SEISMIC ASSESSMENT METHOD FOR EXISTING REINFORCED CONCRETE BRIDGES

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ABSTRACT

Bridges are one of the main and most vulnerable components on transport infrastructure network, due to aggressive environment, degradation during the years of service, steel corrosion etc. A considerable number of existing Albanian bridges have been designed and constructed before 1989 year, according to former design code. Now days the design seismic code and their requirement are change. Therefore we need to assess seismic performance of bridges under different seismic loadings in different levels of reliability regard in requirements of new standards to seismic actions. Developing fragility curve on assessing bridges performance is effectively methodology in evaluation of vulnerabilities of existing reinforced bridges. This study concerns on providing a new method of seismic bridge assessment for bridge typology in Albania by means of fragility curves, considering columns as most vulnerable component. Ductility analysis for circular section piers is estimated by moment curvature curves. The proposed method is also illustrated by two application assessment presented the step by step procedure.

Keywords: Seismic assessment, Fragility curve, Reinforced bridges, moment curvature.

INTRODUCTION

Most of the existing Albanian bridges have been designed according to former design codes, with no regard in requirements of new standards to seismic actions. Therefore we need to assess seismic performance of bridges under different seismic loadings. The current European seismic code does not offer a procedure for seismic assessment of bridges, The European standard EN 1998-3, Part 2 [2] focuses primarily on the seismic design of new bridges. A new seismic assessment procedure for column bridges is presented in the study. This paper aims of providing a new probabilistic framework for seismic assessment highway / railway bridges after an earthquake by fragility curve. The linear response spectrum analysis and the nonlinear static pushover methods are combined in this procedure through various assessment levels and appropriate checks. The assessment is performed for existing reinforced concrete bridge with column, girders, (multi - span simply supported bridges in Albania). This study is focused on performance assessment of reinforced concrete existing bridge (multi – span simply supported girder bridges) by means of fragility curves. The bridges are located in strategic road network in 'Vora' overpass and 'Mifoli' Estacada bridge.

SEISMIC ASSESSMENT PROCEDURE FOR EXISTING REINFORCED-CONCRETE BRIDGE

Seismic assessment framework is set up of four step:
Step 1, Collection of data on geometrical properties of structural and non-structural elements which may affect structural response, including structural details, such as the amount and detailing of

reinforcement, concrete cover, connection between members and their position on seismic tectonic map, importance etc.
Step 2, Determination of the load-displacement characteristics at the top of the piers on simplified model for column bridge bents. Based on the moment *vs.* curvature curves determined in two simplified analytical method and on an assumption for the length of the plastic hinge, load-displacement curves for the top of the piers, considering the different maximum lateral displacement (ductility) levels, are constructed (according to Basöz and Mander).
Assessment of damaged stage based on available plastic rotation capacity, member ductility capacity, demand/capacity ratio and the probabilistic point of view.
Step 3, Generation of analytical fragility curve obtained from the log-normal distribution of probability density function and the cumulative log – normal distribution.
Step 4, Assumption of the performance of the bridge.

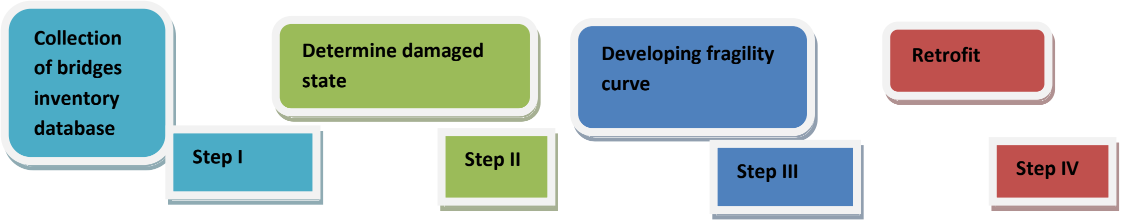


Fig 1. Framework study proposed on seismic assessment of reinforced existing bridges during seismic event

