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Assessment and Proposal Structural Repair Strategies for Damaged Bridges in Velipoja

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Abstract

Velipoja is considered a seismic region in Albania. In the past years, due to the mountainous landscape and presence of several rivers, in the region of Velipoja have been built different bridges and their maintenance has been insignificant compared to their needs. The recent earthquakes, environmental effects and vehicle loads have damaged the bridges and prompting the need for repairing and strengthening their structure. Replacement with new structures raises financial and technical problems. Rehabilitation of existing bridge is one of the most important actual problems. The main purpose of this paper is to examine the existing structure and to develop design strategies to make the structure as insensitive as possible to the unknown characteristic of the input seismic excitation. The most common technique implemented has been steel jacketing, concrete jackets or composite materials jackets[3]. Fiber-reinforced (FRP) composite materials have been used for external strengthening of concrete structural components[4]. This paper presents some retrofit practices and details used in the bridges of Velipoja region.

Keywords: Retrofit, bridges, fiber reinforced composite materials, earthquakes.

[1] The authors collaborated equally to the publication. They are both first authors
[2] The authors collaborated equally to the publication. They are both first authors
[3] M.J.N.Priestley,F.Seible,G.M.Calvi.1996 *Seismic Design and Retrofit of Bridges* ,page 587
[4] http://rb2c.mst.edu/media/research/rb2c/documents/ACMBS-Wu-Shi_Bridge.pdf

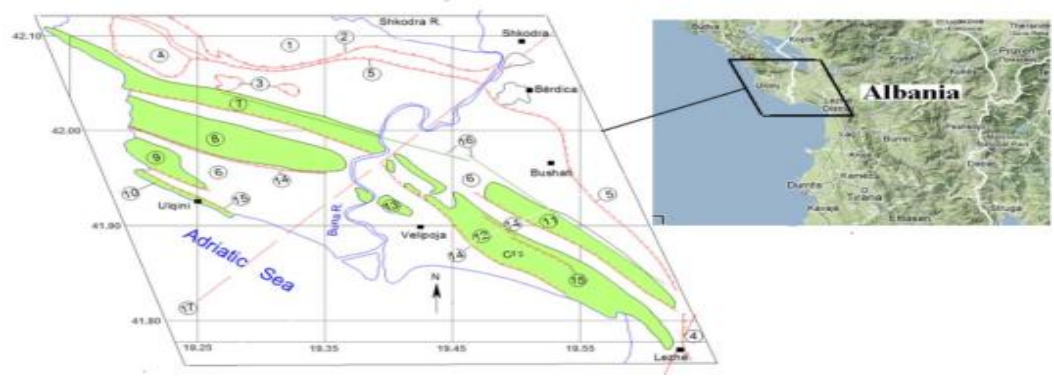
Introduction

Failure of concrete reinforced bridges may results from crushing of the concrete due to unseating at movement joints, lack of confinement, buckling of the longitudinal reinforcement or from a number of deficiencies related to the consequences of elastic design philosophy. In the past earthquakes in Albania, the most common failure of old concrete r/c bridges were due to substructure damage ,falling down of bridge span, liquefaction failure ,column shear failure or abutment slumping. The most common type observed in Velipoja are the simple supported span bridges. They were constructed in 1967, approximately 50 years ago. Seismic design concept and structural codes have changed significantly since the time of construction. It is well known that the design codes at the time of construction had very low requirements for seismic design compared to nowadays requirements. These bridges are not designed for input seismic excitation.

Assessment analysis of an existing bridge is necessary to determine the level of risk .With this risk quantified, rational decisions can be made as to whether the bridge should be retrofitted or replaced, or to except the risk and leave the bridge in the existing state[1].

The objective of this paper is to present the damage of bridges during recent earthquakes and some retrofit technique practices for strengthening damaged bridge components in Velipoja region. Rehabilitation of old bridges intends to restore their structure to their original service.

