Chapter 28

Performance of a Post-Byzantine Triple-Domed Basilica under Near and Far Fault Seismic Loads: Analysis and Intervention

Constantine C. Spyarakos  
National Technical University of Athens, Greece

Charilaos A. Maniatakis  
National Technical University of Athens, Greece

Panagiotis Kiriakopoulos  
National Technical University of Athens, Greece

Alessio Franciosi  
National Technical University of Athens, Greece

Ioannis M. Taflampas  
National Technical University of Athens, Greece

ABSTRACT

In this Chapter a triple-domed basilica constructed at the end of the 19th century is selected as a case study to present a methodology for the selection of the appropriate intervention techniques in monumental structures. The methodology includes in-situ and laboratory testing, application of analytical methods, consideration of geotechnical parameters and regional seismicity. Seismic loads are estimated according to contemporary and older concepts for seismic design. Since the impact of near-fault phenomena on masonry structures has not been thoroughly studied, although considered as responsible for extensive structural damage during major seismic events, a procedure is presented in order to account for the special characteristics of strong ground motion, in the so-called near-fault region. The seismic performance of the structure before and after interventions, using traditional and new technology, is assessed by applying a validated finite element model. Also, the out-of-plane behavior of structural parts is evaluated through kinematic analysis of selective collapse mechanisms.

DOI: 10.4018/978-1-4666-8286-3.ch028
1. INTRODUCTION

During the last two decades there is an increased interest on the maintenance of cultural heritage structures including monuments and historic buildings (Tassios, 2010). The willingness to protect cultural heritage is not exclusively an invention of our times; however, from the perspective of structural engineers there is a number of contemporary parameters that affect their contribution towards this effort.

The most important parameters could be considered the evolution of computational methods, instrumentation for non-destructive evaluation and new materials. Complicated analyses that would demand a vast computational cost a decade ago, nowadays may easily be performed (Spyrakos, 1995; Spyrakos & Raftoyiannis, 1997). New and more accurate instrumentation has allowed the collection of data with less intrusive approaches; thus, allowing the justification to use more elaborate analytical methods and smaller safety factors. The availability of this technology allows for a more scientific and rational application of rehabilitation techniques. Furthermore, new materials are available, including fiber reinforced composites, which may provide solutions in difficult retrofit and strengthening problems. The need to use these materials in monumental structures arises from the limitations that do not allow extended modification in the inertia and/or stiffness characteristics of the overall structure, which may be mandatory with standard retrofit methods. Also, composite materials when properly applied quarantine durability and strength. The production technology and our understanding on the methods of their application continuously grow (Oliveira & Lourenço, 2006; Credali & Ussia, 2011; Spyrakos et al. 2011; Spyrakos et al. 2013).

The process of the overall restoration of a monumental structure requires an understanding of its structural system and behavior; a knowledge that can be obtained from an accurate determination of the stress and deformation distribution of the initial structure and the structure after the intervention. Current technology allows the use of complex and detailed analysis based on a detailed model, as a rule a finite element model, of the structure. An additional parameter that complicates the rehabilitation procedure is that, unlike modern structures, interventions on monuments are subject to restrictions resulting from national standards and international regulations; thus, a retrofit scheme should be not only technically feasible but also acceptable according to such limitations (Spyrakos 2015).

The necessity to protect structures of cultural significance has emerged by the fact that many of them have been constructed with no seismic regulations. Their design has been based on the experience of architects and construction techniques following concepts for seismic design available at the time of construction. As many of them are located in earthquake prone areas, such as the Mediterranean basin, not only they are characterized by significant seismic risk but in many cases they have already suffered damage from seismic activity. This reality has led to the establishment of provisions for the seismic strengthening of monuments (Decreto Del Presidente del Consiglio dei Ministri, 2011; Consiglio Superiore dei Lavori Pubblici 2009; Earthquake Planning Protection Organization, 2011).

Additionally, new findings in Engineering Seismology that derived mainly after the great earthquakes in Northridge, USA 1994 and Kobe, Japan 1995 have enriched our knowledge on strong ground motion characteristics at small distances from active faults, in the so-called “near-fault area” (Somerville et al. 1997). These special characteristics, yet not sufficiently accounted for in several seismic regulations, should be definitely considered in design in order to reduce damages in the near fault area (Spyrakos et al. 2008; Spyrakos et al. 2015).