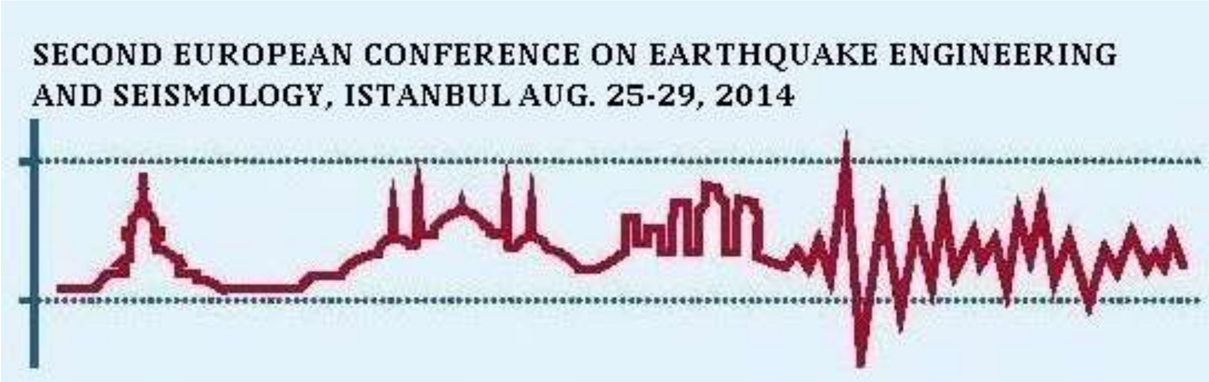

EARTHQUAKE CASUALTY LOSS ASSESSMENT İN A MAJOR CİTY OF ISRAEL– THE CASE OF TİBERİAS

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ABSTRACT

Mitigating the consequences of potential earthquakes requires an estimation of the casualties that may incur, and accordingly the development of an appropriate risk management and response model. Based on an extensive literature review of the consequences of earthquakes, the following parameters were identified as a significant factor in estimating human casualties:

1. The earthquake related hazards in the designated area, namely the seismic vibrations, amplification of the ground acceleration, surface rupture, soil liquefaction, landslides, and tsunamis.
2. The vulnerability of the structures to the seismic hazards. This is assessed by an empirical or analytical approach that combines simulation of seismic events, reaction of the ground, and the capacity of the building stock.
3. Vulnerability of the population due to its socio-economic conditions and demography in the designated area.

This information is crucial to the prior preparedness plans and to the emergency response during and after an earthquake disaster. As a part of the research of “Risk Assessment for Earthquake Casualties in Israel”, Hazus-MH (Hazards U.S. Multi-Hazard) was adapted. This methodology of estimating the potential losses from disasters was developed by FEMA (Federal Emergency Management Agency) in order to examine the effects of natural hazards including strong earthquakes. The city of Tiberias is located along the tectonically active Dead-Sea-Fault, near the lake of Gallile in Northern Israel, and therefore is exposed to a high risk of earthquakes and landslide hazards. Thus it was chosen as a case study in this research. Tiberias covers an area 10.7 sq. km. which are divided into 12 census tracts (GIS ground cells) with forty-five thousand inhabitants.

The goal of this study is to develop and implement a semi-empirical model for casualty estimation that will enable to forecast the extent, types, and severity of casualties that may result in Tiberias and its surroundings in the case of several scenarios of given earthquakes. The expected deliverables will enable the research team to assess the risk, and develop strategies for retrofitting the vulnerable structures, and improve preparedness of the population in the case of destructive earthquakes.

The objectives of the research are as follows:

- To review and quantify the effect of factors that influence injury and death rates in the event of an earthquake;

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- To assess the connection between structural and non-structural damage due to earthquakes and human vulnerability;
- To develop a method to characterize the geological hazards and review the historical seismic background of the city studied.
- To integrate all the above-mentioned modules into a holistic mortality and morbidity risk assessment analytical-empirical model.
- To develop a comprehensive risk assessment model for appraisal of the total loss as a result of the consequences of given earthquake scenarios;

The research method is composed of a multidisciplinary approach combining structural engineering, geological science, emergency medicine, and risk assessment as follows: (1) Characterization of the structures using five attributes (construction year, floor area, building height, occupancy, and tract No); (2) Characterization of the dynamic parameters of the structures and their capacity and fargility curves (Rossetto and Elnashai, 2005; Nasserasadi et al. 2008); (3) Estimate the rates of casualties and the severity of injuries by a modified Delphi consensus reaching method; and (4) A comprehensive risk analysis model.

A comprehensive literature review was conducted in order to appraise the factors that may affect the process of injury and death in earthquakes. The findings indicate that the main factor causing injury and death in earthquakes is building collapse, although other demographic and socio-economic characteristics also contribute to that. The populations that were identified as the most vulnerable and therefore at the highest risk of injury and death during an earthquake are mainly young children and elderly people, the disabled, and the poor. Taking measures to enhance preparedness among these populations may help mitigating the loss of lives by the next strong earthquake.