Picture 1. *Tectonic Features of Velipoja Region (Seismic-tectonic Map of Albania)*[2]



[1]M.J.N.Priestley,F.Seible,G.M.Calvi.1996 *Seismic Design and Retrofit of Bridges*, page 534

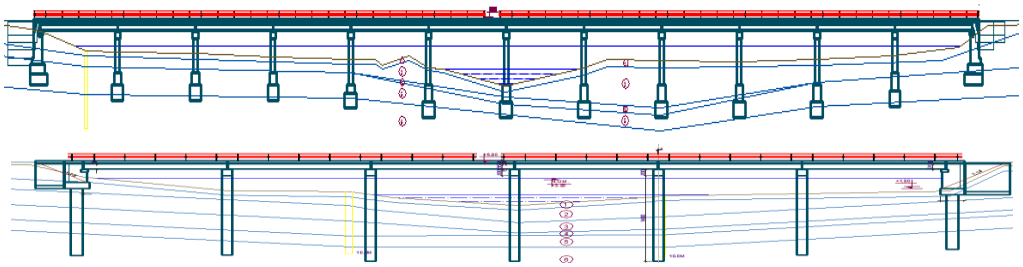
[2]Aliaj, Sh. Sulstarova E. Muco,S (2001). 'Seismic tectonic map of Albania', Seismological Institute Tirane.

Assessment of the Existing Structure

Technical Conditions Assessment of Existing Bridges

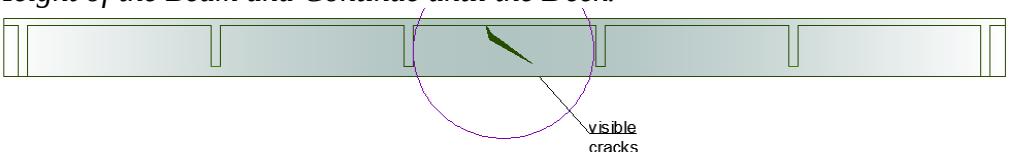
The evaluation of the current technical condition of the existing reinforced bridges structure will be realized with the help of site investigation, tests of materials and original design which depends in a high percentage on the engineer qualification. On site investigation it is recommended to insist on the appeared fatigue defects, critical details, corrosion level, concrete hardness, the structure deformations due to traffic, bridge bearings, similar construction of the same age and type. One of the non destructive testing of the inspection of the service damage in bridge elements is visual inspection. Visual inspection is a very useful method in case of surface cracks. This method includes microscopes, mirrors, portable video cameras, robotic crawlers etc. Detailed safety inspections are definitely required after the seismic hazard since almost all the concrete bridges have extensive visible cracks. Attention was paid to detect deterioration such as cracks of reinforced concrete structures, sliding, settlement, tilting and stability of foundations. Assessment of repair techniques for superstructures includes patching, crack injection, deck overlays, sealers, concrete bridge beams, expansion joints and bearings. The characteristic of the damaged bridge due to the earthquake attack, environmental effects, vehicle loads and service life after carefully investigation can be summarized in the following: 1.From carefully inspection are observed visible cracks on beams and decks 2. Detachment of concrete cover 3.Corrosion and reduction of cross section rebar 4.Quality and strength of concrete is low 5.Spalling 6.Paint is in poor condition and lead based. Deck condition evaluation are defined: **Category 2** .Moderate active corrosion zero to 5 % of deck visible spall or to 5 to 40 % of the deck are having deteriorated and contaminated concrete and active rebar corrosion.[1]

Picture 2.*General View of Bridges (Simple Supported Span Bridges)*

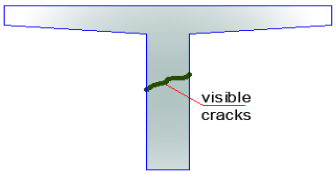


[1]Seismic Retrofitting Manual for highway structures. January 2006

Picture 3. *Visible Cracks (Longitudinal View of Beam) Starting at 2/3 the Height of the Beam and Continue until the Deck.*



Picture 4. *Visible Cracks in the Beam Section*



Picture 5. *Photos of Deteriorated Concrete and Reinforcement. (Damage Details)*

Seismic Assessment of Existing Bridges

The purpose of a seismic assessment analysis of an existing bridge is to determine the level of risk associated with the loss of serviceability, severe damage or collapse[1]. Referring to new seismic hazard maps of Albania, published in 2010, 'Seismicity, seismic-tectonics and assessment of seismic hazard in Albania', expresses peak ground acceleration on ground type A for Velipoja region, the value of a_g is 0.338g. There are two stages to a seismic assessment: 1)General screening and prioritization study to determine which bridges are most likely to pose the greatest risk. 2) A detailed structures analysis of the bridges identified as having high risk in the prioritization phase in relation to site seismicity and soil conditions. The objective of prioritization scheme is to identify and rank all high risk bridges in a specified region so that an optimum allocation of resources for retrofit can be made. In all cases the contributory elements for assessing relative risk can be divided into three major categories: seismicity, vulnerability and importance.

