DEVELOPMENT OF ALTERNATIVE RAPID SCREENING METHOD TO DETERMINE REGIONAL RISK DISTRIBUTION OF MASONRY STRUCTURES

YIĞMA YAPILARIN BÖLGESEL RİSK DAĞILIMININ BELİRLENMESİ İÇİN ALTERNATİF HIZLI TARAMA YÖNTEMİNİN GELİŞTİRİLMESİ

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ABSTRACT

DEVELOPMENT OF ALTERNATIVE RAPID SCREENING METHOD TO DETERMINE REGIONAL RISK DISTRIBUTION OF MASONRY STRUCTURES

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The seismic risk of buildings are of great concern of societies as the loss of buildings interests both the public administration and the insurance companies. More importantly, the collapse of the buildings unfortunately gives rise to loss of inhabitants' lives. Therefore, the determination of the seismic risk of buildings has been an important topic among the structural engineers. The seismic risk assessment of building inventories could only be accomplished by changing the strategy from seeking safety to filtering the vulnerable buildings from the large building stock (i.e. low-pass filtering). To this end, decisions should be made on inexpensively acquired building data and the evaluation process should quickly be implemented. Therefore, a new rapid screening method is developed to estimate the seismic risk of unreinforced masonry (URM) buildings in this study. The method is based on a novel use of binary logistic regression of a large database. The database is composed of 543 URM buildings with detailed seismic assessment results. The method considers number of stories (N), type of slab system (SS), vertical irregularities (VI), visual damage (D), type of masonry material (M), typical story height (H) and typical plan area (A) as the basic estimation variables. These estimation variables have assigned some penalty scores depending on the coefficients derived from the binary logistic regression analysis of the database. 443 buildings from the database are used to generate the penalty scores and 100 buildings are reserved for the test of the proposed method. The correct overall estimation rates of the proposed method for the database (i.e. 443 buildings) and the test database (i.e. 100 buildings) are determined as approximately 95% and 86%, respectively. An evaluation form for the rapid assessment of masonry buildings is also presented in this study.

Keywords: Seismic Vulnerability, Rapid Assessment, Earthquake Risk Estimation, Masonry Buildings

ÖZET

YIĞMA YAPILARIN BÖLGESEL RİSK DAĞILIMININ BELİRLENMESİ İÇİN ALTERNATİF HIZLI TARAMA YÖNTEMİNİN GELİŞTİRİLMESİ

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Yapıların sismik risklilik durumu, deprem anında meydana gelebilecek muhtemel yıkımların toplumun bütününü ilgilendirmesi nedeniyle hem kamu idaresi hem de sigorta şirketleri için önem arz etmektedir. Daha da önemlisi, yıkılan binalar nedeniyle büyük can kayıpları meydana gelebilmektedir. Bu nedenle, inşaat mühendisleri için, yapıların sismik risklilik durumunun belirlenmesi işi önemli bir çalışma alanı teşkil etmektedir. Yoğun yapı stokuna sahip alanların depremsel risk değerlendirmesi, ancak muhtemel hasarın büyük olacağı yapıların, yapı stokunun kalanından ayrılması ile gerçekleştirilebilir. Bu amaçla, düşük maliyetlerle elde edilen veriler sayesinde binalara ilişkin değerlendirmeler hızlı ve etkin bir şekilde yapılarak, dönüşüm uygulamalarının nasıl yapılacağına ilişkin karar verilebilmelidir. Bu tez çalışmasında donatısız yığma yapıların sismik risk durumunun belirlenebilmesi için yeni bir hızlı tarama yöntemi geliştirilmiştir. Yöntem, büyük bir veritabanının ikili lojistik regresyonunun yeni bir kullanımına dayanmaktadır. Veritabanı, 543 adet donatısız yığma yapının detaylı sismik analiz sonuçlarından elde edilen verilerle oluşturulmuştur. Yöntem, temel tahmin parametreleri olarak kat adedi, döşeme tipi, düşey düzensizlik, görsel hasar, taşıyıcı malzeme tipi, tipik kat yüksekliği ve yapı oturum alanını kullanmaktadır. Bu parametrelerin her biri için, veritabanının ikili lojistik regresyon analizinden elde edilen katsayılara dayanılarak ceza puanları atanmıştır. Veritabanından seçilen 443 adet yapı ceza puanlarının belirlenebilmesi için, kalan 100 adet yapı ise yöntemin test edilebilmesi için kullanılmıştır. Ceza puanlarının belirlenmesinde kullanılan 443 adet yapı için, detaylı risk analizi sonuçlarından elde edilen risklilik durumları ("riskli" yada "risksiz"), %93 oranında doğru tahmin edilirken, yöntemin test edilmesi için kullanılan 100 adet yapıda bu oran %86'dır. Ayrıca, yöntemin uygulanabilmesi için hazırlanan yığma yapılara ilişkin hızlı tarama formu tezin ek bölümünde sunulmuştur.

Anahtar Kelimeler: Sismik Güvenlik, Hızlı Değerlendirme, Deprem Risk Tahmini, Yığma Binalar

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SYMBOLS AND ABBREVIATIONS

Symbols

S_{DS}	Short period spectral acceleration coefficient
n_{sk}	Number of stories
O_i	Negativity parameter value
f_{em}	Allowable compressive stress
τ_{em}	Allowable wall shear stress
τ_0	Allowable cracking stress
μ	Coefficient of friction
A_0	Effective ground acceleration coefficient
I	Building importance factor
S(T)	Spectrum coefficient
W_i	Weight of floor
R	Bearing system behavior coefficient
N	Number of stories
SS	Type of slab system
V	Vertical irregularities
D	Visual damage
M	Type of masonry material
H	Typical story height
A	Typical plan area
PS_i	Penalty Score Coefficient

Abbreviations

DD-2	Earthquake ground motion level with a probability of exceeding 50 years (repetition period 475 years)
YSP	Structural system score
PP	Performance Score
GABHR	Guidelines for the Assessment of Buildings under High Risk
TEC	Turkish Earthquake Code
RVS	Rapid Visual Screening
RC	Reinforced Concrete
URM	Unreinforced Masonry Building
GIS	Geographic Information System
SC	Seismic Class

1. INTRODUCTION

Urban transformation is a process in which urban development is reconsidered socially, economically and spatially. The processes of evacuation, demolition and reconstruction of problematic settlement zones constitute the subject of urban transformation. The life and property losses caused by İzmit and Düzce earthquakes in 1999 and Van earthquake in 2011 has shown the importance of urban transformation in Turkey. After these disasters, it has been revealed that some practices should be done by the state in order to renew the areas under disaster risk to prevent future life and property losses. For this purpose, in 2012, Law on the Transformation of Areas Under Disaster Risk No. 6306 was enacted.

The main purpose of the determination of the vulnerability of the building stocks is to take necessary precautions before a possible devastating earthquake manifests. Since the existing building stocks are large in number in the most of developing countries, whose main problem is the unplanned construction, the evaluation of the state of seismic risk of structures becomes difficult due to the lack of qualified personnel and economical reasons. Therefore, it is not possible to examine every existing structure in detail. For this reason, it is possible to determine the areas where the urban transformation should priorly be done by evaluating the structures using easier and faster methods. These methods are generally called as first stage evaluation methods or rapid visual screening methods. The second stage evaluation is performed for buildings that are examined in first stage and considered as risky (i.e. having insufficient lateral loading resistance) in order to determine the seismic performance of these structures in more detail.