ANALYTICAL BRIDGE FRAGILITY METHODOLOGY FOR SEISMIC ASSESSMENT

Fragility is defined as the conditional probability that a structure or a structural component would meet or exceed a certain damage level for a given ground motion intensity. Analytical methods allow both probabilistic demands (D) and capacities (C) to be derived and subsequently used to generate relevant fragilities. When the demand and capacity models follow a lognormal distribution the fragility curves takes the form of below equation: (Hwang et al. 2001; Choi et al. 2004; Shinozuka et al. 2000b; HAZUS99-SR2 1999)

$$P[D < C|IM] = \Phi\left[\frac{\ln(S_d / S_C)}{\sqrt{\beta^2{}_{d|IM} + \beta^2{}_C}}\right] \quad (1)$$

The log-normal distribution has a probability density function.

$$f(x,\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-(\frac{(\ln(x)-\mu)^2}{2\sigma^2})} \quad (2)$$

The cumulative log – normal distribution is obtained by integration of the area below density function as shown in the equation. (3)

$$f(x,\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} \int_0^x \frac{e^{-(\frac{(\ln(x)-\mu)^2}{2\sigma^2})}}{t} dt \quad (3)$$

Where x is the value at which the function is evaluated, μ is the median value of PGA and σ is the log- standard deviation.

APPLICATION DURING ASSESSMENT OF TWO EXISTING REINFORCED BRIDGES IN ALBANIA

All assessed bridges were designed and constructed according former design code prevailing in 1970. These bridges are located in moderate seismic zone.

They are assessed for seismic actions utilizing the linear dynamic response spectrum analysis and nonlinear static pushover analysis of the proposed assessment procedure using simplified model.

Description of Bridges

Two example bridges used for the analysis are shown in Figures 1 and 2.
Bridge 1 is a 19 span simply continuous concrete girders. Each span is 15 m length and an overall length of 313.24 m. The superstructure consists of by 6 precast beams. The deck width is 9 m. Intermediate supports are provided by one – columns bents and by an abutment at each end. The circular reinforced concrete (RC) bridge columns are 1200 mm in diameter with a concrete compressive strength of 30 MPa. Longitudinal reinforcement is provided by 22 Φ28 having a yield strength of 430 Mpa.

Bridge 2 is a 11 span simply continuous concrete girders. Each span is 25 m length and an overall length of m. The superstructure consists of by 6 precast beams. The deck width is 9 m. Intermediate supports are provided by four – columns bents and by an abutment at each end. The circular reinforced concrete (RC) bridge columns are 1000 mm in diameter with a concrete compressive strength of 30 MPa. Longitudinal reinforcement is provided by 20 Φ16 having a yield strength of 430 Mpa.

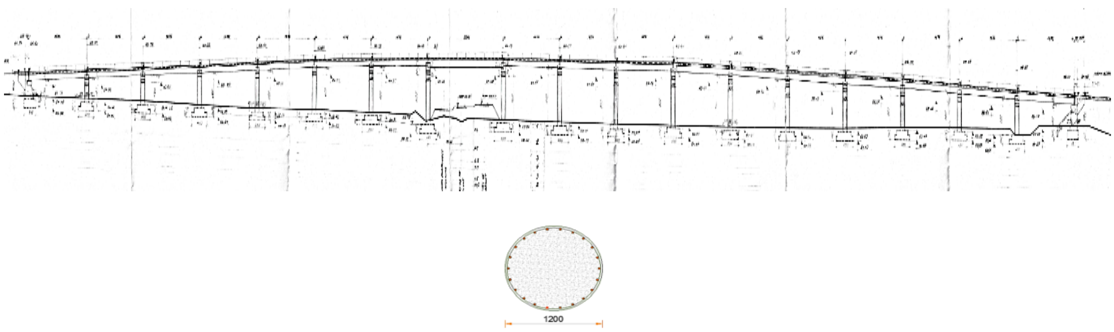


Fig.2 Elevation and Column Section of Bridge 1 (" Design and study Institution of Tirana", 'Center Technic Inventory' Albania)

