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Necessity of Qom's City Buildings Improvement

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Abstract. Earthquakes are natural phenomenon which can cause huge losses of life and economy .Due to locating on seismic belt and its seismic condition, Iran country, is very sensitive to earthquake. Because of estimating importance of damages and casualties through earthquake, many countries have selected different methods for seismic hazard analysis. The objective of the current study is to evaluate the seismic vulnerability of buildings in Qom city based on the Hazus method and geographical information system (GIS). To this end, structure of engineering specification, the peak ground acceleration and soil information layers were utilized for developing a geotechnical map. Since there is a lot of data, SELENA software is used for calculating. The results show that the buildings are in one and six districts need to improvement.

Index Terms— Seismic Hazard Analysis; Hazus Method; improvement of buildings; Fragility Curve; Response Spectrum.

I. INTRODUCTION

The Iranian plateau is located between the continental convergence of the Arabian and Eurasian plates in the central part of the Alpine–Himalayan seismic belt. Thus, the seismicity of this area is very high and the frequent occurrence of moderate to large earthquakes such as Buin Zahra (1962), Tabas (1978), Manjil-Rudbar (1990), Avaj (2002), Bam (2003), Zarand (2005) and Varzaqan (2012) have caused heavy casualties and considerable financial losses to the country. [1]

Qom with a population near one million people is one of the most densely populated metropolises of the Iran. Qom which lies in an area of about 123073 km^2 is limited by the Elburz Mountains in the north and by Zagros heights in the west.

Movement of any of them could lead to a considerable loss of human life and to substantial financial damage.

In this region, there are many faults that Qom-Zefreh fault by 62 km length, Endis fault by 100 km length, Kooshk Nosrat by 137 km length, Siyah Kooh by 34 km length are the most important of them. Seismic history of Qom shows that two hundred sixty earthquakes occurred in recent thirty years which two of them had magnitude Ms>5. [1]

Now a days, vulnerability assessment and modeling behavior of buildings with regard to earthquakes have turned into a major concept in hazards studies (e.g. Rashed and Weeks, 2003[2]; Maithani and Sokhi, 2004[3]; Servi, 2004[4]; Gulati, 2006[5]:Thapaliya, 2006[6]; Cole et al., 2008[7]; Nath and Thingbaijam, 2009)[8].Therefore, many Iranian researchers such as Zahraie and Ershad (2005)[9], Aghataher et al. (2008)[10], AminiHosseini et al. (2009)[11], Hataminejad et al. (2009)[12] and Hashemi and Alesheikh (2012) [13]have identified the effective factors in earthquake hazard assessment and applied various methods in developing a seismic hazard map.

This document concentrates on matters relating to life safety; that is to say ,performance at the ultimate limit state. Emphasis is therefore placed on the identification and elimination of possible undesirable collapse mods that could affect either part of a building or the structure. lack of seismic separation between structural and non-structural items can also be a life safety issue.

II. RESEARCH PROCEDURE

The earthquake loss estimation tool SELENA, which is described herein, provides local, state and regional officials with a state-of-the-art decision support tool for estimating possible losses from future earthquakes. This forecasting capability enables users to anticipate the consequences of future earthquakes and to develop plans and strategies for reducing risk. GIS-based software can be utilized at multiple levels of resolution to graphically show loss results and to prepare response strategies.[14]

This software does not calculate casualties of nonstructural components. This software requires text input files which are consist of soil type information, capacity and fragility curves, probability of collapse of structures, renovation economic losses based on damage type, population information and etc. Generally, fifty three different input files are required for probabilistic analysis. Standard response spectrum, based on IBC-2006, is used for soil classification. This spectrum requires acceleration in periods 0.3 and 1 second. Classification of soil based on shear velocity of soil is also acceptable (International Building Code). [15] Capacity curve is an exact simple mean for prediction of nonlinear displacement response of structure for damage identification. This curve represents actual displacement of a given structure using several spectrums. The used curve in this study has three control points which are design, yielding and ultimate capacity. [16]

Design capacity represents the nominal strength required based on current seismic code provisions. Yield capacity represents the actual lateral strength of the building considering redundancies in design, conservatism requirements of code and actual strength (rather than nominal) of materials.

