【原著論文】

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Applicability of the Visual Screening for Buildings Safety against Earthquakes ～A Case Study on Hatay, Antakya, Turkey～

建物の地震に対する安全性を確保するための目視スクリーニングの適用性検討

～トルコ、アンタキヤのハタイ市の事例 ～

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SUMMARY

The 2023 Turkey-Syria Earthquake has caused one of the most devastating human losses and damage to structural resources in the last decade. To avoid such devastating damage, screening fragile buildings is important. Thus, this research tried to check the applicability of FEMA rapid visual screening for building safety against earthquakes. From Google Street-View images before the earthquake, 99 damaged buildings in Hatay, Antakya, Turkey were evaluated with construction irregularities. Then, a comparison of the level-damaged building group sampling: FEMA total average score, the number of stories, and the aspect ratio of buildings were performed. The results indicate that the differences in the FEMA total average score of the buildings categorized by the observed level of damage are statistically significant. Therefore, the evaluation of building irregularity in FEMA rapid visual screening may apply to the buildings in Turkey, although the FEMA method is designated to apply to the buildings in the United States of America (USA).

Key word

Damaged buildings, Visual screening, Safety, Earthquake, Turkey

1. Introduction

The seismic design and appropriate construction of structures are quite important in earthquake-prone areas. Therefore, all projects in high seismic hazard areas should have the services of technical personnel with knowledge and experience in the construction of earthquake-resistant structures [1].

Due to the severe 6 February 2023 Turkey-Syria earthquake, many buildings have been collapsed. It was reported that the presence of soft story irregularity on the ground level or above the plinth was one of the key reasons for the collapse of many buildings [2]. According to FEMA, the soft story

Table 1. Comparison of most used RVS Methods

	FEMA P-154 [5]	IITK-GGSDMA [6]	EMPI [7]
Methodology	Based on a sidewalk survey and a Data Collection Form	Similar To FEMA P-154 Methodology	RVS is the first stage of three structural assessments
Items considered for scoring	Building type Vertical irregularity Plan irregularity Age of construction (Pre-code, Post-benchmark) Soil type (Some more optional items were prepared as the following steps, but not considered in this study).	Number of Stories Vertical irregularity Plan irregularity Age of construction (Post-benchmark) Soil type	Number of Stories Soil type Vertical irregularity Pounding effect Topographic effect

is a severe vertical irregularity that affects the seismic behavior of a building if the stiffness of one story is dramatically less than that of most of the others. Using the ground floors as commercial stores with little or no infill walls was responsible for plastic hinging in columns, resulting in a pancake-type collapse [3], [4]. This damage was mainly observed in reinforced concrete (RC) buildings constructed after 2000 in Hatay, and Gölbaşı provinces. It indicates that seismic resistance assessment is quite important to avoid damages and collapses of buildings in earthquake events.

In the engineering field, there are many methods available for seismic assessment of structures, which involve detailed structural analysis and design (i.e., equivalent frame method, finite element analysis, adaptive limit analysis). This structural analysis, also known as perform-based methods, has a quantitative approach, which covers demand-capacity (DCR) computation. On the other hand, there are some Rapid Visual Screening (RVS) methods, (i.e., FEMA P-154 [5], IITK-GGSDMA[6], EMPI [7], etc.) as a qualitative procedure for estimating structural scores for buildings.

One of the RVS merits is its simple procedure for quick evaluation of large building stock. This method identifies the riskiest buildings that require further detailed structural assessments. The seismic vulnerability of structures is evaluated by identifying induced characteristics of the seismic response of buildings, such as load-resisting system, seismic region, structural deficiencies, etc. In addition, it is an important assessment for urban planners and decision-makers when applied to a regional scale.

One of the difficulties of RVS methods is collecting accurate data from buildings in a short time. The determination of the expected damage of a building or the need for the next stage of assessment depends on this collected data. Therefore, since first-level evaluation (RVS) is typically based on simplification and approximate indexes, more detailed second and third levels of structural analysis are needed to follow while evaluating an individual building for better predicting expected seismic behavior.

Many RVS methods have been developed worldwide in the last century [8]. According to the difference in building codes and construction practices, the scoring system and parameters taken into account for assessing the vulnerability of buildings also differ from place to place. Table 1 shows a comparison of RVS methods (FEMA P-154, IITK-GGSDMA, EMPI) based on their respective main features. Due to the important approximated seismic behavior of buildings given in a few minutes to stakeholders, the applicability of these methods needs to be verified.

