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-Araştırma Makalesi-

Seismic Damage Prediction of Buildings Using Fuzzy Logic, The Case of Ambarlı Neighborhood at Avcılar

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Abstract

The Kocaeli 1999 earthquake caused great damage of buildings in Istanbul, Avcılar district was the most affected region than any other nearby districts even though they are located further near to the epicenter. In Ambarlı Neighborhood at Avcılar, where the total number of buildings at the time of earthquake was 1338, damage assessment work was carried out on a total of 505 buildings. As a result, 222 buildings were categorized damaged to varying degrees which forms 16.59% of the total buildings in the area. Damage due to an earthquake is an important element of the earthquake risk concept, especially for areas previously suffered critical hazard. Therefore, for such situations with relatively complicated condition involving certain degrees of uncertainty, further investigations using simple but effective tools can lead to better understanding of such events and the consequences. In this study, a model has been developed using Fuzzy Logic method considering four parameters; Ground motion, ground condition, building number of floors and building age. The degree of damage is obtained as a result of the analysis. A post-earthquake damage database of reinforced concrete buildings within a selected zone at Ambarlı neighborhood due to 1999 Kocaeli earthquake has been used to investigate the applicability of the proposed method. The model results were found to reasonably presenting the distribution of damage of the buildings in the area when compared with the recorded damage distribution. The results also show that the model is capable of predicting damage distribution of the existing reinforced concrete buildings against possible earthquakes of large magnitude.

Keywords: Fuzzy Logic, Earthquake, Risk, Damage, Ambarlı

Binalarda Deprem Hasar Tahmini İçin Bulanık Mantık Kullanımı, Avcılar Ambarlı Mahallesi Örneği

Öz

İstanbul Avcılar İlçesi 17 Ağustos Marmara depremi merkez üssüne benzer mesafe ve doğrultudaki komşu ilçelere göre çok daha fazla hasar görmüştür. Depremin olduğu tarihte toplam bina sayısı 1338 olan Avcılar ilçesi Ambarlı Mahallesinde deprem sonrası 505 binada hasar tespiti yapılmıştır. Toplam bina sayısının %16,59'unu oluşturan 222 binanın farklı düzeylerde hasar gördüğü tespit edilmiştir. Binalarda depremden kaynaklanan hasar, özellikle daha önce önemli ölçüde tehlikeye maruz kalmış alanlar için deprem riski kavramının önemli bir unsurudur. Bu nedenle, belirli seviyelerde belirsizlik içeren nispeten karmaşık koşullara sahip bu tür durumlar için, basit ama etkili araçların kullanıldığı araştırmalar, bu tür olay ve sonuçlarının daha iyi anlaşılmasını sağlayabilir. Çalışmada, bulanık mantık yöntemi

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kullanılarak yer hareketi, zemin durumu, bina kat sayısı ve bina yaşı olmak üzere dört parametrenin dikkate alındığı bir model geliştirilmiştir. Hasar düzeyi analiz sonuçlarından elde edilmiştir. Çalışmada geliştirilen modelin uygulanabilirliği, İstanbul Avcılar İlçesi Ambarlı Mahallesi'ndeki 1999 Marmara Depremi sonrası hasar gören betonarme bina veri tabanı kullanılarak araştırılmıştır. Model sonuçları, kaydedilmiş hasar dağılımı ile karşılaştırıldığında bölgedeki binaların hasar dağılımını makul bir şekilde ortaya koyduğunu göstermektedir. Sonuçlar ayrıca, modelin mevcut betonarme binaların olası büyük depremlere karşı hasar dağılımını tahmin etme özelliğinde olduğunu da göstermektedir.

Anahtar Kelimeler: Bulanık Mantık, Deprem, Risk, Hasar, Ambarlı

1. Introduction

Avcılar district is located on the coast of the Marmara Sea, West of the old center of Istanbul about 27 kilometers away, (Figure 1). It has a surface area of approximately 42.59 km²; the population of the district is 457,981 (TÜİK, 2021). The 17 August 1999 Kocaeli Earthquake was of 7.4 on Richter scale, epicenter is roughly 90 km east of the city of Istanbul. Due to strong ground motion, approximately one thousand people lost their lives as a result of building collapses. Avcılar suffered much greater damage during the Earthquake than any other neighboring districts within Istanbul city although it is at 20 km further away from the epicenter.

