Bogazici University

Network of Reseacrh Infrastructures for European Seismology

URBAN EARTHQUAKE SHAKING AND LOSS ESTIMATION by ELER©

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ABSTRACT

Level 2 loss assessment module of the ELER© (Earthquake Loss Estimation Routine) software which has been developed within the JRA-3 component of the EU-FP6 NERIES Project, is essentially intended for earthquake loss estimation (building damage, consequential human casualties and macro economic loss quantifiers) in urban areas. The basic Shake Mapping is similar to the Level 0 and Level 1 modules. The spectral acceleration-displacement-based vulnerability assessment methodology is utilized for the building damage estimation. The following methods can be chosen for the analysis:

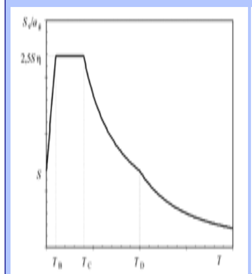
1. Capacity Spectrum Method (CSM), ATC-40, 1996
2. Modified Acceleration-Displacement Response Spectrum (MADRS) Method, FEMA 440, 2005
3. Reduction Factor Method (RFM), Fajfar, 2000
4. Coefficient Method (CM), ASCE 41-06, 2006

The building inventory data for the Level 2 analysis consist of grid- (geo-cell) based urban building and demographic inventories. For building grouping the European building taxonomy developed within the EU-FP5 RISK-UE project and model building types of HAZUS-MH (2003) are used. The software database includes the building capacity and the analytical fragility parameters for both of the building taxonomies. The user has also the capability to define custom capacity and fragility curves in order to use with any selected method of the Level 2 analysis. Once having calculated the damaged buildings by one of the above methods, casualties are estimated based on the number of buildings in different damage states and the casualty rates for each building type and damage level. Modifications to the casualty rates can be used if necessary.

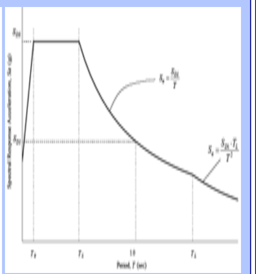
In this study, brief information about the main items of the spectral capacity-based vulnerability assessment methodology is given. Example applications and earthquake loss assessment for Istanbul by ELER Level 2 Module are presented for verification and validation purposes. The results are compared with diffferent software packages' estimations.

Representation of the Seismic Demand

Seismic demand is represented by 5%-damped elastic response spectrum. ELER provides two options for the construction of the response spectral shape:



EuroCode 8 Design Spectrum

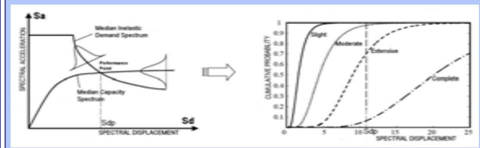


IBC 2006 Design Spectrum

Spectral Capacity-Based Vulnerability Assessment

The so-called Capacity Spectrum Method (ATC-40, 1996 and HAZUS, 1999) developed for the analytical assessment of the structural vulnerabilities evaluates the seismic performance of structures (represented by equivalent single-degree-of-freedom, SDOF, models) by comparing their structural capacity and the seismic demand curves drawn in spectral acceleration (Sa) versus spectral displacement (Sd) coordinates (hence the terminology: capacity spectrum and demand spectrum). The key to this method is the reduction of 5%-damped elastic response spectra of the ground motion (in Sa-Sd or the so-called ADRS format) to take into account the inelastic behavior of the structure under consideration. The performance of the building structure to earthquake ground shaking is then identified by the so-called "performance point" located at the intersection of the capacity spectrum of the equivalent non-linear single-degree-of-freedom system and the earthquake demand spectrum. After estimation of the performance point the damage is estimated through the use of fragility curves. Fragility curves calculate the probability of being equal or exceeding a damage state assuming log-normal distribution of damage.
The main ingredients of the capacity spectrum method can be summarized as follow:

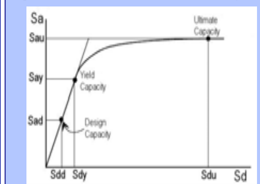
Seismic demand representation : Demand Spectrum
Structural system representation : Building Capacity Spectrum
Structural response assessment : Performance Point
Representation of the damage probability : Fragilit Curves

