International Series on Advances in Architecture

Objectives

The field of architecture has experienced considerable advances in the last few years, many of them connected with new methods and processes, the development of faster and better computer systems and a new interest in our architectural heritage. It is to bring such advances to the attention of the international community that this book series has been established. The object of the series is to publish state-of-the-art information on architectural topics with particular reference to advances in new fields, such as virtual architecture, intelligent systems, novel structural forms, material technology and applications, restoration techniques, movable and lightweight structures, high rise buildings, architectural acoustics, leisure structures, intelligent buildings and other original developments. The Advances in Architecture series consists of a few volumes per year, each under the editorship - by invitation only - of an outstanding architect or researcher. This commitment is backed by an illustrious Editorial Board. Volumes in the Series cover areas of current interest or active research and include contributions by leaders in the field.

Managing Editor

F. Escrig
Escuela de Arquitectura
Universidad de Sevilla
Avda. Reina Mercedes 2
Spain

Honorary Editors

C. A. Brebbia
Wessex Institute of Technology
UK

P. R. Vazquez
Estudio de Arquitectura
Mexico
Associate Editors

C. Alessandri  
Università di Ferrara  
Italy

K. Ghavami  
Pontificia Univ. Catolica  
Brazil

F. Butera  
Politecnico di Milano  
Italy

K. Ishii  
Yokohama  
Japan

J. Chilton  
University of Nottingham  
UK

W. Jäger  
Technical University of Dresden  
Germany

G. Croci  
University of Rome, La Sapienza  
Italy

M. Majowiecki  
University of Bologna  
Italy

A. de Naeyer  
Universiteit Ghent  
Belgium

S. Sánchez-Beitia  
ETS de Arquitectura  
Applied Physics University, Spain

W. P. De Wilde  
Vrije Universiteit Brussel  
Belgium

J. J. Sendra  
Universidad de Sevilla  
Spain

F. Gabriel  
Syracuse School of Architecture  
USA

M. Zador  
Technical University of Budapest  
Hungary

C. Gantes  
National Technical University of Athens  
Greece

R. Zarnic  
University of Ljubljana  
Slovenia
Eighth International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture

STREMAH VIII

Conference Chairman

C.A. Brebbia
Wessex Institute of Technology, UK

International Scientific Advisory Committee

G. Batis  P. Haupl
L. Binda  A.H. Hendrickx
R.F. Borges  S. Hernandez
V. Caputo  W. Jäger
G. Croci  B.P. Leftheris
S. D’Agostino  F. Patania
W.P. De Wilde  S.E. Thomasen
G. Falsone

Organised by
Wessex Institute of Technology, UK
Structural Studies,
Repairs, and Maintenance of
Heritage Architecture
VIII

Edited by

C.A. Brebbia
Wessex Institute of Technology, UK
Preface

This book contains the edited proceedings of the 8th International Conference on Structural Studies, Repairs and Maintenance of Heritage Architecture or STREMAH 2003. The Meeting, which has taken place on a regular basis over the last 13 years, has become a biannual event attracting the best known specialists from all over the world. It offers a channel for the state of the art technology and the most up to date scientific discoveries for the conservation of our cultural heritage.

The public attitude to the benefits and value of our architectural heritage has advanced in recent decades. The importance of old buildings for the historical identity of the region, town or nation is increasingly recognised and appreciated. This requires looking beyond borders to benefit from the experience gained by others. This book makes a significant contribution in this regard as it gathers the most recent advances in research and up to date studies of heritage buildings.

This volume presents a variety of papers on topics such as Structural Issues; Seismic Behaviour; Maintenance and Repairs; Material Problems; Prevention of Structural Damage; Historical and Architectural Aspects; Simulation and Modelling; Timber Constructions; Case Studies and Deterioration Protection and Evaluation of Materials. It also contains two special sessions, one on “The Structural Conservation of the Archaeological Heritage in Italy” organised by Prof S. D’Agostino and G Calabresi of the University of Naples, and another on “Long Term Behaviour of Masonry Structures; Learning from Failures” by Prof L Binda of the Milano Politecnico.

The Editor is grateful to all authors for their excellent contributions and, in particular, to the members of the International Scientific Advisory Committee for their help with the selection process of the papers included in this volume.