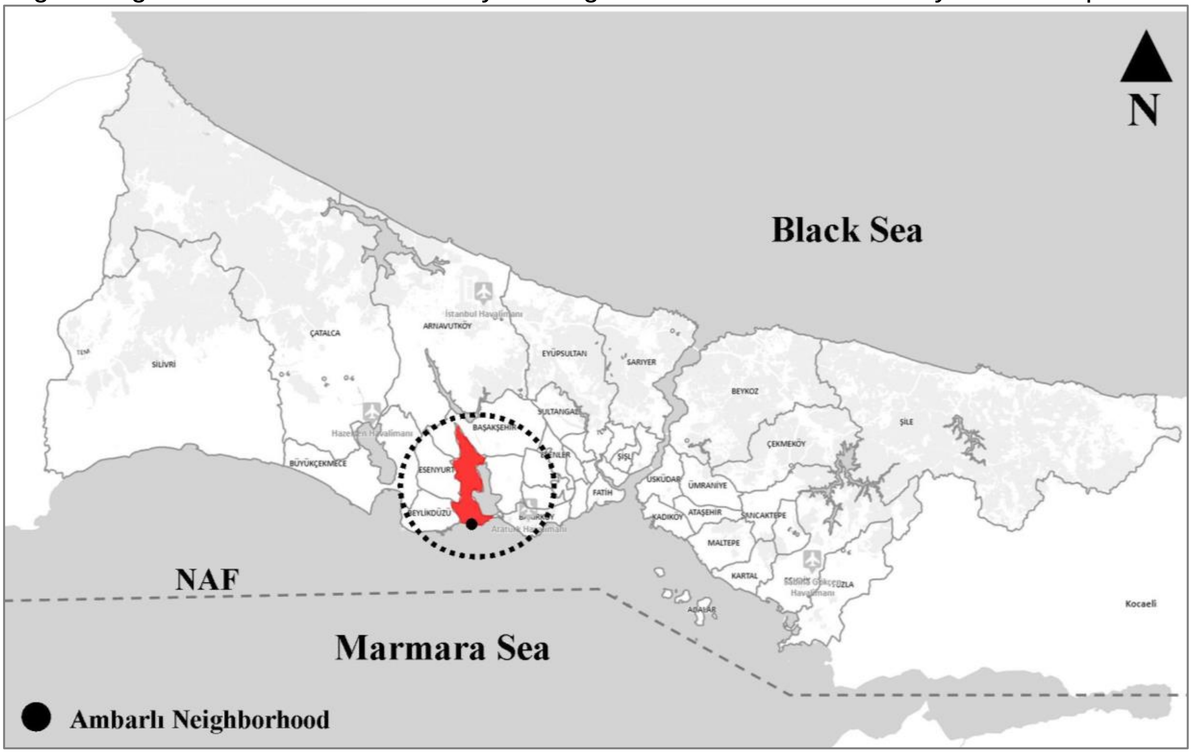

Figure 1. Location map of Avcılar and Ambarlı neighbourhood

Several investigations were conducted by many researchers aiming to find the reason why Avcılar was affected more than other neighboring districts, (Cranswick et al, 2000) stated that the reason for the greater building damages at Avcılar cannot be related to the method of building construction since it is the same in most of Istanbul (Erdik et al, 2003) indicated that all reinforced concrete buildings constructed in Istanbul can be considered of similar vulnerability class. Investigations have been done jointly by the US Geological survey and Bogazici University on the amplification effects reported that the aftershocks records of seismic wave amplitudes were four times greater at Avcılar than other western parts of

Istanbul, Cranswick et al (2000). Previous observations stated that the relatively near surface unconsolidated geological units can significantly influence the strong motion characteristics on the ground surface and thereby increase the damage experienced during an earthquake (Singh et al, 1988; Borcherdt, 1970). The amplification from bedrock to the surface during recent earthquakes has been investigated by Kurtuluş et al (2015). They placed three stations at different depths within a geological site of class D according to NEHRP (1997) and recorded average acceleration amplification were 4 to 12 times. Ergin et al (2004) selected four observational locations on different topographical and geological units at Avcılar, their detected results show no significant variations in the amplification characteristics due to several ground motion events despite the different locations. They concluded that the localized large amplification factors and the resulting heavy damage at Avcılar from the main shock are thus attributed to a deep-seated velocity contrast. Following Kocaeli 1999 Earthquake and despite the unique case at Avcılar several studies aimed at developing general models for estimating seismic effects on buildings at Istanbul city jointly with Istanbul Metropolitan Municipality (JICA, 2002). Building damage is estimated by comparing the response displacement of the building and the displacement in which the building come at the damage, the number of damaged buildings can then be obtained when damage ratio is multiplied by the number of buildings that is counted in “Building Inventory”. Similar work was carried out at Boğaziçi University (KOERI, 2003) and the developed technique has recently been applied for Avcılar district (IMM, 2020) to analyze the earthquake hazard and related urban risk.

Lotfi Zadeh (1965) was the first to introduce the fuzzy set, the subject afterwards became widely used by researchers. The fuzzy set deals with problems having some sort of uncertainty, simulating human thinking and hence, utilize in the real-life application. The theory of fuzzy logic has become used to find indicators of earthquake risk levels, especially when creating analyses that include a kind of overlap between a number of factors and conditions that cause different degrees of damage, from light to severe or complete collapse, they can be considered as linguistic variables. Since there is always a kind of uncertainty in the structural elements, construction materials and ground condition that require an approach during engineering analyses, which is often unavoidable. Thus, fuzzy logic is considered an appropriate solution in assessing the degree of damage due to the flexibility, simplicity and speed required (Usta et al 2018). Fuzzy logic is a very effective approach when a compromise solution is possible involved the exchangeable relations that can be categorized with the special building hazard levels (Şen 2010). Fischer et al. (2002) recommended the use of fuzzy logic algebra in the estimation of structural damage especially when data are available from experiments or field observations. Rashed and Weeks (2003) proposed the incorporation of Fuzzy logic technique with spatial data analysis could overcome deficiencies in the approaches used for vulnerability analysis. Mohanaselvi and Hemapriya (2019) concluded that fuzzy logic technique gives better prediction of building damage levels during earthquake. Kömür and Altan (2005) used the fuzzy logic technique to assess the safety of an existing RC building at Avcılar which was collapsed during 17 August 1999 Kocaeli earthquake implementing a seismic index method and compare the results with the standard analysis for the same building. Şen (2010) applied the fuzzy logic method for hazard categorization of 1249 existing buildings in Zeytinburnu quarter of Istanbul City. A model for preliminary screening stages has been presented for evaluation of the reinforced concrete buildings against possible earthquakes of magnitude seven. Eight input variables were considered in the first stage `Rapid visual screening`; for existing buildings as number of floors, soft storey, weak storey cantilever extension, building quality, pounding effect, hillslope effect, and peak ground velocity (PGV) with one output as hazard level. Şen and Ekinci (2016) apply the fuzzy logic technique for the evaluation of vulnerability of buildings responding to earthquake at Kadıköy, Maltepe districts. Their analysis involves the use of four input parameters; distance to North Anatolian Fault, building structure, geologic structure of soil and the number of building floors and one output of vulnerability risk ratio. Harirchian and Lahmer, (2020), proposed a rapid visual screening methodology based on fuzzy logic system to estimate the vulnerability of buildings, in terms of damage index, considering six input parameters; building height, building age, plan irregularity, vertical irregularity, building quality, and peak ground velocity, with one single output. They used a post-earthquake damage database of reinforced concrete buildings from the Bingöl and Düzce earthquakes in Turkey to examine the applicability of the proposed method.

In this study, a model has been developed using Fuzzy Logic method considering four parameters as ground motion, ground condition, building number of floors and building age. The degree of damage is obtained as a result of the analysis. The distribution of buildings expected to experience certain degree of damage has been presented for a study area of Ambarlı neighborhood at Avcılar district.

2. Buiding Damages at Avcilar Due to 17 Aug. 1999 Earthquake

The Avcılar region to the west of Istanbul was exposed to a major effect due to the 1999 earthquake, and although the affected buildings in the area were not of high altitude, the damage was significant. The total number of buildings in Avcılar before the 1999 earthquake was 14,030 and the distribution building damage is as follows (TÜİK, 2021).

Totally collapsed	28
Heavily damaged	86
Moderately damaged	501
Low damaged	801

Table 1 shows buildings survey data obtained from The Ministry of Public Works and Settlement, Istanbul Provincial. The building number of floors map of Ambarlı prepared according to the existent map, attained from the Municipality Archive Directorate). They are presenting the number of buildings in each neighborhood area of Avcılar with their number of floors categories and building date of construction. It is seen that, the majority of buildings in Avcılar district are of 4 to 6 floors and they were mostly constructed between the years 1980 and 1999.