1. INTRODUCTION

While high seismic-active regions have been widely investigated and understood, areas with low seismic hazard have not been fully recognized as being exposed to high risk of significant losses due to their vulnerable built environment and high exposure of population to seismic hazards. As a result, comparing with those high seismic-active regions with well-prepared risk management plans, a potential major earthquake could cause much more significant consequences to those seismic-quiescent regions due to their relative lack of awareness and preparation for seismic hazards. For instance, public policies for earthquake risk mitigation commonly fail in those areas with moderate seismic hazard due to the unclear economic drivers for seismic risk management plans, and also the lack of awareness in the general public (Prater & Lindell, 2000; Smyth et al., 2004; Bostrom et al., 2008). Therefore, a standardized and straightforward risk assessment methodology is needed for public authorities in seismic-quiescent areas to assess the potential seismic risks and to make corresponding risk mitigation plans for protecting people's lives and properties

For instance, certain cities in Israel, a country with moderate occurrence rate of earthquakes in history, are exposed to high risk of significant consequences due to their old building stock, more than 40% of which were built before 1980, when a national seismic-proof building code was enacted. To save potential losses of properties and lives, National Master Plan 38, an earthquake risk reduction plan to strengthen the vulnerable buildings built before 1980, which do not comply with up-to-date seismic design code, was launched in 2005 by the Israeli government. However, while the plan gradually grabbed attention in some particular cities with high land value such as Tel-Aviv, outlying cities such as Tiberias have been shunned due to their low real estate value and lack of comprehensive loss assessment, which make the investment in mitigation actions seem not to be economically feasible. Consequently, the current seismic, social, and economic loss figures in these seismic-quiescent areas result in a low level of concern in preparing for a potential major earthquake hazard.
A substantial number of researches have focused on loss assessment for high seismic regions. For instance, (Kircher et al., 2006) estimates building damage and human loss due to a repeat of the 1906 San Francisco earthquake using HAZUS software package. Furthermore, by operating HAZUS, Schmidtlein et al. (2011) examine the spatial correlation between social vulnerability and potential

earthquake losses under differing earthquake scenarios in Charleston, South Carolina. These studies address the seismic loss assessment for those areas which are identified as highly seismic-active, or have historical occurrences of major earthquakes. On the other hand, although loss assessment in the areas with infrequent damaging earthquakes starts to grab attention, there are comparatively few studies addressing this significant issue. (Tantala et al., 2008) investigates the potential high seismic risk of New York City due to its tremendous assets and vulnerability of its structures, which were not seismically designed as strong as most in the West Coast. Remo & Pinter, (2012) compare the result of loss estimation from HAZUS to the damage surveys for the 2008 Mt. Carmel, Illinois earthquake and find that HAZUS overestimated the losses from the surveys. Rein & Corotis, (2013) assess potential consequences of major earthquakes for the Denver Region in the U.S., which is presented as a case of the seismic vulnerability of an area that is not generally considered seismically active and find out that potential losses due to earthquakes would be amplified as a result of the low preparation of the public and the perception of people of the earthquake risk. In summary, the aforementioned researches all show the potential high risk in a low seismicity region due to its vulnerability of its built environment and the prevailing social-economic state. Most of the noted studies conduct loss estimate using HAZUS. Although HAZUS has the merit of having a straightforward and standard methodology, the built-in database and model parameters of this U.S. based program may not be applicable in non-U.S. countries. Therefore, modifications of the local parameters and new steps, which can fully represent the attributes of the designated built environment, are in need to perform accurate loss estimation for a non-U.S. adoption of HAZUS. Adopting the GIS-based standardized HAZUS software tool, this study aims to develop a methodology of earthquake loss estimations for a seismic-quiescent area. Therefore, the particular objectives of this study are to: (1) identify special issues of earthquake loss assessment in a seismic-quiescent area, (2) investigate regional parameters and models which can fully represent the characteristic of local built environment, and (3) verify the applicability of the present methodology by a case study in the city of Tiberias, Israel. This study intends to provide public decision makers and stakeholders with a standardized methodology for assessing the potential seismic loss in a seismic-quiescent area with a high seismic risk, so that an effective corresponding mitigation strategy can be achieved.

This paper includes five sections. Following this introduction, the seismic risk assessment model and its application to seismic loss assessment are introduced in section two. This is followed by the description and methodology of the required data for the risk assessment model, including building inventory, demographic data and seismicity scenarios of the case study region. Next, the casualty loss estimation model is modified to reflect the attributes of a low risk perception area. Then, loss expectancy is estimated using probabilistic earthquake hazard analysis. Finally, preliminary results, reservations, and conclusions are presented and discussed.

