

# **Structural Design in Building Conservation**

**Dimitris Theodossopoulos**

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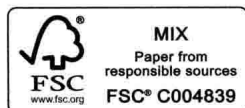
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# Structural Design in Building Conservation

No building is properly conserved if it is not structurally sound. Consequently architects, engineers and conservation officers need an adequate grounding in the technology as well as in the materials and the historic origins of the building.

Structural interventions to historic buildings are however an integral part of the effort to select and update their design and their historic and cultural values. *Structural Design in Building Conservation* deals with such design issues and shows how technical choices integrate with the planning and architectural outcomes in a conservation project. It brings together theory with current conservation technology, discussing the possibilities of structural details and strategies in architectural expression, and is particularly directed at students of architectural conservation technology and practising engineers and architects.

Central to this outline is the discussion of case studies, which is organised around such themes as addition of roofs, requalification of space, strengthening and re-use of fabric, repristination, additions, completions, stiffness adjustments and the correction of past mistakes etc, and the reader is encouraged to appraise directly the solutions.

The book introduces the philosophy of structural interventions within the range of conservation theories and discusses practices in various European countries. It then outlines the main types of strengthening, repairs and interventions in terms of building types and the structural nature of the main elements to be strengthened (linear structures, frames, plates and shells). Significant case studies are presented that cover a very wide range of historic types and conversions, not only monumental masonry structures like neoclassical buildings, major temples, churches, public buildings and museums, but also more utilitarian structures like historic mills, early reinforced concrete structures and vaulting types.

**Dimitris Theodossopoulos** is Lecturer in Architectural Technology and Conservation at the University of Edinburgh, UK. He trained as a civil engineer and is a specialist in architectural conservation.

# Preface

This book aims to introduce the reader to the structural issues and the process of making choices involved in major design interventions to historic architecture, so these are addressed to architects, engineers or conservation practitioners at the early stages of their careers or later stages of their education. The discussion moves beyond the conservation of the building fabric or archaeological evidence towards those projects that seek to present or update the historic and cultural values of these buildings, even by providing new uses or new space configurations. This often appears as removal and alteration of existing fabric or addition of new elements, but in truth the discussion is about those critical acts that permit the understanding of building fabric with historic, artistic or cultural values and the transmission of these values to this and future generations.

Education is fundamental in this sector as only a limited amount can be learned through practice and the learning experience of taking a course permits the right focus and eventually creates the sensitivity such buildings require. The need for such a book became evident to me through my teaching at undergraduate and postgraduate levels in architecture and structural engineering, especially in design projects and dissertations. Because of the syllabus, it is inevitable that the essential steps in dealing with existing fabric (historic construction technology and its culture, conservation theory, building survey, historiography, specialist legislation and management practice) are covered only briefly. But, often, even in specialist courses there is limited time for these essential steps to link with the more complex process of decision-making and explorations that design in historic buildings requires. The range of projects presented is expected to demonstrate that conservation goes far beyond a linear application of techniques or the repristination of a specific past configuration.

In this process of integration to increasing complexity, it is necessary to review initially the range of interventions that usually affect historic buildings, including even those that have disregarded their historic, artistic and architectural values. This discussion is supported by an outline of conservation theories that focus on the treatment of the fabric as a source of historic or artistic evidence. No attempt has been made to offer definitions or discuss the differences between them (preservation, conservation, retro-

## Preface

Gifford in England, Buro Happold and, in particular, Iain Hargreaves in their Edinburgh office, Prof. Andrea Bruno in Turin.

Knowledge of a wide range of case studies became possible by the enthusiastic help of Margarita Escotet, the librarian of the Colegio Oficial de Arquitectos de Asturias COAA in Oviedo, as well as the valuable discussions of both design and professional aspects, and generous permissions by the technical magazines *Architects' Journal*, *New Civil Engineer* and *Structural Engineer*. The libraries at the School of Architecture (ETSAM) and the Colegio de Ingenieros CICCIP, both in Madrid, are also warmly thanked for their support and the very useful recording of architecture and engineering history in their collections.

Access to some key monuments became possible with the generous support of many state agencies, particularly the Soprintendenza Archeologica di Roma and ΤΑΠΑ (Hellenic Archaeological Receipts Fund).