[1]M.J.N.Priestley,F.Seible,G.M.Calvi.1996 *Seismic Design and Retrofit of Bridges*,page 157

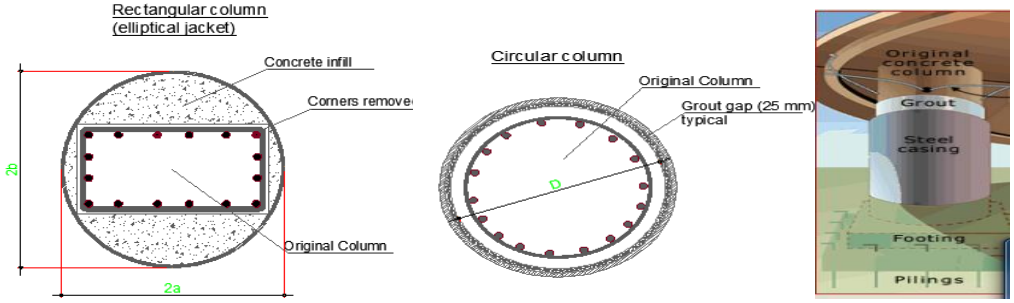
Retroffing Techniques Used for Strengthening Bridges

Most of the structural repair and retrofitting techniques used for ordinary reinforced concrete structure are applicable to reinforced concrete bridges as well. There are five primary retrofit measures used to retrofit bridges: seismic isolation, longitudinal and transverse restrainers, seat extenders, column strengthening and bent cap strengthening. For strengthening of reinforced concrete bridges, external post-tensioning or FRP retrofit may be appropriate:

Column Retrofit (Steel Jacketing)

This procedure can be expected to be fully effective for shear strength enhancement[1]. Two half shells of steel plate rolled to a radius 12.5 to 25 mm larger than column radius are positioned over the area to be retrofitted and are site welded up the vertical seams to provide a continues tube with a small annular gap around the column. The minimum recommended shell thickness is 9.5 mm and the maximum thickness should not exceed 25 mm. This gap is grouted with a pure cement grout, after flashing with water. Rectangular steel jackets on rectangular columns are not recommended. Steel jacketing using carbon fiber sheets or aramid fiber sheets, which are light weight and with relatively easy construction conditions because of no need to use construction machines have been applied to improve the shear and the bending strength.

Picture 6. *Confinement of Columns by Steel Jacketing*



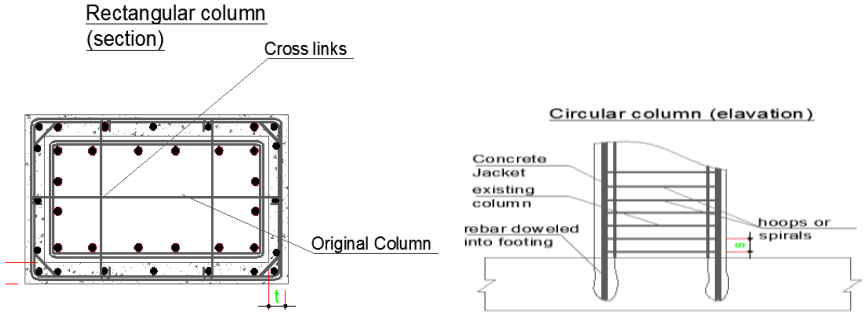
Column Retrofit (Concrete Jacketing)

Addition of relatively thick layer of reinforced concrete in the form of a jacket around column can be use to enhance flexural strength, ductility, and shear strength of columns. Concrete overlays are used also to provide increased confinement of the column. It could be accomplished by either of the following methods: 1.Conventional concrete-Pouring concrete around the member to be strengthened with additional steel reinforcement properly anchored to the existing section. 2. Pneumatically projecting concrete on the reinforced and prepared surface of the member being strengthened with spray gan. 3. Pre-Packed Aggregate Grouting–Pumping of cement grout into washed /graded coarse aggregates placed with properly anchored reinforcement around the