2. BACKGROUND

2.1 Seismic Risk Assessment Tool

Several risk assessment methodologies have been developed based on the typical seismic risk assessment models. Erdik et al., (2005) and Korkmaz (2009) provided loss assessment models for long-term disaster management considering probabilistic seismic hazards. Furthermore, different methodologies and frameworks for seismic loss estimation have been developed and used to conduct a Benefit-Cost-Ratio analysis for different seismic retrofit alternatives. Smyth et al.. (2004), Boylu (2005) Kappos & Dimitrakopoulos, (2008), and Valcárcel et al., (2013). In addition, various seismic loss assessment models have been widely adopted in estimating the probable maximum loss by exceedance probability curves for assisting insurers or reinsurers in pricing the insurance policies. Examples of such studies include Hsu et al., (2006), Tseng & Chen (2012), and Hsu et al.. (2013). However, the complicated mathematical formulas and large number of variables make these loss assessment models difficult to use by a wide range of stakeholders. Moreover, the nature of their non-standardized and proprietary code source prevents other users from modifying the models for their specific needs.

Correspondingly, a number of standardized software packages have been developed with friendly user-interface and open-source database. Most of them also utilize Geographic Information System in presenting the geographic distribution of losses for analyzing particular issues such as emergency facilities layout. Examples include: Taiwan Earthquake Loss Estimation System developed by (Yeh et al., 2006) is designed to estimate the losses under different earthquake scenarios; moreover, the module of Early Seismic Loss Estimation of this program can obtain real-time estimates of seismic hazards and losses soon after the occurrence of earthquakes. KOERILoss, a Turkish-based seismic loss assessment program developed by the Department of Earthquake Engineering of Bogazici University, can also estimate the losses due to earthquake hazards (Erdik et al., 2003). Earthquake Loss Estimation Routine is a European-based software package for rapid estimation of earthquake magnitude and losses throughout the Euro-Mediterranean region. It was developed under the Joint Research Project entitled Network of Research Infrastructures for European Seismology. (Hancilar et al., 2010). Although having the merit of being standardized and straightforward, these regional-based software packages have not been widely validated for their applicability to international settings and thus the international adaption of these local-based tools is still under question mark.

2.2 Seismic Hazards - Tiberias

Tiberias was reported to have been hit by earthquakes several times in its history. Much of the damage had been documented in historical sources that were written by different authors and in many languages (Ambraseys, (2009); Guidoboni & Comastri, (2005); Guidoboni et al., (1994); and references therein). Ideally, a comprehensive characterization of past events is better achieved if it is based on reliable and complete historical sources. However, this is almost never the case whereas considerable share of the sources are doubtful and ought to be screened carefully with a critical approach. Thus, we have graded the reliability of the historical reports and apply a level of authentication to each entry of the events and the damage it caused (Zohar et al., 2013). The result is a compiled list of events that probably hit Tiberias and its close vicinity during the last 2,000 years (Table 1). The list shows seven reported events (363, 749, 1546, 10/1759, 11/1759, 1837, 1927) that mention damage in Tiberias, as well as four others between the 8th and 16th centuries (1033, 1057, 1070, 1202) that do not mention Tiberias but affected strongly nearby locations and thus may be considered as if having hit Tiberias as well. Overall, it is reasonable to assume that Tiberias was most probably damaged at least eleven times since its establishment in 19 CE with irregular intervals of time between the events. The average repeat time would be at the range of ~185 to 150 years, depending whether the counting starts from the first event in our list (31 BC) or the first mention of reported damage in Tiberias (363 CE), respectively (Figure 1). Six of the eleven reports mentioned heavier or larger damage in Tiberias, than that caused by the 1927 earthquake. Since there is no sign of change in the geology and tectonics of the region, it is reasonable to assume that the seismic activity of the last two millennia will continue in the near future. Thus, the experiences of the past damaging earthquakes are extrapolated for hazard and risk assessment to the future. The city is located in vicinity to several active and potentially active faults (Jordan, Ha'on, Almagor, and Beit Hakerem).

2.3 Exposure

The local demographic data was collected in order to assemble a detailed distribution map of the population for different occupancy types at various time-frames. The data was derived from the latest Israel national census survey, conducted in 2008 by the Central Bureau of Statistics (CBS), and data from National Insurance Institute (Social Security). The city of Tiberias is comprised of 16 statistical areas, out of which fourteen are residential areas, one is a commercial area, and one is defined as open area with 41,600 residents and 12,800 households residing within the city limits. The average number of members per household is 3.2. Twenty thousand residents are female (48%) and the rest are male (52%). Forty four percent of households have children under the age of 17 and 24% have elderly household members, who are at the age of 65 and above. The population distributions of daytime and nighttime of all occupancy types are established respectively to consider the effect of different time frame to the loss estimation in earthquakes. For residential occupancy, the daytime population was defined as the residents who reported working from home; the unemployed and those who were above retirement age (>67 of men and >64 of women). The nighttime population was defined as the population whose registered residence address was in Tiberias, assuming that all residents are present in their homes at nighttime.