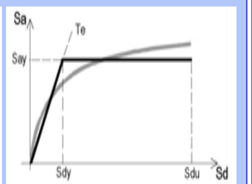


Spectral capacity-based vulnerability and damage assessment methodology

Representation of the Building Capacity

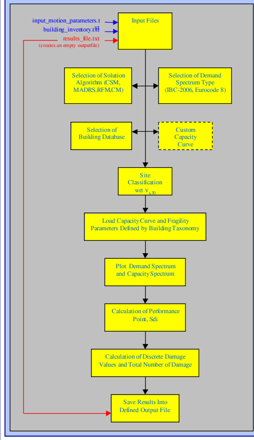
A building capacity spectrum is the plot of the building's lateral load resistance as a function of a characteristic lateral displacement and quantifies the inelastic structural capacity of the structure. For each building type the capacity spectrum has an initial linear section where the slope depends on the typical natural frequency of vibration of the building class, and rises to a plateau level of spectral acceleration at which the maximum attainable resistance to static lateral force has been reached. The capacity spectrum is controlled by the points of design, yield and ultimate capacities. These points can be correlated with the damage limit states.

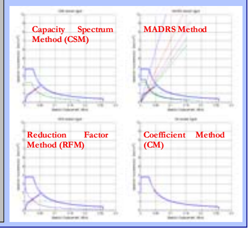




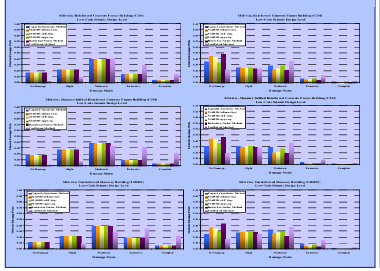
Typical structural capacity spectrum (left) and its simplified form (right)

ELER© Level 2 Module

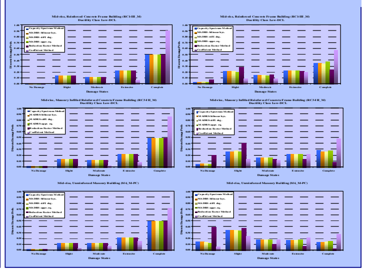




Applications with HAZUS Building Taxonomy

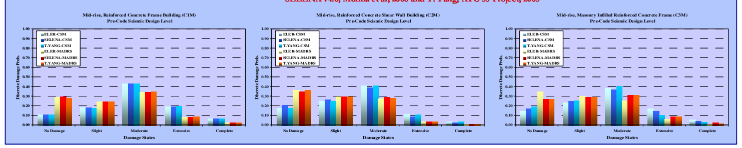


Applications with European Building Taxonomy



Comparison with the Other Studies

SELENA v4.0, Molina et al, 2008 and T. Yang, ATC 55 Project, 2005

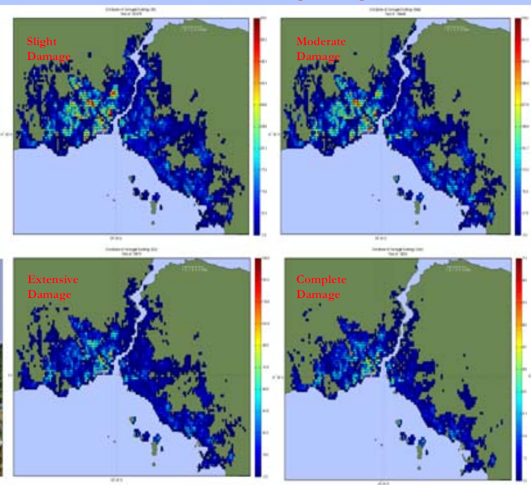


Case Study : Earthquake Loss Assessment for Istanbul

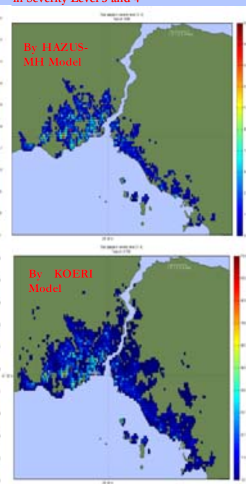
Mw= 7.5 Scenario Earthquake, Boore-Atkinson 2007 Attenuation Relation

Spectral Acceleration Values (%g) at 0.2- and 1-sec periods

Distribution of Damaged Buildings

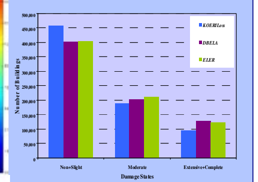


Casualty Distributions- Number of People in Severity Level 3 and 4



Comparison of Results by Different Software Packages

KOERILoss, KOERI, 2002
DBELA, Crowley et al, 2004
(DBELA results from Strasser et al, 2007)



	Number of Damaged Buildings			
	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage
	Boore et al. 1997 and Sadigh et al 1997 Attenuation Relations			
KOERILoss	235,148	187,178	62,259	31,887
DBELA	-	200,918	81,497	46,968
ELER	222,887	210,885	79,152	42,611
	Boore-Atkinson 2007 Attenuation Relation			
ELER	251,879	156,465	39,470	16,224