

DAMAGE-ORIENTED DESIGN CRITERIA FOR EARTHQUAKE-RESISTANT CONCRETE STRUCTURES

vorgelegt von
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von der Fakultät VI – Planen Bauen Umwelt
der Technischen Universität Berlin
zur Erlangung des akademischen Grades

Doktorin der Ingenieurwissenschaften
- Dr.- Ing. -

genehmigte Dissertation

Promotionsausschuss:

Vorsitzender: Prof. Dr.- Ing. Wolfgang Huhnt
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2. Gutachter: Prof. Dr. Ahmet Saygun

Tag der wissenschaftlichen Aussprache: 14. November 2014

Berlin 2015

Heftreihe des Instituts für Bauingenieurwesen
Book Series of the Department of Civil Engineering
Technische Universität Berlin

Band 21

Nilay Çelik

**Damage-Oriented Design Criteria for
Earthquake-Resistant Concrete Structures**

D 83 (Diss. TU Berlin)

Shaker Verlag
Aachen 2015

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the internet at <http://dnb.d-nb.de>.

Zugl.: Berlin, Techn. Univ., Diss., 2014

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Tag der wissenschaftlichen Aussprache: 14.11.2014

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Printed in Germany.

ISBN 978-3-8440-4027-2
ISSN 1868-8357

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

to my parents Selma and Prof.Dr. Tuncer Çelik

PREFACE

This work came into existence during the time as a PhD scholar at Technical University Berlin (TUB) and as a research assistant at Istanbul Technical University (ITU). Although a dissertation is an independent contribution to scientific research and development, many people deserve thanks for their help during the study.

First and foremost I would like to express my deepest gratitude to my supervisor Prof. Dr.-Ing. habil. Yuri Petryna from TUB for his guidance, motivation, friendly advices, patience and support throughout this work. My appreciation is also extended to Prof. Dr. Ahmet Saygun from ITU for his time and willingness to serve as second committee member. I would also like to thank Prof. Dr.-Ing. Wolfgang Huhnt for his kindly serving as the chairman of the committee.

I am deeply indebted to TUB for the PhD Fellowship. Moreover, I wish also express my thanks for the permission of ITU to carry on my research at TUB.

I would like to extend my special thanks to my colleagues Dr. Yavuz Durgun from ITU and Dr.-Ing. André Brendike from TUB for their help and discussions.

Thanks are also due to my dear friends in Berlin and in Istanbul. My special thanks are due to Dipl.-Ing. Juliane Stopper and Dr.-Ing. Arda Karasu for their friendly help and support.

Further to all I am specially grateful to my big family including also my husband Nitel for their continuous love, understanding, support and encouragement.

Nilay Çelik

September 2015

ABSTRACT

In the present work, new seismic damage indices are developed as explicit seismic design or assessment criteria for reinforced concrete (RC) moment frames. These new explicit damage indices are mechanically well-founded for nonlinear static and dynamic analyses and applicable both to individual members as local damage index and to entire structure as global damage index. Both indices vary between 0 non-damaged state and 1 failure state.

Recent codes stipulate to design and assess the structure by using performance-based criteria. Here, various performance levels are specified by utilizing either descriptive criteria or displacement limits. However, the damage state of the structure is rather related to an explicit damage index than to its displacement capacity. Considering this fact, a new performance-based design procedure called as damage-based seismic design is proposed by using the new damage indices.

To follow and verify this new design, a reliable finite element program “FRAME” is developed with the new damage indices within the “MATLAB” environment for 2D nonlinear static and dynamic analyses. The plausibility of the new damage indices and the reliability of the program are tested on laboratory structures given in literature. It is seen that the new damage index is more plausible than the Park and Ang damage index and the results of the program “FRAME”, such as horizontal top displacements, correlate better to the experimental results than those of the programs “IDARC2D” and “RUAUMOKO”.

Finally, the proposed damage-based evaluation procedure is performed on a reference frame designed according to the conventional rules of Turkish Earthquake Code (TDY 2007). Hereby, the frame is subjected to pushover and nonlinear dynamic analyses, and additionally to cyclic pushover analysis, which is proposed in the present work to cover the full load cycle. At the end, the damage-based evaluation is compared with the displacement-based evaluation given in TDY 2007 by means of the frame. The comparison shows that the damage state of the frame is much better quantified in damage-based evaluation than in displacement-based one.

ZUSAMMENFASSUNG

In dieser Arbeit sind neue Schädigungsindikatoren als explizite erdbebensichere Bemessungs- oder Bewertungskriterien für momentenbeanspruchte Stahlbetonrahmentragwerke entwickelt worden. Diese neuen expliziten Schädigungsindikatoren sind aus mechanischer Sicht für statisch und dynamisch nichtlineare Analysen gut geeignet und sowohl auf Bauteile als lokaler Schädigungsindex als auch auf gesamte Strukturen als globaler Schädigungsindex anwendbar. Beide Indikatoren liegen zwischen 0 im ungeschädigten Zustand und 1 im Bruchzustand.

Neue Normen fordern zustandsbasierte (performance-based) Kriterien, um die Struktur zu bemessen und zu bewerten. Hierbei werden verschiedene Zustände mit Verwendung von entweder deskriptiven Kriterien oder Verschiebungsgrenzen definiert. Der Schädigungszustand der Struktur weist einen engeren Zusammenhang zum expliziten Schädigungsindex als zur Verschiebungskapazität auf. Aufgrund dieser Tatsache wird eine neue zustandsbasierte Bemessungsprozedur, die im Weiteren schädigungsbasierte erdbebensichere Bemessung genannt wird, mit den neuen Indizes vorgeschlagen.

Um diese neue Erdbebenbemessung durchzuführen und zu überprüfen, ist ein zuverlässiges Finite Elemente Programm „FRAME“ mit den neuen Schädigungsindikatoren in der Umgebung von „MATLAB“ für die ebene statisch und dynamisch nichtlineare Analyse weiterentwickelt worden. Die Plausibilität der neuen Schädigungsindikatoren und die Zuverlässigkeit des Programms sind mithilfe von in der Literatur vorhandenen Ergebnissen experimentell getesteter Strukturen geprüft worden. Dabei wurde festgestellt, dass der neue Schädigungsindikator von höherer Plausibilität ist als der Schädigungsindex von Park und Ang. Die Ergebnisse vom Programm „FRAME“, wie maximale horizontale Verschiebungen, stimmen zudem besser mit den experimentellen Ergebnissen überein, als die mit den Programmen „IDARC2D“ und „RUAUMOKO“ ermittelten Werte.

Schließlich wird die vorgeschlagene schädigungsbasierte erdbebensichere Bewertungsprozedur an einem Referenzrahmen durchgeführt, der mit den konventionellen, in der Türkischer Erdbebennorm (TDY 2007) angegebenen Regeln entworfen worden ist. Hierbei wird der Referenzrahmen mit der Pushoveranalyse, der nichtlinearen dynamischen Analyse, sowie zusätzlich mit der, im Rahmen dieser Arbeit vorgeschlagenen, zyklischen Pushoveranalyse bewertet, um den ganzen Lastzyklus zu erfassen. Abschließend ist die schädigungsbasierte Bewertung mit der in der TDY 2007 angegebenen verschiebungsbasierten Bewertung verglichen worden. Der Vergleich zeigt, dass der Zustand des Rahmens in der schädigungsbasierten Bewertung wesentlich genauer als in der verschiebungsbasierten Bewertung quantifiziert worden ist.

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