Table 1: List of historical events that damaged Tiberias (marked in bold) or affected significantly its close vicinity without mentioning Tiberias explicitly (damage is marked '*') . The list contains: Event: time of occurrence in year and whenever possible - also the month, day and hour; Affected Area: the damage zone, classified by geographic regions along the Dead Sea Transform (C – Central part; N – Northern part). Magnitude estimated by previous researchers; Average Magnitude – of the estimation given by the previous studies; Size of the event, estimated in the present study according to the grading suggested by Ambraseys & Jackson (1998): Strong: $6 \leq M < 6.9$, Major: $7 \leq M < 7.9$) ; Reliability of the Event: V - Very high; H – High; M – Moderate; P – Poor; Short Description – including comments and references; Severity of Damage: F – felt only; L – light; M - moderate; H – Heavy and S – Severe; Casualties: N – no casualties; F – few; M – many; Reliability of the Damage: V - Very high; H – High; M – Moderate; P – Poor.

Event	Affected Area along the Dead Sea Transform	Magnitude estimated by previous researchers	Average estimated magnitudes	Size of the event, estimated here	Reliab -ility of the event	Short description	Severity of damage	Casualties	Reliability of the damage
363 May 18-19 (night)	C	6.7 (BM); 6.4 (BM5); 7 (TUAR); 6.7 (MIG after BM)	6.7	Strong-Major	V	Two events at Sunday 18/05 (third hour of the night) and Monday, 19/05 at 03:00. According to Cyril, the Bishop of Jerusalem, Tiberias was partly ruined (AM; GCT; KA).	H	-	H
749/Early 750	C	M> 7 (MAR); 7-7.5 (MIG); 7.3 (BM); 7.3, 7.3 (BM5, BM3); less than 7 (KA2, BEG)	7.2	Strong-Major	H	The near-contemporary Byzantine chronicler Theophanes reports of a large event in 748/9 in Syria and Mesopotamia (GCT; AM; KA; KA2). Tiberias was almost totally destroyed with many reported casualties.	S	M	V
1033 Dec 05 (night)	C	7.1 (MIG); 6.7 (BM); 6.7 (BM5)	6.8	Strong-Major	V	Large event heavily damaging Ramla and other cities in the center of Palestine. Around Lake of Tiberias, ground motion caused trees to sway and the water to slosh (GC; AM).	L*	N	H
1759 Oct 30 (03:45)	C-N	Ms ~ 6.6 (AMBR); 6.5 (BM)	6.5	Strong	V	Strong shock in northern Israel-South Lebanon, probably a foreshock of the Nov 25 event (AM). Heavy damage in Tiberias (collapse of many houses)	H	-	V
1759 Nov 25	C-N	7.4 (MIG); MS ~ 7.4	7.3	Major	V	A most destructive earthquake, possible	H	-	V

(19:23)		(AMBR, 1989); Ms = 7.4 (AMJA; WECO); 7 ≤ M ≤ 7.2 (GOM); 7.4 (BM)				epicentral area along the Litany river (AM). Had generated landslides, changes in water course and ground breakage. Tiberias was heavily damaged.			
1837 Jan 01 (16:35)	C-N	7.4 (MIG); M > 7 (AM3); MS = 7.4 (WECO); Ms = 7.1 (NEM after AM3); 6.7 (BM)	7.1	Major	V	Damaging event in southern Lebanon and north of Israel. Nearly total destruction of Tiberias, Hundreds of casualties. Overflow of water in Tiberias baths, sea waves were most likely observed in the Lake of Tiberias (AM).	S	M	V
1927 July 11 (15:04)	C	6.25 (AVN; AVN2); 6.2 (BM2); 6.3 (MIG) = 6.25	6.2	Strong	V	Moderate event with series of aftershocks (AVN). Few houses were damaged with few injuries.	M	F	V

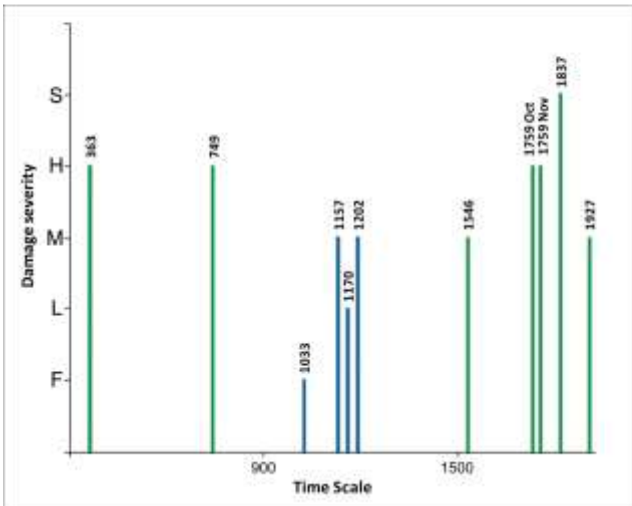

Figure 1. Temporal distribution of damage in Tiberias during the last 2,000 years. Green bars represent events that reported to damage Tiberias while the blue bars represent events that caused damage around Tiberias but Tiberias was not mentioned explicitly. The damage is categorized by degree of severity: F – felt only; L – light damage; M – moderate damage; H – Heavy damage and S – Severe damage.