Procedures to determine the seismic risk determination, generally, carried out according to the technical principles determined by the Law No. 6306 in Turkey. With this law, it is aimed to identify and demolish buildings which have high seismic risk (i.e. buildings with a large probability of severe damage or collapse) under the effect of an earthquake. This target indirectly causes to the construction of new and safer structures instead of available vulnerable structures. The principles for the determination of "risky structures" are technically explained in "Guidelines for the Assessment of Buildings under High Risk (GABHR 2013 and 2019)" which is included in the annex of Law No. 6306.

On the other hand, Rapid Visual Screening Method (RVS) is a quick and easy-to-use method which is used in order to determine the potentially seismically hazardous buildings in any area by a specific scoring system. The RVS procedure uses a methodology based on a “walk-down survey” of a building. A Data Collection Form is filled by visual observation of the building from outside and if possible from inside and the building is scored by considering different parameters with different importance coefficients.

Masonry structures have been constructed since ancient times using various materials such as brick, rock, concrete block or adobe. The walls in masonry structures serve as bearing elements. Slabs, walls and foundation of these walls constitute the structural elements of masonry buildings. In Turkey, in the 1960s, structures such as school, health center and public personnel housing have been constructed as masonry with a blend brick since it does not require superior workmanship. However, the houses with reinforced concrete slab floors and brick masonry walls were not made any longer after the years 1960-1970. After 1970s, reinforced concrete structures became more widespread with the contribution of more abundant production of cement. When the hollow-bricks compared to full-bricks began to be transported economically as far away as possible, reinforced concrete framed structures with hollow-brick walls were replaced with full-brick walled structures. However, masonry structures still constitute significant part of the Turkish building stock and determination of the seismic risk state of such structures has great importance.

The aim of this study is to develop an alternative RVS method which has a statistical background and is easy to use in order to determine the regional seismic risk distribution of masonry structures quickly. In this way, it will be easy and quick to determine which areas should be prioritized for urban transformation. After determining the priority areas for transformation by first stage evaluation method (RVS), the seismic risk states for buildings in these areas can be determined in detail by second stage evaluation method.
The database covering the seismic risk state of masonry buildings according to GABHR 2013 in Turkey from 2013 till 2018 forms the basis of this study. From these data, the parameters which may affect the results of seismic risk analysis of a structure (according to GABHR 2013) were analyzed statistically and the effect of these parameters on the

results of seismic analysis was investigated. As a result of these studies, a scoring-system based on a walk-down survey was formed.

2. LITERATURE REVIEW

This section presents general information about masonry structures and their seismic performance analysis according to GABHR (2013), also some important applications of Rapid Visual Screening (RVS) method in in the world, including Turkey.

2.1. Masonry Structures

Masonry structures are structures with horizontal and vertical load bearing walls formed by a binding mortar of artificial or natural blocks. The strength of the masonry structure depends on both the bond between walls and mortar andthe strength of the masonry material. Masonry structures can be classified into two categories according to the existence of reinforcement and masonry wall material.

2.1.1. Classification for Reinforcement

Masonry structures can be classified into three categories depending on the use of reinforcement: unreinforced, reinforced and confined. Just like the reinforced concrete (RC) case, the aim of reinforcement is to increase the tensile strength and to enhance the ductility of masonry structures which are constructed from brittle construction materials.

2.1.1.1. Unreinforced Masonry Buildings

This type of structures has no RC beams or RC columns. The loads coming from slabs directly transferred to load bearing masonry walls. Since there is no rigid connection between the slab and walls, these structures are vulnerable in the out-of-plane direction (i.e. the perpendicular direction to the plane of the wall) [1]. A typical URM building is shown in Figure 2.1. [2].

Figure 2.1. Photograph of an Unreinforced Masonry Building

2.1.1.2. Reinforced Masonry Buildings

In this type of structures, the reinforcements are horizontally and/or vertically distributed in the masonry walls. Reinforcements are placed inside the masonry material similar to the application in reinforcement concrete construction. The purpose of these building systems is to provide some tensile strength and ductility to the rigid masonry structure [3].

However, this type of masonry building is not very common because it requires a lot of labor and time (Figure 2.2).

Figure 2.2. Reinforced masonry wall (adapted from the website “constructor.org”)

2.1.1.3. Confined Masonry Buildings

This type of structures has RC members in various parts of the walls, such as RC beams and columns (Figure 2.3). The purpose of these additional RC members are to confine the masonry load bearing walls, resulting in more stable behavior. In addition, the RC bond beams placed between the RC slabs and load bearing masonry walls cause more uniform load transfer from the slabs to the vertical members. Masonry materials (i.e. bricks or concrete blocks used in the walls) are the same as unreinforced masonry buildings.

Figure 2.3. Confined masonry building

2.1.2. Bearing Wall Type

The materials used in masonry structures should be divided into two classes as bearing and non-bearing materials. For example, horizontal hollow bricks and adobe bricks are not considered as bearing, whereas vertical hollow bricks with hollow rates less than 35% are considered as bearing. Masonry wall can be classified into four categories depending on the type of the material.

2.1.2.1. Solid Clay Brick

Until early 1970s, production and use of solid clay bricks produced in local factories was widespread in Turkey but nowadays it is replaced by the clay bricks produced in factories (Figure 2.4). The difference between these clay bricks is mainly the production temperature. The clay bricks in local factories are generally produced at temperatures around 900C^o. However, clay bricks in factories are produced at higher temperatures (around 1400C^o), causing an increase in the strength of bricks. The solid brick is shaped by pouring the brick sludge into the molds, compressing and filling the mold completely. Compaction of the slurry in the mold may provide an isotropic structure to the solid clay brick. However, since this process is not automated, there may be large differences in the production stage between the bricks [3].

Figure 2.4. Typical solid clay brick types

2.1.2.2. Hollow Clay Brick

According to the codes, the rate of vertical holes in hollow bricks should be 35% or less (Figure 2.5). However, hollow rate of bricks used in the construction practice are mostly above 45%. Even, bricks with a hollow rate up to 60% are encountered in the investigation of the available building stock in Turkey. As the hollow rate increases, the wall strength decreases as the vertical load bearing area on the wall becomes smaller [4].

Figure 2.5. Hollow brick with hollow rate less than 35%

2.1.2.3. Natural Stone

Unlike brick walls, position of mortar and stone blocks may vary too much in natural stone walls (Figure 2.6). Therefore, mortar and stone form a discontinuous environment. Stone blocks are not in standard size and shape. In contrast to isotropic or orthotropic composition of the brick walls, composition of stone walls are very complex or even amorphous. Stone walls generally have 50-60 cm thickness [3].

Figure 2.6. A building made of **s**tone walls

2.1.2.4. Concrete Block

Concrete blocks are produced by mixing the filling materials such as sand, gravel, tuff slag, brick and tile fractures, pumice stone with cement and water. Then, this mixture is pressed and vibrated in special molds [3]. As concrete blocks are generally rectangle in shape, the masonry walls constructed from concrete blocks have more organized head and bed joints (Figure 2.7).

