EARTHQUAKE HAZARD ASSESSMENTS FOR BUILDING CODES

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SECTION 0: PREFACE

This report covers the period January, 2006-March 2007, granted by US-AID-MERC as an extension of the project without any additional funding.

The project was due on April 2004 and the final report was presented in Oct. 2004 (GII Report No. 537/059/04). In 2004, Dr. A. Shapira, Principal Investigator for the grant was nominated director of the International Seismological Centre (located in the UK) and is replaced by Dr. A. Hofstetter, the director of the Seismology Division of the Geophysical Institute of Israel.

The extension of the project is a necessity that results from the ongoing hostility in the area that practically blocked any attempt of the participants to meet in the region and make significant progress. However, despite political difficulties, due to the well-recognized importance of our work and owing to the political umbrella provided by the RELEMR initiative, we made useful progress which is reported below.

This report is a short summary of the activities during 2006 and first quarter of 2007. Since the activity in 2006 is strongly related to the activity of 2005 (and 2004 as well), we keep some parts of the former report for the clarity purposes of this report. The detailed information, elaborated reports, lists of publications and products are presented in the projects home-page on the internet in:

WWW.RELEMR-MERC.ORG

SECTION I: TECHNICAL PROGRESS

A) Research objectives

The overall aim and specific objective of the project is to produce maps and charts that will provide the necessary seismological data for the implementation of building codes and regulations in Jordan, Israel and the Palestinian National Authority (PNA). An important task that remains incomplete is the development of probabilistic seismic hazard maps for different areas within the region at different frequency ranges and damping ratios. Within that task site response effects as well as the dynamic characteristics of existing buildings need to be determined, and used as a basis for recommending the next generation of building codes for the region.

Following recent project meetings in Aqaba (January, 2004), in Ankara (January, 2005), in Chania (September, 2005), in Malta (April, 2006) and in Barcelona (December, 2006) it became clear that our research activities should also be associated with the assessment of the vulnerability of existing building to ground shaking. It is clear that building construction in the future, in great parts of the study region, will adhere to traditional construction practices. Consequently, better understanding the vulnerability of existing building and estimation of expected losses from future earthquakes, becomes an important element in the process of developing building codes and regulations.

B) Research accomplishments

The Aqaba meeting in January 2004, performed under the auspice of RELEMR was indeed a "break through". It provided the necessary tools for performing site investigations and empirical determinations of dynamic characteristics of buildings. Seismic microzoning studies were completed during the report period for the cities of Aqaba, Tafila, Karak and Amman in Jordan and for the

cities Kiryat Shemona, Dimona, Arad, Bet Shean, Afula, Petach Tikva and in the Bay of Haifa, Israel, in addition to local studies for sites in Eilat, Lod and Ramla (Israel).

Farther modifications were made to the software package, SEISPECT, which is used for those investigations. The software and manual are provided free to any interested scientist.

An earthquake of magnitude 5.1 occurred in the Dead Sea basin on February 11, 2004. It was followed by an Mw=4.7 earthquake on July 7, 2004. These events were widely felt all over the Levant and triggered a number of strong motion instruments. The acceleration recordings provided a good opportunity to compare predicted seismic hazard functions with observations. It was very encouraging to observe a high level of agreement between observed and predicted amplitude spectra and consequently, a relatively good agreement between the observed and the predicted acceleration response spectra at different sites.

