

EARTHQUAKE-RESISTANT CONFINED MASONRY CONSTRUCTION

THIRD EDITION

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**NATIONAL INFORMATION CENTRE OF EARTHQUAKE ENGINEERING
Indian Institute of Technology Kanpur
Kanpur (India)**

2018

Cover photo: The photographs on the cover page show confined masonry construction at the IIT Gandhinagar Campus at Palaj, Gujarat, India.

This is the third edition of the publication. Previous editions were published in 2007 and 2008 by NICEE.

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Development of this book was supported by the Building Materials and Technology Promotion Council (BMTPC), New Delhi, Indian Institute of Technology Gandhinagar (IITGN), and the National Information Centre of Earthquake Engineering (NICEE) at Indian Institute of Technology Kanpur, India. The views and opinions expressed in this book are those of the authors and not necessarily of BMTPC, IITGN or NICEE.

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ISBN 978-93-80903-06-4

FOREWORD TO THE THIRD EDITION

It has been more than a decade since the first edition of *Earthquake-Resistant Confined Masonry Construction* presented readers with an extremely friendly exposition of a new building typology with the required technical details. The popular acceptance of the original English text led to its Hindi translation in 2012. A step-by-step construction guidebook with easily understandable drawings was also published in both English and Hindi languages to ensure accurate on-site implementation. Both these publications were well received and have helped to promote confined masonry construction for earthquake resistance.

Confined masonry has been in use for more than a century mostly through informal process. However, it is only in the recent years with the development of technical details and proper documentation, it is breaking into modern building construction as a preferred alternative to low-rise RC buildings. Many concerns of Indian engineers and contractors have been addressed during the first large-scale successful application of confined masonry construction for the student hostels and faculty/staff housing at IIT Gandhinagar campus. We hope this project will be instrumental in popularizing confined masonry in the country.

NICEE is immensely grateful to Profs. Svetlana Brzev and Keya Mitra for undertaking the challenge of rewriting and expanding this monograph. Both Profs. Brzev and Mitra were intimately associated with IIT Gandhinagar project from the architectural/functional planning to final construction stages and this new edition has significantly benefitted from their first-hand experience. We extend our sincere thanks to Prof. Sudhir K. Jain for providing leadership not only to pioneering IIT Gandhinagar project but also to the publication of this monograph.

We thank our readers for the interest they have shown for Confined Masonry publications in previous years and we hope that this expanded edition will be more useful to our readers. We welcome your comments and suggestions; please write to us at nicee@iitk.ac.in

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FOREWORD TO THE FIRST EDITION

The vulnerability of Indian constructions in the past earthquakes has been amply demonstrated by the recent damaging earthquakes. These include not only the non-engineered constructions carried out by the common man, but also many “engineered” buildings. Addressing this problem requires simultaneous work on several fronts. On one hand, we need to ensure that more and more constructions comply with the design and construction requirements of the building codes. On the other hand, we need to develop and propagate construction typologies that are inherently better in responding to earthquakes.

Construction typologies differ from place to place for various reasons, including availability of local materials and skills, climatic conditions, living habits and traditions. There have been successful interventions in the Indian sub-continent towards introducing construction typologies that resist earthquakes better. For instance, after the 1897 Assam earthquake in India, a new Assam Type Housing was developed that became prevalent in the entire north-eastern India. Similarly, after the devastating 1935 earthquake in Quetta (Baluchistan), a new type of masonry (Quetta Bond) was evolved. It is in this context, that the National Programme on Earthquake Engineering Education (NPEEE) and the National Information Centre of Earthquake Engineering (NICEE) are pleased to offer this outstanding publication by Dr Svetlana Brzev on “Earthquake-Resistant Confined Masonry Construction”.

Most houses of up to four storeys in India are built of burnt clay brick masonry with reinforced concrete slabs. Depending on the building and the seismic zone of its location, certain earthquake resistant features are required in such buildings as per the Indian codes, e.g., the lintel band, corner reinforcement, etc. However, such aseismic features are often not provided in the buildings due to a variety of reasons. On the other hand, a number of such buildings in the urban areas now tend to include a number of small reinforced concrete columns. One could combine these building elements into a rational structural system of “confined masonry” which will have far better earthquake performance.