Figure 2.7. A building made of concrete block walls

2.2. Detailed Seismic Analysis Principles For Masonry Structures According to GABHR 2013

The principles for the determination of risk state of masonry buildings are explained in Guidelines for the Assessment of Buildings under High Risk (GABHR) [5]. Bearing system specifications of existing buildings are taken into consideration for the detection of risky buildings.

The knowledge level of the investigated building may be minimum or comprehensive. If the static project of the building is not available, Minimum Information Level is used. If the building's static project is available and the site-controlled structural system features are compatible with the project, Comprehensive Knowledge Level is used. If projects of building do not comply with the sizes and amount of reinforcements determined on site, the building should be considered as minimum knowledge level (Table 2.1). For masonry buildings, coefficient of knowledge level is always selected as 0,9.

Table 2.1. Knowledge level coefficients for buildings

Information Level	Coefficient of Knowledge Level
Minimum	0.9
Comprehensive	1.0

For seismic analysis of the building, bearing wall materials should firstly be determined by removing the plaster (Figure 2.8). After the determination of the bearing wall type, allowable compressive stress value specified in Turkish Earthquake Code (2007) is selected for the specified wall type (Table 2.2) [6].

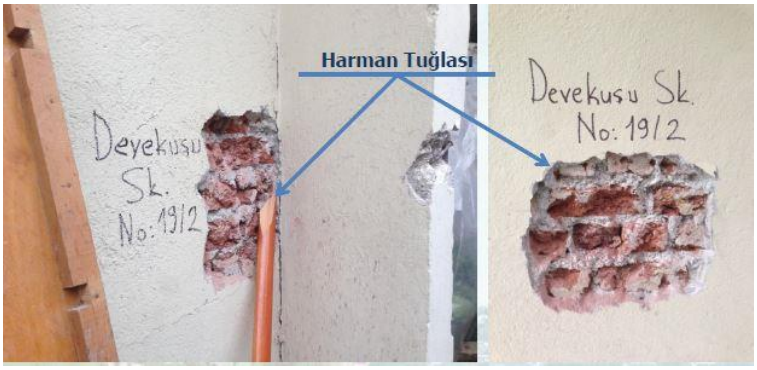

Figure 2.8 Determination of type of material of the structure

Table 2.2. Allowable compressive stress values for masonry walls

Wall Type	Allowable Compressive Stress f_{em} (MPa)
Hollow Clay Brick (Hollow ratio less than 35%)	1.0
Hollow Clay Brick (Hollow ratio between 35%-45%)	0.8
Hollow Clay Brick (Hollow ratio more than 45%)	0.5
Solid Clay Brick	0.8
Stone	0.3
Solid Concrete Block	0.8

The allowable compressive stress values are decreased in order to consider the reduced capacity due to the slenderness of the walls (Table 2.3). A reduction factor should be calculated for each wall and the factor should be applied to the allowable compressive stress values calculated from Table 2.2.

Table 2.3. Reduction coefficients according to the slenderness ratio

Slenderness Ratio	6	8	10	12	14	16	18	20	22	24
Reduction coefficient	1.0	0.95	0.89	0.84	0.78	0.73	0.67	0.62	0.56	0.51

Since the shear strength of walls also depends on vertical stresses present in the walls, it is necessary to calculate the stresses carried by walls due to the vertical effects only. The normal stresses in the walls are compared with the reduced allowable stresses according to the masonry wall type. If the stress found by dividing the cross-sectional area of the wall reduced by the cross-sections of the doors and window gaps in the wall is greater than the allowable pressure stress according to the wall type, that wall is considered as failed (i.e. insufficient capacity).

The relative shear stiffness of the wall pieces between doorways or window openings in each wall axis of the masonry building is calculated from the expression $k\,A/\,h$. Here, A is the horizontal cross-sectional area of the solid wall piece and h is the smallest height of the gaps on both sides of the solid wall piece. If the cross-section of the wall is rectangular k = 1.0, if the wall has end members or if there is a perpendicular tooth or strut at the end of the wall, k = 1.2. Shear stiffness of a wall axis is the sum of shear stiffness of wall parts in that axis. Shear stiffness center of the building is calculated from shear stiffness of the wall axes. Earthquake force of each floor is distributed to the walls according to their stiffness.

The earthquake force coming to a wall is divided by horizontal cross-sectional area of the wall and the shear stress on the wall is calculated. The result is compared with allowable shear stress τ_{em} found in Eq. 2.1. If the result is greater than τ_{em}, wall is considered as failed (i.e. insufficient capacity).

$$\tau_{em}=\tau_0+\mu\sigma \qquad (2.1)$$

In this equation, τ_{em} is allowable wall shear stress, τ_0 is allowable cracking stress, μ is coefficient of friction (it can be taken as 0.5) and σ is the vertical wall stress found from G+nQ loading which comes from walls and slabs. τ_0 values depending on wall types are given in Turkish Earthquake Code 2007 (Table 2.4).

Table 2.4. Allowable cracking stress values for masonry walls

Wall Type	Allowable Cracking Stress τ_0 (MPa)
Hollow Clay Brick (Hollow ratio less than 35%)	0.25
Hollow Clay Brick (Hollow ratio more than 45%)	0.12
Solid Clay Brick	0.15
Stone	0.1
Solid Concrete Block	0.2

In order to create a 3D model of the building, floor plan is prepared for each floor of the building (Figure 2.9). The placement, length, gap and thickness of vertical beams and walls on each floor of the masonry building are indicated in the floor plan. Number of stories and story heights of the building are also indicated.