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Ultimate capacity represents the maximum strength of the building when the global structural system reaches a fully plastic state.

Parameters of capacity curve are obtained using Hazus table. These parameters are based on moderate code design level levels in concrete and steel and low code design level for masonry structures. (Optimized building damage module that uses seven combinations of design levels and building quality)

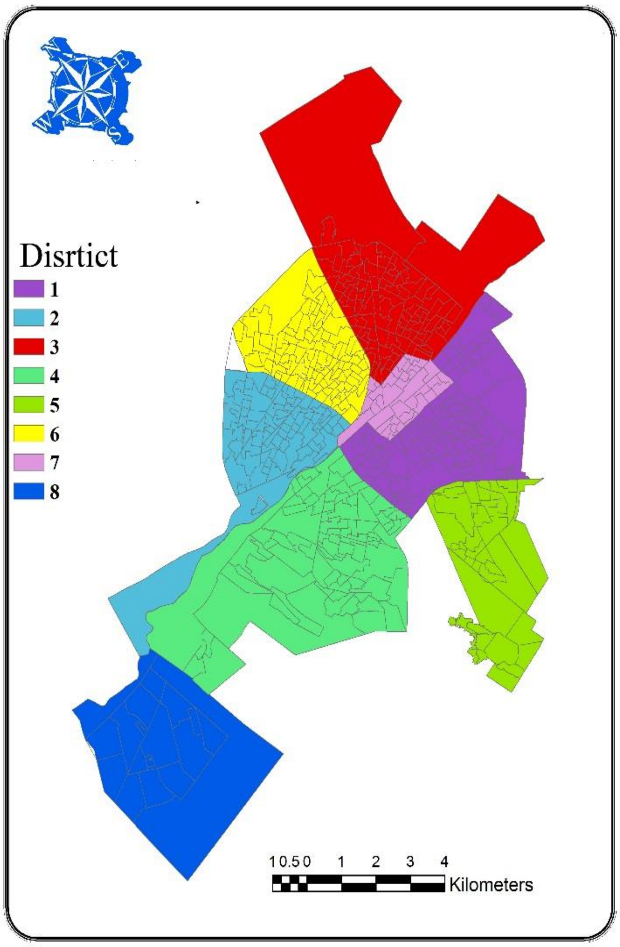

Fig. 1 District of Qom city

III. DATA PREPARATION AND ANALYSIS

A. *Construction materials of structures*

There are different classifications for the materials used in the construction of buildings. One of the most important is the ranking done in Standard 2800 (BHRC, 2005)[17] for earthquake -proof structures. In this regulation, structures are divided into three categories according to the materials used for construction; these are steel, concrete and masonry buildings (brick and cement block or stone) as well as sun-dried mud. The results of the research by experts in laboratory experiments and observations from previous earthquakes indicate that sun-dried mud brick buildings are vulnerable structures which totally collapse the most during an earthquake with a magnitude greater than 6 (Mahdizadeh, 2011)[18]; (the vulnerability of masonry, concrete and steel buildings decreases (table. 1).

District	Structural Type		
	Masonry	Steel	Concrete
1	5481746	1449348	468628
2	3609775	590808	512252
3	4628820	1269747	321700
4	3978690	3432951	1158467
5	1704238	546527	71948
6	4310170	382935	57502
7	1651112	522662	176773
8	43417	815007	1552199

Table1 Area of existing buildings (m^2) [19]

B. *Age of construction*

The optimal lifetime of structures in Iran is usually 30 yr. The longer a building's lifetime is, the greater is its vulnerability. Furthermore, according to Standard 2800 (BHRC, 2005,the amount of structural damage shows a step-linear function in an earthquake because the quality and the type of construction materials changed at each period during various editions of the regulations (BHRC, 1988, 1999, 2005). Thus the structures can be divided into three groups according to their vulnerability:

Building age with younger than 10 yr, between 10–30 yr, and 30–50 years shown in Figures 1 to 3. However, older buildings do not enjoy adequate safety and are likely to be vulnerable to severe damage or total collapse under strong seismic excitations.