Regarding the applicability of RVS, Harirchian et al.[9] performed a comparison with a seismic assessment and observed damage to RC buildings from a sidewalk survey after the Bingol earthquake on May 1st, 2003. However, the results presented are insufficient, due to the limited number of damage cases in a moderate-severe earthquake, in contrast with this study. Therefore, it is important to evaluate the applicability of RVS based on severe damage cases in a large earthquake.

This research aims to verify the applicability of the FEMA P-154, by referring to the damage cases in the 2023 Turkey-Syria Earthquake. One of the merits of the FEMA P-154 is that its survey is quickly done in minutes. It is one of the most followed RVS methodologies implemented in many countries, due to its capability to evaluate the seismic safety of a large inventory of buildings quickly and with minimum access to structures, by taking into account the building's structural characteristics [10], [11]. Although, as a possible demerit of FEMA P-154, Harirchian et al. [9]indicate that other methods give a better estimation than FEMA P-154, the evaluation of the applicability of FEMA P-154 with severe structural damaged buildings is meaningful.

2. The building damage in the 2023 Turkey-Syria Earthquake

According to AFAD (Disaster and Emergency Presidency of Turkey), the 2023 Turkey-Syria Earthquake occurred on February 6th at 1.17 UTC (local time 4:17 AM, UTC +3) on the East Anatolian Fault (EAF) with magnitude M7.7. This earthquake occurred in the southwestern part of Turkey, near the northern border of Syria. The hypocenter was located at N37.288°, E37.043°, approximately 40 km northwest of Gaziantep, and 33 km southeast of Kahramanmaras, with a focal depth of 8.6 km (AFAD). The earthquake was followed 11 minutes later by a magnitude M6.8 aftershock and 9 hours later by a magnitude M7.5 earthquake [12].

As the first step of the study, the authors focused on Hatay, Antakya, Turkey, which was heavily affected by the earthquake.

According to the World Bank and Global Facility for Disaster Reduction Recovery report [13], Hatay, Kahramanmaras, Gaziantep, Malatya, and Adiyaman provinces in Turkey registered the most devasting damage to buildings and infrastructure (81% of estimated damages). Of these provinces, Hatay experienced the most relevant damage (36% of total damages).

After the earthquake, damaged buildings were identified by the Ministry of Environment, Urbanization & Climate Change of Turkey [14].

Figure 1 shows a close-up view of the identified location of houses and damage levels in Hatay. Herein, "collapsed" is defined as a building in ruins, "heavily damaged" as concrete construction destroyed, and "slightly damaged" as repairable buildings after the seismic event. See the details in the reference [15].

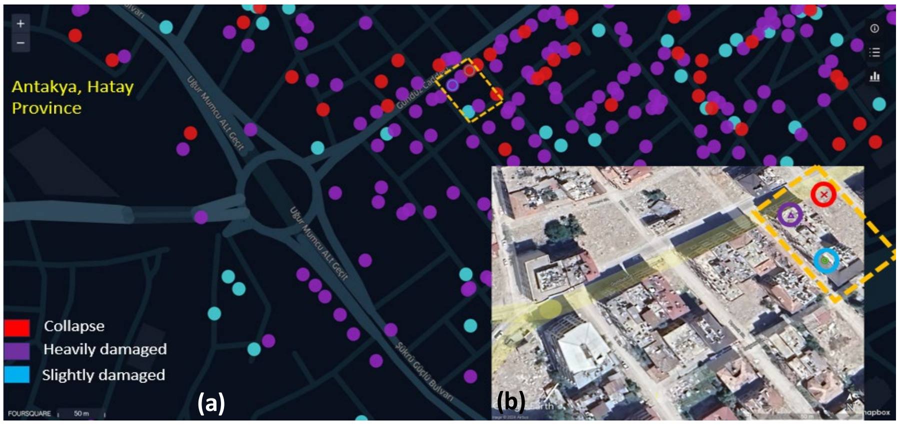

Figure 1. Example of the identified location of houses and damage levels considered in Hatay (Close-up view).

(a) 2023 Turkey Earthquake Building Damage Assessment Map [14]

(b) Damaged buildings from satellite images. (Google Earth)

3. The method of analysis to check the applicability of visual screening

3.1 Purpose and Methodology

The purpose of this research was to check the applicability of FEMA rapid visual screening for building safety against earthquakes. Therefore, the authors selected buildings with different views and different damage levels, but with the same conditions in other factors. After that, the relationships between the RVS scores obtained from building views and observed damage level were confirmed.