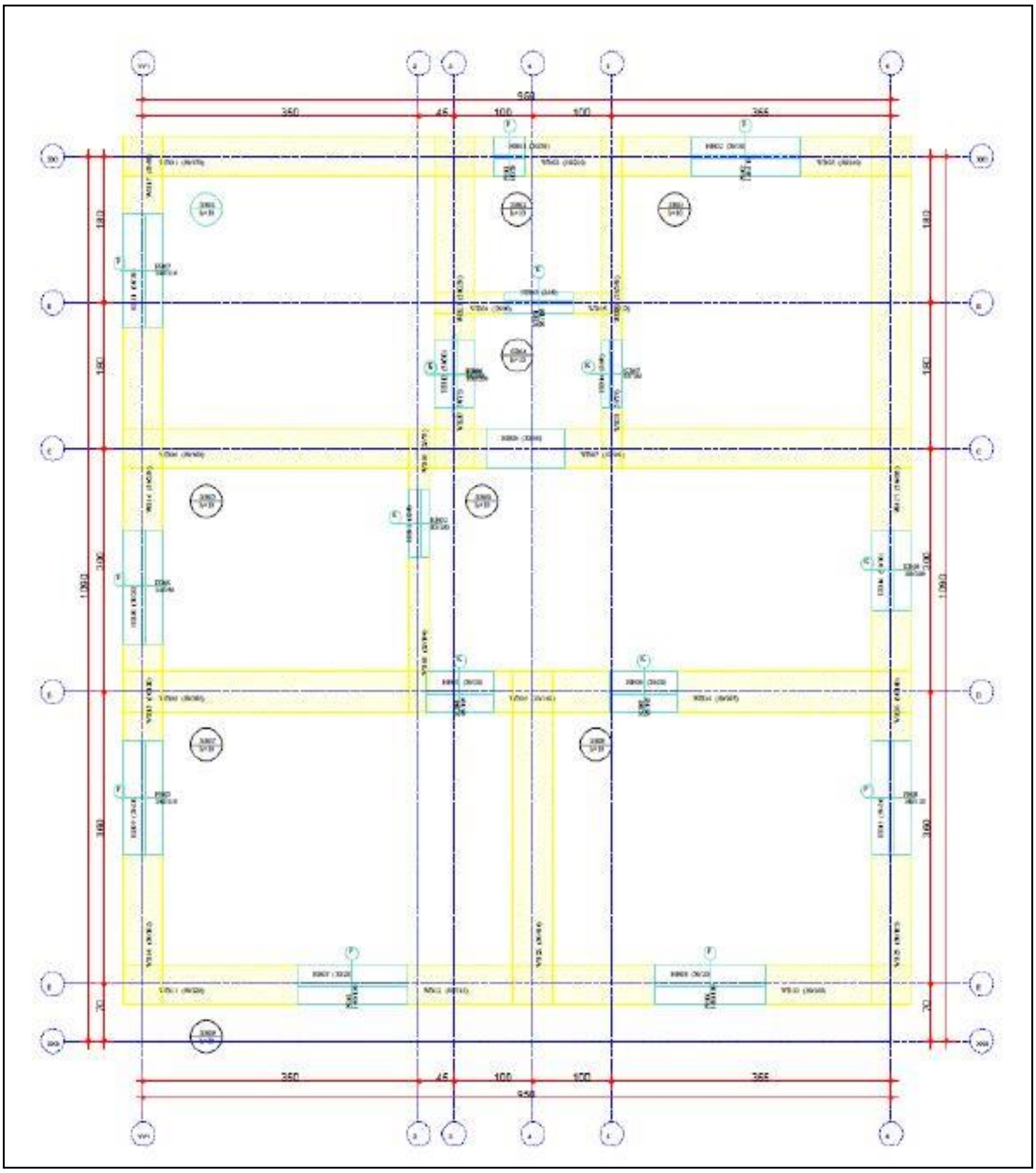

Figure 2.9. A floor plan sample

After preparation of floor plans for each floor, a three-dimensional model of the structure is generated and the seismic analysis stage is started (Figure 2.10). If the seismic analysis is to be performed with a software, the parameters of the building are entered into software.

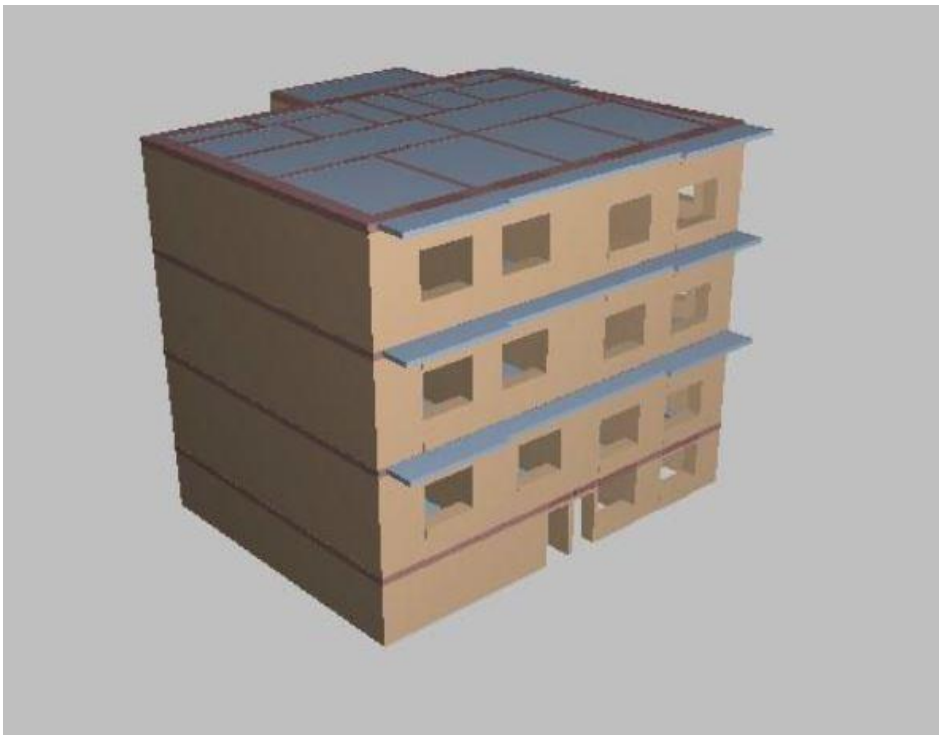

Figure 2.10. Generating 3D model of building

The shear stresses caused by the earthquake loads on the building walls are calculated according to Equation 2.2 by assuming $S(T_1) = 2.5$ and $R_a(T_1) = 2.0$.

$$V_i = \frac{A_0.I.S(T).W_i}{R} \quad (2.2)$$

Here, A_0 is effective ground acceleration coefficient and I is building importance factor which are selected from Turkish Earthquake Code 2007 (Table 2.5, 2.6). S(T) is spectrum coefficient which is selected 2.5 for masonry buildings, W_i is weight of floor and R is bearing system behavior coefficient which is selected as 2.0.

Table 2.5. Effective ground acceleration coefficients

Earthquake Zone	A_0
1	0.4
2	0.3
3	0.2
4	0.1

Table 2.6. Building importance coefficients depending on building types

Building Type	Building Importance Coefficient
1. Buildings to be used after earthquake and buildings containing hazardous materials **a) Buildings required to be used immediately after an earthquake (Hospitals, dispensaries, health centers, fire brigade buildings and facilities, PTT and other communication facilities, transportation stations and terminals, energy generation and distribution facilities; province, district governor and municipality administrative buildings, first aid and disaster planning stations)** **b) Buildings containing or storing toxic, explosive, flammable, etc. materials**	1.5
2. Crowded buildings where people stay long-term and buildings where valuable goods are stored. **a) Schools, other educational buildings and facilities, dormitories, military barracks, prisons, etc.** **b) Museums**	1.4
3. Crowded buildings where people stay long-term **Sports facilities, cinema, theater and concert halls, etc.**	1.2
4. Other Buildings **Houses, workplaces, hotels, building type industrial structures, etc.**	1.0

To identify “risk state” of the building, shear strength of bearing walls on the critical floor is compared with shear stress demands under earthquake effects. The comparison is done separately for both directions of the building. In any direction, if shear force contribution of walls with insufficient strength to the floor shear force is above %50, the building is considered as “Risky Building”.

2.3. Seismic Risk Determination Methods and Previous Rapid Visual Screening (RVS) Applications For Masonry Buildings

The seismic risk of buildings is of great concern to public administration, insurance companies, and to the inhabitants whose lives are at stake if buildings collapse. Determining seismic risk has therefore been an important topic in the structural engineering community. Some efforts have been made to detect the seismic risk of individual buildings by utilizing some advanced analysis techniques, i.e. detailed seismic assessment procedures [7-10]. In some methods, even the nonlinear behavior of the buildings and their components is considered during the assessment procedure [11-16]. All these methods require a detailed analysis of the material and geometry of the assessed building, which takes significant time, manpower and computational power. Plus, these methods cannot be employed to determine the seismic risk of a building stock or to filter the most vulnerable buildings from a large building stock. They can only be implemented on buildings that have already been assumed to be vulnerable to the effect of seismic actions.