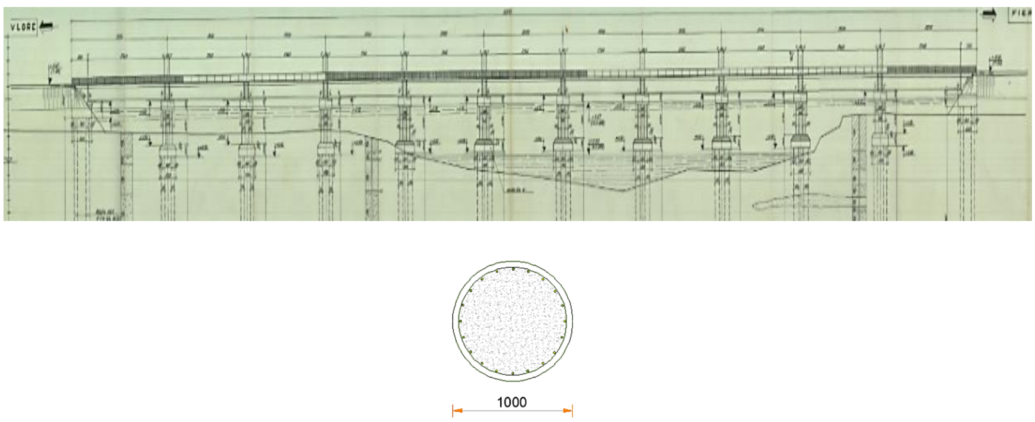


Fig.3 Elevation and Column Section of Bridge 2 (" Design and study Institution of Tirana", 'Center Technic Inventory' Albania)

MOMENT-CURVATURE CURVES AND DAMAGE STATES

Nonlinear response characteristics associated with the bridge are based on moment-curvature curve analysis taking axial loads into account.
These moment-curvature curves for a column of Bridge 1 and Bridge 2 are plotted

in Figure 4, 5.

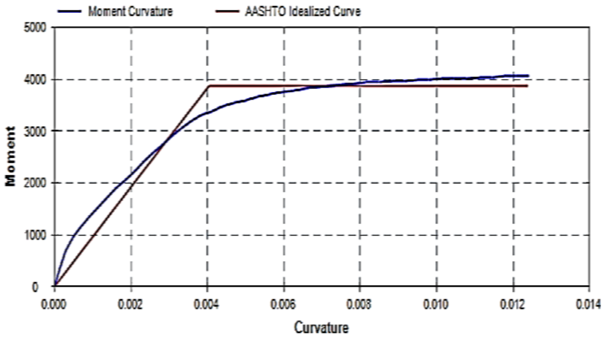


Fig.4 Moment curvature relationship for bridge column (moment curvature SE-MΦ software)

Table1. Spectral acceleration and maximum ground acceleration for probability 10%/10 year and 10%/50 year. (Sh.Aliaj, S.Kociu, B.Muco, E. Sulstarova: Seismic, Seismic-tectonic, and assessment of seismic risk of Albania ,Tirane 2010)

Position	Coordinate		Probability	PGA	Sa			
Tiranë	V	L		0.01s	0.2s	0.5s	1.0s	2.0s
Vorë	41.39	19.63	10%10 10%50	0.136 0.271	0.323 0.635	0.171 0.366	0.086 0.187	0.037 0.08