Table 1. Number of buildings and the percentage in each neighborhood area at Avcılar (TÜİK, 2000a; TÜİK, 2000b)

Neighborhood	**Total No. of buildings**	**Building number of floors**						**Building construction date**			
		<4		4 to 6		>6		<1980		1980 to 1999	
		No	%	No	%	No	%	No	%	No	%
Üniversite	618	122	19.7	392	63.4	104	16.8	73	11.8	545	39.6
Ambarli	1 338	233	17.5	898	67.1	207	15.4	259	19.4	1079	80.6
Cihangir	1 682	290	17.2	1115	66.2	277	16.4	151	8.9	1530	90.9
Denizköşkler	1 825	200	10.9	1209	66.2	416	22.7	242	13.2	1580	86.6
Firuzköy	1 761	1121	63.6	628	35.6	12	0.67	214	12.2	1542	87.6
Firuzköybalikyolu	1 804	1371	75.9	425	23.5	8	0.44	2	0.11	1800	99.7
Gümüşpala	1 467	199	13.5	948	64.6	320	21.8	155	10.5	1311	89.4
Merkez	937	72	7.6	520	55.5	345	36.8	138	14.7	798	85.2
Mustafakemal Paşa	1 316	263	19.9	794	60.3	259	19.6	159	12.1	1155	87.7
Tahtakale	1 282	1030	80	247	19.3	5	0.39	4	0.31	1278	99.6
Total	**14 030**	**4901**		**7176**		**1953**		**1397**		**12618**	

3. The Example of Ambarlı Neighbourhood

There were 1338 total number of buildings within Ambarlı neighborhood at Avcılar before 1999 earthquake (Table 1), 94% of the buildings are of reinforced concrete moment resisting frame system. According to TÜİK (2000a), 48% of the buildings were completed between 1990-2000 and 34% between 1980-89. Considering building number of floors, 57% of the building stock is of 5-6 floors and 10% is of 4 floors. Considering the year of construction; 4 and 5 floor buildings were mostly built between 1980-1989, whereas 6, 7 and 9 floors buildings were mostly built between 1990-2000. Figure 2 graphically presents the distribution of the buildings in Ambarlı neighborhood according to the year of construction and number of floors.

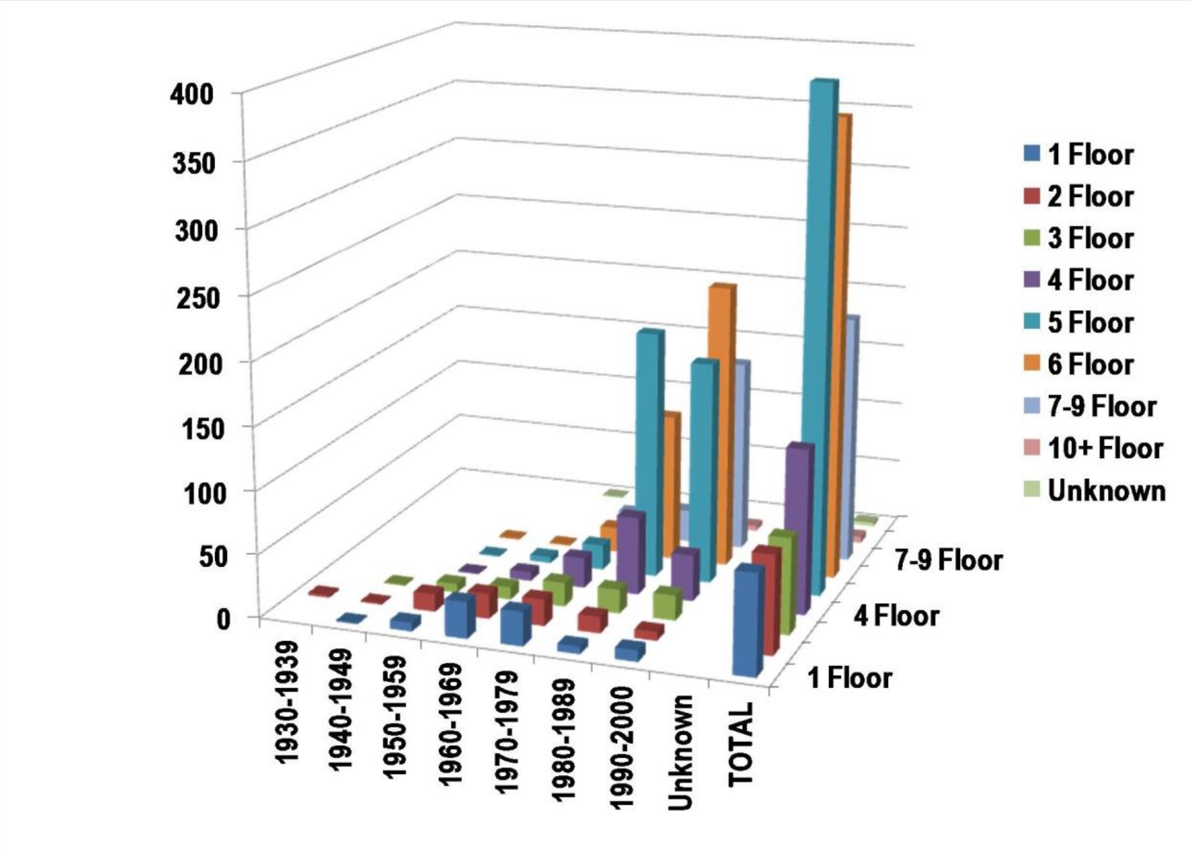

Figure 2. Distribution of the number of floors of the buildings in Avcılar District, Ambarlı Neighborhood according to the year of construction

Damage assessment work was carried out on a total of 505 buildings at Ambarlı in the locations shown in Figure 3, (Yücel, 2009). 16.59% of buildings and 23.80% of flats were damaged to varying degrees

The criteria used for categorizing the degree of damage is similar to that given by the European Macroseismic Scale 1998, EMS-1998, and according to Table 2 where five degrees of damage are considered as Non, Low, Moderate, Severe (High) and Collapse (very high). In addition, a photographed example of each damage degree is illustrated.

