IABSE Bulletins

# Case Studies

# 2

Andreas Lampropoulos (Editor)

# Case Studies on Conservation and Seismic Strengthening/ Retrofitting of Existing Structures

International Association for Bridge and Structural Engineering (IABSE)

Copyright © 2020 by
International Association for Bridge and Structural Engineering

All rights reserved. No part of this book may be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

ISBN 978-3-85748-173-4
DOI: https://doi.org/10.2749/cs002

Publisher:
IABSE
Jungholzstrasse 28
8050 Zurich
Switzerland

Phone: Int. +4143 443 97 65
E-mail: secretariat@iabse.org
Web: www.iabse.org

Case Studies

# 2

Andreas Lampropoulos
(Editor)

# Case Studies on Conservation and Seismic Strengthening/ Retrofitting of Existing Structures

International Association for Bridge and Structural Engineering (IABSE)

# Preface

The repair and strengthening of existing structures is an urgent need worldwide, especially in earthquake prone areas. Recent earthquakes have demonstrated that despite the continuous developments of novel materials and new strengthening techniques, the majority of the existing structures are still unprotected and at high seismic risk. Most of the existing structures need to be structurally upgraded either because they have been damaged during previous earthquakes or because they have been designed without or with old seismic code provisions. The repair and strengthening framework is a complex process, and there are often barriers in the preventative upgrade of the existing structures related to the cost of the applications and the limited expertise of the engineers.

The selection of the appropriate method each time is dependent on a large number of parameters such as the local environmental and geotechnical conditions, the type of the structure, the material characteristics and the condition of the existing structural elements, the availability of materials and technologies, the purpose of the structure, and the seismicity of the area. Therefore, the conservation and strengthening of an existing structure is an open-ended project. The engineers need to consider various options thoroughly, and the selection of the appropriate strategy is a crucial parameter for the success of these applications.

Another challenging part is the evaluation of the condition of the existing structures. In most cases, the lack of detailed drawings and documentations of the existing old structures, the limited accessibility to “hidden” structural elements, and the uncertainties in the evaluation of the material properties of the existing structures encompasses a high degree of uncertainty. At the same time, the code provisions in this field are quite limited and have been recently developed or are still under development. There are still techniques that are not sufficiently covered by the existing regulations. The design process is, in most cases, not strictly specified by the codes adding an extra layer of complexity to the engineers who do not have the required experience and can only hardly find limited examples of previous applications in the literature.

This document contains a collection of nine case studies from six different countries with different seismicities (i.e. Austria, Greece, Italy, Mexico, Nepal, and New Zealand). Various types of structures have been selected with different structural peculiarities such as buildings used for different purposes (i.e. school buildings, town hall, 30-storey office tower), a bridge, and a wharf.

Most of the examined structures are reinforced concrete structures, while there is also an application on a Masonry building.

This document is the second in a series of documents to be published by IABSE in the very important field of "Maintaining and Upgrading the Structural Performance of Existing Structures." The first document entitled "IABSE SED 12: Case Studies of Rehabilitation, Repair, Retrofitting, and Strengthening of Structures," was published in 2011, edited by Professor Mourad M. Bakhoum and Dr Juan A. Sobrino. The topic examined is quite broad, and the repair or strengthening techniques is highly dependent on the type of the existing structures and the materials used. Therefore, the development of a potential future collection of case studies focused on the repair and strengthening of additional types of structures, and especially steel construction and bridges would be desirable.

This document follows a consistent format for all the sections of every chapter as proposed by Professor Mourad M. Bakhoum for IABSE SED 12. For each of the examined studies of this document, the local conditions are described followed by the main deficiencies that are addressed. The methods used for the assessment of the *in situ* conditions are also presented and alternative strategies for the repair and strengthening are examined followed by the structural analysis before and after the structural upgrade. Details about the construction procedures are also presented.

The main aim of this collection is to present a number of different approaches applied to a wide range of structures with different characteristics and demands acting as a practical guide for the main repair and strengthening approaches used worldwide.

The Editor would like to express his appreciation and sincere thanks to the reviewers Professor Shunichi Nakamura and Professor Charis Gantes for their thorough and valuable comments and suggestions.