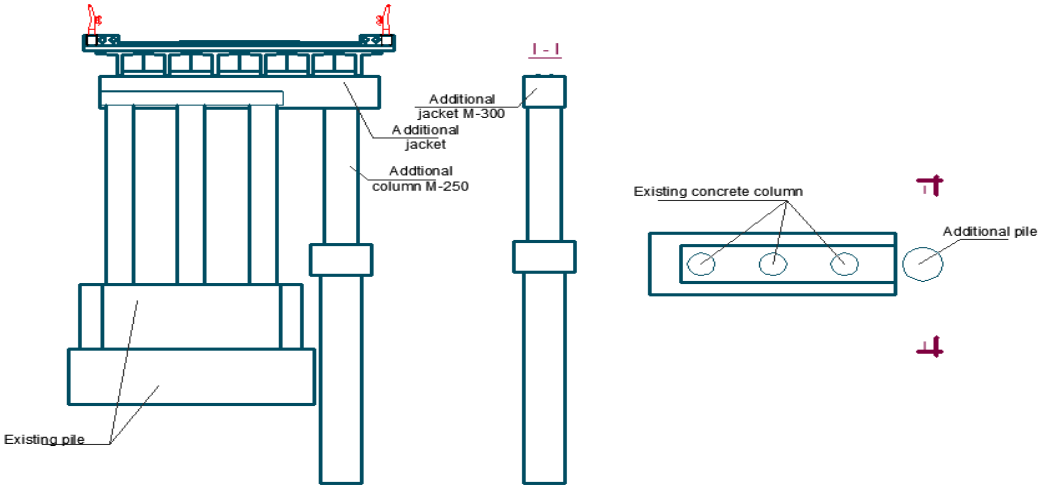
[1]M.J.N.Priestley,F.Seible,G.M.Calvi.1996 *Seismic Design and Retrofit of Bridges*,page 587

member to be strengthened in a tightly sealed formwork[1]. It is one of the best ways of jacketing a concrete member as it results in a dense mix with good surface finish. Enhanced confinement of circular columns is relatively easy to achieve with a concrete jacket, by use of close-spaced hoops or a spiral pitch. Jackets results in increase in dimensions as well as dead weight of the retrofitted member.

Picture 7. *Confinement of Columns by Concrete Jacketing*



Picture 8. *Cross Section of Pile*



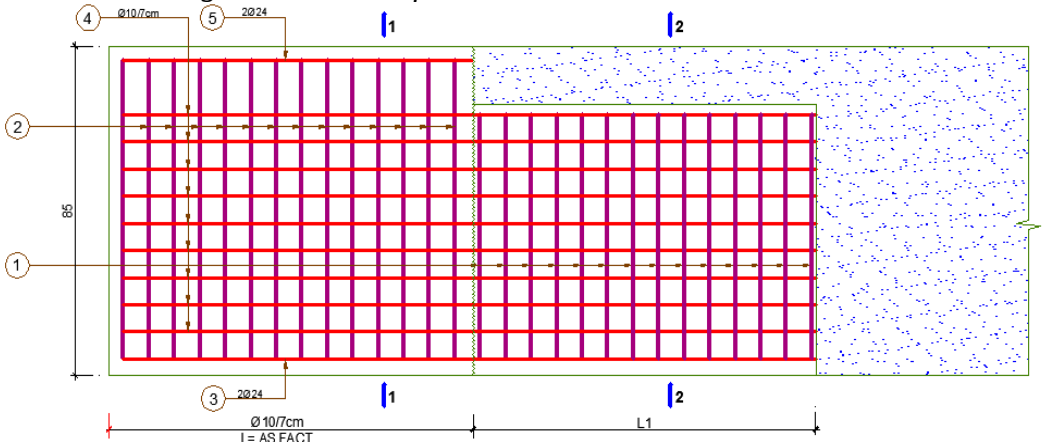
Picture 9. *Concrete Column Overlay by Concrete Jacketing*

[1]DElDOT Bridge design Manual May 2005.