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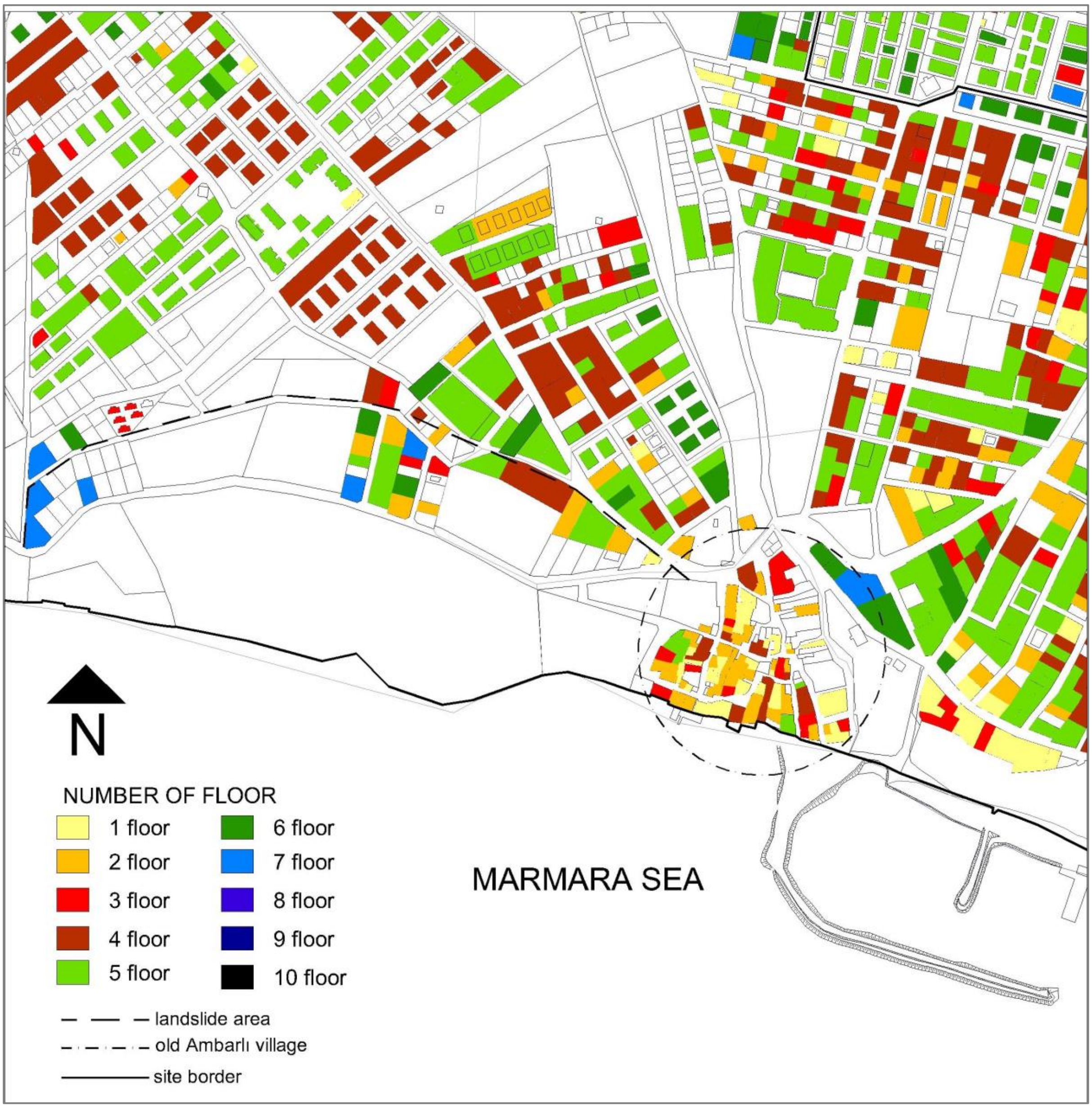


Figure 3. Selected study area at Ambarlı and Building number of floors

At Ambarlı, a total of 222 buildings were damaged with various degrees forms 16.59% of the total buildings in the area. The percentage distribution of the damaged buildings according to the established criteria as shown in Figure 4; 11.14% were slightly damaged (Low), 4.79% were moderately damaged (Moderate), 0.29% were severely damaged (High), and 0.37% were collapsed (Very high). For Ambarlı neighbourhood, the distribution of damage for building number of floors and building construction date are also given in Tables 3a and 3b respectively. It is seen that the buildings of heights less than 4 floors were not suffered from severe damage or collapse, even if they are of relatively old construction date (i.e. before 1979). Furthermore, although 94% of damaged buildings are of 4 to 6 floors, only 4% of them were heavily damaged or collapsed.

Table 2. Criteria for the description of building damage

Damage level	Description	Typical building damages at Avcılar 1999, (Yücel, 2009)
No damage	No damage, small cracks	
Low damage	Isolated non-structural damage, cracks in the interior walls or ceilings, damage in water lines	
Moderate damage	Significant non-structural damage and slight structural damage	
High damage	Heavy non-structural damage and important structural damage	
Very high damage (Collapse)	Collapsed buildings or condemned to demolition	

The distribution of damaged buildings at Ambarlı neighborhood as shown in Figure 5, the degree of damage according to the established criteria is indicated. It is seen that there is no specific pattern to the damaged buildings could be established but it is observed that more damaged buildings located on or near steep slope gradients, this probably due to the enhanced lateral spreading of the ground due to seismic action. However, most of damaged buildings are of low and moderate degrees and it may be possible to say that the highly damaged and collapsed buildings can also be attributed to their structural deficiencies.