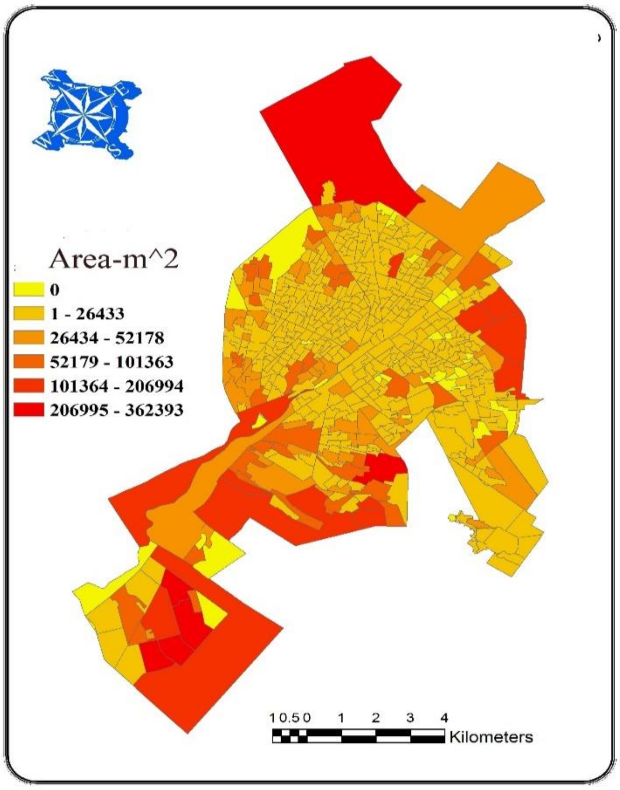

Fig. 2 Age of construction (10 years)

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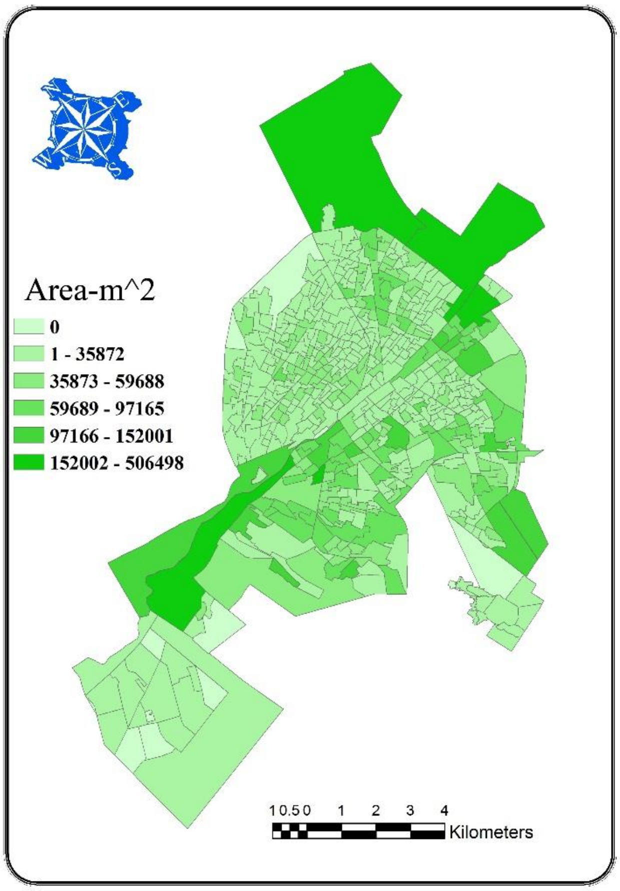

Fig. 3 Age of construction (10-30 years)