Finally, the Editor would like to especially thank the IABSE Bulleting Board members, in particular Professor Mourad M. Bakhoum, for his invitation to develop a second version of a Case Study document on this field following IABSE SED 12 and the Chair of the Bulletin Board, Dr Harsha Subbarao, for his continuous encouragement and support during the preparation of the document.

Dr Andreas Lampropoulos
(Editor)

**Contributing Authors**
**(Listed as per chapter sequence)**

**Andreas Lampropoulos (Editor)**
University of Brighton, UK

**Christos Giarlelis**
Equidas Consulting Engineers, Greece

**Evlalia Lamprinou**
Equidas Consulting Engineers, Greece

**Constantinos Repapis**
University of West Attica, Greece

**Stephanos Dritsos**
University of Patras, Greece

**Dimitrios Baros**
University of Patras, Greece

**Rakesh Dumaru**
University of Porto, Portugal

**Hugo Rodrigues**
ESTG - Polytechnic Institute of Leiria, Portugal

**Humberto Varum**
University of Porto, Portugal

**Enzo Martinelli**
Università degli Studi di Salerno, Italy

**Ciro Faella**
Università degli Studi di Salerno, Italy

**Emidio Nigro**
Università degli Studi di Napoli "Federico II", Italy

**Carmine Lima**
Università degli Studi di Salerno, Italy

**Joe White**
Holmes Consulting, Netherlands

**Hamish McKenzie**
Holmes Consulting, New Zealand

**Rob Presland**
Holmes Consulting, New Zealand

**Alistair Boyce**
WSP-Opus, New Zealand

**Engliang Chin**
Tonkin and Taylor, New Zealand

**Gareth Morris**
Holmes Consulting, New Zealand

**Mark Browne**
Holmes Consulting, New Zealand

**Kirsti Murahidy**
Tonkin and Taylor, New Zealand

**Mike Jacka**
Tonkin and Taylor, New Zealand

**Dimitrios Stefanoudakis**
Civil Engineer, Austria

**Eftychia Apostolidi**
University of Natural Resources and Life Sciences, Austria

**José Jara**
Universidad Michoacana de San Nicolás de Hidalgo, México

**Bertha Olmos**
Universidad Michoacana de San Nicolás de Hidalgo, México

**Guillermo Martínez**
Universidad Michoacana de San Nicolás de Hidalgo, México

# Table of Contents

Think Stronger.
Think Safer.
Think Taylor.

Taylor Devices Inc. is the leading manufacturer of world-class Fluid Viscous Dampers that will increase seismic resiliency and greatly reduce material cost.

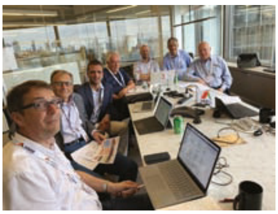
These seismic damping devices can allow for the immediate re-entry of a structure after an earthquake with minimal downtime.

taylor devices inc.

Download Our Comprehensive Damper Manual
www.taylordevices.com


# Learn, Contribute, Share!

**IABSE fosters realisation of brilliant ideas into worthwhile projects through the deployment of Task Groups. A Task Group (TG) is a group of experts who are brought together to do a focused and specific task with expected deliverables such as SED, Bulletin, SEI article(s), workshop, e-learning material...**

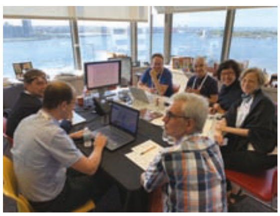


## JOIN
### a Task Group

Super Long Span Bridge Aerodynamics?
Seismic Resilience of Reinforced Concrete Structures?
Disaster Debris Management?
Above are a few of the 45 Task Groups currently formed. Check out the updated list online to find the one that suits your interest and expertise!

## Form
### a Task Group

Didn’t find the Task Group you’re looking for?
Create your own Task Group and join IABSE’s network of professionals!



