SEISMIC RISK ASSESSMENT AS A BASIS FOR SUSTAINABLE URBAN DEVELOPMENT

BALKAN UNIVERSITY PRESS

Title: Seismic Risk Assessment as a Basis for Sustainable Urban Development

Author: Kefajet Edip

Edition: 1st Edition

No. of Publication: 43

Name of Book Series: Academic Research

Book Series Editors: Snezana Bilic; Emin Idrizi

No. of Publication in Book Series: 3

Print: Arberia Design

Circulation: 100

Design: Seyfullah Bayram

ISBN: 978-608-4868-41-5

DOI: https://doi.org//10.69648/YKET1326

This edition is published by the Balkan University Press in Skopje, North Macedonia, 2024.

Balkan University Press

Makedonsko Kosovska Brigada, Skopje 1000

Balkan University Press is a brand of the International Balkan University.

SEISMIC RISK ASSESSMENT AS A BASIS FOR SUSTAINABLE URBAN DEVELOPMENT

Kefajet Edip

BUP BALKAN UNIVERSITY PRESS

I dedicate this book
to my mother Bahtisha Edip, dipl. ing. architect
and to my father Jusuf Edip, dipl. ing. architect,
with love and respect.

Contents

List of Abbreviations

GIS	Geographic Information System
GUP	General Urban Plan
DUP	Detailed Urban Plan
LUP	Local Urban Plan
PIOVS 81	Technical Regulations for Design and Construction of Buildings in Seismic regions, 1981
SUP	Special Urban Plan
AL	Alluvial ingredients
BSHAP	Harmonized Seismic Hazard Maps for the Western Balkan Countries
csv	Comma separated value
DAF	Dynamic Amplification Factor
DS	Damage State
ESHM20	European Seismic Hazard Model 2020
ESRM20	European Seismic Risk Model 2020
FEMA	Federal Emergency Management Agency
GEM	Global Earthquake Model

GPS	Global Positioning System
GSIM	Ground motion prediction equation
Lat	Latitude
Lon	Longitude
MPI	Mio-Pliocene sediments
Mw	Magnitude
NEHRP	National Earthquake Hazards Reduction Program
NRML	Natural Hazard Risk Markup Language
PGA	Peak Ground Acceleration
poes	Probabilities of exceedance
PSHA	Probabilistic Seismic Hazard Analysis
Sa	Spectral acceleration
SHMA	Seismic Hazards Mapping Act
VMTK	Vulnerability Modelers' Toolkit
Vp	Velocity of primary seismic waves
Vs	Velocity of shear seismic waves
XML	Extensible Markup Language

Figures and Tables

Figures

Tables

Acknowledgments

Hereby I would like to acknowledge that this book is based on my doctoral dissertation titled “Seismic Risk Assessment as a Basis for Sustainable Urban Development” (Edip, 2023). I completed my doctoral dissertation under the supervision of Prof. d-r. Roberta Apostolska at the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) at Ss. “Cyril and Methodius” University in Skopje. I am very grateful to my supervisor for her dedicated work and support throughout my doctoral studies. Also, I would like to extend my gratitude to all professors who did the evaluation of my doctoral dissertation. The committee members were: Prof. d-r. Roberta Apostolska (supervisor), prof. d-r. Veronika Shendova (member), assoc. prof. d-r. Radmila Salik-Makreska (president of the committee), assoc. prof. d-r. Julijana Bojadzieva (member), all four of them from IZIIS, and prof. d-r. Divna Pencic (member) from the Faculty of Architecture at Ss. Cyril and Methodius University.

Thank you,
Skopje, October, 2024
Kefajet Edip, PhD.

Preface

Contemporary urban planning aims to achieve the goals of sustainable development, among which the main goal is the mitigation of risks from natural disasters. However, rapid urbanization is pressurizing urban planning, which makes it difficult to implement the principles of sustainable development in urban planning. Many human settlements have developed in territories exposed to one or multiple natural hazards. Earthquakes are considered to be the most devastating natural phenomena especially when they happen in densely populated and vulnerable urban environments.

The research topic of this book, which is based on the author's doctoral dissertation, is the assessment of seismic risk in urban environments as a basis for sustainable urban development. The seismic safety of the built environment relies on the buildings designed and constructed according to valid seismic design codes. However, the urban tissue of cities also consists of buildings built in different periods, before and after the introduction of seismic design codes, and as a result of different types of reconstructions and adaptations, it has a dynamic character. Buildings constructed before the introduction of seismic design codes have unknown levels of seismic safety, which implies that urban environments are vulnerable to seismic risk.

Also, in this book, through a review of the urban planning practices in some earthquake-prone countries, an introductory analysis was done to define the existing role of urban planning in the mitigation of seismic risk.

A pilot study in the Municipality of Karposh in Skopje was selected with the purpose of defining the level of seismic risk and identifying the urban parameters that have an influence on the seismic risk. Skopje is a territory with relatively high seismicity. The earthquake in 1963 was the greatest natural catastrophe in the history of the city and, at the same time, was the beginning of the construction of modern Skopje.