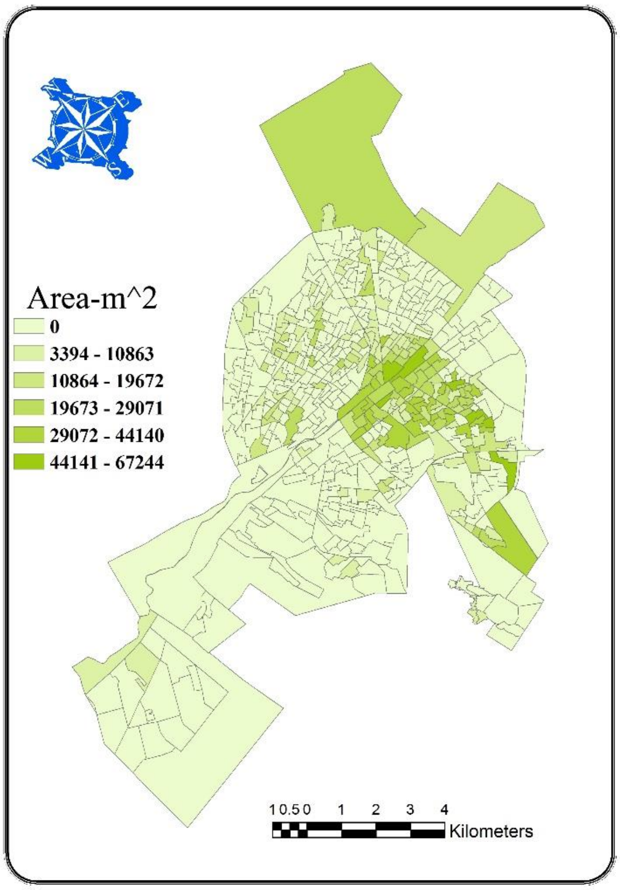

Fig. 4 Age of construction (30-50 years)

C. Structure damage

Steel Moment Frame (S1):

Slight Structural Damage: Minor deformations in connections or hairline cracks in few welds.

Moderate Structural Damage: Some steel members have yielded exhibiting observable permanent rotations at connections; few welded connections may exhibit major cracks through welds or few bolted connections may exhibit broken bolts or enlarged bolt holes.

Extensive Structural Damage: Most steel members have exceeded their yield capacity, resulting in significant permanent lateral deformation of the structure. Some of the structural members or connections may have exceeded their ultimate capacity exhibited by major permanent member rotations at connections, buckled flanges and failed connections. Partial collapse of portions of structure is possible due to failed critical elements and/or connections.

Complete Structural Damage: Significant portion of the structural elements have exceeded their ultimate capacities or some critical structural elements or connections have failed resulting in dangerous permanent lateral displacement, partial collapse or collapse of the building. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S1 buildings with Complete damage is expected to be collapsed.

Steel Braced Frame (S2):

Slight Structural Damage: Few steel braces have yielded which may be indicated by minor stretching and/or buckling of slender brace members; minor cracks in welded connections; minor deformations in bolted brace connections.

Moderate Structural Damage: Some steel braces have yielded exhibiting observable stretching and/or buckling of braces; few braces, other members or connections have indications of reaching their ultimate capacity exhibited by buckled braces, cracked welds, or failed bolted connections.

Extensive Structural Damage: Most steel brace and other members have exceeded their yield capacity, resulting in significant permanent lateral deformation of the structure. Some structural members or connections have exceeded their ultimate capacity exhibited by buckled or broken braces, flange buckling, broken welds, or failed bolted connections Anchor bolts at columns may be stretched. Partial collapse of portions of structure is possible due to failure of critical elements or connections.

Complete Structural Damage: Most the structural elements have reached their ultimate capacities or some critical members or connections have failed resulting in dangerous permanent lateral deflection, partial collapse or collapse of the building. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S2 buildings with Complete damage is expected to be collapsed.

Steel Frame with Cast-In-Place Concrete Shear Walls (S4):

This is a "composite" structural system where primary lateral-force-resisting system is the concrete shear walls. Hence, slight, Moderate and Extensive damage states are likely to be determined by the shear walls while the collapse damage state would be determined by the failure of the structural frame.

Slight Structural Damage: Diagonal hairline cracks on most concrete shear wall surfaces; minor concrete spalling at few locations.

Moderate Structural Damage: Most shear wall surfaces exhibit diagonal cracks; some of the shear walls have exceeded their yield capacities exhibited by larger diagonal cracks and concrete spalling at wall ends.

Extensive Structural Damage: Most concrete shear walls have exceeded their yield capacities; few walls have reached or exceeded their ultimate capacity exhibited by large through-the wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement. Partial collapse may occur due to failed connections of steel framing to concrete walls. Some damage may be observed in steel frame connections.