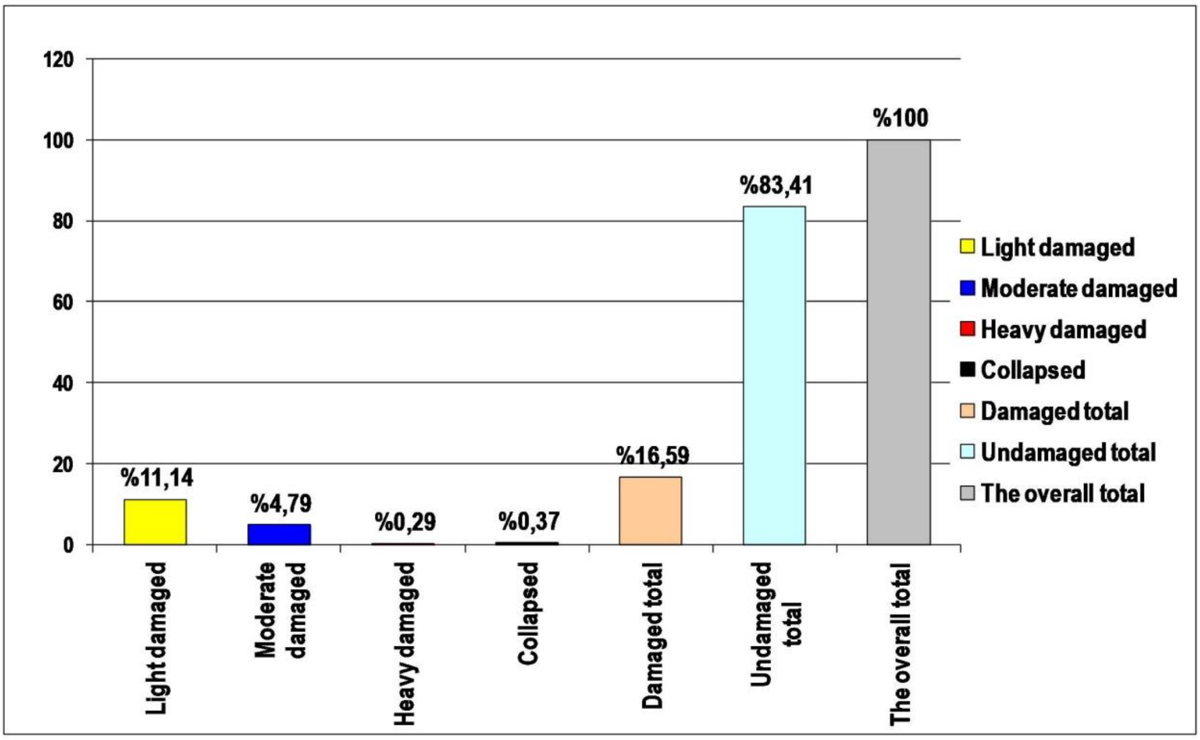


Figure 4. Distribution of damage caused by the 17 August 1999 earthquake in Avcılar district, Ambarlı Neighborhood.

Table 3. Distribution of damage for buildings at Ambarlı;

a) Building number of floors

(Number of floors)	Damage degree				Total
	Low	Moderate	Severe	Collapse	
Less than 4		2			2
4 to 6	140	60	4	5	209
More than 6	9	2			11
TOTAL	149	64	4	5	222

b) Building construction date

Construction Date	Damage degree				Total
	Low	Moderate	Severe	Collapse	
Before 1979	31	17			48
1980-1999	118	47	4	5	174
TOTAL	149	64	4	5	222

4. Fuzzy Input and Output Variables for Damage Prediction

The proposed Fuzzy logic system for predicting the damage degree levels was implemented using the toolbox in MATLAB which has been formed according to Mamdani type inference. However, according to the feature of the data in the present study, triangular or trapezoidal membership functions have been used. The rules were formed after membership functions were assigned to the output variable. The Defuzzification method was chosen to be used in the fuzzy logic system as the central point of the shape.

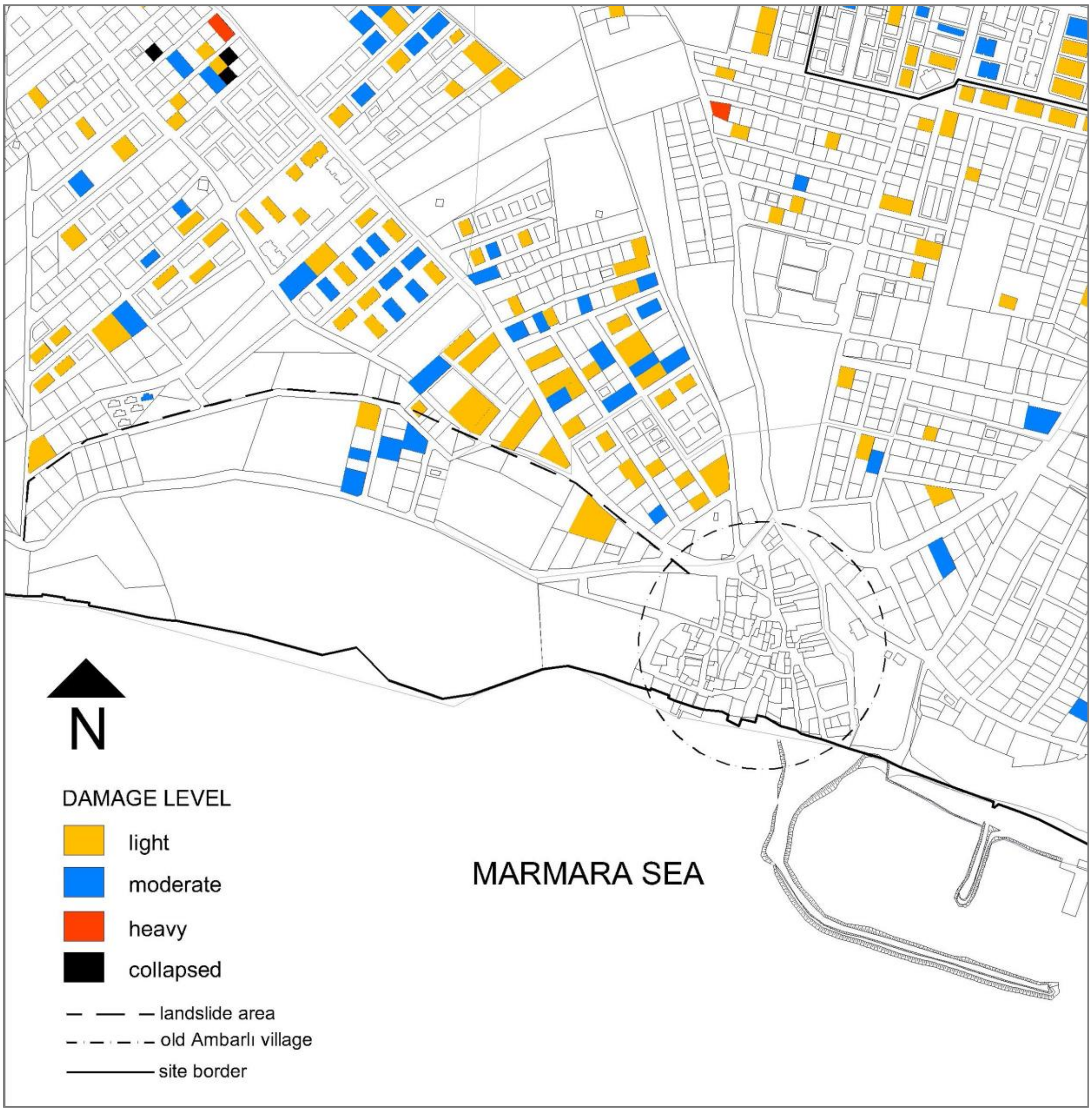


Figure 5. Location of damaged buildings at Ambarlı due to 1999 earthquake

In the proposed fuzzy logic damage prediction model, the following four fuzzy input variables; ground motion, ground condition, building number of floors and building age and one output, the degree of damage are considered.

1. Ground motion: The characterization of the amplitude of seismic ground motion is made using the peak ground velocity (PGV). The numerical values at the desired locations are based on the reported data according to Boğaziçi University (KOERI, 2003), IMM (2020). It is fuzzified into three membership functions as Low, Medium and High within a range between (0 and 100 cm/s), as illustrated in Figure 6a.