For the methodology, the authors used Google Street View to capture building images before the earthquake. As for the limitation of the data resource, Google Street View gave us some photos from a limited number of points. Furthermore, the height of the viewpoint was almost the same, and a close-up view is not available. Thus, some details of the buildings were difficult to obtain.

Figure 2 is an example of a building image from the road nearby in the study area. This photo was taken after the 2023 Turkey-Syria Earthquake, and the building was categorized as slightly damaged. Due to the copyright limitation of Google Street View, the original image used in this study, which was taken before the earthquake cannot be shown in the paper. However, Figure 2 is a quite similar one.

Figure 3 shows the FEMA score sheet used in the study. The sheet for very high seismicity was used. To use the FEMA score sheet, the first thing to be done is to identify the building type. Then it gives the basic score. After that, with the level of irregularities and some other factors, we have some modifications that affect the score. If the score is high, it means the building is safe. And if the score is low, it is dangerous.

For example, the building shown in Figure 2 is a system-type C3, which corresponds to reinforced concrete buildings with unreinforced masonry infills and RC buildings with concrete shear walls.

Figure 2. Example of building image from roads nearby.Source:https://www.iclr.org/wpcontent/uploads/2023/07/EERI-LFE_20230630_ICLR.pdf

And most of the buildings in the study area were of this type. Based on the FEMA sheet presented in Figure 3, first, the building type was identified as RC buildings, thus system type C3 was selected. The basic score for this type was 1.2. Then, a score modifier of -0.7 was assigned for the severe irregularity.

Since the years of construction of the buildings in the area were unknown to the authors, buildings were assumed to have been constructed before 1998, when the seismic code was introduced in Turkey. Note that, according to the Minister of Environment, Urbanisation, and Climate Change [16], more than 97% of the collapsed buildings in certain locations of Hatay, including Gaziantep and Kahramanmaras, were constructed before 2000. Thus, the modifier -0.1 of pre-code was applied to all the buildings. However, since there are no quite new buildings in the picked-up study area, no modifier of post benchmark was applied to all the buildings (±0.0).

According to the literature [17], the soil of type C was assumed to be the whole area. Note that, according to the National Earthquake Hazards Reduction Program (NEHRP), Type C corresponds to a soil classification type, which includes very dense soil and soft rock (sandstone). And we had no modifier value for this soil type (±0.0).

These are the procedures used to evaluate the score from Google Street View images. And as an example, the final score of 0.4 was assigned to the building shown in Figure 2.

3.2 Data Collection

The study area was the city's center as shown in the red lines in Figure 4. The city's main roads were used to define the area as shown in Figure 5. From the microzonation map of Hatay Province [17],

Irregularities

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}																	
FEMA BUILDING TYPE Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}	*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

Mainly C3

Figure 3. FEMA Basic Score parameters were obtained from the FEMA data collection form used for the 99 damaged buildings. Source: Adapted from FEMA.

