Some retrofitting techniques for Albanian bridge

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Abstract

Based in the world experience about on the seismic design of new bridges and retrofitting of existing ones, now days in Albania it is one of the priority to the implementation of modern codes (Euro codes). Generally the bridges were designed for nominal seismic forces without provisions of ductility. So it is understandable that the earlier designed bridges will not be able to resist the effects of earthquakes in the future. These structures may require seismic evaluation and retrofitting. The protection of bridges from damage in earthquakes has direct relevance in prevention of aggravation of disaster, as disruption of transportation routes hampers relief and rescue operations immediately following the earthquake. Several retrofitting techniques have been developed for bridges in recent years. Many of the existing bridges can be retrofitted by these techniques.

This paper presents the important issues: structural deficiencies; retrofit philosophy, retrofit techniques, recent developments and effectiveness of retrofit techniques. In Albania the most prevalent type of the old bridges are simple supported span and the new bridges are simple supported superstructures with continued slab. The most commonly observed type of failure for this type of bridges is a girder falling off the supports due to longitudinal response. To prevent such type of failure, the adjoining spans should be interconnected by connection rods/restrainers/linkage bolts.

Introduction

In recent earthquakes all over the word, the numerous damages of bridges had been the motivation in the earthquake resistant design and retrofitting of bridges. The bridges constructed prior to 1970 were not designed for adequate seismic resistance as the ductility provisions were not incorporated in the seismic codes till then. As a result the bridges designed before this year lack in earthquake resistance and ductility and may be vulnerable to significant damage even from moderate earthquakes. The post earthquake damage surveys in recent earthquakes have confirmed this view. It has also been revealed from damage surveys that many of the damages that occurred in bridges and flyovers could be prevented by proactive measures of seismic retrofitting prior to earthquakes. Many of the reinforced concrete piers designed earlier had inadequate shear capacity due to lack of transverse steel and confinement, inadequately lapped longitudinal steel, and premature termination of longitudinal steel. The superstructures were vulnerable to falling down in the absence of restraining devices, bearings were deficient in accommodating large seismic displacement and bearing seat was inadequate. These deficiencies had an adverse impact on the performance of bridges. An existing bridge can be replaced by a newly designed bridge to meet earthquake demands or upgraded in its strength by appropriate retrofitting measures. The retrofitting is often an economical alternative than replacement. The strategy to be used

when selecting a retrofit measure should be one that reduces the probability of total collapse or severe
structural damage to the bridge.
There are two types of situations that require retrofitting in bridges:
- the existing bridges that are deficient to meet requirements of current codes but are vulnerable to damage, these bridges have not yet experienced even moderate earthquakes.
- the existing bridges that are damaged in earthquakes.

The bridges in the later category require both repair and retrofitting. There are many retrofitting techniques developed for upgrading earthquake resistance in bridges. The techniques are equally applicable to bridges damaged in earthquakes. The principal issues facing the retrofitting are: evaluation of seismic capacity of existing bridges, identifying structural deficiencies, ageing effects, decision on level of retrofitting, hazard levels for design, performance criteria, developing alternate strategies of retrofitting, choice of right strategy, re-evaluation of retrofitted structure, validating effective retrofitting measures and health monitoring of retrofitted bridges. There are not many codes and guidelines developed for the retrofitting of bridges. There are many issues that still need more research and development. The objective of the paper is to present an overview of retrofitting techniques and discussion on many of the issues highlighted above.