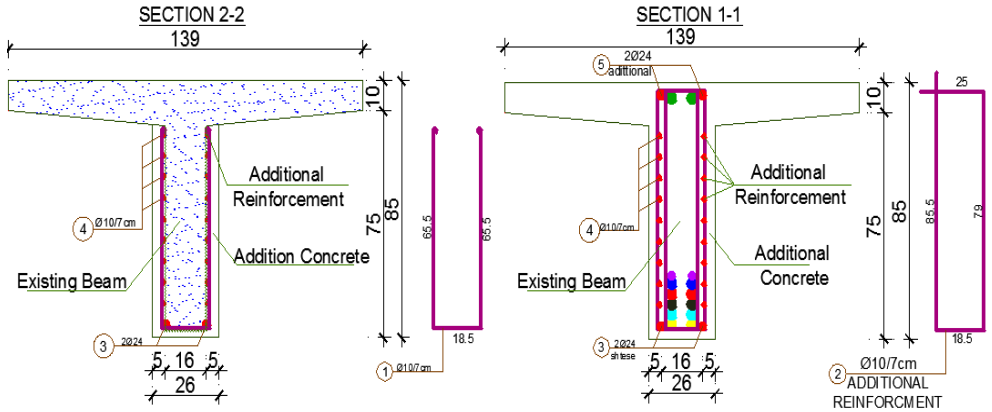
Retrofit of Cap Beams and Deck Rehabilitation

The general approach to retrofitting bent caps to increase the shear or flexural strength of the bent cap .There are three ways to achieve the enhanced strength in the bent beam: with post tensioned rods, external shear reinforcement or through addition of concrete or steel bolster.