2. Ground condition: The geology of Avcılar is mainly of Bakırköy and Güngören consisted mainly of stiff soil classified as (class D) according to the NEHRP (1997), shear wave velocity $(Vs)_{30}$ is generally higher than 180 m/s (IMM, 2020). However, other parameters are considered important which related to the building distance from slope gradient. Therefore,

the ground condition is represented by ground index (IG) expressed as the ratio between $(Vs)_{30}$ and slope gradient (Sg) in percent. The value of (Sg) was assigned a minimum value of 5% to represent low slope ground and hence the ground index (IG) is calculated according to the following formula;

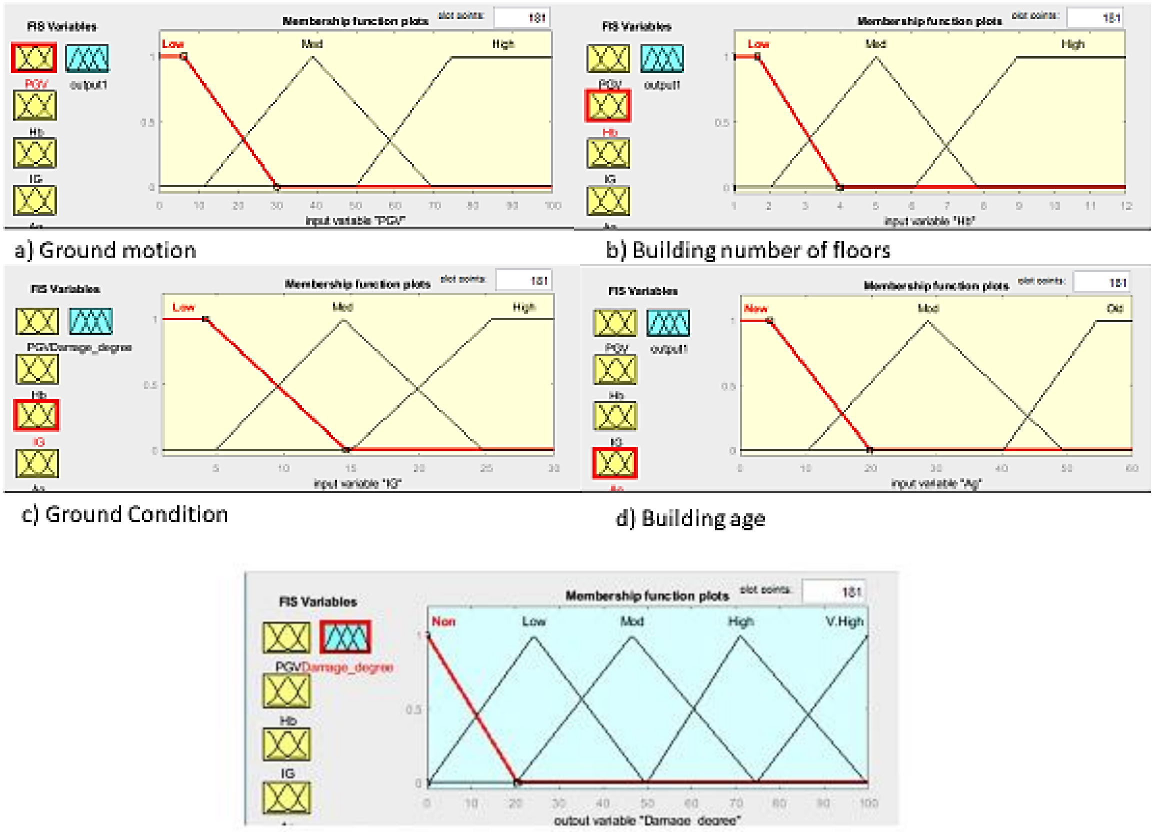
$$IG = \frac{(\mathrm{Vs})\ 30}{\mathrm{Sg}} \tag{1}$$

The range of ground index is fuzzified into three membership functions as low below 15, medium between 5 and 25 and high above 15 as in Figure 6b.

3. Building number of floors (Hb): Representing the building height, classified into three classes Low, Medium and High considering the buildings number of floors; less than 4 (Low), between 2 and 8 (Medium), and more than 6 (High) as presented in Figure 6c.

4. Building age (Ag): This parameter is classified into three different input variable membership function based on the building construction date as New, Moderate and Old based on the building construction date as New (age <20 years), Moderate (10 < age < 50), and Old (age > 40 years) as presented in Figure 6d.

The inference engine is used for fuzzy measurements to determine which control rules are stored in the fuzzy rule base. The fuzzy groups describing the damaged state of the building are then converted to the degree of damage (as a percentage from 0 to 100%) by defuzzification. Damage degree prediction mainly dealt with five grades such as; non, low, medium, high and very high as shown in Fig. 6e.



a) Ground motion
b) Building number of floors
c) Ground Condition
d) Building age
e) Degree of damage

Figure 6. Input and Output membership functions

A total of 81 rules have been established for damage class identification. Some of the combined fuzzy-rules are given below:

IF PGV is High AND IG is Low AND Hb is High AND Ag is High THEN Damage is Very High.
IF PGV is High AND IG is Moderate AND Hb is High AND Ag is High THEN Damage is High.
IF PGV is High AND IG is Moderate AND Hb is Low AND Ag is Low THEN Damage is Low.
IF PGV is High AND IG is Low AND Hb is Low AND Ag is Moderate THEN Damage is Non.
IF PGV is High AND IG is High AND Hb is High AND Ag is Moderate THEN Damage is Moderate.
IF PGV is Moderate AND IG is Low AND Hb is High AND Ag is Moderate THEN Damage is Moderate.
IF PGV is Moderate AND IG is Moderate AND Hb is Low AND Ag is high THEN Damage is Non.
IF PGV is Low AND IG is Low AND Hb is Moderate AND Ag is Moderate THEN Damage is Non.
IF PGV is Low AND IG is Moderate AND Hb is High AND Ag is high THEN Damage is Low.

5. Results And Discussions

The membership functions and rule relations belonging to the input and output variables were presented in graphic surface as in Figure 7. It is seen how the degree of damage is changed with both the building`s number of floors and building age.