Earthquake Damages of Bridges
In order to design suitable retrofit measures, it is appropriate to highlight common bridge damage types and failures that has occurred in past earthquakes in Albania. These types of failures are to be often required to be dealt with in retrofitting of bridges. The common types of earthquake damages of bridges in Albania are:

- Falling down of bridge spans
- Bearing failure
- Expansion joint failure
- Substructure damage
- Liquefaction failure

Structural Deficiencies

The observation of performance of bridges in past earthquakes world over has highlighted following deficiencies in bridges:

Superstructure: Traditionally there is no linkage provided between two adjacent spans in the case of multi–span simply supported bridges as a result spans are dislodged from supports due to out of phase motion in piers or bearing failures. The bearing failure occurs in fixed bearings when these are unable to withstand the seismic force generated in the superstructure. In many cases, spans fall down from their supports resulting into irreparable damage. Superstructure deficiency is also associated with inadequate seat length at expansion joints on the supports or at the abutments resulting into unseating of span.

Bearings: The traditional rocker and roller bearings have not shown satisfactory performance in earthquakes. There have been problems of jumping, inadequacy of bearings in accommodating displacements.

Inadequate seat width on supports: The inadequacy of seat width on bearing supports or at expansion joints have caused unseating of span.

Substructure: The various types of deficiencies observed in RC columns and piers are:
- Lack of flexural strength,
- Lack of shear strength
- Insufficient transverse reinforcement and confinement
- In adequate lap splicing of longitudinal steel
- In adequate ductile detailing in plastic hinge region of columns
- Premature termination of longitudinal steel in piers
- Insufficient strength of joints between pile cap beams.

Inadequacy of foundation and soil strength: Liquefaction of soil often results in damage due to unequal settlements and loss of span types of failures. Abutment failure can occur due to increased earth pressure; abutment slumping is known to occur in soft soils. Inadequate strength of footings, wells and/or piles can result in foundation failures.

Retrofit Philosophy

Design Philosophy: The design philosophy for retrofitting should normally conform to that for new bridge design. This is the minimum design performance expected from a retrofitted structure. The design philosophy for new structures is as follows:
The structure is designed to resist Design Basis Earthquake (DBE) with only minor damage, which should be repairable.
The structure is designed to resist Maximum Considered Earthquake (MCE) with some structural damage but controlled so as to prevent collapse.
Higher Level of Performance: A higher degree of performance can however be specified to control damage such as the availability of vital communication route immediately after the earthquake. This will restrict the occurrence of category of damage specified, such as loss of girder supports, collapse of substructure and liquefaction failure of foundation soil. The purpose of this level of retrofit is to prevent collapse, as well as to provide serviceability after a major earthquake. The performance level is to be specified prior to retrofit design.

Decision to Retrofit: There are two basic decisions required at the beginning of under taking retrofitting of bridges
- whether to retrofit or not
- level to which bridge should be retrofitted.

The first decision should be based on results of detailed seismic evaluation and level of risk. The second decision may involve reduction of seismic risk by incorporating retrofitting measures such as extending seating width and/or providing restrainers. The additional reduction in risk is possible by providing other types of seismic devices such as energy dissipating devices/dampers, and base isolation bearings between super and substructure. In case of substructures jacketing for increase in strength and ductility and detailing of plastic hinge region shall be specially required.

Retrofitting Steps
The major steps in retrofitting of bridges are as follows:

Preliminary Screening: The seismically deficient bridges are identified by preliminary screening. The screening procedure is mainly based on:
- Seismicity
- Vulnerability

- Importance.

The prioritization of bridges to be retrofitted can be made on the basis of rating procedures based on above factors.

Detailed Seismic Assessment: The detailed seismic evaluation of expected performance of existing bridge is necessary to determine seismic capacity, weaker sections and mode of failure. The strength evaluation can be made according to codes following dynamic methods of analysis and push over analysis techniques. It is normally desired that assessment procedure should be more precise than code.

Selection and Design of Retrofit Measures: On the basis of detailed seismic assessment, it should be determined whether individual component level retrofit such as extending seating width, providing restrainer or a global retrofit of complete bridge is to be undertaken. The global retrofit may include: jacketing of bridge piers, replacement of bearings and retrofit of foundations.

Re-analysis of Retrofitted Structure: The retrofitted structure should be re-analyzed using dynamic analysis. The checking of design of retrofitted structure should be based on current design codes.