A significant number of the issues presented here have been either tested in my lectures or explored through teaching models and some of my students in Edinburgh who made particular contributions need to be thanked, including Adam Neep, Laura Barr, Lee Kynoch, Emma Garland, Shona Black, Melinda Jin, Weifeng Kong, Lynne Mackay, Marietta Galazka, Alexandra Kuklinski, Jamie Henry and Xuhong Zheng. Our work would not have been possible without the innovative and enthusiastic support of our technicians Alistair Craig, Malcolm Cruickshank and Rachel Travers. Special thanks to my friend Andy Jones for his invaluable help with my original structural models for the vaults in Holyrood Abbey.

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Finally, I offer the most important thanks to my wife Cristina González-Longo, an architect and teacher also specialising in conservation. Without her love, patience, sacrifice, insight from professional practice, critical eye, personal encouragement and faith in my project this book would not have been possible. I also hope the book can transmit some of the balanced and measured approach to things that my parents gave me through their love and education.

Greece, my country of origin, and Spain, where my wife Cristina comes from (especially the North, Asturias and its capital Oviedo). Many other examples also come from Nottingham and Edinburgh where I have developed my academic career.

## Thanks

Appreciation of these issues throughout my work could not have been possible without the essential education from my professors in the field, and in particular those in the Sapienza in Rome, Professor Giorgio Croci, Professor Giovanni Carbonara and Dr Alberto Viskovic, as well as Prof. Dionysios Veras in Patras. They have all been inspirational figures as educators, critics and professionals in the field. My supervisors in my PhD in Edinburgh (Prof. Braj Sinha, Prof. Asif Usmani and Prof. Angus Macdonald) are also warmly acknowledged for helping me set my enthusiasm for historic structures in a truly scientific context.

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My work in the field as well as the preparation of the book put me in contact or collaboration with some unique operators in Edinburgh, including Ted Ruddock, Bob Heath, John Addison and Douglas Johnston, and in England, such as Poul Beckmann and James Sutherland. I have to acknowledge my inspiration from Prof. Charles McKean at Dundee University and, in particular, a lecture where he discussed the intervention at Koldinghus Castle, maybe this whole book started indirectly from that point. Special mention should be made to my friends in Nottingham Civic Society, Hilary Silvester and Ian Wells, for their unique insight into conservation problems in the area and for introducing my wife and me to some incredible sites.

The preparation of the book was also an opportunity to get to know better some projects and the work of some exceptional European architects and engineers such as Angela Garcia de Paredes in Madrid, Francisco Partearroyo and his team in Arquimatica also in Madrid, Inger and Johannes Exner in Denmark, form-TL in Germany, GMP von Gerkan Marg und Partner in Hamburg, Estudio Primitivo Gonzalez in Valladolid, Geoff Clifton and

## Preface

represent the aspirations and attitudes of the community and they have not only to capture the values the building or monument represents for them, but also to express them through the intervention in a clear and sustainable manner and transmit them to future generations. The designer, therefore, needs a genuine confidence that only the knowledge of the monument and its conditions can provide, backed by a will to actively look for adequate solutions. It is the aim of this book to promote the development of such skills by highlighting the challenges and the successful, or not so successful, battles of designers and their relationships with the essence of the material in their hands.

I hope the reader will place this book within other efforts to inspire designers to develop their own critical and dialectic approach to historic buildings, with respect to their design characteristics and history of human interactions with them. Past books on the subject, such as those by S. Cantacuzino (1975), C. Schittich (2003), Cramer and Breitling (2007), or the carefully illustrated and compiled *Atlante del Restauro* by my professor, G. Carbonara (2005), have opened the way towards a synthesis of all the disciplines around conservation and the reader is strongly encouraged to read this book as a continuity of those efforts.

Similarly, there are textbooks that deal with the technical issues in much more depth than the space of this book permits (Beckmann and Bowles 2004; Croci 1998, 2001; Robson 1999; Forsyth 2007a, 2007b; Alvarez and Gonzalez 1994; CIRIA 1994; Ashurst 1998; etc.), and the design potential of the techniques described there is explored in the chapters that offer introduction to the case studies. These are summarised in Chapter 3 and the presentation highlights what I believe, from my own experience, an engineer or architect who starts in conservation needs to know. At the same time, the discussion of structural issues revolves around contemporary debates which recognise the stronger inter-relationship with environmental performance, the increased sensitivity of regulations to disproportionate collapse and fire, the links with materiality, a balanced functionalism and, essentially, a clear expression of the role of structure in the character of a building.