The Editor
Halkidiki, 2003
CONTENTS

Section 1: Historical and Architectural Aspects

The concept of proportion in heritage architecture: a study of form, order and harmony
R.F. Borges 3

Conflict of Ancient Greek and Christian architecture during the first millennium
B.P. Leftheris 13

The Old City of Ghadames: an epitome of desert environment engineering
A. Abufayed 23

Covered bridges speak to a careful observer: insight into the geometry and manufacture of Smith trusses
M. Reckard 35

Technology and repairs in Castelli e ponti di mastro Nicola Zabaglia (Rome, 1743)
M.G. D’Amelio & N. Marconi 45

Mortars for intervention in monuments and historical buildings
I. Papayianni & M. Stefanidou 57

The shell structures of the Baroque
F. Escrig, V. Compán, J. Sánchez & J.P. Valcárce 65

Ancient civic palace of Saluzzo: strengthening works
G. Pistone, F. Antonino & D. Zorgniotti 75
Section 2: Long Term Behaviour of Masonry Structures:
Learning from Failures
(Special Session organised by L. Binda)

Experimental study on the damaged pillars of the Noto Cathedral
L. Binda, A. Saisi, R. De Benedictis & S. Tringali

Failures due to long-term behaviour of heavy structures:
the Pavia Civic Tower and the Noto Cathedral
L. Binda, A. Anzani & A. Saisi

Monitoring of long-term damage in Gothic Cathedrals
P. Roca, J.L. González, F. Aguerri & J.I. Aguerri

Experimental research on the creep behaviour of historic masonry
A. Anzani & G. Mirabella Roberti

Creep modelling of masonry historic towers
E. Papa & A. Taliercio

Repair techniques for creep and long-term damage
of massive structures
C. Modena & M.R. Valluzzi

Testing and modelling of masonry creep and damage
in uniaxial compression
J. Pina-Henriques & P.B. Lourenço

Section 3: Deterioration, Protection and Evaluation of Materials

Study on the deterioration and conservation
of the monument dedicated to the Fallen
in the “Risorgimento” battles, Ravenna (Italy)
M. Macchiarola, S. Belacchi, D. Pinna, G. Ercolani, A. Ruffini & C. Fiori

In lab and in situ assessment of masonry stones’ mechanical properties
through the micro-drilling technique
G.E. Exadaktylos, Ch.Th. Papadopoulos, M.Ch. Stavropoulou
& A. Athanassiadou

Investigation of the protective effect of inorganic coating
with corrosion inhibitors against deterioration of structural damages
G. Batis, P. Pantazopoulos & A. Routoulas

Osmotic fabrics for historical building external surfaces protection
E. Attaiianese, G. Caterina & G. Duca
Epoxy resins used for the repair of timber structures: The problem of short- and long-term performance evaluation  
H. Cruz & J. S. Machado  

C. Bertolini Cestari & T. Marzi  

Impact of fuel reformulation on pollution-induced stone degradation  
P. Buttini & G. Perego  

Section 4: Simulation and Modelling  

The moisture and temperature fields in the sandstone cupola of the “Church of Our Lady” in Dresden, Germany  
P. Häupl & H. Fechner  

Structural behaviour of Gothic vaults  
J.P. Valcárcel, J. Domínguez, E. Martín & F. Escrig  

A contribution to the analysis of historical structures using LHS method  
J. Žák, A. Florian, & P. Hradil  

Finite element modeling of Guastavino tiled arches  
E.P. Saliklis, S.J. Kurtz & S.V. Furnbach  

Response of multiple-leaf masonry arch-tympani to dynamic and static loads  
A. Drei & A. Fontana  

Application of Bott-Duffin inverse to static and dynamic analysis of masonry structures  
T. Aoki & T. Sato  

A first approach to the load path method on masonry structure behaviour  
G. De Tommasi, P. Monaco & C. Vitone  

Limit analysis of masonry walls with rectangular openings by equivalent shear panel model  
T. Takada, T. Aoki & C. Genovese  

Unilateral contact analysis and failure prediction in stone bridges  
M.E. Stavroulaki & G.E. Stavroulakis
Structural assessment of a wooden bell-tower
*N. André, P. Galimard & P. Morlier*

Natural fire simulation in 19th century fireproof buildings
*I. Wouters & M. Mollaert*

Modelling micro-structure aspects of masonry walls by a simplified approach
*S. Casolo & F. Peña*

**Section 5: Structural Issues**

Structural defects and solutions: A case study of Fort Cornwallis, Penang, Malaysia
*M.R. Ismail, A.G. Ahmad & H. Awang*

Structural analysis of the main apse vault of St. George of Greeks Cathedral built c.1390 at Famagusta, Cyprus
*A. Atun*

Compressive strength of compressed earth block masonry
*G. Bei & I. Papayianni*

Visualisation and evaluation of structural characteristics and problems of a Classical Ottoman bath
*Ö. Çizer & M.H. Turan*

Assessment of structural damages and development of rehabilitation procedures for the Old City of Ghadames, Libya
*A. Abufayed & S.A. ElAzhari*

Preliminary investigation on the preservation of Machu Picchu ruins: Discussions from topographical and geological aspects
*M. Fujisawa & T. Kakimi*

The influence of deterioration on the lifetime of timber structures
*J.-W.G. van de Kuilen*

**Section 6: The Structural Conservation of the Archaeological Heritage of Italy**
(Special Session organised by S. D’Agostino)