Assessing seismic risk of building inventories can only be accomplished by changing the strategy from seeking safety to filtering out vulnerable buildings from the larger building stock (i.e. low-pass filtering). To this end, the method should enable decisions to be made using inexpensively acquired building data and the evaluation process to be implemented quickly [17].

Rapid visual screening method (RVS) is a methodology based on a scoring system which has been developed to identify buildings being potentially seismically-hazardous. The RVS procedure uses a methodology based on a walk-down survey of a building. For this purpose, a Data Collection Form is filled based on visual observation of the building from the exterior, and if possible, the interior.

Although several researchers have tried to generate simple methods to assess the seismic risk of reinforced concrete (RC) structures [18-24], the literature shows a limited number of efforts to propose rapid screening (or filtering) methods applicable to unreinforced masonry (URM) building stocks [2, 10, 25-27]. D’Ayala [25] attempted to correlate damage states with fragility curves to determine the seismic vulnerability of masonry structures. However, this method requires the fragility curve for the location of the building, which reduces the applicability of this process, as fragility curves are scarce in number. Shah et al. [26] used a building classification with respect to the masonry material used, the state of the building, construction quality, building shape irregularity and the level of earthquake-resistant design. They used the European Macroseismic Scale [28] and applied defined vulnerability classes (A to F) to determine the risk level of masonry structures. However, the outcome of this method still lacked correlation with real performance. In another approach, Achs and Adams [27] proposed a rapid visual screening method that used penalty scores for structural parameters including seismic hazard, regularity in plan, regularity in elevation, horizontal stiffness, local failure, secondary structures, soil condition, foundation, and state of preservation. The penalty scores were derived from comprehensive preliminary in-situ inspections and measurements of Viennese brick masonry buildings [29]. In recent studies, researchers have also used additional technology to increase assessment speed [30]; Rajarathnam and Santhakumar [30] used aerial photographs on a geographic information system (GIS) platform to accelerate rapid visual screening. However, none of these methods is based on a large database of masonry structures with detailed seismic assessment results, and all lack correlation between rapid screening scores and detailed analysis results.

2.3.1. Simplified Method for Determining Regional Earthquake Risk Distribution of Buildings (GABHR2019 Appendix-A)

This method is used to determine priorities and regional distribution of potentially risky buildings in certain areas under the Law No. 6306. This method can be used for defining the regional risk situation and it can be applied in areas containing statistically significant number of buildings as required by science and technique and cannot be used for risk assessment of single building [10]. Details about application of this method for masonry buildings is presented in this section.

In the method, DD-2 earthquake ground motion level is used and the parameter value (S_{DS}) is selected from the Turkey Earthquake Hazard Map. By using the relationship between parameter value and soil classes, earthquake hazard zones given in Table 2.7 are determined.

This method can be used for masonry buildings with 1 to 5 stories. The parameters required for using the method are as follows:

- Masonry building type: Bearing system type of the building is determined (unreinforced masonry, confined masonry, reinforced masonry or mixed). Determination of the masonry building type is shown in Figure 2.12.
- Number of stories: Number of floors (n_{sk}) is determined by taking into account Figure 2.12.
- Position of the building/ Slab level compared to contiguous building: The location of contiguous buildings can affect earthquake performance due to collision. The buildings on the edge are affected the most negatively by this situation. Collision effect is determined by external observations. Position of the building and slab level compared to contiguous building are evaluated together. Five different states are set for this parameter: discontiguous, contiguous and middle-floor level same, contiguous and middle-floor level different, contiguous and edge/corner-floor level identical, contiguous and edge/corner-floor level different. Determination of position of the building and slab level compared to contiguous buildings is shown in Figure 2.12.
- Appearing quality of workmanship and walls: The material type and quality of workmanship are controlled separately and both of these determinations are classified as good, medium and bad separately. In addition, the existing damage is detected and the building damage is selected as yes or no.
- Plan irregularity: Plan irregularity is determined in three categories according to plan geometry: regular, irregular and extreme irregular. Determination of plan irregularity is shown in Figure 2.12.
- Amount of walls: On the critical floor of the building (usually the ground floor), the length of the façade walls in both directions perpendicular to each other is determined. Accordingly, if the length of the door and window gaps in the front or side façade on the ground floor is less than 1/3 of the façade length, the amount of walls is considered as high, if the length of gaps is between 1/3 and 2/3 of the façade length, it is considered as medium and if the length of gaps is higher than 2/3 of façade length, it is considered as low. Determination of amount of walls is shown in Figure 2.12.
- Vertical Gap Irregularity: According to the vertical placement of the door and window gaps in the building, the vertical gap layout classified as regular, less

regular and irregular. The determination of vertical gap irregularity is shown in Figure 2.12.

- Different number of stories according to the façade: It is determined that if different facades of the building have different number of floors or not. Difference of the stories according to the façade is shown in Figure 2.12.
- Soft Story/Weak Story: In addition to the story height difference, the apparent stiffness difference between the stories will be determined observationally. The determination of the soft story/weak story status is shown in Figure 2.12.
- Adverse effects of out-of-plane behavior: It is determined whether the masonry building walls tend to behave out of plane. Adverse effects that trigger out-of-plane behavior in masonry buildings and which can often be detected outside the building can be listed as follows:

  a. Poor wall-wall and wall-slab connections (cracks or damage presented in connections, no RC beam)

  b. Absence of slab that behaves as rigid diaphragm (Masonry structures with reinforced concrete slabs are considered to exhibit this type of behavior)

  c. Mortar quality is too low or there is no mortar. (causes the wall to decompose in an out-of-plane direction)
- Roof Material: This parameter is only determined for masonry buildings with earthenware roof.
- Geographical coordinates: Coordinates must be determined in accordance with Turkey Earthquake Hazard Map coordinate system. DATUM WGS 1984