The employment rate from the national census 2008 is used to estimate the daytime population distribution of other occupancies. The population of educational occupancy is comprised of 1) children between the age of 6 to 17, which accounts for a quarter of Tiberias residents and 2) 10% of Tiberias civilian labor force. The daytime population of industrial occupancy is composed of 22% of employment, including industrial, agriculture, and construction workers. Commercial related occupations such as banking, accommodation serveries and restaurant take 36% of the labor force and constitute the daytime population of commercial occupancy. The rest of employment belongs to the health services (12%) and community and public sector (20%).

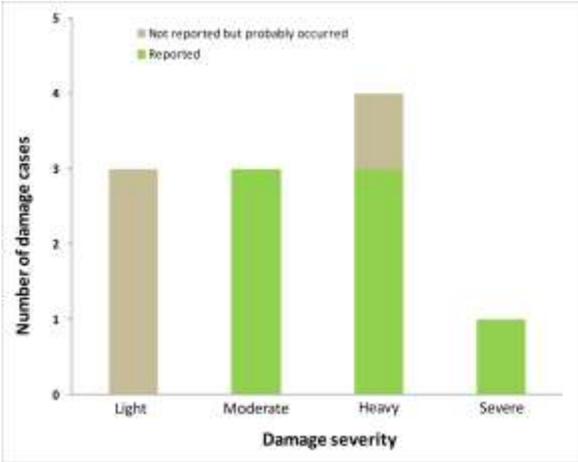

Figure 2. Damage Recurrence and its Severity in Tiberias during the Last 2000 years

Another distinctive local demographic characteristic of Tiberias is its active tourist industry, which reflects the significant change in number of people present in the city during peak season. The touristic index is defined as the ratio of the number of tourist arrival divided by residential population and can be used to assess the number of visitors in hotels during different periods of the year (Zuccaro & Cacace, 2011). As shown in Fig. 3 the tourist index in the city of Tiberias, comparing to the average tourist index is 3.8, the month of August is the peak tourism month with the highest tourist index of five. These values reflect high touristic attendance in the city in the peak touristic season.

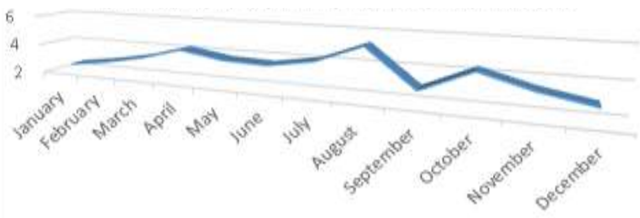

Figure 3. Touristic index is defined as the ratio of the tourist arrivals divided by resident population in the City of Tiberias

3. METHODOLOGY

3.1 HAZUS Methodology and Application

Hazard United States (HAZUS), developed by the US Federal Emergency Management Agency, is a free standardized GIS-based risk assessment tool for hazard analysis and has been widely validated for its applicability in the US (Kircher et al., 2006; Tantala et al., 2008; Schmidtlein et al., 2011; Remo & Pinter, 2012; and Rein & Corotis, 2013). Despite the fact that HAZUS was originally designed for the use in the United States, this standardized seismic risk estimation software has been adopted and validated worldwide because of its merit of being allowed for modification for international settings (Gulati, (2006), Peterson & Small, (2012), and Ploeger et al., (2010)). The possibility to supplant the databases and to modify the default functions with local parameters places the basis for the application of HAZUS to an international setting. Therefore, adopting HAZUS for an international local scale setting requires to carefully performing a series of operations of each module. HAZUS has four major modules: the hazard identification, built environment inventory, physical and social-economic vulnerability, and the loss module. The estimated loss is calculated by linking the hazard scenario to the inventory collection considering its vulnerability. The outputs of the loss estimation include social loss including the number of casualties, injuries, displaced household and shelters, and both direct and indirect economic losses. Despite the lengthy procedure needed for modification, the international users can equally benefit from the final outcome as US users from this proven hazard loss assessment tool. In this paper, adopting HAZUS software package to estimate earthquake losses in a seismic-quiescent area, we firstly evaluate the seismicity of the study area in careful consideration of soil conditional and attenuation functions. Twelve earthquake scenarios following four active faults are generated and selected for assessing the loss estimate. Next, the building inventory and demographics data are collected from street survey and various sources. Finally, using the Modified Delphi technique, local casualty matrices are established.