In order to assess the dynamic characteristics of different categories of reinforced concrete buildings in Jordan, representative analytical models were developed by the Royal Scientific Society of Jordan using SAP2000N. The parameters investigated included the level of seismic hazard (different seismic zones were considered), soil conditions as well as the building height (number of stories). The models were analyzed dynamically using the response spectrum of the Uniform Building Code (UBC 1997). Results of the dynamic analyses were compared with those obtained through the application of the static force procedure of local and international codes. Based on the fact that low-rise stone-concrete buildings (buildings that utilize stone masonry walls backed by plain concrete as exterior walls) are the most dominant in the Jordanian residential building stock, an effort was made to assess their seismic vulnerability. The majority of the Jordanian residential buildings were designed and constructed without any due consideration of providing an adequate level of lateral load resistance. The resulting deficiencies and weak links in stone-concrete buildings were analyzed. A comprehensive questionnaire targeting both designers and builders was devised to assess the seismic vulnerability of this type of construction and build what maybe described as an "expert opinion" regarding the seismic response of typical residential buildings. Furthermore, recommendations to overcome the observed structural deficiencies and to improve the construction practice were given. However, in order to implement these recommendations into the construction practice, experimental investigations are required to assess their viability and applicability. Further research and investigation is deemed necessary to assess the seismic response of the common Jordanian structural systems and to develop a suitable methodology for the assessment of their seismic vulnerabilities. Future research needs are also discussed.

The Jordanian scientists completed a set of probabilistic hazard maps for rock conditions, in terms of Peak Ground Acceleration, PGA, and of Spectral Acceleration, SA, (at 0.1, 0.2, 0.3, 0.5, 1.0, and 2.0 s period) for a probability of exceedence of 10% in 50 years using the attenuation relationships of Ambraseys et al. (1996).

To determine the effective natural period and stiffness of common buildings, the Earth Sciences and Earthquake Engineering Centre of En Najah University, Nablus, performed several structural analysis by using 2D and 3D models for ten buildings (also using the structural analysis programme SAPS2000). Also, the natural period of selected buildings has been measured experimentally by using the micro tremors (ambient vibration measurements).

Comparing the results of the natural periods obtained applying the UBC97 and IBC2003 with those analytically and experimentally calculated, the following was concluded:

The natural period of building computed using the UBC97 method is a general value, (no specific structural system or mass are specified). A more exact value can be determined using dynamic analysis.

The natural period of local framed building determined using dynamic analysis is larger by about 25% - 30% of that computed by using the UBC97 method, because of the large mass. Also, the natural period of perimeter walls building determined using dynamic analysis is less by about 12%-30% than that computed by using UBC97 method.

The natural period determined using space frame analysis is less than that determined using plane frames analysis because of the increase of stiffness of the slab.

In frame buildings, the natural period of interior frames is larger than that of exterior frames because of larger mass (both have the same stiffness). And in the perimeter wall buildings, the natural period of the interior frame is larger than that of exterior frame because of the larger mass and much less stiffness than the exterior frame.

The natural period of buildings is decreased by about 10% as the mass of building is decreased by 20% in frame and perimeter wall buildings.

The workshop in Barcelona (December, 2006) can be considered as the highlight of this project. The fundamental seismic hazard map for building codes in Jordan, Israel and the Palestinian territories was completed in an earlier stage of this MERC project a few years ago. As additional knowledge was accumulated and more work was done towards the drafting and implementing building codes (see previous project reports) it became essential to merge new information and re-examine previous evaluations. Consequently, the main goal of the Barcelona (2006) meeting was to compare different versions of seismic hazard maps proposed for building codes in Jordan and Israel into one regional map, which also complies with recent hazard assessments in Lebanon, Syria and neighboring parts of Egypt and Saudi Arabia. Taking into account the above mentioned research and studies (presented in various recent workshops) we devoted large part of the time and efforts for updating of the catalogues and software (prior to the meeting) and reproduced seismic hazard maps for the whole region. In addition, the Barcelona meeting served as a concluding meeting for a series of meetings and studies that were done at each participating institute. Those studies were presented and discussed. We were fortunate to have a group of scientists from non-participating countries (i.e. Saudi Arabia, Lebanon, and Syria). Those researchers were willing to share with us their knowledge and experience, and their seismological catalogue as well.

C) Scientific impact of cooperation

The meetings in Ankara, Turkey, in Chania, Crete, and in Valetta, Malta, facilitated again by the RELEMR initiative, provided the opportunities for the project participants to meet and discuss the results. Both meetings emphasized on earthquake engineering. The RELEMR meeting in Ankara provided training on analysis of strong motion recordings.