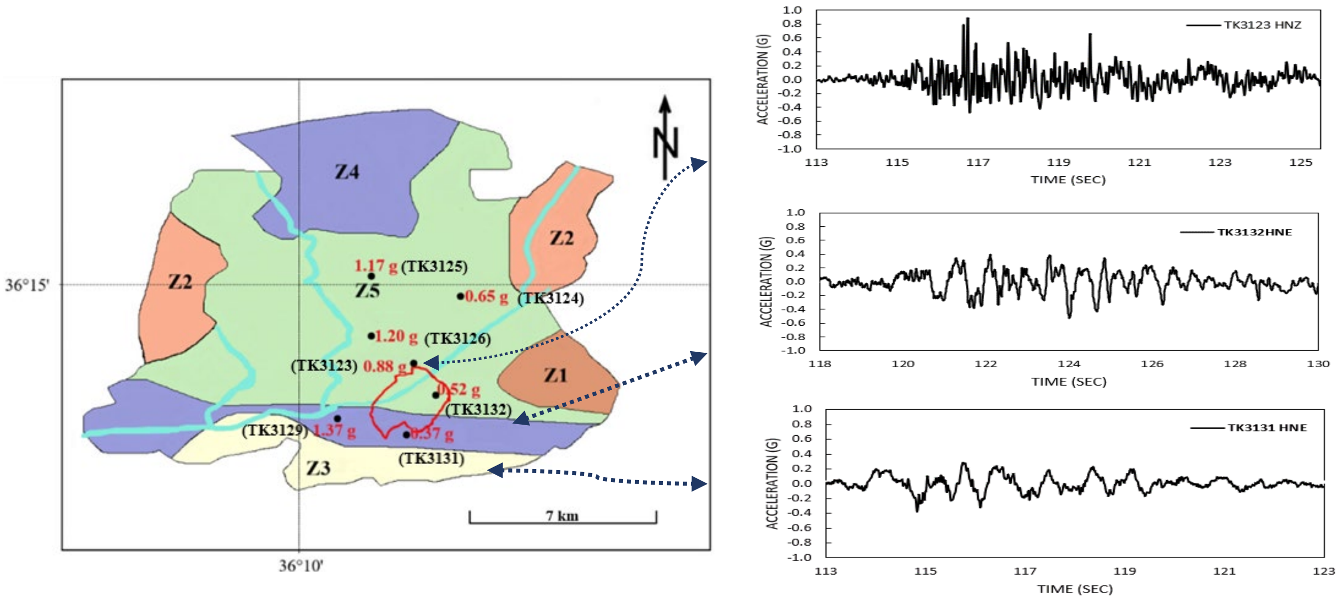

Figure 4. The study area (red polygon), microzonation of Hatay [17], and strong motion observation sites nearby (black dot) [18],[19],. Source: Adapted from Google Earth

this area was located in Zone 4 and Zone 5.

There were seven (7) strong motion observation sites near the area, as shown in Figure 4. The observed shaking level of the M7.7 earthquake (PGA: Peak Ground Acceleration) of the area was about 0.37 g to 0.88 g, although stronger shakings beyond 1 g were observed outside of the area. And, the difference of shakings within the study area was not significant. As shown in Figure 4, the seismic waveforms observed around the study area were not so different except for the high-frequency component observed in TK3123, where a spiky peak provided a larger PGA. Note that, although the difference in high-frequency shakings remained, our methodology of picking up all three different damage levels of buildings nearby can minimize the effects of these shaking differences in the study area.


Figure 5. Summary of picked-up buildings in the study area., 99 damaged buildings with three levels of seismic damage (33 sets) on satellite images.

As shown in Figure 1(a) each building was assigned a red, purple, and blue color by classifying its observed damage. Thus, as shown in the photo in Figure 1(b), the corresponding building was identified by the satellite images. In addition, the authors tried to find all three different levels of damaged buildings nearby (less than 65 m). This is because the three buildings nearby may have experienced almost the same level of shaking, and other factors except the building shapes were almost the same.

Thus, the difference in the characteristics of the buildings may be the main reason for the difference in the damage level.

In short, a set of damaged buildings representing three (3) buildings nearby with different levels of damage (collapsed, heavily damaged, slightly damaged) were defined.

Figure 5 shows the summary of picked-up buildings. There are 99 damaged buildings with three levels of seismic damage (33 sets).

Table 2 lists the total 33 sets of three-level damaged building groups with important characteristics considered in this study.

As the next step, FEMA rapid visual screening sheets were used to assess the characteristics of the buildings surveyed. In addition to the FEMA Score, the number of stories and aspect ratio indexed as the number of stories divided by the width of buildings were used.

This is because the authors think high-rise buildings and slim buildings are unstable. Also, this information can be obtained by visual inspection. Then the characteristics of three building groups with different levels of damage were compared.

4. Results of analysis

Figure 6 to Figure 8 shows a comparison of FEMA scores, number of stories, and aspect ratio of 33 building sets.

From Figure 6, it can be observed that most collapsed buildings have a 0.3 score. In contrast, most of the slightly damaged buildings are 0.4 or more. And the scores for heavily damaged are between these, except for set 18. In the majority, the score of heavily damaged buildings is less or equal to the score of collapsed buildings. In addition, the score of slightly damaged is less or equal to the score of heavily damaged buildings. Interestingly, FEMA scores are equal in three sets for collapse, heavily and slightly damaged, particularly in sets 1, 3, 22, 23, and 32. This is because the difference cannot be identified from the visual screening for this data. For example, it can be the difference that comes from the level of deterioration on the interior of the structures. This just means about the limitations of the visual screening.

Figure 7 shows that the 2 buildings with 8 stories are the tallest. And one was collapsed, but the other was slightly damaged.

In Figure 8, the level of damage in slim buildings can be discussed. In set 20, the slimmest building was collapsed. However, in set 19, the building with the smallest aspect ratio collapsed.