Retrofitting Techniques

The retrofitting of bridge may be required in each of the components: superstructure, bearings, substructure and foundations. The extent of retrofitting will be based on detailed seismic assessment following dynamic methods of analysis. The retrofitting techniques for superstructure and bearings are described below :

Superstructure

Superstructures will not normally need strengthening due to their high rigidity and large flexural capacity. Superstructure deficiency is associated with their unseating at expansion joints or on bearing supports due to relative displacements. The most commonly observed type of failure in superstructure of simple supported bridges is a girder falling off the supports due to longitudinal response. To prevent such type of failure, the adjoining spans should be interconnected by connection rods/restrainers/linkage bolts.

A typical example of linkage and tying of spans by restrainer, is given in Fig. 1 and 2. An example of vertical restrainer retrofit is shown is Fig. 3. The unseating prevention for steel girders is often made by tying webs together with steel plates over the supports.

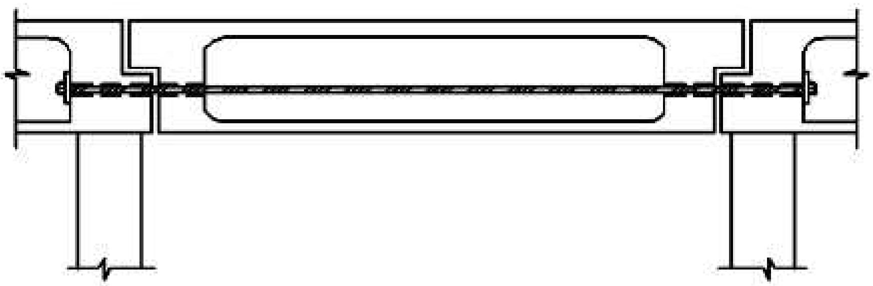

Fig.1 – Restrainer retrofit of suspended span.

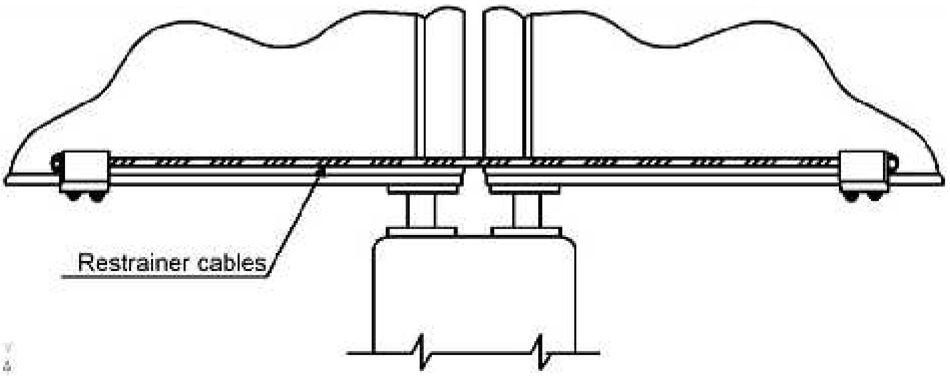

Fig.2 – Restrainer at pier without positive tie to pier

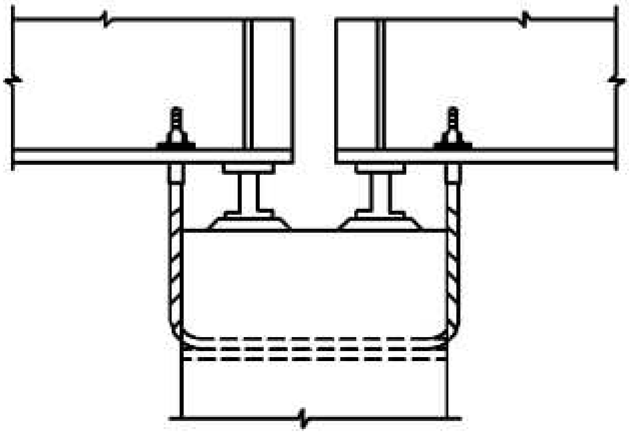

Fig.3 – Vertical motion restrainer retrofi

Bearings

Bridge bearings are one of the most vulnerable components in resisting earthquake. Bearing deficiencies are associated with inadequate seat width and inadequacy to accommodate displacements in earthquakes.

