall be valuable in two directions:
   - lessons learnt on the vulnerability of different building typologies and/or construction techniques and details; this information shall be used to improve the seismic design regulations;
   - statistical information for different building typologies and different seismic demands; this information might be used for both seismic design regulations and for fragility/vulnerability and risk analysis.