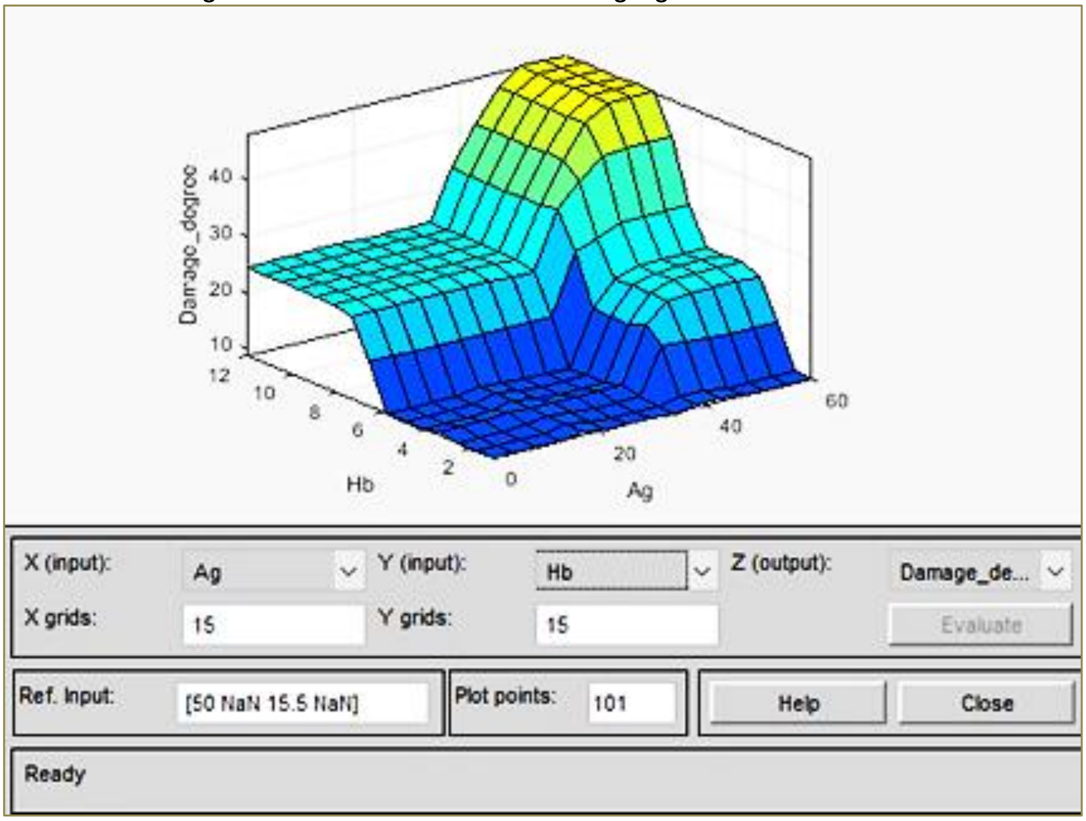


Figure 7. Graphic surface presentation of the degree of damage related to building number of floors and building age

As an example of estimated output with different input variables values can be observed from Figure 8, where PGV is set as high (strong ground motion) and moderate values are given to all other parameters, the resulting output is predicted as 24.4 %. The defuzzification values in the created fuzzy logic model, were evaluated in the range; less than 20% in No damage, 20-35% in low damage, 35-55% in moderate damage, 55-75% in high damage and over 75% in a very high damage.

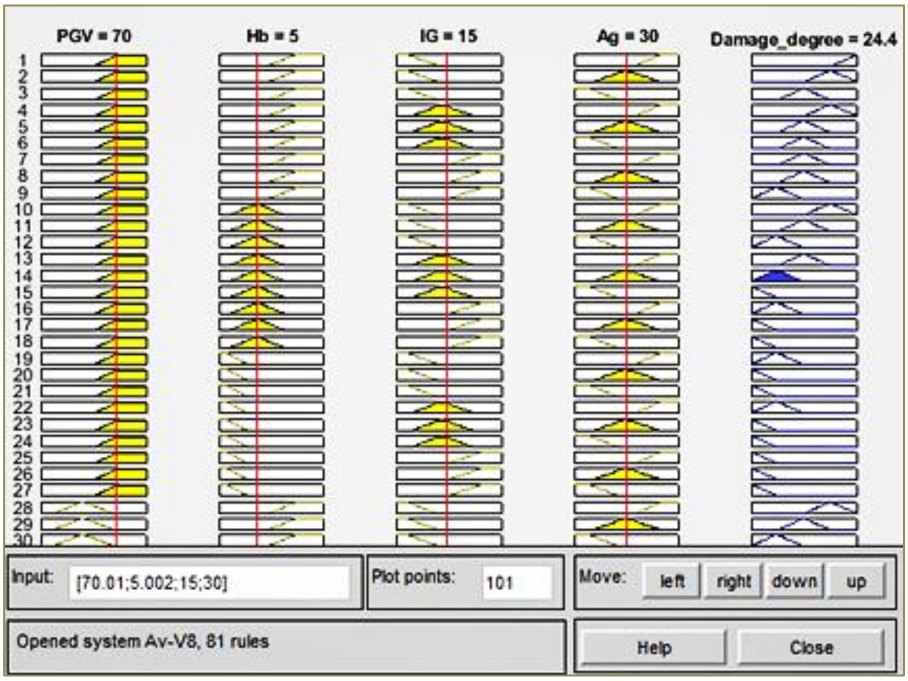


Figure 8. Output views with different input variables values

The Fuzzy model is applied for the condition at Ambarlı neighborhood based on the recorded data for reinforced concrete buildings constructed in the area before Kocaeli 1999 earthquake and considering earthquake of strong motion (Mw > 7.0) hence, assuming High PGV value of (70 cm/s), The shear wave velocity $(Vs)_{30}$ is given a values with a range between 150 m/s to 300 m/s, therefore the value I_G was estimated depending on the slope gradient at any specific location within the study area ranging between 5 % to 30 %.

The selected area at Ambarlı shown in Figure 3 where a total of 457 buildings were tested in the model based on their number of floors (Hb), age of construction (Ag), Ground condition index (I_G) and peak ground velocity (PGV). However, by dividing the study area into smaller zones of approximately similar ground index (I_G) and implementing a simple mapping technique to enable obtaining specific parameters for any building location. Since the model predicts the amount of the expected degree of damage for any assigned building data, the distribution of damage within the study area is therefore determined.

The model predictions are presented in Figure 9, it is seen that out of 457 buildings there are 127 buildings exhibited low damage and 39 of moderate damage compared with 109 and 48 recorded damaged respectively. The predicted low damage buildings are (14.1%) greater than the recorded while the predicted moderately damaged buildings are (23%) less than the recorded. The predicted highly damaged buildings are only 4 compared with 2 recorded. No buildings are predicted as very highly damaged (or considered as collapsed) even though, it was recorded 2 buildings were collapsed within the selected study area. However, the model predictions can be considered generally comparable and seems to be reasonably capable of simulating the seismic hazard effect at the area.