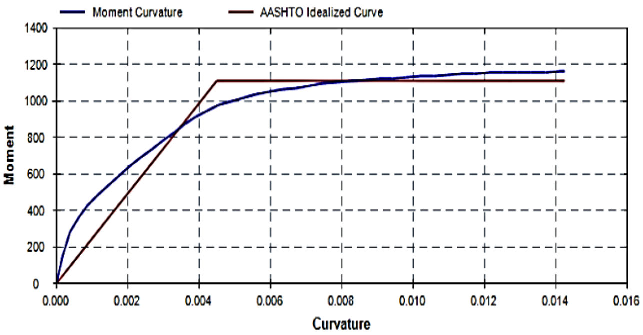


Fig.5 *Moment curvature relationship for bridge column (moment curvature SE-MΦ software)*

Table2. Spectral acceleration and maximum ground acceleration for probability 10%/10 year and 10%/50 year. (Sh.Aliaj, S.Kociu, B.Muco, E. Sulstarova: Seismic, Seismic-tectonic, and assessment of seismic risk of Albania,Tirane 2010)

Position	Coordinate		Probability	PGA	Sa			
Vlorë	V	L		0.01s	0.2s	0.5s	1.0s	2.0s
Vlorë	40.46	19.48	10%10 10%50	0.121 0.249	0.281 0.581	0.144 0.33	0.073 0.166	0.03 0.072

The table 3 and 4 is divided into three column.

The first column gives the damage state of the bridge assumed from the demand and the capacity model, and moment curvature section analysis. *(S* is a parameter conceptually related to seismic demand at the site where the bridge is located).

The second column presents the description of the damage state, respectively.

The third column gives the ductility capacity from displacement based design Evaluation.

Table3. Bridge 1

Damage state	Descriptio n	Ductility displacement limits
Sa(0.2s)=0.635g Collapse	Column collapse	6.07
Sa(0.5s)=0.366g Controlled damage	Incipient column collapse	3.5
Sa(1s)=0.187g Slight damage	Cracking, spalling	1.78

Sa(2s)=0.08g No damage	First yield	0.76

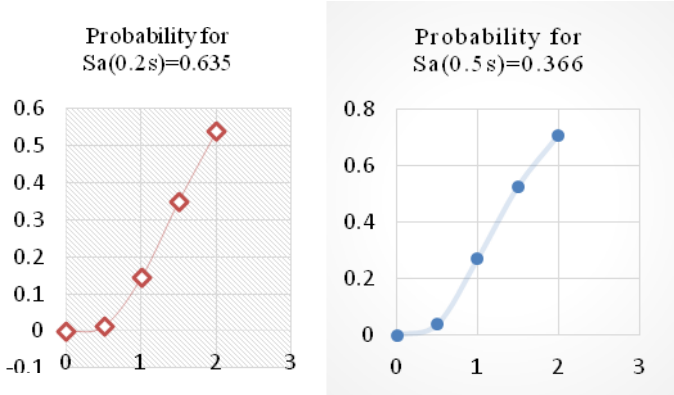
Table4. Bridge 2

Damage state	Description	Ductility displacement limits
Sa(0.2s)=0.581g Controlled damage	Incipient column collapse	3.04
Sa(0.5s)=0.33g Slight damage	Cracking, spalling	1.72
Sa(1s)=0.166g No damage	First yield	0.86
Sa(2s)=0.072g No damage	First yield	0.37

FRAGILITY ANALYSIS

The fragility curves for Bridges 1 and 2 associated with four damage states (no damages, minor damages, controlled damages, collapse) which have been determine in section 5 are plotted in Figures 6 and 7,respectively, as a function of peak ground acceleration.
These curves are developed using push over and time history analyses for simplified bridge models.