Complete Structural Damage: Structure may be in danger of collapse or collapse due to total failure of shear walls and loss of stability of the steel frames. Approximately 8%(low-rise), 5%(mid-rise) or 3%(high-rise) of the total area of S4 buildings with Complete damage is expected to be collapsed.

Reinforced Concrete Moment Resisting Frames (C1):

Slight Structural Damage: Flexural or shear type hairline cracks in some beams and columns near joints or within joints.

Moderate Structural Damage: Most beams and columns exhibit hairline cracks. In ductile frames some of the frame elements have reached yield capacity indicated by larger flexural cracks and some concrete spalling. Nonductile frames may exhibit larger shear cracks and spalling.

Extensive Structural Damage: Some of the frame elements have reached their ultimate , spalled concrete and buckled main reinforcement; nonductile frame elements may have suffered shear failures or bond failures at reinforcement splices, or broken ties or buckled main reinforcement in columns which may result in partial collapse.

Complete Structural Damage: Structure is collapsed or in imminent danger of collapse due to brittle failure of nonductile frame elements or loss of frame stability.
Approximately 13%(low-rise), 10%(mid-rise) or 5%(high-rise) of the total area of C1 buildings with Complete damage is expected to be collapsed.

Concrete Shear Walls (C2):

Slight Structural Damage: Diagonal hairline cracks on most concrete shear wall surfaces; minor concrete spalling at few locations.

Moderate Structural Damage: Most shear wall surfaces exhibit diagonal cracks; some shear walls have exceeded yield capacity indicated by larger diagonal cracks and concrete spalling at wall ends.

Extensive Structural Damage: Most concrete shear walls have exceeded their yield capacities; some walls have exceeded their ultimate capacities indicated by large, through-the-wall diagonal cracks, extensive spalling around the cracks and visibly buckled wall reinforcement or rotation of narrow walls with inadequate foundations.
Partial collapse may occur due to failure of nonductile columns not designed to resist lateral loads.

Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to failure of most of the shear walls and failure of some critical beams or columns. Approximately 13%(low-rise), 10%(mid-rise) or 5%(high-rise) of the total area of C2 buildings with Complete damage is expected to be collapsed.

Unreinforced Masonry Bearing Walls (URM):

Slight Structural Damage: Diagonal, stair-step hairline cracks on masonry wall surfaces; larger cracks around door and window openings in walls with large proportion of openings; movements of lintels; cracks at the base of parapets.

Moderate Structural Damage: Most wall surfaces exhibit diagonal cracks; some of the walls exhibit larger diagonal cracks; masonry walls may have visible separation from diaphragms; significant cracking of parapets; some masonry may fall from walls or parapets.

Extensive Structural Damage: In buildings with relatively large area of wall openings most walls have suffered extensive cracking. Some parapets and gable end walls have fallen. Beams or trusses may have moved relative to their supports.

Complete Structural Damage: Structure has collapsed or is in imminent danger of collapse due to in-plane or out-of-plane failure of the walls. Approximately 15% of the total area of URM buildings with Complete damage is expected to be collapsed.

D. Economic loss

SELENA can also estimate the total amount of economic losses (in any input currency) due to structural damage in any geographical region.

Economic loss for building renovation (and for reconstruction, in the case of complete damage) is computed based on the following equation [14]:

$$L_{eco} = C_r \sum_{i=1}^{N_{OT}} \sum_{J=1}^{N_{BT}} \sum_{K=1}^{N_{DS}} A_{i,j} P_{j,k} C_{i,j\,k} \qquad (1)$$

Where N_{OT} is the number of occupation types, N_{BT} presents the number of building types and N_{DS} is the number of damage states. In this equation, C_r , is regional cost multiplier (currently is set to 1.0, but can have different values for each geographical region in order to take into account the geographic cost variations); $A_{i,j}$ is the area of building type *j* with type *i* occupancy (in m^2); $P_{j,k}$ is the damage probability of a structural damage type *k* (slight, moderate, extensive or complete) in the building type *j* and $C_{i,j,k}$ is the cost of renovation or reconstruction (per m^2) for structural damage *k* in building type *j* with *i* occupancy.