Picture10. *Longitudinal View of Beam*

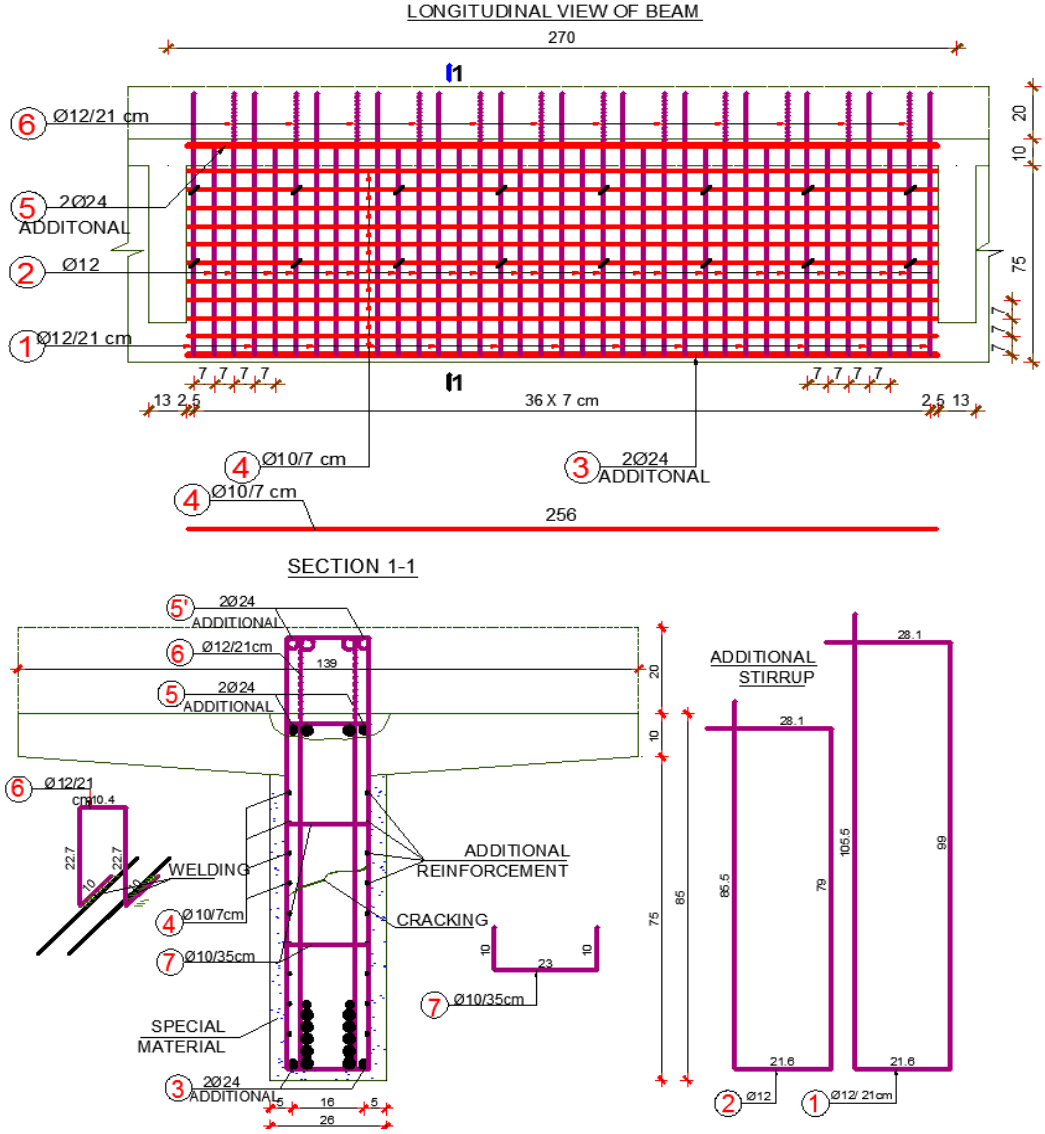


Picture11. *Details Used to Enhance Shear and Flexural Strength of Beams Retrofitting*[1].



[1]Technical project of 'Reconstruction of Velipoja Bridges ' S.P.I.T ltd

Picture12. *External Shear Reinforcement and Concrete Additional of the Beam*



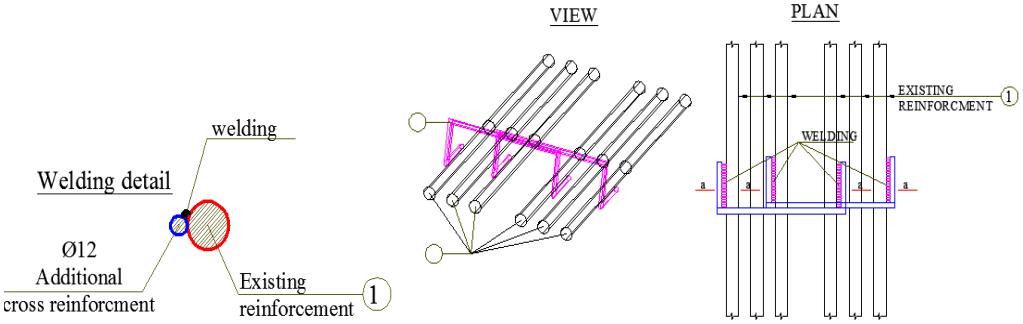
Measures for concrete beam repairs can be summarized as the following steps:

1. Beams repairing to be in the length between two diaphragms (L=2.7m)
2. Removal and cleaning of the damaged concrete. Removal of concrete within the saw – cut area may be performed by jack hammering or hand chipping. After removal the remaining concrete surface should be cleaned of loose concrete using high pressure air or water. Properties of the repair material should conform as closely as possible with the existing concrete (which can be obtained by Sika or Mapei). Cement based cast in –place concrete is used for the repair of deteriorated areas 75 mm deep no more. (A pre mixed micro concrete, modified with special additives to reduce shrinkage)[1]

[1]http://www.dot.state.fl.us/structures/structuresresearchcenter/Final%20Reports/0510847%20sum.pdf

3. Steel corroded beyond acceptable levels normally requires supplemental reinforcement. The entire surface of beams from both sides will place grill 7x7 that can be created by stirrups and additional longitudinal bars. The whole surface to be filled with special materials (Sika or Mapei) or retrofit with CFRP sheets.
4. Reinforced bar can be realized with Fe-44k and concrete M-300

Picture 13. *Connection Detail of Additional Reinforcement with Existing*



Conclusions

This paper presented the damage of bridge structure during recent earthquakes in Velipoja region and some retrofit practices for strengthening the existing highway bridges .This bridges have been used for approximately 50 years and are not designed for seismic actions. As result the structural assessment is necessary to make rational decisions whether the bridges should be retrofitted or replaced. To evaluate the damage is important to add more date from site investigation, tests materials and original design. Their structures suffer from a high level of deterioration of concrete and reinforcing steel. The on-site investigation of bridge structures and the materials tests showed visible concrete damage and significant weakening of the structures. Maintenance is necessary to preserve the intended load carrying capacity of the bridge and to ensure the safety of those using it.

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