During the meetings in Chania and Malta project participants from Jordan, The Palestinian National Authority, Israel and the USA discussed the topic of vulnerability of buildings to earthquakes and presented the different approaches used

in their countries for assessing building vulnerability. This workshop was followed by parts I & II workshops on the HAZUS (Hazard US) software developed by/for the US Federal Emergency Management Agency for assessing the impact of earthquakes and a workshop (parts I & II) on the stochastic method for the prediction on seismic ground motions, presented by Dr. D. Boore of the US Geological Survey.

The ESSEC wisely used the materials and systems provided by the project to be implemented in training courses on:

Measuring micro tremors by the 12 channel amplifier, using the Seismic Data Acquisition (SDA), and the Seismic Interpretation Software (SIP), and the software for spectral analysis of seismological data (SEISPECT), and measurement by 24 channel seismograph.

The training included theoretical and practical parts: the theoretical part included an introduction to the software, data processing using existing data and data analysis and interpretation. While the practical part included field training on setting up the equipment and installing and operating the field software for the seismic data acquisition (SDA).

The participants in these training courses were students from the faculty of Engineering at An-Najah National University as well for junior researchers and engineers from private and governmental sectors. The courses focused on the benefits of the micro tremors as a rapid and inexpensive technique for assessing site effect by determining the predominant periods of the sites during earthquakes.

The last meeting in Barcelona (Dec. 2006) aimed at merging the hazard maps used in the Building Codes of Jordan and Israel. Due to participation of other scientists from countries that do not participate in the project the geographical boundaries of the map are beyond the borders of Jordan, Israel and Palestinian Authority.

D) Description of project impact

We are proud to report that the outcome of the projects activities has been implemented in both Israel and Jordan.

In Israel, the Standards Institution of Israel has adopted (2004) the seismic hazard map in the Israeli Building Standard 413. In 2005 a number of hazard maps (Peak Ground Accelerations for different levels of probability of occurrence) were prepared for an updated code for the safe construction of bridges.

In Jordan, the Jordanian government took over a responsibility to develop the Jordanian Buildings Code .The Jordan code loads and forces shared the country into four seismic zones A, B, C, D the most active risk in zone A along the Dead Sea rift valley. The scientific work described above is part of these efforts.

During 2005, the ESSEC and its staff from engineering community made the required preparations and conducted three workshops in the Palestinian main cities. The main goal of the workshops was to highlight the importance of hazard maps, building code requirements and seismic vulnerability of common buildings which was accomplished through the project Earthquake Hazard Assessment for Building Codes. The target groups, in those workshops, were engineers and planners from consulting firms, contractors, NGOs, PNA Institutions and International organizations working in the area. The invitations and announcement for participating in the workshops were performed through advertisement in the local newspapers and invitation letters to different governmental and non-governmental institutions.

The merged map will serve as the seismic hazard map in the Building Code of each country.

E) Strengthening of data exchange and cooperative research of Middle East institutions

Technical assistance was provided by GII for the repair and upgrading the seismic systems and the associated software.

The recent workshops on building vulnerability, HAZUS and Synthetic accelerations have significantly improved the capabilities of the Middle East institutions to better evaluate earthquake hazards for improved building codes.

The hands on workshops provided better understanding and familiarity with processing software and evaluation procedures.

The project has strengthened the data exchange between the participants. It is strongly manifested every time a felt earthquake occurs in the area.

All the workshops and especially the last one in Barcelona (Dec. 2006) have proved us that data exchange and cooperative research is a feasible target. The final outcome (the regional hazard map) is composed based on the knowledge and experience of participating and non-participating countries.

GII maintained the project's web site which provides means for continuous interaction and communication between the participants over the Internet. Furthermore, it appears that many people, which are not part of the project, from various countries in the Middle East, enter the web page and take advantage the reports and publications there.