The possible retrofit solutions are:

- replacing steel bearings by elastomeric bearings
- replacing rocker bearing using concrete cap .

A typical example of replacement of bearing is shown in Fig. 4 and 5.

4.

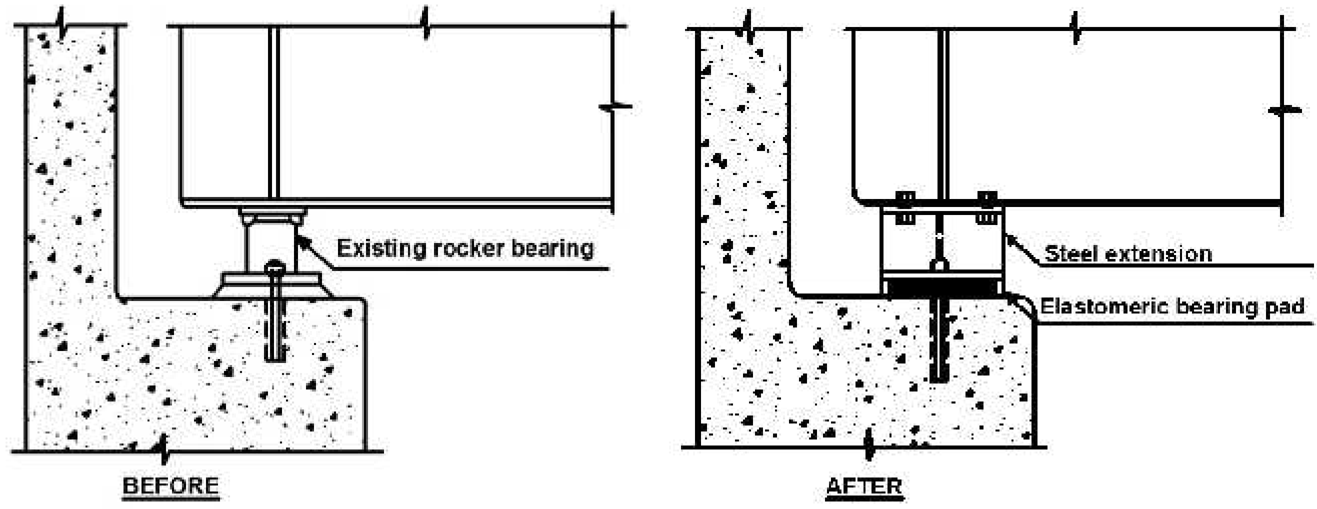

Fig.4 – Replacement of rocker bearing using a steel extension

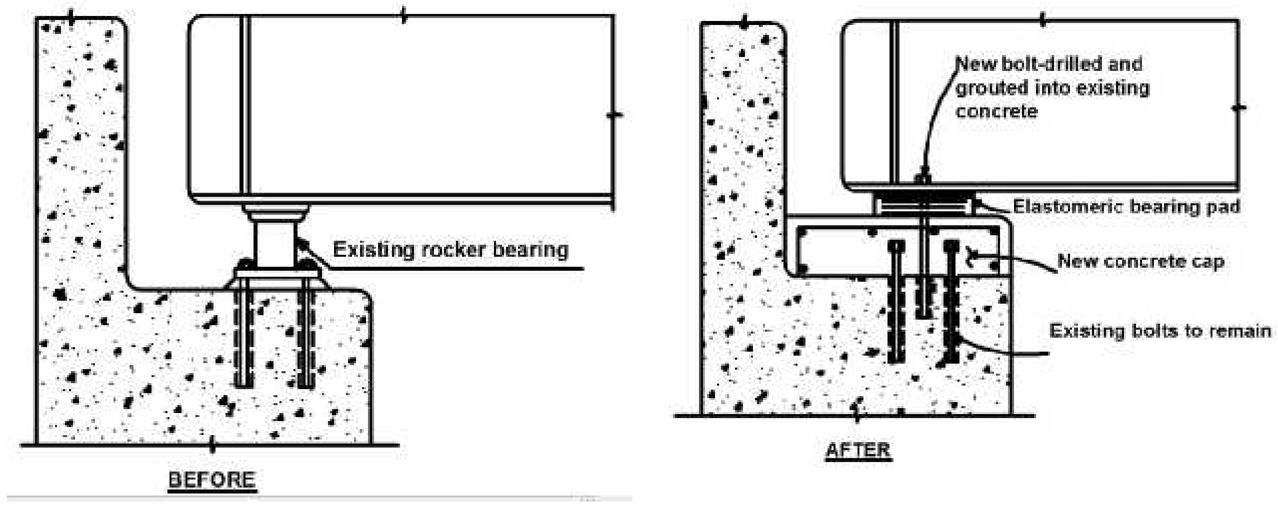

Fig.5 – Replacement of rocker bearing using a concrete cap

Effectiveness of Retrofit Techniques

The success of retrofit scheme depends on how effective it is in enhancing strength and ductility of the member/structure. The real test of retrofit schemes is the observation of performance of such structures in earthquakes. The effectiveness of retrofit schemes is studied by conducting cyclic test on model/prototype components in the laboratory. The study of hysteretic behavior under cyclic test of both original and retrofitted structure reveals the increase in stiffness, strength and ductility. Shake table testing of original and retrofitted structure is more rational method of testing effectiveness of retrofit measures.

Research and Development Issues

There are significant advances in seismic retrofitting of bridges, yet there are issues that need further research for effective use of retrofitting methods. The following issues need further research:
Seismic assessment: Development of seismic assessment techniques of existing bridges, particularly those bridges, which have been damaged in earthquake.
Level of retrofitting: The level to which retrofitting should be done for DBE and MCE seismic conditions. This is related with retrofit philosophy adopted for bridges.
Validation techniques: The validation techniques could be analytical and/or experimental. The experimental techniques include: quasi-static cyclic load testing techniques, shake table testing and pseudo dynamic testing and observation of performance in earthquakes.