Similarly, many new four or five storey “reinforced concrete frame” buildings being constructed in small and large towns lack a proper frame system, and either do not undergo formal structural engineering or undergo inappropriate structural engineering. Most of the 130 multi-storey apartment buildings that collapsed in Ahmedabad in the 2001 earthquake fall in this category. Again, it should be possible to construct such apartment buildings in confined masonry without incurring additional costs and without having to go for newer building materials.

It is hoped that this monograph will help sensitizing and educating the building professionals in India and elsewhere about the excellent features of confined masonry. We are thankful to Dr Svetlana Brzev who spent several weeks in winter 2005 at IIT Kanpur to develop first draft of this monograph under the sponsorship of the NPEEE. Her commitment and enthusiasm, as well as support from several colleagues, were critical for publication of this monograph in the present form. The initial funding from NPEEE for visit of Dr Brzev to IIT Kanpur, and the support of numerous donors of NICEE are gratefully acknowledged.

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PREFACE

This book is written for building professionals interested in learning more about confined masonry (CM) construction and for those who would like to promote its application in India. In many developing countries such as India, a significant death toll during earthquakes is caused by poor performance of unreinforced masonry (URM) buildings, and inadequately designed and poorly constructed reinforced concrete (RC) buildings that are highly vulnerable to strong ground shaking. In India and many other countries, URM and RC are the technologies of choice for housing construction, with the design applications ranging from one-storey family houses to multi-storey apartment buildings. Over the last 100 years, CM construction has emerged as a building technology that offers an alternative to both URM and RC frame construction in countries and regions of extremely high seismic risk. This book is part of an initiative launched in India to promote CM construction based on its proven record of good seismic performance.

That CM construction looks similar to RC frame construction with masonry infills and that it uses the same components of masonry walls and RC confining members are two facts expected to assist in an easy transition from the construction perspective. CM construction practice does not require new or advanced construction skills or equipment, but it is important to emphasize that quality construction and sound detailing are critical for its satisfactory earthquake performance.

Based on its proven record of good seismic performance in other countries, a few initiatives have been launched to promote CM construction in India. As a result of these initiatives, the first large scale application of modern CM construction in India was recently completed on the permanent Palaj, Gandhinagar, campus of the Indian Institute of Technology Gandhinagar (IITGN). To create awareness and promote application of CM in the Indian subcontinent, several publications have been developed and published in India, mostly through the National Information Centre of Earthquake Engineering (NICEE). This publication was originally authored by Svetlana Brzev as a monograph “Earthquake-Resistant Confined Masonry Construction”, published by NICEE in 2007. More than 3000 copies of the monograph were circulated in English and Hindi over the last 10 years.

This third edition has been significantly updated to provide a comprehensive overview of global advancements in CM in terms of construction practices, design, and research studies. This book contains nine chapters. Chapter 1 provides a brief overview of the seismic history of the Indian subcontinent vis-a-vis its seismotectonic profile and explains how buildings resist earthquakes. Chapters 2 to 4 discuss the main features of CM construction and how CM is different from RC frame construction. Factors that influence the performance of CM structures are introduced to assist the reader in understanding the important issues. Chapter 5 documents the performance of CM buildings in past earthquakes worldwide. Chapter 6 presents CM construction architectural design guidelines that highlight the key considerations for conceptual design of CM buildings and provide several recommendations for ensuring their seismic adequacy. Chapter 7 illustrates a simple method for checking whether a layout designed by the architect is suitable from the seismic design perspective. Though seismic design is primarily the responsibility of a structural engineer, the architect can perform a preliminary check to confirm that the proposed wall layout is likely to be

satisfactory. Two design case studies presented in this chapter illustrate how to perform these checks.

Since CM involves both masonry and RC construction, the importance of good practices related to the field execution of these two construction technologies cannot be overemphasized. It is expected that the readers are familiar with good practices related to masonry and RC construction, practices not covered in this monograph. Chapter 8 contains key recommendations related to the construction of CM buildings, showcasing model construction specifications for CM buildings.

CM construction has a great potential for saving lives and property in areas of high seismic risk in India. It is expected that the explanations of key concepts of seismic design and construction of CM buildings found in this book will be useful to building professionals and academics interested in learning more about this construction technology and in engaging in its design and construction.