Fig.6 Fragility curve for railway overpass Vorë – Laç (Bridge 1)



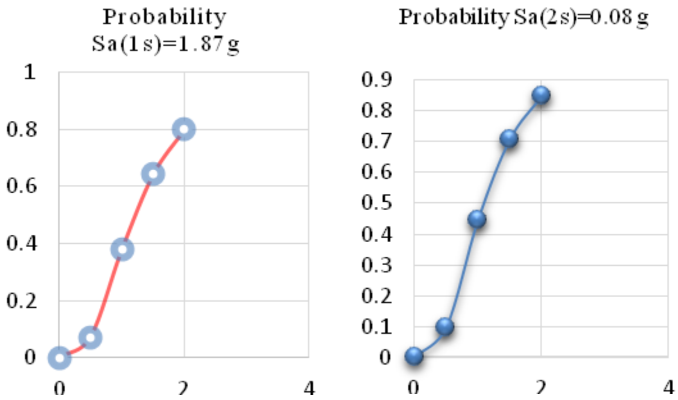
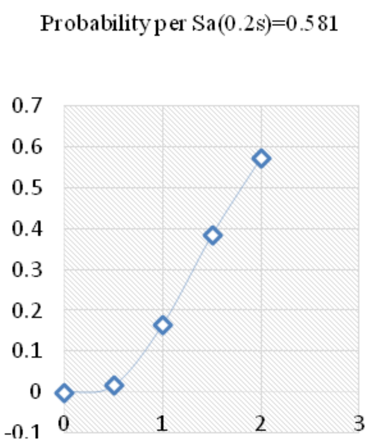
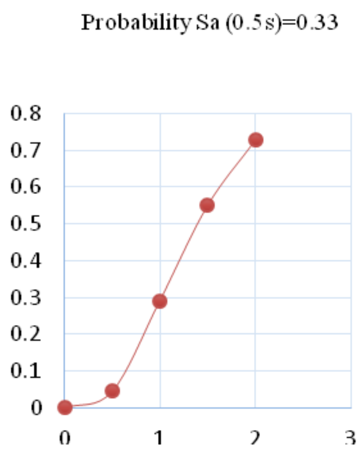
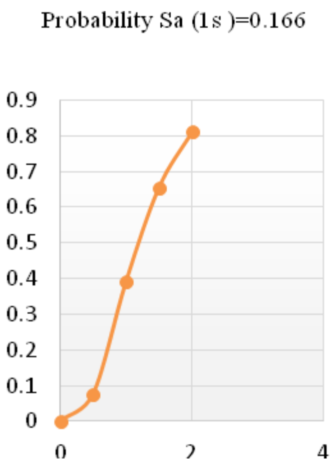
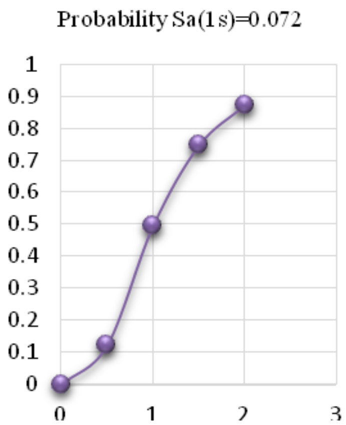


Fig.7 Fragility curve for Mifoli bridge (railway- highway Bridge 2)









CONCLUSION

The study is providing a new probabilistic method and step by step procedure for seismic assessment caused by seismic loadings and aims to provide useful information of damage state after earthquake. This paper present the seismic fragility analysis for typical Albanian bridge designed before 1989 year (Vora overpass and Mifoli Estacade).

The ductility capacity is determined based on moment curvature section analysis and displacement based design methodologies, considering column as most vulnerable component of bridge. For different values of spectral acceleration are assessed damages state of column bridge for capacity/demand ratio and probability exceeding of damaged state, developing fragility curve.
It is observed from the results of the fragility analysis that this typical bridges in Albania have more than 50% probability of exhibiting slight damage, controlled damage and collapse when subjected to earthquakes with PGAs equal to 0.187g ; 0.33g ; 0.581g ; 0.635g for each of the four damage states, respectively.

The authors conclude that the presented seismic assessment procedure could easily find its place as an everyday tool in retrofit and seismic design decision making for reinforced concrete column bridges.

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