Figure 9 shows the comparison of the average FEMA scores in building groups. The building group with less damage shows a higher FEMA score. We have applied ANOVA (Analysis Of Variance) [20], to check the significance of the trend. This trend is statistically significant since the

Table 2. List of three-level damaged building groups

Number of set	Level of damage	Location (latitude, longitude)	FEMA SCORE	Stories	Aspect Ratio
1	Collapse	(36.193685, 36.151802)	0.4	4.0	0.2034
	Heavily	(36.194006, 36.151765)	0.4	4.0	0.259
	Slightly	(36.194301, 36.151229)	0.4	4.0	0.176523
2	Collapse	(36.196488, 36.15001)	0.3	2.0	0.27241
	Heavily	(36.196352, 36.149812)	0.4	4.0	0.52816
	Slightly	(36.196106, 36.149998)	0.4	5.0	0.41502
3	Collapse	(36.19617, 36.15167)	0.3	3.0	0.22579
	Heavily	(36.195965, 36.151678)	0.3	7.0	0.2429
	Slightly	(36.195847, 36.151476)	0.3	7.0	0.535519
4	Collapse	(36.197592, 36.153968)	0.3	4.0	0.54926
	Heavily	(36.197587, 36.154186)	0.7	4.0	0.2657
	Slightly	(36.197338, 36.15397220)	0.7	5.0	0.25661
5	Collapse	(36.197136, 36.158167)	0.3	5.0	0.30378
	Heavily	(36.196999, 36.158755)	0.4	5.0	0.23056
	Slightly	(36.196862, 36.15905)	0.4	4.0	0.495032
6	Collapse	(36.199957, 36.159736)	0.3	5.0	0.61411
	Heavily	(36.198115, 36.158847)	0.3	4.0	0.2225
	Slightly	(36.19654, 36.157773)	0.4	3.0	0.144912
7	Collapse	(36.200204, 36.160404)	0.3	8.0	0.62305
	Heavily	(36.199472, 36.160294)	0.3	7.0	0.79819
	Slightly	(36.199178, 36.160856)	0.7	3.0	0.271452
8	Collapse	(36.199603, 36.160542)	0.3	6.0	0.26707
	Heavily	(36.199176, 36.160516)	0.4	5.0	0.25417
	Slightly	(36.198747, 36.160847)	0.4	8.0	0.420508
9	Collapse	(36.197767, 36.162149)	0.3	2.0	0.11814
	Heavily	(36.197912, 36.162074)	0.3	3.0	0.20439
	Slightly	(36.197833, 36.162283)	0.4	3.0	0.323063
10	Collapse	(36.197974, 36.163036)	0.3	2.0	0.20873
	Heavily	(36.19776, 36.162737)	0.3	2.0	0.43114
	Slightly	(36.198001, 36.163273)	0.7	2.0	0.223432
11	Collapse	(36.19745, 36.164455)	0.3	2.0	0.07576
	Heavily	(36.197355 , 36.164219)	0.3	4.0	0.55643
	Slightly	(36.197672, 36.16411)	0.4	2.0	0.101383
12	Collapse	(36.197098, 36.164666)	0.3	6.0	0.17468
	Heavily	(36.197092 , 36.165088)	0.3	4.0	0.22291
	Slightly	(36.197211, 36.165076)	0.4	2.0	0.153602
13	Collapse	(36.196111, 36.165327)	0.3	5.0	0.21132
	Heavily	(36.196316 , 36.165758)	0.4	4.0	0.15152
	Slightly	(36.19615, 36.165501)	0.4	4.0	0.402161
14	Collapse	(36.201126, 36.161011)	0.3	2.0	0.15131
	Heavily	(36.199562, 36.163722)	0.3	5.0	0.42102
	Slightly	(36.199178, 36.160856)	0.4	3.0	0.240242
15	Collapse	(36.201452, 36.162309)	0.3	2.0	0.42421
	Heavily	(36.200799, 36.163225)	0.3	2.0	0.51495
	Slightly	(36.20043, 36.163795)	0.5	1.0	0.066824