Svetlana Brzev and Keya Mitra

ACKNOWLEDGMENTS

The first edition of this document was prepared during Svetlana Brzev's visit to the Civil Engineering Department of the Indian Institute of Technology Kanpur in December 2005. The visit was sponsored by the National Program for Earthquake Engineering Education (NPEEE). Professors Sudhir K. Jain, Durgesh C. Rai, and C.V.R. Murty provided invaluable support and encouragement in the course of this endeavour. The document was reviewed by Dr. Sergio Alcocer, Director, Institute of Engineering, National University of Mexico, UNAM, Mexico, Dr. Durgesh C. Rai, Professor, Civil Engineering Department, IIT Kanpur, India, and Mr. Andrew Charleson, Associate Professor, School of Architecture, Victoria University of Wellington, New Zealand. The second edition was published in 2008.

This third edition of the book has about 80% new content and the chapters have been expanded with many more examples of buildings, building damages and experimental outcomes for which the authors are grateful to a host of individuals and institutions who have allowed their material to be used for this book. This publication would not have been possible without the support of the Indian Institute of Technology Gandhinagar (IITGN), where Svetlana has been a Visiting Professor since 2014. This has enabled both collaboration between the authors, and broader communication with those interested in confined masonry in India. A grant by the Building Materials and Technology Promotion Council (BMTPC) for promotion of confined masonry as a building typology in India to Professor Sudhir K Jain provided some very helpful financial support. Special thanks are due to Dr Shailesh Agarwal, Executive Director, BMTPC New Delhi and to Prof Jain for their support and encouragement. The authors gratefully acknowledge assistance of Dr. T.S. Kumbar, IITGN Librarian and the Library staff for providing access to numerous international research publications.

The book was reviewed by structural engineer Andrew Charleson, Associate Professor, School of Architecture, Victoria University of Wellington, New Zealand, architect Vivek Rawal, People in Centre, of Ahmedabad, India, and structural engineer Hima Shrestha, NSET, Kathmandu, Nepal. The reviewers provided insightful and extremely useful review comments that we attempted to address, and in so doing, vastly improved the clarity and contents of the book. The authors also acknowledge valuable comments by Prof. Durgesh C Rai of IIT Kanpur and Mr. Anal Shah of N.K. Shah Consulting Engineers LLP, Ahmedabad, India.

Architect Narendranath Mitra, of SPACESCAPES Kolkata provided us with the case examples for which we are grateful. Shamik Sambit Chatterjee and Ayan Roy, students of the Department of Architecture, Town and Regional Planning, Indian Institute of Engineering Science and Technology, Shibpur created original illustrations. Architect Prithul Saha, M.Arch., CEPT University, Ahmedabad, created numerous illustrations and revised many of the original illustrations in response to comments from our reviewers. We are especially thankful to Prithul for his excellent work and for preparing InDesign layout of this book.

We thank Garrett Nicol, USA for patiently proofreading the manuscript and suggesting improvements on language and style. Marjorie Greene, USA advised us in finalizing the design and layout of the book drawing upon her vast experience in writing and editing

technical content, and we thank her for her help. Finally, we thank Suresh Ailawadi and the entire NICEE team under the stewardship of Prof.Durgesh C Rai, National Coordinator-NICEE for facilitating the printing of this book.

CREDITS

The authors gratefully acknowledge the following organizations and individuals that have kindly given permission to reproduce the photographs in this publication:

Earthquake Engineering Research Institute, USA
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Durgesh Rai, IIT Kanpur, India
Vikrant Jain, IIT Gandhinagar, India
Kiran Rangwani, M.Tech, IIT Gandhinagar, India
L.K. Bhargawa, CPWD, India
C.F. Porst, USA
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Maggie Ortiz, USA
Junwu Dai, PR China

Several photographs were reproduced from the World Housing Encyclopedia, an Internet-based project sponsored by the Earthquake Engineering Research Institute and the International Association for Earthquake Engineering (www.world-housing.net).

Special thanks are due the Earthquake Engineering Research Institute, USA for allowing us to incorporate graphics and text from the publication Seismic Design Guide for Low-Rise Confined Masonry Buildings by R. Meli, S. Brzev, M. Astroza, T. Boen, F. Crisafulli, J. Dai, M. Farsi, T. Hart, A. Mebarki, A.S. Moghadam, D. Quiun, M. Tomazevic, and L. Yamin.

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