More information: **www.iabse.org/TaskGroup**

Chapter

1

# Seismic Rehabilitation of a School Building in Cephalonia, Greece

**Christos Giarlelis,[1] Evlalia Lamprinou[2] and Constantinos Repapis[3]**

[1]Structural Engineer, Equidas Consulting Engineers
[2]Structural Engineer, Equidas Consulting Engineers
[3]Associate Professor, Department of Civil Engineering, University of West Attica

**Abstract**
The 2014 earthquake sequence in Cephalonia, Greece, resulted in a number of structural failures. In Argostoli, the capital of the island, a school building suffered light damage; however, the structural assessment following the analysis procedures of the recently published Greek Code for Structural Interventions, showed that seismic strengthening is required. The structure was built on the aftermath of the catastrophic 1953 Ionian earthquake sequence based on older code requirements, which are much outdated, as indicated from the results of both modal response spectrum analyses and non-linear static analyses. The retrofit aims to increase the very low structural capacity of the building and as a means for that the use of concrete jackets is selected. Based on the results of the assessment, it was decided that concrete jackets should be applied to all columns, while large structural walls running along the transversal direction were strengthened with single-sided reinforced concrete jacketing. The interventions are limited by architectural demands and cost considerations. However, analyses of the strengthened structure show that the interventions improve its seismic behaviour adequately. The detailing of interventions is thoroughly presented. What makes this case study interesting is the unusual structural system of the building, which is an ingenious combination of frame elements and lightly reinforced concrete walls and its behaviour to one of the strongest recent Greek earthquakes. The rehabilitation study had to model correctly the structure and propose interventions that were in agreement with the architectural demands and the cost consideration.

**Keywords:** Earthquake, Structural assessment, Seismic rehabilitation, Reinforced Concrete, Strengthening

## 1.1 Introduction

On 26 January and 3 February, 2014, two strong earthquakes of magnitudes M6.1 and M6.0, respectively, ruptured the western part of the island of Cephalonia (*Fig. 1.1*). The epicentre of

Chapter

2

# Modification and Strengthening of a Characteristic Reinforced Concrete Building in Patras, Greece

**Stephanos Dritsos, Professor and Dimitrios Baros, PhD**

Department of Civil Engineering, University of Patras, Patras, Greece

**Abstract**
The design and application of strengthening measures aiming to effectively counter possible weaknesses related to the extensive architectural modification of a characteristic reinforced concrete building is discussed in this chapter. Several balconies were removed as part of the architectural interventions. Externally bonded reinforcement consisting of steel and fibre reinforced polymer laminates was applied as an "answer" to possible changes in flexural stress of selected structural elements in the immediate area of the demolitions. A unique anchorage system was also designed and applied as an answer to the loss of development length of the main reinforcement bars of selected beams due to the removal of their cantilever parts.

**Keywords:** flexural strengthening; externally bonded reinforcement, laminates, rebar anchor plates

## 2.1 Introduction

The continuous advancement in structural engineering practice, namely structural analysis, design and construction procedures, as well as the improved understanding and representation of the effects of earthquakes on structural elements has undeniably led to the increased safety of modern buildings compared with those designed and built decades ago. However, the latter represent the bulk of the built environment in major urban areas. The questionable seismic performance of such buildings is usually the main reason for assessing and, if necessary, strengthening them to comply with the performance objectives set out in modern codes for seismic assessment and retrofit of structures.

In most cases, the design and application of a complete system that will effectively upgrade the performance of an existing structure is a challenging process. It requires knowledge of the respective code framework, complex numerical modelling and analysis procedures, and, most importantly, deep understanding of the available structural intervention techniques and their effects on structural elements. The latter is of major importance when designing and applying a structural retrofit system as a "counterbalance" to specific weaknesses, which may occur as a result of local

Chapter

3

# Seismic Performance Assessment, Retrofitting, and Loss Estimation of an Existing Non-Engineered Building in Nepal

**Rakesh Dumaru, PhD Graduate,[1] Hugo Rodrigues, Adjunct Professor[2] and Humberto Varum, Full Professor[3]**

[1]Faculdade de Engenharia da Universidade do Porto, Porto, Portugal
[2]RISCO, ESTG - Polytechnic Institute of Leiria, Leiria, Portugal
[3]CONSTRUCT-LESE, Faculdade de Engenharia da Universidade do Porto, Porto, Portugal

**Abstract**

The non-engineered building built before 2004 remained after Gorkha earthquake although such structures demonstrate seismic deficient. Therefore, the present study aims to carry out detail seismic performance of such building to investigate as-built seismic performance and its performance after intervention of retrofit measures. Two *in situ* tests were performed, which includes Schmidt hammer test and ambient vibration test. The adaptive pushover analysis and dynamic time history analyses were performed for as-built and retrofitted building. The retrofit measures increase the stiffness and maximum base shear capacity of the buildings. In addition, such retrofit measures improved single storey drift concentration in existing building such that uniform drift profile can be attained. Furthermore, the probability of exceeding damage states can be significantly reduced and mainly found to be more effective in minimizing higher damage states, such as partial collapse and collapse states. The maximum expected annual loss occurs between 0.1 g and 0.2 g PGA (Peak Ground Acceleration). It was revealed that the steel braced building was found to be relatively more effective in enhancing the seismic performance, whereas reinforced concrete shear wall found more economic feasible retrofit measure for this particular building.