16	Collapse	(36.201487, 36.162175)	0.3	4.0	0.23312
	Heavily	(36.201535, 36.162951)	0.4	3.0	0.10657
	Slightly	(36.201048, 36.162695)	0.4	2.0	0.154726
17	Collapse	(36.201658, 36.161865)	0.3	4.0	0.49558
	Heavily	(36.202635, 36.162236)	0.3	3.0	0.21646
	Slightly	(36.203864, 36.162059)	0.4	2.0	0.196474
18	Collapse	(36.201971, 36.165879)	0.3	3.0	0.2378
	Heavily	(36.202077 , 36.165962)	0.4	3.0	0.22513
	Slightly	(36.202649, 36.166408)	0.3	3.0	0.240909
19	Collapse	(36.205548, 36.16377)	0.3	6.0	0.28055
	Heavily	(36.205479, 36.163215)	0.3	5.0	0.66534
	Slightly	(36.205045, 36.163322)	0.4	6.0	0.685293
20	Collapse	(36.205336, 36.164923)	0.3	5.0	0.79506
	Heavily	(36.205345, 36.164894)	0.3	5.0	0.18433
	Slightly	(36.205744, 36.164071)	0.4	5.0	0.400023
21	Collapse	(36.205202, 36.166242)	0.3	5.0	0.31306
	Heavily	(36.205437, 36.16603)	0.3	4.0	0.18206
	Slightly	(36.205982, 36.165693)	0.4	5.0	0.408618
22	Collapse	(36.204024, 36.167777)	0.3	3.0	0.3542
	Heavily	(36.204577 , 36.168326)	0.3	4.0	0.48593
	Slightly	(36.203617, 36.168713)	0.3	3.0	0.346975
23	Collapse	(36.203759, 36.167798)	0.3	2.0	0.20397
	Heavily	(36.204506 , 36.168274)	0.3	2.0	0.20784
	Slightly	(36.20402, 36.168059)	0.3	3.0	0.204216
24	Collapse	(36.203488, 36.167378)	0.3	2.0	0.25859
	Heavily	(36.20336 , 36.167609)	0.4	3.0	0.42131
	Slightly	(36.203507, 36.167569)	0.4	3.0	0.496242
25	Collapse	(36.202515, 36.172263)	0.3	4.0	0.42813
	Heavily	(36.202408 , 36.170965)	0.4	1.0	0.0919
	Slightly	(36.20249, 36.170911)	0.4	3.0	0.414946
26	Collapse	(36.205018, 36.172892)	0.3	3.0	0.49185
	Heavily	(36.205018 , 36.172892)	0.3	3.0	0.33042
	Slightly	(36.205035, 36.173086)	0.4	3.0	0.329805
27	Collapse	(36.20612, 36.173658)	0.3	2.0	0.46392
	Heavily	(36.206383 , 36.173796)	0.3	2.0	0.18703
	Slightly	(36.206033, 36.173093)	0.4	3.0	0.402197
28	Collapse	(36.208442, 36.175657)	0.3	4.0	0.2297
	Heavily	(36.208641, 36.175912)	0.3	2.0	0.53125
	Slightly	(36.20827, 36.175555)	0.5	2.0	0.3029
29	Collapse	(36.208553, 36.175426)	0.3	4.0	0.62257
	Heavily	(36.209289, 36.175231)	0.4	5.0	0.44173
	Slightly	(36.208976, 36.175209)	0.4	3.0	0.391463
30	Collapse	(36.209112, 36.174813)	0.3	4.0	0.52682
	Heavily	(36.174679, 36.208861)	0.4	3.0	0.57594
	Slightly	(36.174404, 36.208965)	0.4	2.0	0.255443
31	Collapse	(36.210415, 36.15726)	0.3	2.0	0.33548
	Heavily	(36.210182, 36.157302)	0.3	3.0	0.34879
	Slightly	(36.209997, 36.157408)	0.3	1.0	0.096489
32	Collapse	(36.207303, 36.157376)	0.4	2.0	0.39725
	Heavily	(36.20722,36.157258)	0.4	3.0	0.46467
	Slightly	(36.207436, 36.157225)	0.4	2.0	0.24542
33	Collapse	(36.206588, 36.158966)	0.3	2.0	0.26702
	Heavily	(36.206722, 36.158898)	0.3	3.0	0.66339
	Slightly	(36.206875, 36.158817)	0.4	3.0	0.317897