DATA COLLECTION FORM FOR MASONRY BUILDINGS				
BUILDING ID INFORMATIONS			DATE:	
			ORDER	
BUILDING ID NO			PHOTO OF BUILDING	
CITY				
DISTRICT				
NEIGHBORHOOD				
STREET				
BUILDING NO				
BUILDING NAME				
BLOCK				
PLOT				
LAYOUT				
UAVT BUILDING CODE				
ESTIMATED BUILDING AGE				
GEOGRAPHIC COORDINATES	LATITUDE		LONGITUDE	
BUILDING TYPE	☐ RESIDENTAL	☐ COMMERCIAL	☐ INDUSTRIAL	
	☐ PUBLIC	☐ DERELICT		
BUILDING TECHNICAL INFORMATIONS				
BEARING WALL TYPE	☐ SOLID CLAY BRICK	☐ CONCRETE BLOCK	☐ ROCK	☐ HOLLOW BRIQUETTE
	☐ VERTICALLY HOLLOWED BRICK	☐ GAS CONCRETE	☐ ADOBE	☐ HORIZONTALLY HOLLOWED BRICK
MASONRY BUILDING TYPE	☐ UNREINFORCED MASONRY		☐ CONFINED MASONRY	
	☐ REINFORCED MASONRY		☐ MIXED (MASONRY+RC)	
NUMBER OF STORIES				
POSITION OF BUILDING	☐ SEPERATE	☐ CONTIGUOUS MIDDLE	☐ CONTIGUOUS CORNER	
SLAB LEVEL COMPARED TO CONTIGUOUS BUILDING	☐ SAME		☐ DIFFERENT	
APPARENT QUALITY OF MASONRY WALLS	☐ GOOD	☐ MEDIUM	☐ BAD	
MASONRY WALL WORKMANSHIP	☐ GOOD	☐ MEDIUM	☐ BAD	
PRESENT DAMAGE	☐ NO		☐ YES	
PLAN IRREGULARITY	☐ REGULAR	☐ IRREGULAR	☐ EXTREME IRREGULAR	
RC BEAM	☐ ABOVE WINDOW	☐ ABOVE WALL	☐ NONE	
PLAN LENGTH OF GROUND FLOOR (FRONTAGE) (m)		GROUND FLOOR GAP AMOUNT (FRONTAGE) (m)		
PLAN LENGTH OF GROUND FLOOR (LATERAL FAÇADE) (m)		GROUND FLOOR GAP AMOUNT (LATERAL FAÇADE) (m)		
VERTICAL GAP IRREGULARITY	☐ REGULAR	☐ LESS REGULAR	☐ IRREGULAR	
STORY DIFFERENCE ACCORDING TO FAÇADE	☐ NO		☐ YES	
SOFT STORY/WEAK STORY	☐ YES		☐ NO	
SLAB TYPE	☐ RC	☐ WOOD	☐ VOLTO	
MORTAR MATERIAL	☐ CEMENT	☐ LIME	☐ MUD	☐ NONE
WALL-WALL CONNECTION	☐ GOOD		☐ BAD	
WALL-SLAB CONNECTION	☐ GOOD		☐ BAD	
ROOF MATERIAL	☐ TILE	☐ CONCRETE	☐ SHEET METAL	☐ EARTHENWARE
SOIL TYPE	☐ ZA	☐ ZB	☐ ZC	
	☐ ZD	☐ ZE		
NOTES:				

Figure 2.11. Data collection form for masonry buildings

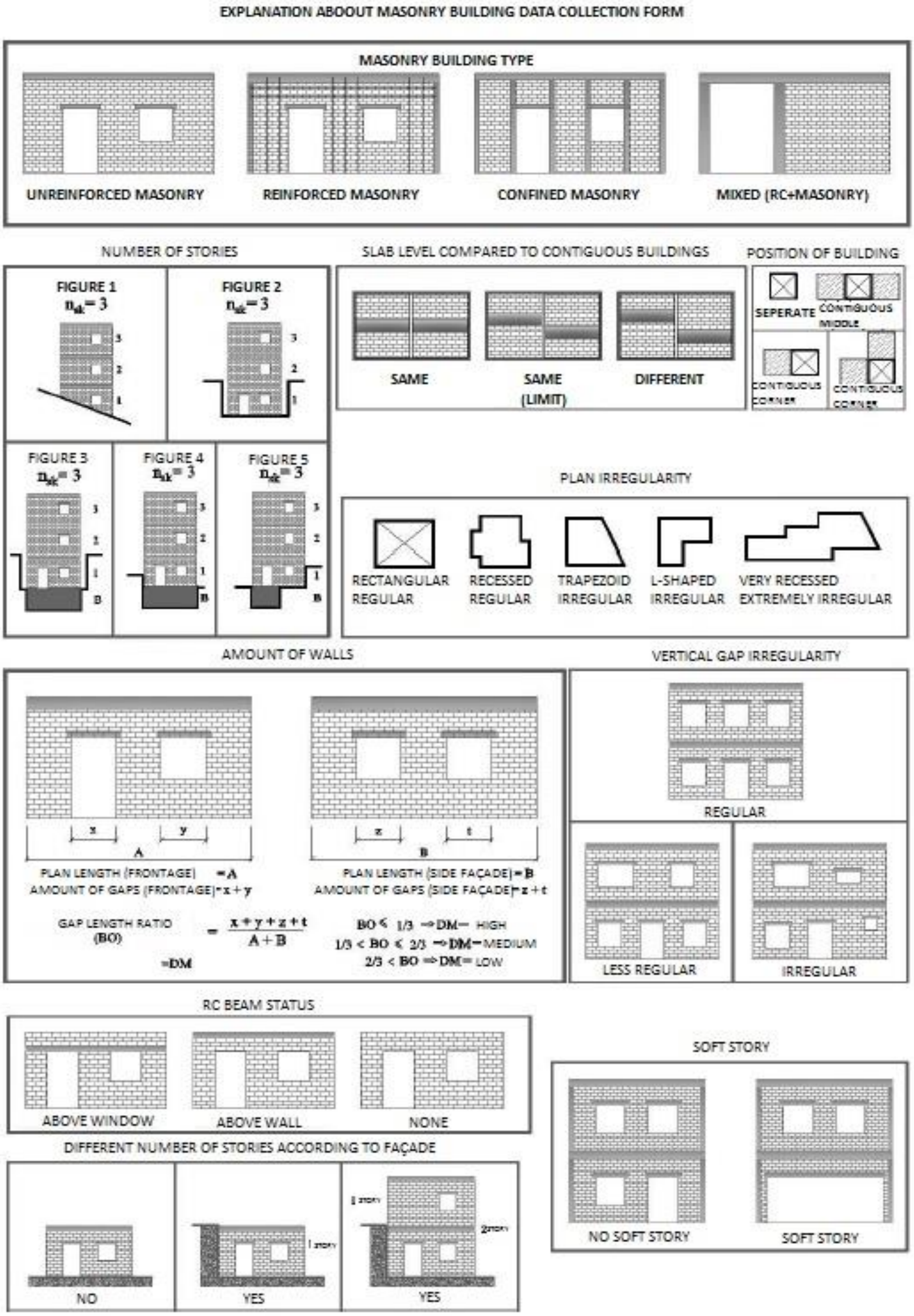

Figure 2.12. Data collection form for masonry buildings (continued)