Access to Italian, Spanish and Greek sources, I hope, is a great benefit for the reader and not a limitation. It has often been a problem in my teaching to refer to examples with an advanced theoretical or technical approach that are not easily available in the English language. I hope to use in the future more examples from Germany, the Americas or China that can enrich the cultural context of designing with historic fabric (Stubbs *et al.* 2011). It is inevitable, however, that I should draw many examples from Italy, and specifically Rome, as through my studies there I became familiar with the rich stratification and cultural interactions of the monuments and sites there. It is essential for anyone who starts working in this field to engage with such strong examples as they highlight complexity but also the wide range of choices in their conservation, by operators from these and past generations. It is also inevitable that many other examples come from



fitting, etc.), but some terms that I find pointless or offensive to a historic building, such as adaptive reuse, are omitted altogether. Rather than providing stiff definitions or a prescriptive approach, theories, regulations and charters are discussed as the cultural luggage of the operator who then has to make the critical decisions on the integration of the new intervention with the character of the building.

Current theory of structures and mechanics cannot, of course, apply to historic fabric in the same precise manner as in the design of modern buildings, but designers often work in the preliminary design of a structure using conceptual schemes of behaviour. Classifications to building types were deemed necessary here as well (cellular vs. frame structures, vaults, etc.), as also was the study of their behaviour with regards to standardised actions (dead load, wind, earthquake) where the performance of the new interventions needs to be certified. Assessment of the behaviour of the existing building has also specific needs within this context which need to be highlighted as part of the preparation process.

It is often the case that incorporating a new structure requires strengthening or upgrading of the load-bearing capacity of the existing structure or specific ways of linking their performance or completely detaching them. A range of techniques is briefly presented that are relevant to the problems.

The contribution of this book is in highlighting how these essential steps build towards a critical dialogue and updating of historic architecture to values that can be shared among generations. A range of design interventions has been selected in Chapter 6 according to the most frequently encountered structural problems, which often do not correspond directly to the architectural priorities. On the contrary, the case studies may have a strong component of structural resolution that has affected the architectural choices, either through preservation or enhancement of the building or site. In this key part of the book, the applications of the more theoretical earlier chapters become evident as does the process where the needs of the existing fabric are innovatively treated or combined with those of the proposed one.

Each area is introduced with a summary of the technical issues and the way they often affect the design procedure. A major case study is then examined in more detail following an outline that encourages the readers to understand the options available to the designers and validate the solutions: the historic and material conditions of the existing fabric are presented in terms of the design intentions and the possible strategies are discussed, guiding the reader to evaluate the actual solution through alternatives or critical enquiry.

I believe this is a fundamental approach towards the design of the most respectful yet architecturally successful intervention to a historic building. The designers, architect or engineer, work in liaison with the client, contractors and regulatory authorities and have a professional role to balance their needs and abilities in order to deliver their design. They also

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## Chapter 1

# Theoretical aspects of structural interventions

Many of the approaches that are represented by the areas of intervention discussed in this book clearly stem from a specific necessity (create a new enclosed space, strengthen a ruin, remove internal supports). Other interventions have to do with the preservation and presentation of the fabric and fall into clearer definitions of conservation. The key question in such projects is always 'what to conserve' and the answer does not always have to do with the building matter itself.

Whatever its scale or scope, an intervention starts eventually as a critical act of a similar nature to design (Bonelli 1963), which weighs the values the historic building will carry forward, resulting in their more fruitful integration in the project and a richer interrogation. Reflection on current conservation theories, therefore, is necessary at the decision-making process and widens the range of choices. Study of their evolution and application to structural design in this chapter will search the synthesis of the purely architectural aspects with the strictly materialistic ones, attempting a sketch of a theory pertinent to building fabric and structural issues. Compared to architectural design, structural design and technical advancements have followed different rhythms and processes throughout history (Ousterhout 2008), which may result in different, or even conflicting, values to be conserved. Similarly, the structural project might have very different priorities, e.g. an addition or removal could cause disproportionate complex interactions with other parts of the building.

However, it should become clear that emphasis on the structural aspects has to do mainly with professional divisions of the discipline or specific design or construction skills rather than a different conceptual approach. Structure occasionally contains prevailing values of its own (Charleson 2005) but this should not divert from the fact that it is an integral part of the architectural organism and, even at its most utilitarian aspect (public infrastructure like viaducts or dams), it is an essential part of our built environment.

