Risk Management, Assessment and Mitigation, RIMA 2010

University Politehnica Bucharest, 20-22 April 2010

Vulnerability Assessment of R/C Buildings for Earthquake Insurance Purposes

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The earthquake insurance issue

Generally, States used to provide funding, as a legal obligation, in order to reconstruct the buildings after a catastrophic earthquake. This responsibility of the State creates tremendous financial problems concerning the central budget. In such a situation, risk burden sharing should be made through the establishment of an efficient earthquake insurance system implementing the State and the insurance and reinsurance companies.

For instance, we recognize notable earthquake insurance systems in Japan , California , New Zeeland and Turkey . Unfortunately, in Europe and especially in Balkan region there is no such a system despite the fact that there are countries with high seismicity (Greece, Romania, etc).

The ambiguity and the uncertainty of the seismic phenomenon as well as the lack of communication between state's decision makers, insurance companies and structural engineers has not allowed until today the development of the particular sector.

Current practice of the seismic insurance deals mostly with the criteria which involve only financial and seismological characteristics without taking under consideration the conformation of a structure which directly or indirectly introduce the parameter of the structural behavior.

Given the aforementioned issues the focus of the earthquake insurance is how insurers approach the earthquake problem to set fair and reasonable rate of coverage against earthquakes.

The assessment of earthquake insurance rates of coverage against earthquakes

In order to evaluate the seismic risk, which introduces the risk rated premiums, one of the parameter is the seismic hazard of the region and the other is the vulnerability of the exposed values.

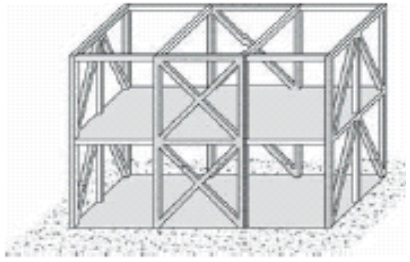
Once, obtaining the seismic hazard which definitely exists in a particular region of great importance is the vulnerability of the buildings within this area, in other words the excepted structural damage which should cover the insurance company.

At the current presentation a methodology for the evaluation of the seismic vulnerability of R/C structures is described in two levels, based on the asset visual screening process and introducing also the knowing level of the person who is running the valuation check (Insurer, Engineer) as well as the greatness of the hazard to be insured.

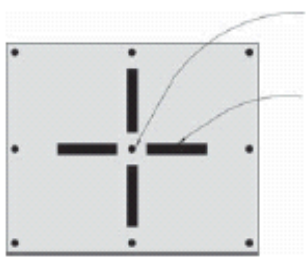
The methodology is applied to the Greek design circumstances.

The assessed vulnerability could be used for the estimation of risk rate premiums.

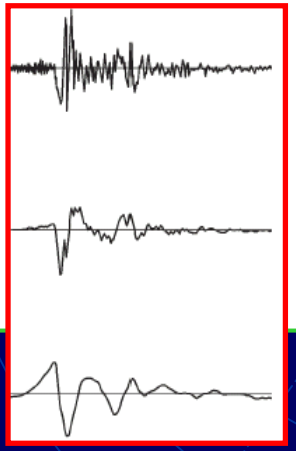
(a) Shear walls

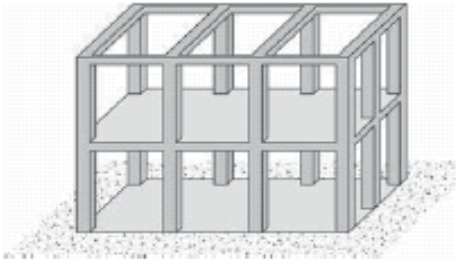


(b) Braced frames

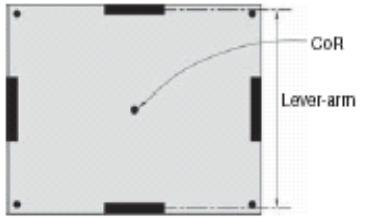


Plan
(a) No torsional resistance

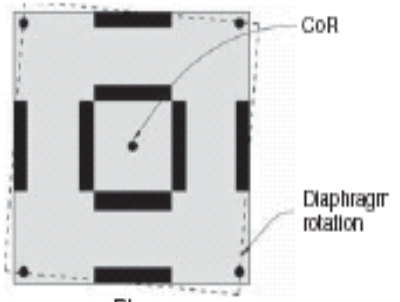




(c) Moment frames



Plan



Plan

- It is well known that there are different structural systems with different seismic behavior.
- There are structures with different vulnerability in the same seismic zone.
- Furthermore, there is a possibility for structures with the same vulnerability to behave in a different manner in the same earthquake intensity.