- The effect of bearing system type is considered as a positive score. Structural system score (YSP) shows the parameter which reflects the impact of the structural system type on the earthquake performance of the building. YSP is taken as; 0 for unreinforced and mixed masonry buildings, 30 for confined masonry buildings and 60 for reinforced masonry buildings.
- If quality of materials and masonry wall workmanship is good, negativity parameter value (O_i) is taken as 0, if it is moderate, O_i is taken as 1 and if it is bad, O_i is taken as 2.
- If plan irregularity status of the building is regular, O_i is taken as 0, if it is irregular O_i is taken as 1 and if it is extremely irregular O_i is taken as 2. On the ground floor of the building; if amount of masonry walls is high O_i is taken as 0, if it is medium O_i is taken as 1 and if it is low, O_i is taken as 2. If RC beam is existed in the building, O_i is taken as 0, if there is no RC beam, O_i is taken as 1.
- Vertical gaps are regular in the building, O_i is taken as 0, if it is less regular, O_i is taken as 1 and if it is irregular, O_i is taken as 2. If there is no difference in number of stories according to façade and no soft story/weak story in the building, O_i is taken as 0, otherwise O_i is taken as 1.
- If there is no earthenware roof in the building, O_i is taken as 0 and if the building has earthenware roof, O_i is taken as 1.
- If at least three of the negativities that lead to the out-of-plane behavior of the masonry building walls are present in the building, it is assumed that there is weakness in the out-of-plane direction. In case of the sum of negative parameter values 11, 12, 13 and 14 in Table 2.10 is 3 or more, O_i is taken as 1, otherwise O_i is taken as 0.
- If the position building is separate, O_i is taken as 0, if it is contiguous or corner-contiguous, O_i is taken as 1.
- The Performance Score (PP) of the building is calculated from Equation 2.3. Base scores for masonry buildings are given in Table 2.7. Building negativity scores are given in Table 2.8, 2.9, 2.11 and 2.12.
- In case of determination of out-of-plane behavior, negativity score (OP_i) is taken as 10 (OP_i=-10).
- In case of determination of earthenware roof, OP_i is taken as 10 (OP_i=-10).

The performance score (PP) is calculated for each building as a result of applying the method to the buildings in the examined region. Calculated performance scores are sorted from top to bottom. Risk distribution between regions can be determined using the distribution of the scores calculated in this way.

Table 2.7. Base Score Table

Number Of Stories	Earthquake Danger Zone		
	Zone 1 $S_{DS} \geq 1.0$	Zone II-III $0.5 \leq S_{DS} < 1.0$	Zone IV $S_{DS} < 0.5$
1	110	120	130
2	100	110	120
3	90	100	110
4	80	90	100
5	70	80	90

Table 2.8. Current Status and Quality Negativity Scores

Material Quality (0/1/2)	Masonry Wall Workmanship (0/1/2)	Present Damage (0/1)
-10	-5	-5

Table 2.9. Plan Irregularity Scores

Geometry (0/1/2)	Amount of Walls (0/1/2)	RC Beam (0/1/2)
-5	-5	-5
-10	-5	-5
-10	-10	-5
-15	-10	-5
-20	-15	-5

Table 2.10. Negativity Parameter Values (O_i)

Negativity Parameter No	Negativity Parameter	Situation 1		Situation 2	
		Parameter Detection	Parameter Value	Parameter Detection	Parameter Value
1	Position of Building	Seperate	0	Contiguous/ Contiguous-Corner	1
2	Quality of Material	Good	0	Medium, (Low)	1, (2)
3	Workmanship	Good	0	Moderate, (Low)	1, (2)
4	Present Damage	No	0	Yes	1
5	Plan Irregularity	Regular	0	Irregular, (Extremely Irregular)	1, (2)
6	RC Beam	Above wall, above window	0	None	1
7	Amount of Walls	High	0	Medium, (Low)	1, (2)
8	Vertical Gap Irregularity	Regular	0	Less Regular, (Irregular)	1, (2)
9	Story Difference According to Façade	No	0	Yes	1
10	Soft Story/ Weak Story	No	0	Yes	1
11	Slab Type	RC	0	Wood, Volto	1
12	Adobe Material	Cement	0	Lime, Mud, None	1
13	Wall-Wall Connection	Good	0	Bad	1
14	Wall-Slab Connection	Good	0	Bad	1
15	Roof Material	Tile, Sheet Metal, Concrete	0	Earthenware	1

Table 2.11. Vertical Irregularity Scores

Number of Stories	Gap Layout (0/1/2)	Story Difference According to Façade (0/1)	Soft Story/ Weak Story (0/1)
1	0	-5	0
2	-5	-5	-5
3	-5	-5	-5
4	-10	-5	-10
5	-10	-5	-10

Table 2.12. Position of Building and Slab Level Negativity Scores

Seperate	Contiguous Middle-Same	Contiguous Corner-Same	Contiguous Middle-Different	Contiguous Corner-Different
0	0	-5	-5	-10

Although many parameters are considered in this method, the result of the method does not predict the risk status of the structure. If we look at the parameters considered by the method, it is obvious that the evaluation of any structure will take quite a long time. Therefore, it would be inconvenient to use this method, which does not give any idea about the risk status of the structure, only to determine the risk distribution of masonry buildings.

3. DEVELOPMENT OF ALTERNATIVE RAPID SCREENING METHOD FOR UNREINFORCED MASONRY BUILDINGS

In this study, an attempt was made to propose a new rapid screening method based on detailed seismic assessment results. For each building in the database, the scores from the detailed seismic assessment analysis were calculated. In this proposed method, the rapid screening was based on penalty scores obtained from a large database of Environment and Urbanization Ministry. 543 URM buildings from various cities in Turkey with available detailed seismic assessment results from 2013 till 2018 provided by the Guidelines for the Assessment of Buildings under High Risk (GABHR2013). These data contain eight parameters which may effect the results of seismic analysis done according to GABHR 2013 (Guidelines for the Assessment of Buildings under High Risk). 443 buildings from the database were used to generate the penalty scores and 100 buildings were reserved for the test of the proposed method. In this method, linear assessment of URM buildings was implemented under the effect of seismic actions using response spectrum analysis (i.e. modal analysis) [31].

The basic estimation variables in the proposed method were number of stories (N), type of slab system (SS), vertical irregularities (VI), visual damage (D), type of masonry material (M), typical story height (H) and typical plan area (A). These estimation variables were assigned some penalty scores depending on the coefficients derived from the binary logistic regression analysis of the database. The correct estimation rates of the proposed method for the database (i.e. 443 buildings) and the test database (i.e. 100 buildings) were determined as approximately 94% and 86%, respectively.

3.1. Definition of the URM Building Database

The URM buildings were selected to cover a wide range of the selected basic estimation variables (i.e. N, SS, VI, D, M, H and A). The possible subcategories for the selected estimation variables are presented in Table 3.1. These categories were formed based on the available database and based on some pre-analysis whose details given below.

Table 3.1. Subcategories for the Selected Estimation Variables

Estimation Variables	**Possible Values**						
Number of Stories (N)	1	2	3	4	5	6	7
Type of Slab System (SS)	RC Slab with RC Bond Beam		RC Slab without RC Bond Beam		Others		
Type of Masonry Material (M)	Solid Clay Brick	Hollow Clay Brick	Stone	Solid Concrete Block	Others		
Typical Story Height (H)	≤ 2.4m		2.4 < H ≤ 3.2m		> 3.2m		
Typical Plan Area (A)	≤ 50m^2		50 < A ≤ 200m^2		> 200m^2		
Vertical Irregularities (VI)	Yes			No			
Visual Damage (D)	Yes			No			

443 buildings from the database were used to generate the penalty scores and 100 buildings were reserved for the test of the proposed method. 443 buildings were firstly classified according to the level of seismicity based on spectral response acceleration parameter at short periods (S_{DS}). Since the analyses in the database were conducted according to GABHR (2013), the earthquake zone parameters (1st, 2nd, 3rd and 4th degree earthquake zones) of these structures according to TEC2007 have been made compatible with TEC2019 [9]. To do this, buildings located in the 1st earthquake zone according to TEC2007 are considered as buildings with S_{DS} values greater than or equal to 0.75 g and these buildings are classified in Seismic Class (SC1). The same approach was applied to buildings located in other earthquake zones. So, sites with S_{DS} values between 0.50g and 0.75g belonged to the second Seismic Class (SC2), sites with S_{DS} values between 0.25g and 0.50g were classified as the third Seismic Class (SC3) and sites with S_{DS} values less than 0.25g were named as Seismic Class (SC4). Due to insufficient data in SC3 and SC4, these seismic classes were decided to be combined during the statistical model formation. Consequently, the number of buildings in SC1, SC2 and SC3-4 are 172, 133 and 138, respectively.