E. Damage Functions Specification

Building damage functions are in the form of semi logarithmic fragility curves which relate the probability of reaching or exceeding a building damage state for a given PESH (Potential earth science hazards) demand parameter (e.g., displacement response spectrum). Figure 1 provides an example of fragility curve for four damage states used in this methodology.

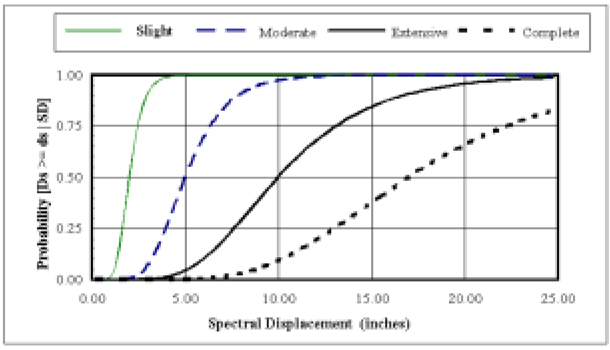

Fig. 5 Fragility Curves for Slight, Moderate, Extensive and Complete Damage [16]

Each fragility curve is defined by a mean value of the PESH demand parameter (i.e., either spectral displacement, PGD, spectral acceleration, PGA) corresponding to the damage state threshold and its variability. For example, the spectral displacement, S_d , which defines the threshold of a particular damage state (ds) is assumed to be defined as follow [16]:

$$S_d = S_{d,ds} \times \varepsilon_d \qquad (2)$$

Where $S_{d,ds}$ is the mean value of spectral displacement for damage state, ds, and ε_d is a lognormal random variable with unit median and logarithmic standard deviation.

IV. PROBABILISTIC ANALYSIS

The probabilistic analysis procedure denotes the use of spectral ordinates which are taken from probabilistic seismic maps. In addition to the acceleration values (PGA, Sa_T) for each geographical region, the geographical coordinates of the centroid have to be provided. Probabilistic seismic maps are generally developed for rock conditions such that soil amplification is not included in the spectral ordinates .[14]
Output files of this software are consist of mean damage ratio (MDR), economic losses, damaged building area, number of human losses and damage probabilities.
Because of high volume data, ArcGis software is implemented in order to show results.