The key parameter is the predisposition of a building to collapse which is described by:

- **the structural conformation**
- **building age**
- **maintenance of building**
- **possible structural transformations**
- **vicinity with a gas system, etc**

The risk assessment process (risk rated premiums) is most commonly probabilistic in nature for both hazard and vulnerability.

However, vulnerability curves and damage probability matrices are general estimators without taking into account the specific characteristics of each building.

For earthquake insurance purposes it is more convenient to use an asset-screening methodology, which describes the actual condition of a structure.

The use of an asset screening methodology reduces the adverse selection problem

which face the insurers in setting premiums with respect to the risk

Properties are priced to reflect the current risk through the assets screened vulnerability factors

'Adverse selection problem occurs when the insurer cannot distinguish between probability of a loss for good and poor risk categories'

The basis of the screen asset methodology for earthquake insurance purposes

The basis of the suggested methodologies is on the philosophy of the methods of rapid visual screening taking into account the observed damage from the real seismic events.

In such a way an easy view of the structural factors which increase the risk of failure through a quantification approach is used.

The repetitiveness of damage unveil the structural vulnerability factors

Earthquake events

- San Fernando, 1971
- Bucharest, 1977
- Thessaloniki, 1978
- El Asnam, 1980
- Mexico, 1985
- Loma Prieta, 1989
- Erzincan, 1992
- Northridge, 1994
- Kobe, 1995
- Aigio, 1995
- Chi-Chi. 1999
- Kocaeli, 1999
- Athens, 1999

Vulnerability factors

- **Short column effect**
- **Soft story mechanism**
- **Change of stiffness and mass**
- **Torsion**
- **Pounding**
- **Construction quality**
- **Structural changes without permission**
- **Year of construction (Seismic code used)**
- **Ground shaking hazard**
- **Local soil conditions**

Structural change without permission,

Thessaloniki, 1978

Soft story mechanism, Lefkada, 2003

Short column mechanism, Northridge, 1994

Vulnerability of structural system, Northridge, 1994

Vulnerability assessment of r/c buildings

The methodologies are described in two levels: one simple and one compound taking under consideration the level of the covered risk to be insured as well as the level of knowledge that the person who do the evaluation has.

1. **Vulnerability Insurance Card (building/apartment) of the exposed property.**

Evaluation from a properly trained insurer. It is proposed for the use of low insurance risk.

2. **Vulnerability Insurance Envelope of the exposed property.**

Evaluation from a proper trained engineer. Proposed for the use in high insurance risk.

1. Vulnerability Insurance Card

Basic ranking criteria of estimated exposed value (Building Construction: R/C)

Estimated Property	Initial Marking	Basic Criterion of Seismic Vulnerability		Basic Influence Mark	Seismic Hazard Zone	Mark of Zone Influence
(EP)	**(IM)**	**(BCoSV)**		**(BIM)**	**(SHZ)**	**(MoZI)**
BUILDING	**300**	***CD1***	Regulation Of Reinforced Concrete 1954	- 50	I	- 20
		CD2	Regulation Of Reinforced Concrete 1954 Seismic Regulation 1959	- 40		
APARTMENT		***CD3***	Regulation Of Reinforced Concrete 1954 Seismic Regulation 1984	- 30	II	- 30
ESTABLISHMENT BASEMENT STORE		***CD4***	Regulation Of Reinforced Concrete 1991 Seismic Regulation 1984/1992	- 20	III	
		CD5	Regulation Of Reinforced Concrete 1991 Seismic Regulation 1992/1995	- 10		- 40

Basic Marking Criteria for Estimated Value

Partial Marking Criteria for Estimated Value

Partial marking criteria of evaluated exposed value (Building Constructions R/C)