3.2 Casualty Loss Matrix

The HAZUS-MH social loss estimation module is based on the assumption that there is a strong correlation between the building damage and the number and severity of casualties (Noji and Kelen, 1990. The methodology provides estimations regarding the number of human casualties (indoor and outdoor) caused only by building and bridge damage. The casualties are classified according to a four-level injury severity scale. Three time-scenarios are taken into consideration (day, night, and commuting) in order to reflect the highest casualties for the population present at work/school, home and rush hour times. The module uses a casualty matrix based on the ATC-13 multidisciplinary experts opinion, and was calibrated in the early 2000s to reflect different trends and casualty information derived from several earthquake events in California. The current study aims to evaluate the assumptions underlining the methodology regarding earthquake-induced death and injury rates.

The figures presented indicate that the casualty rates in the HAZUS-MH are relatively low and raise the concern that when applied outside the U.S., it may underestimate the casualty numbers. Since historical data is not available for the Israeli region (last lethal earthquake occurred in 1927 and casualty field data was poor) and in order to determine this issue, a survey was developed and conducted among twenty Israeli experts from different disciplines (e.g. engineers, physicians, risk management professionals, and search and rescue team members – all experienced in the earthquake field). The method used was similar to the original matrix development by HAZUS-MH. The survey was conducted in a modified Delphi technique in order to reach a consensus higher than 75%. The modified Delphi technique is a method designed to collect various views and perspectives and enables reaching consensus by using an iterative process of discussion, feedback and revision (Thangaratinam and Redman, 2005). The survey used in the present study was an online survey, in the first round the experts were asked to assess and evaluate the current casualty rates and their applicability to Israel. In order to enable the experts that were not engineers to comprehend the extent of structural damage as a result of an earthquake (and its possible influence on the occupants), the survey included an appendix that contained detailed descriptions and visual examples of the expected damage as depicted in Fig.4. In addition, the experts were asked to indicate causes or phenomena, which may alter the casualty rates expected in Israel in their opinion. The preliminary results revealed that factors such as the standard of finishing materials which is considered lower compare to those in California, and the fact that the local population lacks the experience and perhaps the knowledge regarding earthquake protective behavior and their level of preparedness is relatively low (Sofer 2008), may alter casualty rates in a future earthquake event in Israel. Further rounds of the survey after compiling more data will be conducted in order to fully understand and assess the factors influencing the process of casualty estimation in a future earthquake scenario in Israel.

The experts evaluated that the casualty rates due to extensive and complete damage to structures (without collapse) will be higher, compared to those offered in the current matrix, regarding indoor casualties. The reason for this is, as previously mentioned, the lower standard of finishing materials in the structures, that may disconnect from their position and fall, possibly hitting occupants present in the structure and causing injuries. Regarding severity of injuries (in all building types): the experts have appraised the increase in severity 1 casualties (light injuries) as an addition of 50 % to the current rates. Severity 2 casualties (hospitalized injuries) were also appraised as an addition of 50% to the current rates. Severity 3 casualties (life threatening injuries) were appraised as an addition of 25% to the current rates, and severity 4 casualties (fatalities) were appraised as an addition of 20% to the current rates. An exception in the HAZUS-MH matrix are URM structures (unreinforced masonry bearing walls) that pose higher threat to their occupants and are given systematically higher casualty rates compare to other structures. In Israel, according to a field survey conducted in this current study, URM structures are common in old cities (as in Tiberias or Jerusalem), and are thus considered to have very low resistance to earthquakes. For these building types, the experts appraised the addition to current casualty rates by 60% in all injury severity levels. Regarding outdoor casualty rates, the experts evaluated that in extensive damage state to structures the severity 1 casualties (light injuries) will increase in 15%, again due to falling objects or debris from structures. The rest of the casualty rates assumed by HAZUS-MH for different damage levels, were accepted by the local experts as sufficiently representing the estimations regarding a strong earthquake that may occur in Israel.

Figure 4. A sample webpage from the experts' survey assessing HAZUS-MH casualty matrix

4. RESULTS

This section is regarded as "preliminary" because the results relate to U.S. inventory rather than a local Israeli that has significant portion of soft-storey reinforced concrete buildings whose fragility curves have not been implemented. Moreover, Israeli code development has not been compared to the U.S. levels of code. One might argue that up to 1995 all the Israeli inventory is pre-code or low-code compared to that in the U.S. When complete implementation is achieved, damage and losses might jump ten-fold. Consideration of landslides that are expected in parts of Tiberias has not been accounted for yet and again damage and losses are expected to rise. Given the above reservations, the authors proceeded with assessing damage using HAZUS for 6.0 Mw and 7.0 Mw earthquake scenarios in Jordan Fault. The analysis classified the building inventory according to 3 age categories parallel to the Israeli Code development considering American code: before 1981 as no code, between 1981 and 1990 Low Code, and from 1991 as High Code.