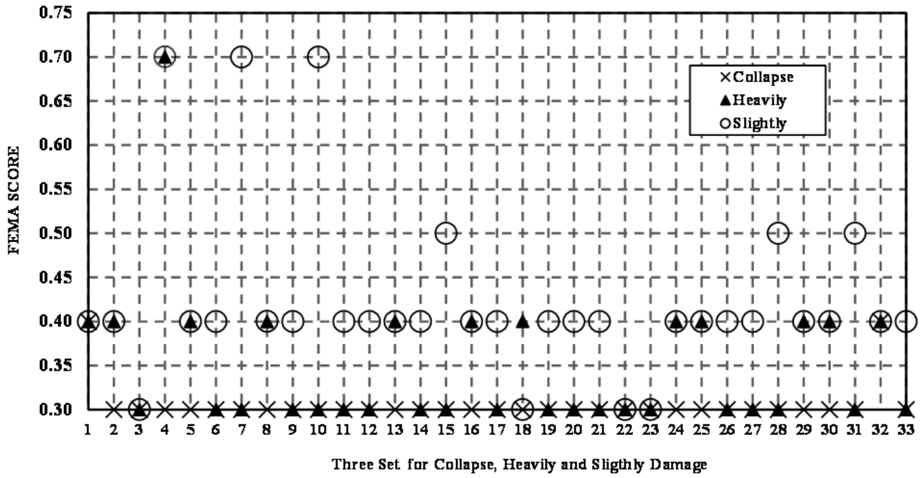

Figure 6. Comparison of the FEMA Scores of each Set of Buildings.

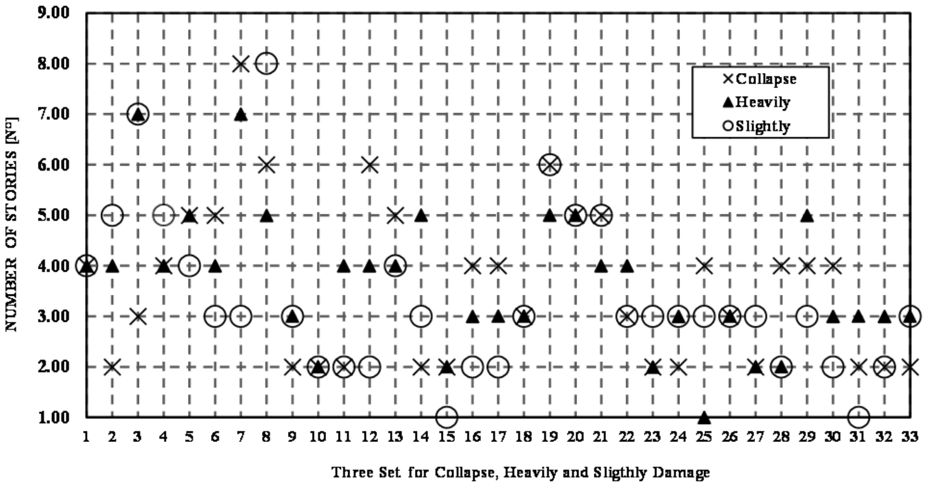

Figure 7. Comparison of the Number Stories of each Set of Buildings.

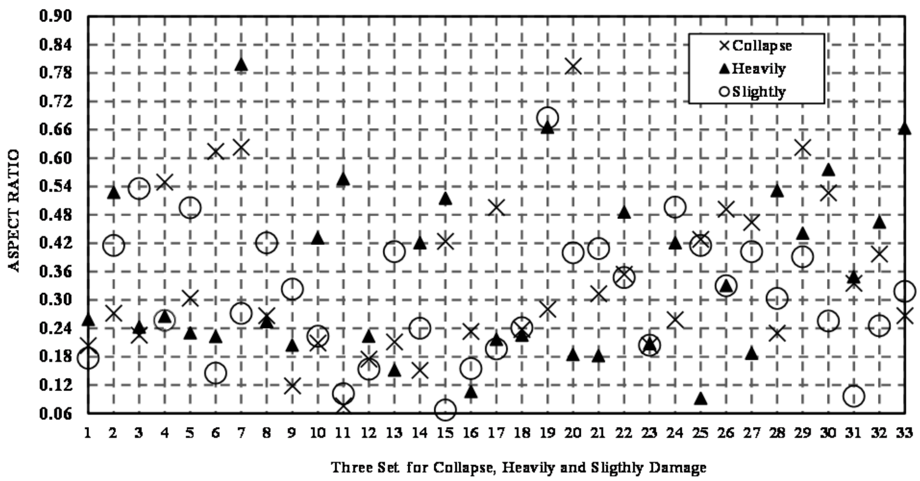

Figure 8. Comparison of the Aspect of Ratio of each Set of Buildings.

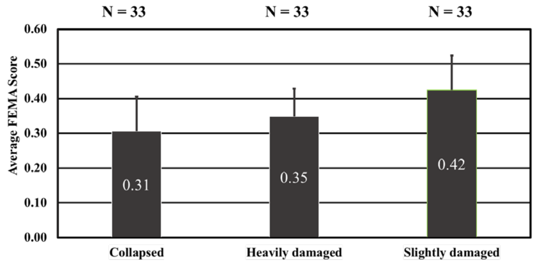

Figure 9. Average FEMA Score per level of damage.