**Keywords:** non-engineered, retrofit techniques, ambient vibration test, fragility curves, cost–benefit analysis, sensitivity analysis, risk curve

## 3.1 Introduction

The reinforced concrete (RC) buildings built before the implementation of any design codes and guidelines, whose structural sections and reinforcement details resemble only to carry gravity loads, were classified as non-engineered buildings. In context of Nepal, it includes RC buildings built before 2004, after which Nepal Building Code (NBC), that is, NBC 205:1994[1] guideline was implemented. It provides ready to use dimensions and detailing for structural elements, but

Chapter

4

# Retrofitting of School Building Located in Southern Italy

**Enzo Martinelli, PhD, Associate Professor,[1] Ciro Faella, Full Professor,[1]
Emidio Nigro, PhD, Full Professor[2] and Carmine Lima, PhD, Research Assistant[1]**

[1]Università degli Studi di Salerno, Fisciano, Italy
[2]Università degli Studi di Napoli “Federico II”, Napoli, Italy

**Abstract**
This paper summarizes the main features of the seismic retrofitting project of a school building located in Montella (AV), Italy. Specifically, it describes the as-built status in terms of structural organization, member detailing, and existing materials properties. Then, it outlines the main assumptions and results obtained from seismic analysis, of both as-built and retrofitted structure. Comments about the construction stage are also reported by describing the main operations put in place with the aim to realize the shear wall system, which is the main retrofitting intervention, and some local strengthening measures consisting in steel plating and jacketing of some under-designed RC members. Some emphasis is placed on the realization of micro-piles and extra foundations of the aforementioned shear walls. Besides its specific interest, the reported project may be intended as representative of a wide class of seismic assessment and retrofitting projects that have been realized in Italy in the last decade.

**Keywords:** school building, reinforced concrete frame, shear walls, micro-piles, steel jacketing

## 4.1 Introduction

A significant share of school buildings have been built during the past decades and are currently in need for retrofitting. Specifically, according to the “registry” (*anagrafe*) realized in 2015 by the Ministry of Education, University and Research (MIUR), the stock of Italian school buildings consists of about 42 000 constructions, 55% of which have been realized before 1976.[1] As it is well-known, almost all the Italian territory is characterized by medium-to-high seismic hazard[2]; Therefore, the intrinsic vulnerability, deriving by the fact that the majority of school buildings have been designed without the modern principles of earthquake engineering,[3,4] leads to significant values of seismic risk, also because of the exposure of young human lives. More than any quantitative data and formal statistics, the consequences of the seismic event occurred in 2002

Chapter

5

# Seismic Strengthening of the Majestic Centre, Wellington, New Zealand

**Joe White, PE CPEng MIPENZ CEng MIStructE, Business Manager, Netherlands (formerly Wellington), Holmes Consulting LP and**
**Hamish McKenzie, CPEng MIPENZ, Principal – North Island NZ, Holmes Consulting LP**

**Abstract**
The Majestic Centre is a 30-storey office tower in the centre of Wellington, New Zealand. The structure has a dual lateral system (reinforced concrete (RC) moment frame + shear cores) and hollow-core floors. The building's assessed seismic performance was found to be below expected levels, leading to a strengthening exercise. Over a period of 5 years, the structures performance was raised to meet current seismic loading requirements, at a cost of €50M.

**Keywords:** dual system, transfer beam, diaphragm, frame elongation

## 5.1 Introduction

The Majestic Centre is an iconic landmark in Wellington, the capital city of New Zealand. Constructed circa 1991, it is a 30-storey modern office tower and the tallest building in the city. The building was assessed in 2011 using a performance-based approach and found to have a lower than expected level of seismic performance. Over a period of 5 years, at a cost of NZ$83.5 million (€50M), the building has been systematically strengthened, while remaining fully tenanted. The project has spurred new assessment and strengthening techniques and overcome several major logistical challenges to reach a successful completion.