Structural control techniques: The passive methods such as base isolation, passive energy dissipating devices like dampers and active methods are to be explored further for their application in retrofitting.
Design procedures: Design procedures of retrofitting using advanced composite materials are required to be developed.

Conclusion

The above study, retrofitting is a process that serves to reduce the possibility of exposure to total destruction or severe structural damage in the future. This process passes in several stages by which we will determine whether this process is practical or economic to strength weak elements according to the new standards. It would be a necessary method for bridges of particular importance
Depending on the report Capacity- Request will determine whether it will do retrofit or not. The most used and most economical retrofitting there were expansion joints and bearings, and retrofit process for pile and liquefied soils are very expensive.
The realization of the stability of the structure can be realized with:

- Longitudinal joint restraint
- Vertical motion restraint
- Replacement bearings.

This process recommends strengthen weak elements according to the new standards, for two reasons:

1. The cost of reinforcing element according to the new standards is not greater than the cost of the partial reinforcement of the structure.
2. Retrofit goes through several stages which will extend throughout the life of the structure.

In Albania, retrofit is used by interfering in the capacity of structure by raising the height of the beam in automobile bridges, reinforcing pile and columns or in railway arch type bridges. This is show in the image below:

Fig.6 - Bridge in Burrel-Albania, reinforcement of vertical column

Genuine interventions of retrofit have not yet been applied in our country.

References

- Seismic Retrofitting Manual for Highway Bridges
- Bridge Design to Eurocodes