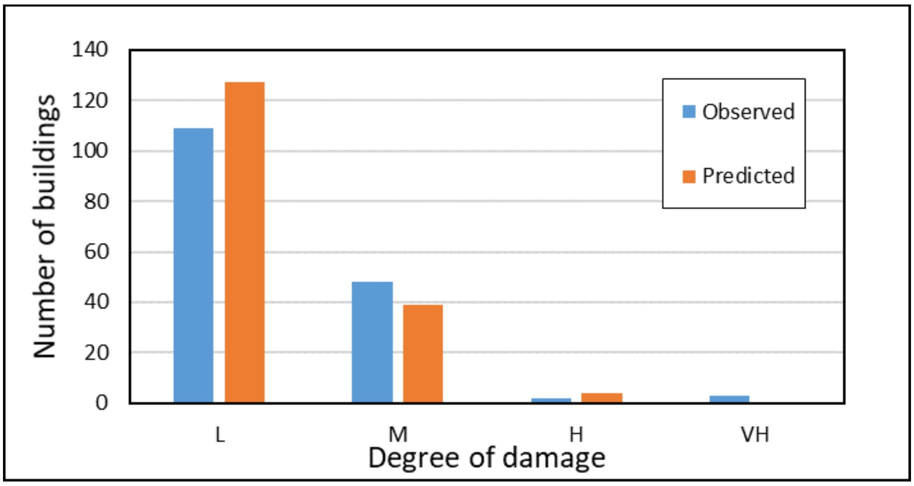


Figure 9. Observed and predicted building damage at Ambarlı selected study area due to 1999 earthquake

Since the predicted results of the model did not show any buildings with very high degree of damage (collapse level). This can be attributed to the possible structural defects of some buildings in the area; they must have been suffered high structure vulnerability.

The structure vulnerability is defined as the structure response to the subjected hazard level, therefore structures with high vulnerability are expected to experienced higher degree of damage than those with low structure vulnerability when they were exposed to the same hazard level (Şen, 2010). The structure vulnerability for any specific reinforced concrete building is related to several factors. Kömür and Altan (2005) stated that the observations made on the damaged reinforced concrete buildings after several earthquakes revealed that the causes of the damage could be classified into three main categories: (a) improper arrangement of the architectural and constructional systems, (b) inappropriate detailing and/or proportionality, and (c) poor supervision during construction.

Structure vulnerability was investigated by many researchers (Tesfamariam, and Saatcioglu, 2008; Fischer et al 2002; Kömüra and Altan 2005; Sanchez-Silva and Garcia 2001, Allali, et al, 2018). Since most of the structures at Avcılar are of reinforced concrete moment resisting frame system commonly built according to similar practice, are arbitrarily assumed to have similar structure vulnerability. It is consequently considered that any two neighbor buildings with relatively identical height exposed to the same hazard level and constructed within the same time period should exhibit similar risk of damage. However, this is not always the case due to the probable variation in their structure vulnerability. The vulnerability of any building is not limited to the structure system properties and structure material quality but also to other environmental aspect and the usage during structure life span. High vulnerability could also happen as a result of extensive deterioration and lack of maintenance for example corrosion of structure elements in certain buildings.

The expected scenario for seismic degree of damage due to probable future strong motion earthquake (Mw > 7.0) for Ambarlı neighborhood was examined using the developed model. The predicted percent of damaged buildings with the degree of damage assuming future scenario are presented in figure 10 and compared with that predicted due to 1999 earthquake. The results show that 32% of the buildings would exhibit low damage and 17.6% would exhibit moderate damage compared with 27.7% and 8.2% observed during Kocaeli 1999 earthquake. A very distinctive percent increase of moderately and highly predicted damaged buildings during future strong earthquake which may exceed 50 %. This is related to the higher percent of aged buildings included into the inventory building database without exception of the buildings which were subjected to recent development scheme in the area proposed by IMM involving demolishing and reconstruction activities. Most of the predicted damages are expected to be in old buildings of age exceeding 40 years therefore, the scenario is presenting the worst case. The most dangerous case is the expected highly damaged buildings which are estimated as 4.6 % and even though no buildings are predicted as very highly damaged, some of the highly damaged buildings might undergo collapse depending on their structure vulnerability.

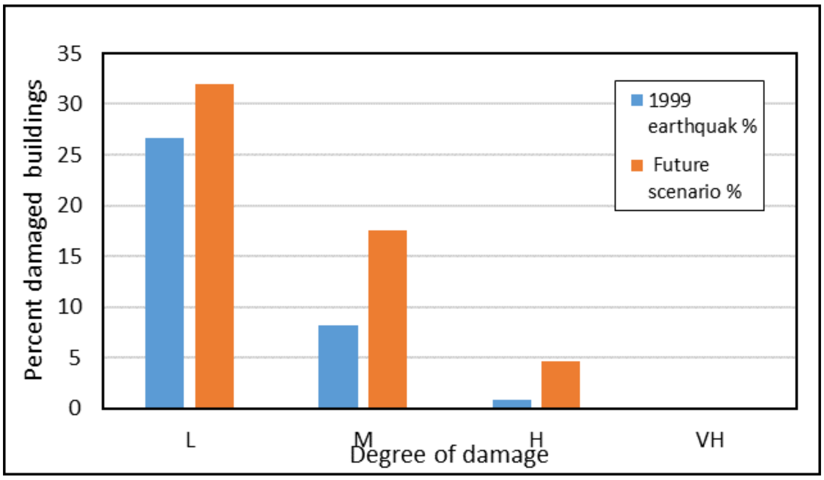


Figure 10. Model future scenario prediction of the percent of damaged buildings compared with that observed during 1999 earthquake

6. Conclusions

A surveyed work for damaged buildings in Ambarlı neighborhood at Avcılar after 1999 earthquake is presented in this work and the building damages are investigated using the technique of fuzzy logic and the predicted results are compared with that observed. The main conclusions are as follows;

-The fuzzy logic method is reasonably predicting building damage distribution for the selected case study of Ambarlı area after 1999 earthquake. The predicted low damaged buildings are slightly higher by (14.1%) than the observed while in case of moderate damage, it is lower by (23%).

-Assuming future scenario of strong motion earthquake, the predicted building damage show greater percentage damage values than the observed due to 1999 earthquake, for all damage categories (low, moderate & high) as,(32%, 17.6% & 50%) respectively.

-Generally, no buildings are predicted to collapse and hence, the state of building collapse is depending on the structure vulnerability. Furthermore, most of the predicted damaged buildings are those of aged construction date generally above 40 years with heights above three floors.

The results of the expected future scenario represent the worst case because it depends on the present situation. However, considering the changes currently underway by the IMM in terms of development work, such as demolishing and rebuilding old buildings (over 40 years age), would significantly reduce the expected risk of high damage, especially if this is accompanied with the adoption of strict standards based on modern specifications.

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