The project team comprised Holmes Consulting (Structural Engineers), Tonkin & Taylor (Geotech Engineers), Fletcher Construction Company (Main Contractor), The Building Intelligence Group (Project Manager), WSP Opus (Architects) and Beca (Peer Reviewer) (*Fig. 5.1*).

### 5.1.1 The Building

The Majestic Centre sits on a sloping site in the centre of the city. The building is 116 m tall, comprising a 25-storey tower with a 5-storey podium beneath. The tower dominates the building's presence, providing high-grade commercial space for approximately 2700 people. The podium

Chapter

6

# Thorndon Container Wharf: Temporary Works for Recovery of Container Operations (New Zealand)

**Rob Presland,[1] Alistair Boyce[2] and Engliang Chin[3]**

[1]Technical Director, Holmes Consulting LP, Wellington, New Zealand
[2]Technical Principal – Maritime, WSP-Opus, Christchurch, New Zealand
[3]Senior Geotechnical Engineer, Tonkin and Taylor, Wellington, New Zealand

**Abstract**
The Thorndon Container Wharf sustained severe damage in the November 2016 M7.8 Kaikoura earthquake. Substantial works, of a temporary nature, were required to restore the wharf for container handling operations. The temporary securing works included gravel columns within the reclamation fill and restraining and underpinning of the wharf. All of these works were designed and constructed over a 9-month period to provide a temporary facility for container handling operations for a period of up to 3 years. The temporary securing works were required to secure the container cranes, maintain support to the wharf structure, and ensure the reclamation behind the wharf had sufficient strength to support lateral loads imposed by the restraining system. This was to enable container operations to recommence and to maintain business continuity, pending action on replacement or reinstatement of the container wharf. This paper outlines the development of the design of the temporary works to secure and return to operations a 125- m working length of wharf and reclamation.

**Keywords:** wharf, seismic damage, assessment, repair, existing reinforced concrete structures, structural analysis

## 6.1 Introduction

The Thorndon Container Wharf (TCW) is a marginal wharf that forms the eastern edge of the CentrePort container terminal operational area in Wellington, New Zealand (*Fig. 6.1*). The wharf provides approximately 585 m of berth for vessels for the loading and unloading of containerized cargo, using two 750-tonne Liebherr ship-to-shore gantry container cranes positioned on the wharf.

The wharf was constructed in stages from the late 1960s by the Wellington Harbour Board. Precast concrete driven piles, cast *in situ* reinforced concrete main beams, and precast, prestressed concrete deck units make up the typical wharf structure. The area behind the wharf was reclaimed as part of container port expansion works, which included construction of the wharf structure.

Chapter

7

# Christchurch Town Hall Complex: Post-Earthquake Ground Improvement, Structural Repair, and Seismic Retrofit

**Gareth Morris,[1] Mark Browne,[2] Kirsti Murahidy[3] and Mike Jacka[4]**

[1]Structural Engineer, Holmes Consulting, Christchurch, New Zealand
[2]Structural Engineer, Holmes Consulting, Christchurch, New Zealand
[3]Geotechnical Engineer, Tonkin and Taylor, Christchurch, New Zealand
[4]Geotechnical Engineer, Tonkin and Taylor, Christchurch, New Zealand

**Abstract**
The Christchurch Town Hall (CTH) complex contains six reinforced concrete buildings constructed circa 1970 in Christchurch, New Zealand (NZ). The complex is used for performing arts and entertainment, with an Auditorium that is internationally recognized for its acoustics. It is listed as a Grade-1 heritage building due to its cultural and historical significance. Unfortunately, the CTH foundation system was not originally designed to accommodate liquefaction-induced differential settlement and lateral spreading effects, as highlighted by the 2010–2011 Canterbury earthquake sequence. Although the most extreme ground motions exceeded the NZS 1170.5 code-defined 1/2500 year earthquake loads, the CTH structures performed remarkably well for a design that pre-dated modern seismic codes. Most of the observed structural damage was a result of the differential ground deformations, rather than in response to inertial forces. The post-earthquake observations and signs of distress are presented herein. The primary focus of this paper is to describe two major features of the seismic retrofit project (initiated in 2013) which were required to upgrade the CTH complex to meet 100% of current NZS 1170.5 seismic loadings. Firstly, the upgrade required extensive ground improvement and a new reinforce concrete mat slab to mitigate the impacts future ground deformations. Soil stabilization was provided by a cellular arrangement of jet-grout columns, a relatively new technique to NZ at the time. The new mat slab (typically 600–900 mm) was constructed over the stabilized soils. Secondly, upgrading the superstructure had many constraints that were overcome via a performance-based design approach, using non-linear time-history analysis. Recognizing the heritage significance, the superstructure “resurrection” as a modern building was hidden within the original skin minimized disruption of heritage fabric. Retrofit solutions were targeted, which also minimized the overall works. The 2015–2019 construction phase is briefly discussed within, including jet-grout procedures and sequencing considerations.