The only practical way to conduct meetings between Middle East participants is to continue doing it under the umbrella of the RELEMR meetings. However we found out that these meetings are also useful in other ways: 1) it is a very good opportunity for the participants to expose the work and studies that were done; 2) the scientific discussion serves as a critical review of the studies.

F) Future work

This specific project terminated on March 31, 2007. Since we view this project as a first major step among many in the domain of cooperative seismology and construction engineering in the Middle East we plan to further pursue the goal of preparing the seismological and engineering information needed for improved building codes. Realizing that the main goal of this project namely; implementation of modernized building codes in the region, has been achieved and realizing that most of the available funds have been used, we shall try to emphasis on future joint meetings (apparently, possible only under the umbrella of RELEMR) and farther elaborate on the following topics:

1) Site effects and their implementation in building codes.
2) Synthetic accelerograms and Shake maps.
3) Earthquake vulnerability of buildings in the region.
4) Assessment of earthquake losses.
5) GII will continue to maintain the project's web site which provides means for continuous interaction and communication between the participants over the Internet.
6) Produce colored map for public distribution of loci of epicenters in the project area.
7) Risk maps (i.e. for main or selected cities).

SECTION II: Project Management and Cooperation

A) Managerial Issues:
The project was fairly well integrated into the RELEMR activities, especially at the later stages of the project and provides a platform to conduct meetings between the project collaborators. Apparently, the only practical way to conduct meetings between Middle East participants was to continue doing it under the umbrella of the RELEMR meetings.
Much of the cooperation is performed over the internet. GII's programmer maintains the project's web-site which is constantly being updated.

B) Special Concerns:
Everybody is very much concerned about the political situation in the region. We are thankful for receiving the prolongation for another 18 months, which helped us in fulfilling our final goal. The collaborative aspect of the project, as was originally planned, was based on a series of meetings and workshops to be held at the premises of the collaborating institutions. The unfortunate political situation did not allow such meeting to occur. We made significant progress through working over the internet (see www.relemr-merc.org) and during RELEMR meetings.

C) Cooperation, Travel, Training & publications:
Cooperating investigators traveled to the RELEMR meeting in Ankara, Turkey (January 2005), Chania, Crete (Sept. 2005), Valetta Malta (Apr. 2006) and Barcelona, Spain (Dec. 2006).
Publications and Reports associated with the project are presented on the project's web site: www.relemr-merc.org

D) Future cooperation & work:
Although the project terminated we still plan to continue elaborating, mainly under the umbrella of RELEMR, with similar seismological and engineering studies to update and improve seismic hazard assessment all over the Middle East.

FINANCIAL BALANCE (at the end of the project on March 31, 2007)

		GII	ESSE	NRA	USA
Salaries	Budget	76,000	0	0	0
	Used	73,892	0	0	0
	Balance	2,108	0	0	0
Equipment	Budget	6,000	58,500	81,500	0
	Used	6,000	58,491	81,500	0
	Balance	0	9	0	0
Travel	Budget	7,600	10,600	9,200	11,200
	Used	7,600	10,600	9,200	11,205
	Balance	0	0	0	-5
Workshops	Budget	56,400	53,350	57,950	10,450
	Used	45,324	53,350	57,950	10,450
	Balance	11,076	0	0	0
Mat. & Supply	Budget	19,000	13,000	19,000	2,000
	Used	7,172	13,000	19,040	2,000
	Balance	11,828	0	-40	0
Publ. & maps	Budget	7,000	5,000	9,000	0
	Used	586	5,060	8,960	0
	Balance	6,414	-60	40	0
Consultation	Budget	6,000	30,000	50,000	0
	Used	5,553	30,000	50,000	0
	Balance	447	0	0	0
TOTAL	Budget	178,000	170,450	227,150	23,650
	Used	146,127	170,501	227,150	23,655
	Balance	31,873	-51	0	-5