4.1 Building damage and economic losses

Five categories are defined in HAZUS for building damage: no damage, slight, moderate, extensive and complete. The number of damaged buildings is converted from the probability of damage to the buildings for each building type. Analyzing the number of damaged buildings of unreinforced masonry (URM) for scenarios Jordan 6.0 Mw and Jordan 7.0 Mw, as depicted in Fig.4, 79% and 95% of URM buildings are damaged, respectively, as expected that URM is recognized as one of building types which is most seismically vulnerable (Spence, 2011). 55% and 77% of the concrete frame structures are damaged under scenarios of 6.0 Mw and 7.0 Mw, respectively as depicted in Figure 4. Here we investigate the vulnerability of a building type with its built year by measuring the percentage of damaged buildings with associated built year to the total number of buildings for each building type. Fig. 5 depicts that the buildings built before 1980 account for most damaged buildings for both concrete frame and URM. 44% and 64% of URM built before 1980 are estimated to be collapsed under scenarios of 6.0 Mw and 7.0 Mw, respectively, and 55% and 77% of the concrete frame structures are damaged under scenarios of 6.0 Mw and 7.0 Mw, respectively. It can be observed that the vulnerability of the building inventory is increased along with the ages of the building. In this study, the economic loss considers both the loss due to direct physical damage of structural components represented by repair cost, and the loss comes from damaged contents.

4.2 Casualty loss

The HAZUS program breakdowns casualty into four injury severity levels from the severity requiring basic medical aid to the most severe injury causing instantaneous death. In this study, the casualty is estimated at night time of the day, namely 2 a.m., as the worst case because it is assumed that all people are at home at night. Analyzing the rate of casualty caused by URM for scenarios of 6.0 Mw and 7.0 Mw, as depicted in Fig.6, 7.7% and 15.6% of residents of URM buildings are injured or death, respectively. This result shows that URM is recognized as one of the most hazardous building types in terms of casualty in the study area. Comparing to the URM, concrete frame has lower casualty rates of 1.5% and 2.1% for given scenarios of 6.0 Mw and 7.0 Mw, respectively.

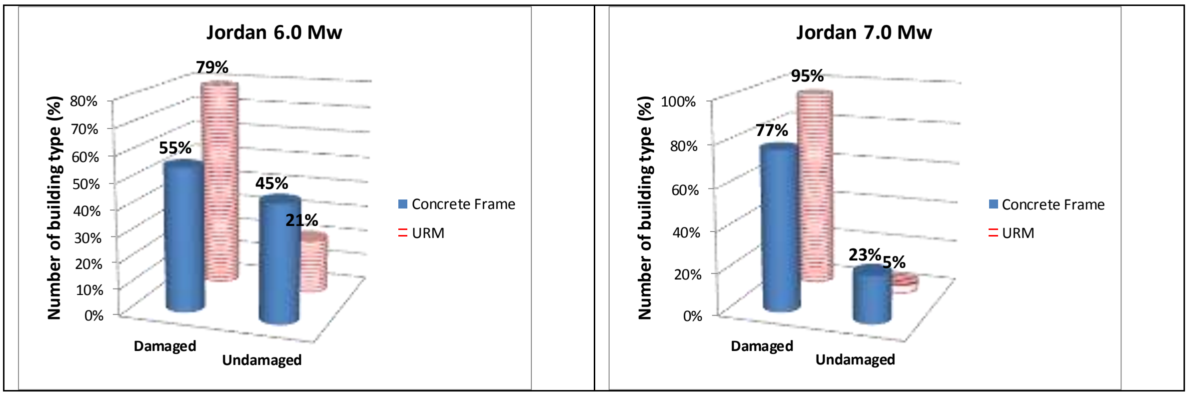

Figure 4. Building damages in different building types for given earthquake scenarios