For the seismic risk assessment of the pilot study in the first place, the components of risk, hazard, exposure, and vulnerability, were defined. The seismic hazard was defined using both deterministic and probabilistic approaches. Seismic hazard information was based on ESHM20 (Danciu et al., 2021). In the deterministic approach, two scenario earthquakes were selected: a Mw 6.6 earthquake at 10 km and an earthquake with Mw 7.1 at a 100 km radius distance from the pilot study area. Within the probabilistic seismic hazard analysis approaches, the intensity of ground shaking was defined for two return periods, 95 and 475 years. The local site conditions of the pilot study area were defined in accordance with data from the soil study carried out by IZIIS (Dojcinovski et al., 2013) and regional site parameters available in ESRM20 (Crowley et al., 2021).

The exposure model was prepared for two urban scenarios: the existing (scenario 1) and the planned site (scenario 2). The existing site building stock information was based on previous studies carried out by IZIIS (Necevska-Cvetanovska et al., 2013; Apostolska et al., 2018). The planned site was based on the Detailed Urban Plan (Tajfa Plan, 2015). Taxonomy consisting of attributes such as construction period (seismic design code level), material and type of structural systems, the height of the building, plan shape of the building, and position of the building in the urban block was defined for each entity from the exposure models of scenarios 1 and 2.

According to the construction period, the building stock was classified into three periods: prior to 1964 (no seismic design codes were applied), between 1964 and 1981 (designed according to the first seismic design code), and after 1981 (designed according to the current seismic design code). Regarding the material and type of structural systems, there are buildings with reinforced concrete moment frame structures, reinforced concrete infilled frame structures, reinforced concrete dual frame-wall system structures, confined masonry structures, and unreinforced masonry structures. In both scenarios, there are buildings with mixed structural systems, which are the result of structural interventions made on existing buildings, such as expanding the floor area and adding stories. The structural interventions in some buildings were made by using expansion joints, while in others, the structural interventions were applied directly to the original structure.

The vulnerability model was formulated by selecting existing vulnerability curves from the ESRM20 (Crowley et al., 2021) in accordance with the taxonomy of the entities present in the exposure models for scenarios 1 and 2.

The seismic risk assessment for the two urban scenarios of the pilot study was done by using the program Open Quake Engine 3.13 (GEM, 2022). Based on the approach of analyzing seismic hazard, deterministic and probabilistic, the Scenario earthquake and Classical Probabilistic calculators were used. The results obtained from seismic risk assessment were presented for different damage levels in correlation with taxonomy, construction period, and selected urban planning parameters. Also, damage distribution maps were generated in QGIS 3.14 (QGIS team, 2020). The probability of economic and life losses obtained from the Classical Probabilistic calculator was analyzed as well. As was expected, in general terms, the greatest damage appears at buildings with masonry structures constructed before the introduction of the first seismic design codes of 1964, and this type of structure is mostly present in the exposure model of urban scenario 1.

Based on the conducted research, the following general conclusions can be made:

- In urban planning, seismic hazards are taken into account, but seismic risks are not considered.
- Some urban planning parameters, such as the height of the building, position in the urban block, plan

shape, and occupancy type, create a base for the formulation of irregular architectural configurations. If the seismic risk is not considered the noncritical use of these urban parameters can give way to increased damage when an earthquake hits.

- In urban plans aiming at the existing urban settlements, urban parameters that control the growth of the built environment do not clearly define the status of the existing buildings from the construction aspect. Whether the increased floor area means demolishing the existing and rebuilding a new building, or the existing building remains as it is and additional floor area and stories are added to is not stated in the urban plan. Allowing the addition of floor areas and stories to existing buildings creates mixed structures with unknown levels of seismic safety.
- In the existing National practice and regulations of urban planning, there is no methodology that treats seismic risk in existing urban districts.
- In this research, based on the doctoral dissertation of the author, in accordance with the newest research in the world, a methodology for seismic risk assessment and defining the role and importance of selected urban parameters in the structural response of buildings was successfully implemented on the pilot study, the urban settlement in the Municipality of Karposh.

The methodology for seismic risk assessment and defining the role of selected urban parameters in the structural response of buildings conducted in the doctoral dissertation can be used as an instrument for urban planners in the preparation of urban plans and at the same time support the city authorities in the processes of decision making and building seismically safe and sustainable urban environments.

Kefajet Edip

CHAPTER 1

Seismic Risk Assessment as a Basis for Sustainable Urban Development

Introduction

Although, in the last few decades, disaster prevention has become part of the spatial planning approaches, the integration of risk assessment into the process of spatial planning is not completely realized yet. The importance of spatial planning in reducing vulnerability of cities to different types of hazards, including seismic hazard, is highly emphasized.

In urban settlements where there is high density of population, seismically vulnerable buildings and infrastructure, an earthquake can cause a disaster. Seismically active regions are home to many cities, and the building stock of these cities consists of buildings constructed in different periods, before and after the adoption of the seismic design codes, which can cause an increase in seismic risk. In some of the European countries exposed to earthquakes, such as Greece, Italy, Poland, and Spain, the urban planning practice refers to the hazard factor while