**Keywords:** Christchurch, liquefaction, jet-grout, performance-based, retrofit, soil–structure.

Chapter

8

# Strengthening and Modernization of a Characteristic Masonry Building in Vienna, Austria

**Dimitrios Stefanoudakis[1] and Eftychia Apostolidi[2]**

[1]Civil Engineer, MSc. Dr.techn., Vienna, Austria
[2]Research Associate, DI MSc, University of Natural Resources and Life Sciences, Vienna, Austria

**Abstract**
Historical buildings from the period of Promoterism constructed between 1850 and 1910, called "Gründezeitgebäude," represent a main part of the building stock in Vienna. A typical building from this period is presented, along with the pathology of such buildings. A step-by-step strengthening and modernization strategy is described, including structural analysis data and design of sections data before and after interventions, along with detailing according to the respective codes.

**Keywords:** earthquake, strengthening, brick floors, timber floors, historical building, masonry

## 8.1 Introduction

The city of Vienna is located in a weak earthquake zone with a seismic return period of 475 years. The strongest earthquake recorded in Austria was in the year 1590 (M 5.75) with an epicentre 30–40 km outside of Vienna[1] and an earthquake in 1972 with the intensity of ~60 % of the aforementioned earthquake just caused a few damages to the existing buildings. In spite of many wars, but fortunately just few natural disasters, the city of Vienna still has a good conserved building stock inside the city centre. This area was inside the city wall, called the "Ring," which was removed between 1858 and 1875 and was replaced by the "Ring" avenue. Outside this down town-city centre area, there are newer buildings, called "Gründerzeit" ("the Founder Epoch") buildings, constructed between 1850 and 1910 the age of promoterism. These buildings with typically decorated façades still dominate the townscape of Vienna. They are taller and more slender than the older mainly baroque buildings. "Gründerzeit"-buildings are clay-brick masonry buildings of 2 to 6 stories with wooden joist floors. The roof floor is mostly a timber floor, and the cellar floor is a brick arch (*Fig. 8.1*). There are about 30 000 such buildings in Vienna. The existing buildings from the "Period of Promoterism" are of high importance for the city as cultural heritage and they are still used as residential buildings. They are very popular to live in, although they are less comfortable and less safe than modern buildings.

Chapter

9

# Strengthening and Retrofitting of Motín de Oro II Bridge in Mexico

**José M. Jara, Titular Professor, Bertha A. Olmos, Titular Professor and Guillermo Martínez, Titular Professor**

Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México

**Abstract**
This chapter presents the studies conducted to retrofit an existing bridge in a seismic prone area of Mexico. The Motín de Oro II Bridge was built in the 1970s with a continuous box girder superstructure and wall-type substructure. From the 1970s to nowadays, the design truck loads in Mexico have been substantially incremented and many bridges built in that period have required to be evaluated and, in some cases, rehabilitated and retrofitted. Firstly, the study presents the results of visual inspections of all parts of the bridge and a description of the preliminary studies conducted to determine the material properties, to evaluate the river flow characteristics and to calculate the scour depth. Secondly, the chapter discusses the initial structural analyses of the bridge subjected to the original gravitational and seismic loads and to the current loads before the intervention. These analyses allow to select the structural elements that require to be retrofitted and the best strategy to follow. Finally, the study presents results of the numerical retrofitted model and the experimental assessment of the dynamic properties based on ambient vibration measurements. Additionally, the scour protection and the general construction procedure are also described.