Nr.	Partial Criterion of Seismic Vulnerability	Structural regulation- Construction year					
	(PCoSV)	Until the 1954 **CD1**	1954 - 1964 ***CD2***	1985 - 1991 ***CD3***	1992 - 1995 ***CD4***	1996 - 2000 ***CD5***	2001 – ... ***CD6***
PCoSV-1	Actual state of the building	-15	-15	-10	-5	-5	---
PCoSV-2	Previous seismic charges	-15	-10	-5	-5	-5	---
PCoSV-3	Existence of pilotis Existence of lobbies in the basement	-15	-15	-15	-15	-10	-5
PCoSV-4	No existence of underground Basement	-15	-10	-10	-10	-5	-5
PCoSV-5	Existence of intermediate floor with	-15	-15	-15	-15	-10	-5
PCoSV-6	Conformation of building in plan	-15	-15	-15	-10	-5	-5
PCoSV-7	Buildings Height-Setbacks	-15	-10	-10	-5	-5	---
PCoSV-8	Distance from nearby buildings	-15	-10	-10	-5	-5	---
PCoSV-9	Passage of pipes Drainage, Sewerage Water supply at the maze of columns, walls	-15	-15	-15	-10	-5	-5
PCoSV-10	Use Change/ dispositions of the building / apartment	-15	-10	-10	-10	-5	---
PCoSV-11	Existence of heavy façade elements	-15	-10	-10	-5	-5	---
PCoSV-12	Building connected with natural gas network	-15	-15	-15	-15	-15	-15
PCoSV-13	Internal existence of dangerous inflammable material	-15	-15	-15	-15	-15	-15
PCoSV-14	Existence of Fragile material of high value in the internal of the apartment or/and building apartments	-15	-15	-15	-15	-15	-15

High Vulnerability Criterion, (H): -15 Points
Medium Vulnerability Criterion, (M): -10 Points
Low Vulnerability Criterion, (L): -5 Points
High Structural Vulnerability: $0 < SV \leq 180$ Points → High Insurance Danger
Medium Structural Vulnerability: $180 < SV \leq 220$ Points → Medium Insurance Danger
Low Structural Vulnerability: $220 < SV \leq 300$ Points → Low Insurance Danger

Structural Vulnerability, SV

2. Vulnerability Insurance Envelop

Basic Marking Criteria for Estimated Value

Basic Marking Criteria of Estimated Value (R/C Buildings)

Estimated Property	Origin Marking	Marking of Building System (MoBS)			Basic Influence Mark	Seismic Hazard Zone	Zone Influence Mark
(EP)	(OM)	Crt.	Description	Design Regulation	(BIM)	(SHZ)	(ZIM)
Reinforced Concrete Buildings	180	MoBS-1	Building with Frame	Regulations Concrete 1954 Seismic 1959	-15	I	-5
		MoBS-2	Building with Frame + Shear Walls	Regulations Concrete 1954 Seismic 1959	-15		
		MoBS-3	Building with Frame	Regulations Concrete 1954 Seismic 1959 Additional articles 1984	-10	II	-10
		MoBS-4	Building with Frame + Shear Walls	Regulations Concrete 1954 Seismic 1959 Additional articles 1984	-10	III	-15
		MoBS-5	Building with Frame	N.E.A.K. N.E.K.Ω.Σ.	-5	IV	
		MoBS-6	Building with Frame + Shear Walls	N.E.A.K. N.E.K.Ω.Σ.	-5		
		MoBS-7	Without Seismic Regulation / No Building Permission		-180*		

Partial Marking Criteria of the Estimated Value (R/C Building)

Nr.	Vulnerability Criterion	Vulnerability Grade		Structural System
1.	Floor Mechanism / Short columns at the ground floor level (Pilotis)	L M H	-5 -10 -15	
2.	Pounding	L M H	-5 -10 -15	
3.	Previous Seismic Actions	L M H	-5 -10 -15	
4.	Bad condition due to lack of maintenance / low construction quality	L M H	-5 -10 -15	**MoBS-1** **MoBS-2** **MoBS-3**
5.	Change in Use / Add without permission	L M H	-5 -10 -15	**MoBS-4** **MoBS-5**
6.	Vertical non regularity	L M H	-5 -10 -15	**MoBS-6**
7.	Horizontal non regularity	L M H	-5 -10 -15	**MoBS-7**
8.	Torsion Possibility	L M H	-5 -10 -15	
9.	Floors with Short columns Not continuous Load Paths	L M H	-5 -10 -15	
10.	Soil B		-5	
11.	Soil C,D,X		-10	
12.	Soil C,D,X and 5 floors over		-15	