This review will also show that, at least in Europe, philosophy and practice also differ between countries. This makes even the regulatory, professional and educational framework quite variable in scope or its ability

to create or regulate conservation professionals, so it is worth summarising the most interesting currents.

### 1.1 Conservation and design

Most valuable architectural conservation theories try to reconcile two key aspects: how to define the original values of the building and how to make them relevant to present and future generations, through a design approach which recognises and composes the complex issues and the operators. Of course, intervention to pre-existing buildings is something that has always happened, in a similar range of approaches to today's (such as the gradual substitution of timber columns with poros ones at the temple of Hera in Olympia; mannerist and Baroque transformations of medieval churches in Rome; or conversion of abbeys into stately homes in Britain).

The key stages presented in this section still inform the debate today and they are discussed as a spectrum of attitudes to building fabric by restorers and designers rather than a historic overview. Conscious efforts to establish an operative attitude towards historic fabric in the form of a conservation theory developed in parallel with the emergence of modern architecture and technology in the nineteenth century, either as a consequence (E. Viollet-le-Duc) or reaction (John Ruskin). The stylistic approach of the former (referred to as *restauro stilistico* in Italian) aims to re-create a formal unity and was expressed in an arbitrary re-introduction of styles and idioms, as in the case of Carcassonne, or the restoration of cathedrals, while he was also an advocate of the prominent use of modern materials such as steel. His philosophy often resulted in extensive new fabric being added, which imitated the original tectonics and made a selective use of contemporary techniques, as was the case in the long restoration of the Olite Palace (Fig. 1.1), destroyed in 1813 (Yáñez and Yáñez 1925; Gil Cornet 2004).

J. Ruskin, with his strongly moral, almost obsessive quest for authenticity, influenced a wide range of thinkers and architects (such as the Society for the Protection of Ancient Buildings (SPAB) in England) with an anthropomorphic approach, which sees historic buildings as living organisms with a life and the right to die. Repair, rather than restoration, which often 'freezes' fabric in a worn-out state instead of substituting new, is actively promoted, as in the case of St Giles in Holme (Fig. 1.2; see also Truman (1946)).

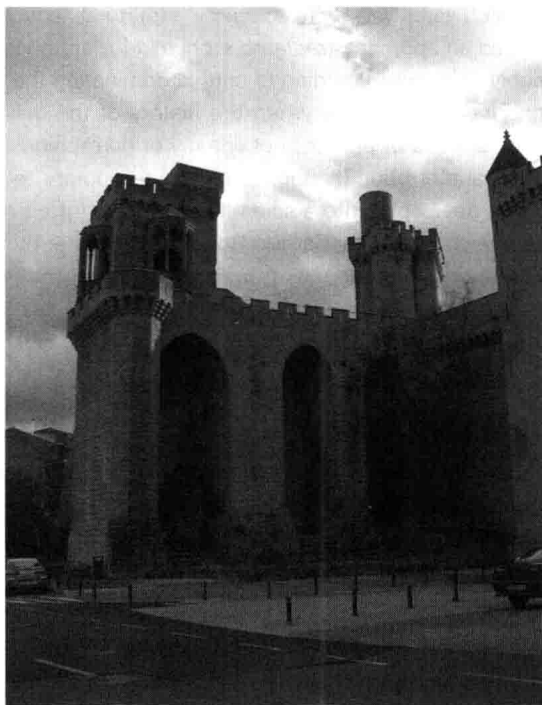
These two attitudes often polarised the argument away from the true values of buildings, which are seen as a composition of elements that simply can be either stylistically recomposed or left untouched. The simplistic common origin of both attitudes ignores the technically rich and culturally complex process of design as well as the historic processes buildings are subject to in their life cycle. This historic dimension, on the other hand, can have a disproportionately large influence on various national policies.

When emphasis is strictly on a monument's capacity as a document, conservation will try to be as factual as possible, based on extensive



**1.1**

A purely stylistic approach in the reconstruction of Palacio Real de Olite, Spain, by José and Javier Yáñez Larrosa, 1937–66



**1.2**

St Giles church in Holme, outside Newark, Nottinghamshire, restored in 1932 by K. Harley-Smith according to SPAB principles