**Keywords:** Ambient vibration measurements, external pressstressing tendons, increased live loads, scour depth, pushover analyses, bridge rehabilitation

## 9.1 Introduction

México has a road network with more than 16 000 bridges. The Ministry of Communications and Transportation has a yearly plan of visual inspections to evaluate bridge pathologies based on a governmental program called Mexican Bridge System. Most of the bridges are visited at least once a year to fulfil a survey that quantifies different aspects related to the safety of the structure. At the end, all variables involved are combined and evaluated with a final number in the range of 1–5. The lowest value means general good state with minor actions required, and the highest value implies actions that must be immediately attended.

# About the Authors

**Dr Andreas Lampropoulos** is a Principal Lecturer and Course Leader for BEng/MEng Civil Engineering courses at the University of Brighton. He obtained his Diploma (2003), MSc (2005) and PhD (2010) degrees in Civil Engineering (Structural Division) from the University of Patras in Greece.

His main research agenda spans the areas of novel construction materials and seismic strengthening/retrofitting of existing structures.

He currently serves as the Chair of IABSE Task Group 1.1 'Improving Seismic Resilience of Reinforced Concrete Structures' and Task Group 5.5 'Conservation and Seismic Strengthening/Retrofitting of Existing Unreinforced Masonry Structures', and he is the Chair of the Outstanding Paper Award Committee (OPAC) of the IABSE's Structural Engineering International (SEI) journal.

He is also a member of the International Federation for Structural Concrete *(fib)* Task Group 8.1 'Model Technical Specification for Repairs and Interventions' and Task Group 6.6 'Retrofitting of Precast Structures in Seismic Areas' as well as a member of the BSI Mirror Group for Eurocode 8 Part 3 (B/525/8 Panel 3).

# IABSE Bulletins

## Case Studies

### Objective:

To provide in-depth information to practicing structural engineers, in reports of high scientific and technical standards on a wide range of structural engineering topics.

### Topics:

Structural analysis and design, dynamic analysis, construction materials and methods, project management, structural monitoring, safety assessment, maintenance and repair, and computer applications.

### IABSE Bulletin Board:

H.Subbarao, (Chair), D. Laefer, (Vice Chair), M. Bakhoum,C. Bob, M.W. Braestrup, N.P. Hoej, H.H. Snijder, R. Mor, M.G. Bruschi, S. Kite, F. Nalon, G. Pircher, M. Knobloch, A. Schumacher, O. Larsson Ivanov, Y. Offir, S. Dan, Y. Xia

### Publisher:

The International Association for Bridge and Structural Engineering (IABSE) is a scientific / technical Association comprising members in 90 countries and counting 56 National Groups worldwide. Founded in 1929 it has its seat in Zurich, Switzerland. IABSE's mission is to promote the exchange of knowledge and to advance the practice of structural engineering worldwide. IABSE organizes conferences and publishes the quarterly journal Structural Engineering International (SEI), as well as Conference Proceedings and Bulletins including the Structural Engineering Documents (SED) and the Case Studies series. IABSE also presents annual awards for achievements in structural engineering.

### For further Information:

IABSE
Jungholzstrasse 28
8050 Zürich
Switzerland

Phone: + 4143 443 97 65
E-mail: secretariat@iabse.org
Web: www.iabse.org

**Case Studies on Conservation and Seismic Strengthening/Retrofitting of Existing Structures**

Recent earthquakes have demonstrated that despite the continuous developments of novel materials and new strengthening techniques, the majority of the existing structures are still unprotected and at high seismic risk. The repair and strengthening framework is a complex process and there are often barriers in the preventative upgrade of the existing structures related to the cost of the applications and the limited expertise of the engineers. The engineers need to consider various options thoroughly and the selection of the appropriate strategy is a crucial parameter for the success of these applications.
The main aim of this collection is to present a number of different approaches applied to a wide range of structures with different characteristics and demands acting as a practical guide for the main repair and strengthening approaches used worldwide. This document contains a collection of nine case studies from six different countries with different seismicity (i.e. Austria, Greece, Italy, Mexico, Nepal and New Zealand). Various types of structures have been selected with different structural peculiarities such as buildings used for different purposes (i.e. school buildings, town hall, 30 storey office tower), a bridge, and a wharf. Most of the examined structures are Reinforced Concrete structures while there is also an application on a Masonry building. For each of the examined studies, the local conditions are described followed by the main deficiencies which are addressed. The methods used for the assessment of the in-situ conditions also presented and alternative strategies for the repair and strengthening are considered.

9 783857 481734