Partial Marking Criteria for Estimated Value

Quantification of partial vulnerability criteria

Quantification of Partial Vulnerability Criteria

Nr.	Vulnerability criterion	Marking criterion
1.	Floor Mechanism / Short columns at the ground floor level (Pilotis)	(H): MoBS-1, MoBs-2, MoBS-3,MoBS-7. (M): MoBS-3. (L): MoBS-5, MoBS-6.
2.	Pounding towards buildings nearby	(H): Cases where there is no joint between buildings. Cases of corner buildings. (M): Cases where there is a medium difference in stiffens between two buildings. (L): Cases with small aseismic joint not respecting the codew prescription [7].
3.	Previous Seismic Actions	(H): Characterization by previous earthquake Red (post seismic damage mark). (M): Characterization by previous earthquake Yellow / Orange. (L): Characterization by previous earthquake Green.
4.	Bad situation due to lack of maintenance / low construction quality	(H): Validation by the on site screening process. (M): Examples of bad maintenance: Corrosion of reinforcement, fissures due to (L): settlements, signs of poor workmanship, fissures on masonry, etc.
5.	Change in Use / Add without permission	(H):Change or transformation of the initial structural system. Additional loads, loads not taken under consideration during the first design. Change of importance category.
6.	Vertical non regularity	**Qualitative Criteria:** (H):Different level foundation. Non continuous and non regular distribution of vertical elements, short columns except pilotis. Building typeMoBS-7. (M): Joint between different level foundation or between vertical elements. (L): Buildings designed and constructed according to [7] (MoBS-6). **Quantitative Criteria:** (H): Mass Change $\Delta mi>0.50$, Stiffness change of layer $\Delta Ki>0.50$. (M): Mass Change $0.35<\Delta mi<0.50$. Stiffness change of layer $0.35<\Delta Ki<0.50$. (L): Mass Change $\Delta mi<0.35$. Stiffness change of layer $\Delta Ki<0.35$.
7.	Horizontal non regularity	**Qualitative Criteria** (H): Complex shape buildings L,E,Π,T., Buildings with $L_{max}/L_{vmin} > 4$. Buildings with external sides under acute angles. Intense geometrical anomalies in plan. Indirect connections between elements. Building type MoBS-7. (M): Structural r/c walls changing according to height of building. (L): Buildings designed and constructed according to [7] (MoBS-6).
		Quantitative Criteria (H): $d(CM-CR)>0.35L_{min}$ (M): $0.20<d(CM-CR)<0.35L_{min}$ (L): $d(CM-CR)<0.20L_{min}$
8.	Torsion Possibility	**Qualitative Criteria** (H):Non symmetrical arrangement of structural r/c walls. Building type MoBS-7. (M): Structural r/c walls changing according to height of building. (L): Buildings designed and constructed according to [7] (MoBS-6). **Quantitative Criteria** (H): Percentage 50% of short columns into a middle floor. Non continues columns (M): Percentage 35% of short columns into a middle floor. Non continues columns (L): Percentage 20% of short columns into a middle floor. Non continues columns.
9.	Lack of diaphragm action	**Qualitative Criteria** (H): Different level of plate in the same story. Corner holes, or in general large openings. Inadequate connection with vertical elements. Building type MoBS-7. (M): Lack of under ground basement. Setbacks creating weak zones. (L): Buildings designed and constructed according to [7] (MoBS-6). **Quantitative Criteria** (H): Holes in a story of more than 35% of the total story area. (M): Holes in a story of no more than 25% of the total story area. (L): Holes in a story of no more than 15% of the total story area.
10.	Soil B	(L):Soil category according to [7].
11.	Soil C,D	(M), (H): Soil category according to [7] / Elaborate geotechnical study.
12.	Near fault	(H): Necessity of elaboration of geotechnical study.

Concluding Remarks

1. The earthquake insurance cover is a basic need for modern society. This is especially true to developing countries, or in case of financial crisis where the economics of States are fragile.
2. The suggested practical methodology in two levels, according to the risk insured to be covered, is based on earthquake engineering theory, practical engineering experience and observed seismic damage from past earthquakes. Using the aforementioned methodology it is easily responded the question of how a structure is designed and constructed in order to resist the expected earthquake.
3. In this context providing to the insurance company the vulnerability parameter whish is necessary for the assessment of pure risk premium rate.

Thank you for your attention !!