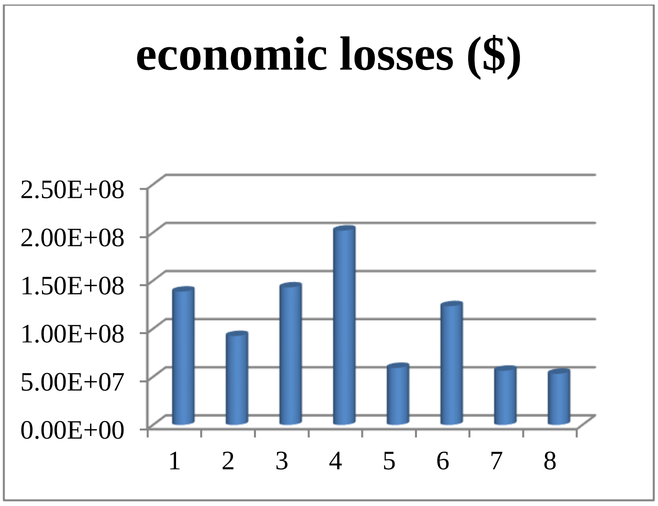

Chart .1 Amount of economic losses of Qom

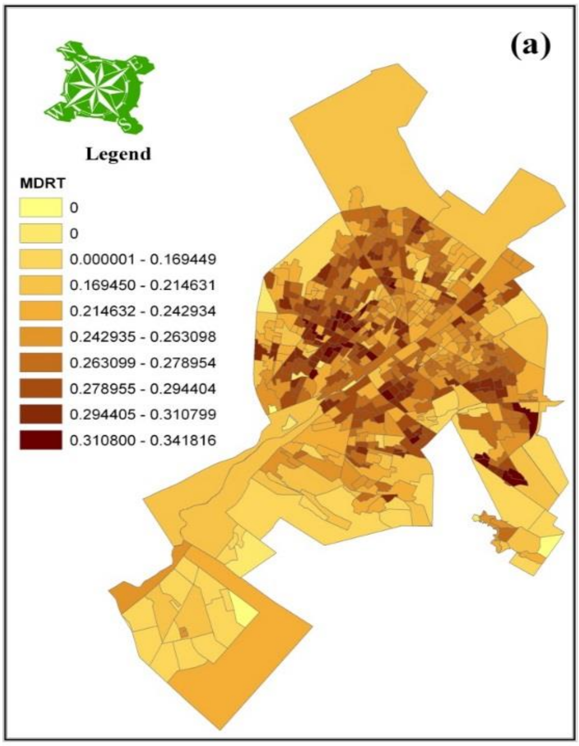

Fig.6 Mean damage ratio computed for different zone of Qom

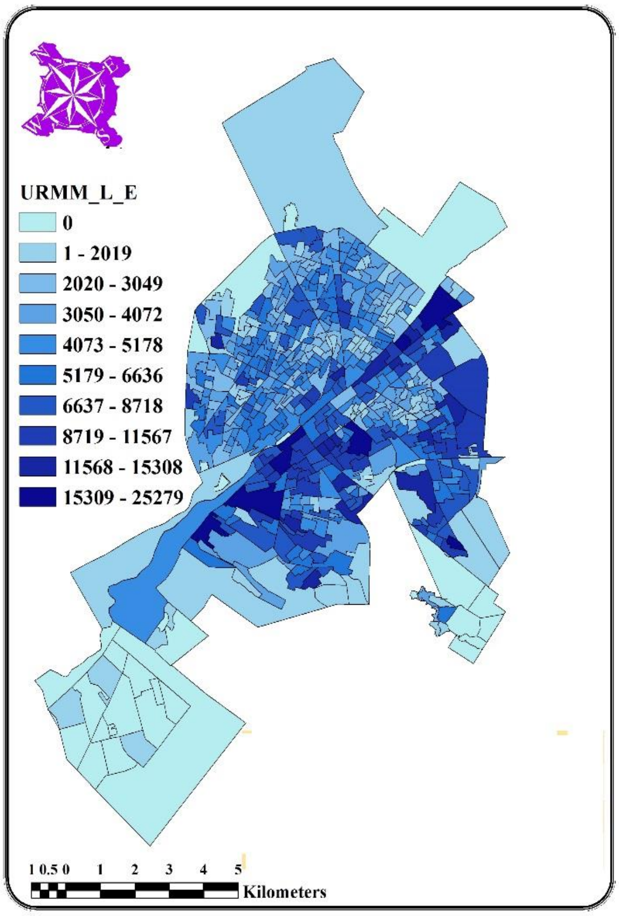

Fig.7 area of Unreinforced Masonry Bearing Walls buildings that damage Extensively

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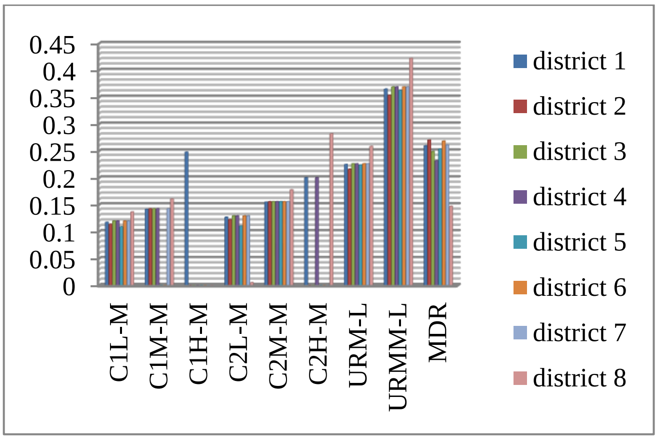