The concept of reversibility in the structural restoration of archaeological sites
*S. D’Agostino & M. Bellomo*
Extraordinary maintenance work carried out on the arch of Titus in Rome
M.L. Conforto & S.D’Agostino

Safety assessment of the foundations of the Basilica of Maxentius in Rome
G. Calabresi & M. Fattorini

The mausoleum of Cecilia Metella on the Appia Antica: a structural contribution to its restoration and adaptation for use
S. D’Agostino & M. Bellomo

Section 7: Prevention of Structural Damage

An optimisation algorithm for the collapse detection of stone masonry structures
P. Trovalusci & C. Baggio

Risk to old bridges due to ship impact on German inland waterways
M. Curbach & D. Proske

Using reinforced concrete yoke to strengthen arch bridges: fracture mechanism analysis and computation mode
J.T. Zhou

Section 8: Seismic Behaviour

Performance-based seismic design criteria for historic buildings
S.E. Thomesen

Numerical simulation of the behavior of Byzantine churches under gravitational and seismic actions
G.C. Manos, L. Papas, V.J. Soulis & A. Diagouma

Seismic rehabilitation of cathedral towers in Peru
D. Torrealva, A. Blanco, G. Tumialan & A. Nanni

Earthquake structural problems and urgent measures undertaken to support the Katholikon of Dafni Monastery in Athens, Greece
A. Miltiadou-Fezans, T.P. Tassios, N. Delimikolas, E. Chorafa, E. Zarogianni & I. Chandrinos

Response of the building “Mercado Torroja” of Algeciras, under seismic load
A. Corz, J. Franco & J. Domínguez
Integrated system for building survey and evaluation of seismic retrofit possibilities
M. Bostenaru Dan

Modified estimation method of fundamental periods of historic buildings with masonry shear walls in Taiwan
W.-S. Chang, M.-F. Hsu & C.-J. Chen

Assessment of the seismic vulnerability of unreinforced masonry buildings
Gr.G. Penelis, A.J. Kappos & K.C. Stylianidis

Cracks modelling in presence of notch and seizure effects in historical buildings damaged by an earthquake in Piedmont
R. Roccati & M. Roselli

Section 9: Case Studies

Computer modelling of the Basilica of Pilar in Zaragoza (Spain)
S. Hernández & L.E. Romera

A small valley in Greece and its bridges throughout the centuries
M. Karaveziroglo, E. Karayianni, E. Stavrakakis & A. Vaggelakos

Structural analysis for the reconstruction design of the old bridge of Mostar
M. Orlando, P. Spinelli & A. Vignoli

Rehabilitation of a Cruzeiro in Portugal
A.L. Velosa & P. Cachim

Weld repair of the U.S. Capitol dome

Contribution to the study of restoration of the Museum of fine arts of Algiers, Algeria
M.A. Allal

Rehabilitation of traditional mills
J.C. Viegas & J.A. Miranda

Static analysis of the Turris Lybisonis Roman multispan stone arch bridge
I. Mura, Z. Odoni & M. Perra
Construction of a fountain in the form of a concave-convex concrete shell  
*V. Kilar*

**Section 10: Maintenance and Repairs**

The role of geotechnical engineering in the preservation of our architectural heritage  
*V. Caputo*

The maintenance of historic iron and steel structures: repair techniques  
*G.G. Nieuwmeijer & G.J. Arends*

Setting of the restoration project for durability  
*A. Guida, F. Fatiguso & I. Mecca*

The influence of the boundary conditions in rising damp in historical constructions  
*V.P. Freitas & M.I.M. Torres*

World heritage in odd shoes: Reconstruction of the central building of the Budapest University of Technology and Economics  
*M. Armuth & Gy. Visnovitz*

Pultruded composite shear spike for repair of timber members  
*D. Radford, R. Gutkowski, D. Van Goethem & M. Peterson*

Roots and buildings  
*C. Mattheck, I. Tesari & K. Bethge*

Building maintenance: a re-discovered culture  
*C. Bertolini Cestari*

The reactivation of a historic shaft-building  
*S. Niederhagemann*

**Section 11: Material Problems**

The effect of aggregate composition on physical and mechanical characteristics of repair mortars  
*P. Manita & T.C. Triantafillou*
Flexural bearing capacity and related ductility demand for masonry sections under nonlinear constitutive law
C. Cucchiarra, L. La Mendola & M. Papia

Section 12: Timber Construction

Behaviour and rehabilitation of queen post timber trusses: A case study
M. del Senno & M. Piazza

In-situ evaluation of timber roof structures of historic buildings

Inspection of timber construction by measuring drilling resistance using Resistograph F300-S
R. Kappel & C. Mattheck

Semi-destructive methods for evaluation of timber structures
B. Kasal, M. Drdacky & I. Jirovsky

Index of Authors