ATC-31

Evaluation of the Performance of Seismically Retrofitted Buildings

by
APPLIED TECHNOLOGY COUNCIL
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Preface

In August, 1990, the National Institute of Standards and Technology awarded Applied Technology Council (ATC) a contract to evaluate the effectiveness of building seismic retrofitting methods in the areas affected by the 1987 Whittier Narrows, California, and the 1989 Loma Prieta, California, earthquakes. This project scope was based on indications that a substantial number of buildings had been retrofitted in the two affected areas prior to the earthquakes. The evaluation was to be based on retrofitted building data collected by ATC in a prior survey of members of the Structural Engineers Association of California (SEAOC) and on additional data collected from SEAOC members, other practicing engineers and building departments.

The purpose of this ATC-31 project report is to provide information of value to seismic retrofit design practitioners on the past seismic performance of retrofitted buildings. The report includes background materials on past and current California seismic retrofitting regulations and practice, a description of the project data and the data collection methodology, a summary of the data analysis methodology and the project conclusions and recommendations. The document includes summaries of reported damage for unreinforced masonry and tilt-up concrete buildings retrofitted with various approaches. Conclusions on the effectiveness of the various retrofit approaches for these building types are presented. Reduced data are presented without assessments or conclusions for building types such as wood and concrete frames for which insufficient data were submitted. A recommendation is made to support similar subsequent studies by providing for data collection on retrofits through the building permit process and on performance through the postearthquake damage assessment process.

OAK Engineering, Belmont, California, a structural and earthquake engineering firm with experience in seismic evaluation and retrofitting of buildings, served as the project subcontractor. Onder Kustu and Anca Strassman of OAK Engineering conducted the additional data collection efforts and performed the required data reduction, evaluation, analysis, and report for the project. RDD Consultants, Boulder, Colorado, edited the final draft manuscript for review and prepared the final report for publication. Robert A. Bruce was Project Director for ATC.

Members of the Project Engineering Panel, who provided overall review and guidance for the project, were: Eugene E. Cole, William T. Holmes, Donald R. Kay, Frank Lew, Doc Nghiem and James A. Willis. The affiliations of these individuals are provided in the Project Participants List.

ATC gratefully acknowledges the many SEAOC members, other practicing engineers and building departments who took the time and effort to complete and submit the questionnaires. The project would have been impossible without this assistance. ATC also acknowledges Structural Engineers Association of Northern California Past President Ted Canon and Structural Engineers Association of Southern California Past President Ron Nelson for allowing requests for questionnaires to be announced at their general meetings.

Finally, ATC gratefully acknowledges the assistance, support and cooperation provided by National Institute of Standards and Technology Project Officer Robert D. Dikkers.

Information on other completed ATC projects and reports are provided at the end of this document.

Christopher Rojahn (Principal Investigator)
ATC Executive Director

Summary

This study was undertaken to evaluate the effectiveness of the various seismic retrofitting methods used to strengthen building structures. Towards this objective, structural and damage data were collected and evaluated for retrofitted buildings affected by the Whittier Narrows (October 1, 1987) and the Loma Prieta (October 17, 1989) California earthquakes. Only buildings that had been seismically retrofitted prior to these earthquakes were evaluated. The data were obtained by mailing survey forms to the membership of the Structural Engineers Association of California, reviewing public records of the various local jurisdictions in the affected areas, interviewing building owners and practicing engineers, and studying other sources.

Data for 113 retrofitted unreinforced masonry (URM) and 43 concrete tilt-up buildings were collected and stored in a relational database system and used to evaluate the various retrofit methods. Fewer buildings of a number of other building types were also evaluated and added to the relational database system.

The study concludes that an improved structural performance is gained by thorough (complete) retrofitting of URM and tilt-up buildings. To the extent allowed by the data, this study also compares various reported design approaches to retrofitting these buildings. Lastly, the study finds that arbitrary and incomplete retrofitting of these types of buildings may not significantly improve their performance when subjected to large earthquake ground motions.

Difficulties encountered in collecting sufficient and reliable data for this project indicate an urgent need to systematically collect and disseminate data on retrofitted buildings. This requires identification and documentation of retrofitted buildings on an ongoing basis as well as improvements in postearthquake damage assessment and reporting procedures.

Currently, retrofitting is required for unreinforced masonry buildings in certain jurisdictions in California. Engineering standards that are less stringent than for new buildings are available for retrofitting of unreinforced masonry buildings. However, similar retrofitting standards for other building types are not available; complete seismic retrofitting of such buildings to meet the latest standards for new buildings is typically required when major renovations are undertaken. It is recommended that retrofitting standards be developed for all hazardous existing building types. These standards should be periodically reviewed and revised based on the evaluation of the performance of retrofitted buildings in earthquakes.

This study and other similar studies can help improve the safety of existing buildings. Toward this objective, it is recommended that the results of this and other similar studies be disseminated to building owners, government agencies, and practicing engineers involved in retrofitting of existing buildings.

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