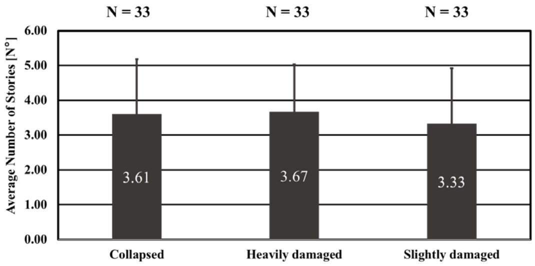

Figure 10. Average Number of stories per level of damage.

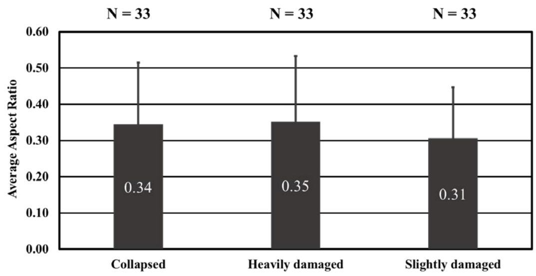

Figure 11. Average Aspect ratio per level of damage.

p-value is quite small ($p = 2.80 \times 10^{-8}$).

Figure 10 shows the comparison of the average in the Number of stories in building groups. The building group with less damage tends to have a smaller number of stories. However, this trend is statistically insignificant from statistical verification with ANOVA ($p = 0.63715$).

Figure 11 shows the comparison of the average aspect of ratio in building groups. The building group with less damage tends to have a smaller aspect ratio. However, this trend is statistically insignificant from statistical verification with ANOVA ($p = 0.48511$).

5. Discussion

The main goal of this study was to verify the applicability of the FEMA P-154, by referring to the damage cases in the 2023 Turkey-Syria Earthquake. The results indicate that the differences in the FEMA total average score of the buildings categorized by the observed level of damage are statistically significant. Therefore, the evaluation of building irregularity in FEMA rapid visual screening may apply to the buildings in Turkey, although the FEMA method is designated to apply to the buildings in the United States of America (USA).

Based on the fact that there is no statistical significance in the comparison by the number of stories and aspect ratio, the irregularity of buildings evaluated in the FEMA score sheet can be the only important factor to be considered in seismic safety assessment in visual screening.

However, the authors only evaluated the efficiency of the FEMA Score sheet based on the building irregularities. The age of construction of buildings and their differences were not considered, due to the lack of data. Structure types were not considered as well, because most of the structures were the same, with a few different building types. In addition, the parameters of soil conditions and their type differences were not discussed in this research. Because the soil conditions in this case study are uniform, we could not discuss the relationship between the collapse or damage of the building and the ground conditions.

Note that, if the soil conditions vary, the applicability of RVS may change. For instance, maybe the score tendency of the FEMA score could be changed in liquified areas. Also, the authors did not have enough data to evaluate the design code in the target area. These non-evaluated aspects remain to be discussed for future study.

In this limited case, the authors could not confirm the overall applicability of the Rapid Visual Sheet. For instance, the age of construction of the buildings, the effects of the structure types, and the soil conditions were not considered in this study. Nevertheless, the effectiveness of the irregularities in the FEMA scoresheet was confirmed. And it reveals that the balance of the structure is very important. We can say this fact is the same for both USA buildings and Turkish buildings.

The evaluation of the FEMA score is a qualitative not quantitative method such as probability. But to do a seismic retrofit, explaining cost-benefit is important. Thus, probability estimation by using fragility curves is often utilized in practice. Then, modifying the fragility curves by referring FEMA score shall be considered in the next stage.

6. Conclusions

This research aimed to verify the applicability of the FEMA P-154, by referring to the damage cases in the 2023 Turkey-Syria Earthquake.

This study had the following results:

1) The building group with less damage showed a higher FEMA score. This trend was statistically significant.
2) The building group with less damage tended to have a smaller number of stories. However, this trend was statistically insignificant.
3) The building group with less damage tended to have a smaller aspect ratio. Nonetheless, this trend was statistically insignificant.
4) The evaluation of building irregularity in FEMA rapid visual screening may apply to the buildings in Turkey, although the FEMA method was designed to apply to the buildings in the United States of America (USA).

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