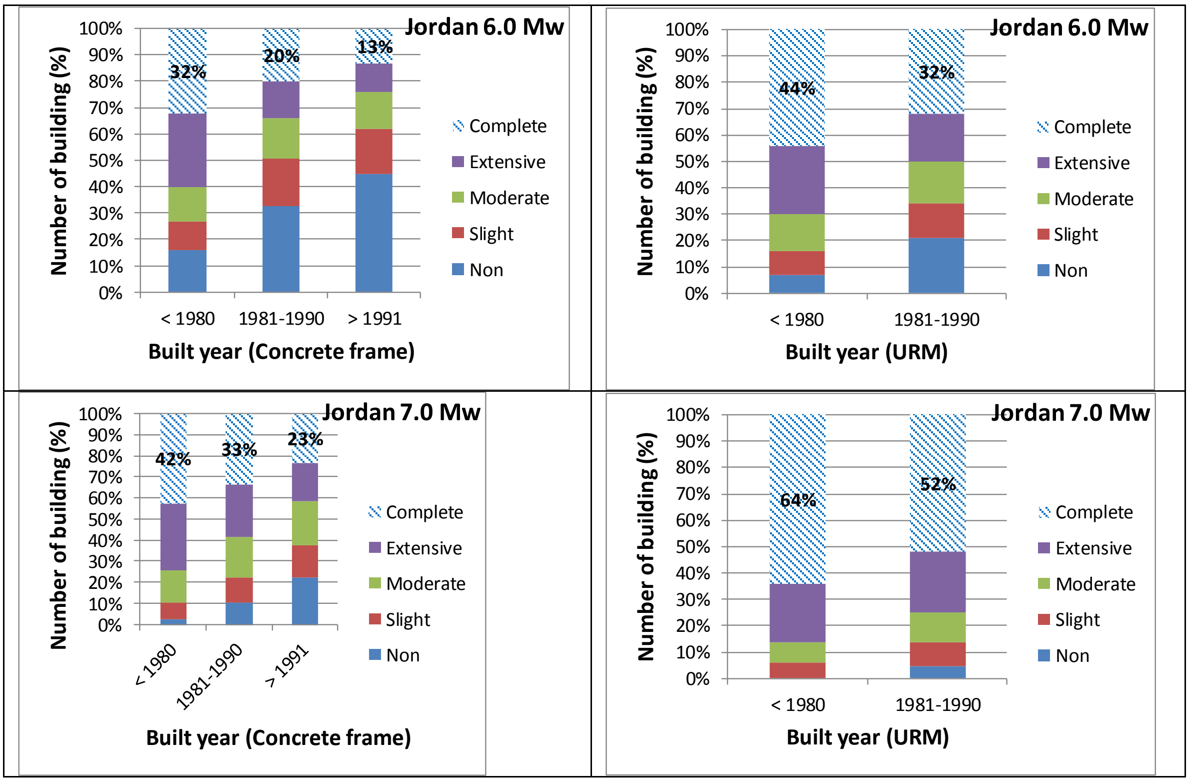

Figure 5. Building damage in different building types with associated built year for given earthquake scenarios

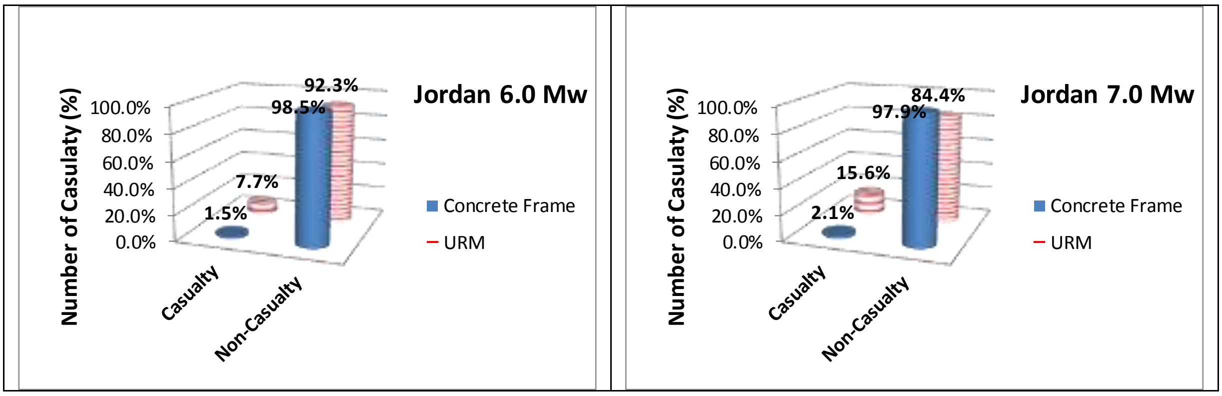

Figure 6. Casualties in different building types for given earthquake scenarios

5. CONCLUSIONS

HAZUS is expected to provide accurate loss estimation when a complete correct Israeli building inventory with its typical fragility, code development, and loss matrices are implemented. Damage, casualty rates, and loss are expected to increase tenfold. The present analysis and calculations were carried out according to classification of the Israeli building inventory in Tiberias according to the Israeli codes but with the employment of the parallel American Seismic standards. Two seismic scenarios were examined 6.0 and 7.0 Mw at the Jordan Fault. Preliminary results indicate that the existing building inventory is highly vulnerable to the seismic scenarios: between 55-95% of the building inventory is expected to be damaged in the two given scenarios. Between 13-42% of RC structures are expected to be completely collapsed and between 32-64% of the URM structures are expected to be completely collapsed. The latter expectancies express high vulnerability of the buildings' inventory. These figures are expected to rise as the fragility curves will be adapted to the Israeli building inventory. The risk expectancies will be analysed in accordance with the casualty matrices. A comprehensive multi-disciplinary methodology has been put forward. The methodology may be elaborated and further implemented in critical energy facilities.

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