Chart .2 Mean damage ratio computed for concrete and masonry structures

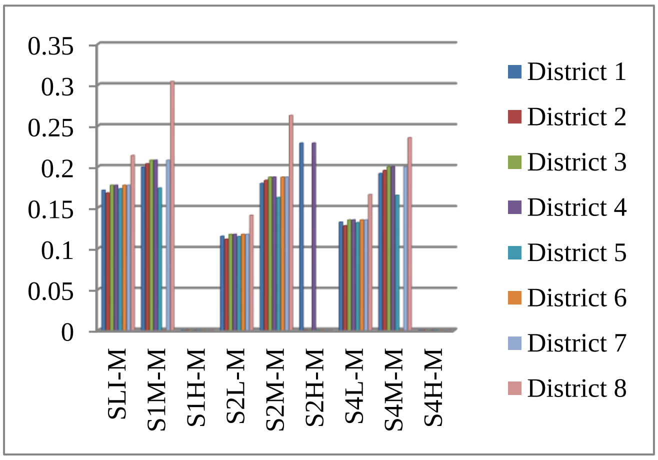

Chart.3Mean damage ratio computed for steel structures

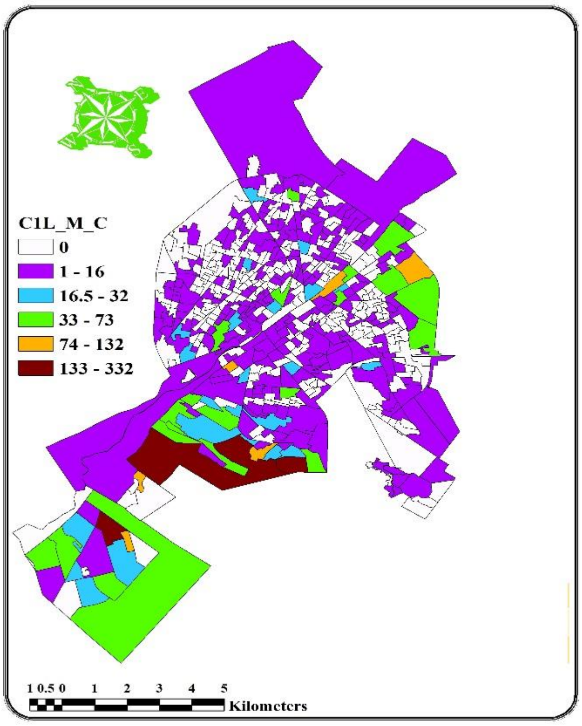

Fig.8 the area of Concrete Moment Frame schools that damage completely

V. CONCLUSIONS

In this study, the vulnerability of Qom school buildings has been investigated according to geotechnical and structural criteria and sub criteria by using a combination of GIS and Hazus methods. Since all geotechnical and structural criteria, despite having an important role in the vulnerability of schools, do not have the same importance and value, the vulnerability of buildings cannot be reviewed only by inspecting each element individually. Therefore, to achieve the correct results, all elements have been considered simultaneously.

Analysis provides if an earthquake based on 2800 code occurs, economic losses are 1078660213$.

Results show that the amount of casualties in districts one and six are more than the others, because, these districts contain more dilapidated and masonry buildings than other districts.

There are about 230000 buildings in Qom city that 28% of them had built in recent ten years.

According to the 2800 earthquake code, 13% of buildings no damaged, 21% damaged slightly, 31% damaged moderately, 20% damaged extensively and 15% damaged completely.

The results show that the schools are in rather good condition.

APPENDIX

S1L	Steel Moment Frame, low-rise
S1M	Steel Moment Frame, mid-rise
S1H	Steel Moment Frame, high-rise
S2L	Steel Braced Frame, low-rise
S2M	Steel Braced Frame, mid-rise
S2H	Steel Braced Frame, high-rise
S4L	Steel Frame with Cast-in-Place Concrete Shear Walls, low- rise
S4M	Steel Frame with Cast-in-Place Concrete Shear Walls, mid- rise
S4H	Steel Frame with Cast-in-Place Concrete Shear Walls, high- rise
C1L	Concrete Moment Frame, low rise
C1M	Concrete Moment Frame, mid rise
C1H	Concrete Moment Frame, high rise
C2L	Concrete Shear Walls, low rise
C2M	Concrete Shear Walls, mid rise
C2H	Concrete Shear Walls, high rise
URML	Unreinforced masonry bearing walls, low rise
URMM	Unreinforced masonry bearing walls, mid rise

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