The subcategories for typical story height (H) and typical plan area (A) were adjusted by performing a separate preliminary binary logistic regression analysis of the whole database. The limits for typical story height were determined first and then the same approach was used for typical plan area. Details of the preliminary analysis for typical story height have been presented for brevity. A typical story height limit was selected and values were transformed to binary data according to the limit height value. Afterwards, binary logistic regression analysis [32] determined the coefficient of the typical story height. A new limit was selected and the same procedure was repeated until a significant change in the coefficient (i.e. more than 20%) was observed. From this preliminary analysis, the subcategories for typical story height (H) and typical plan area (A) were determined, as presented in Table 3.1.

In the first stage of the study, URM buildings in the selected database were analyzed. Detailed seismic assessment results of each building were obtained using the linear assessment procedure provided in GABRH2013 [5]. Numerical models of each building were generated using the equivalent frame method [12, 33], then response spectrum analysis was performed to obtain the seismic demands as suggested by GABRH2013 [5]. Finally, the shear force demands (Vd) on each URM wall were compared with available shear capacities (Vc), and the URM walls with insufficient shear capacities (Vd > Vc) were classified as collapsed. The building score was then calculated by taking the ratio of total shear forces carried by URM walls with insufficient capacities to total base shear. If the score of the building was over 50%, the building was deemed susceptible to collapse ("risky"). If the score was under 50%, it was classified as "non-risky.". The details about this seismic assessment analysis were explained in detail in Section 2.2. Figures 3.1 - 3.3 shows the scores of URM buildings from the detailed seismic assessment according to GABHR2013 [26] for each seismic class. Buildings with scores in excess of 50% are deemed to be vulnerable to seismic demands (i.e. within collapse limit or "risky"). These buildings are shown as circles, while "non-risky" buildings are represented by triangles.

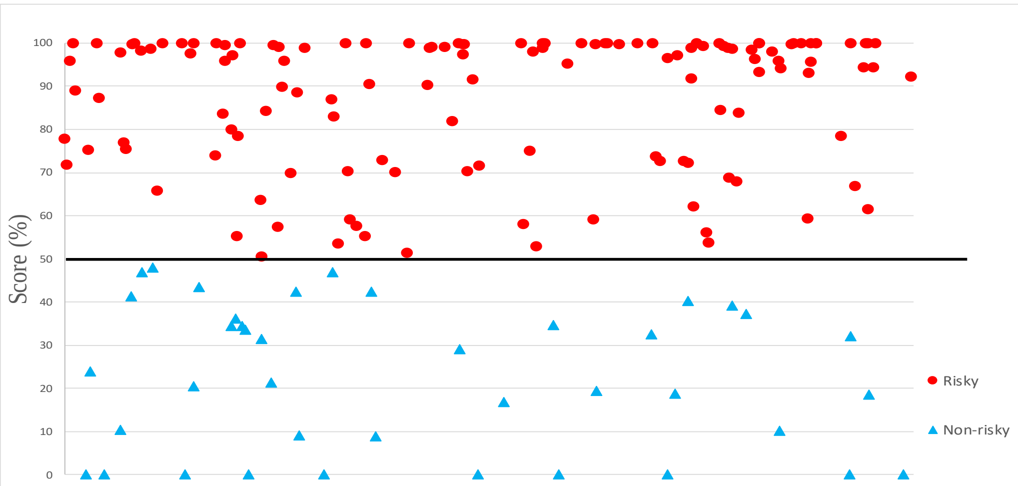

Figure 3.1. Scores of URM Buildings from the Detailed Seismic Assessment in SC1

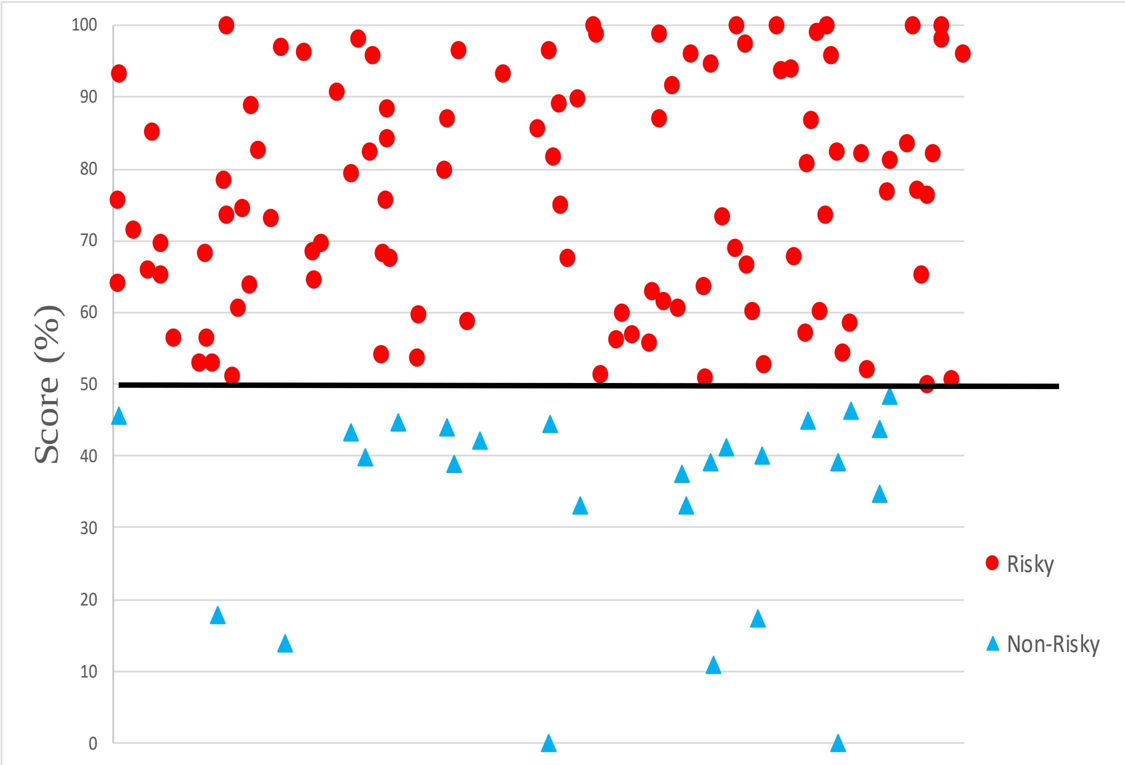

Figure 3.2. Scores of URM Buildings from the Detailed Seismic Assessment in SC2

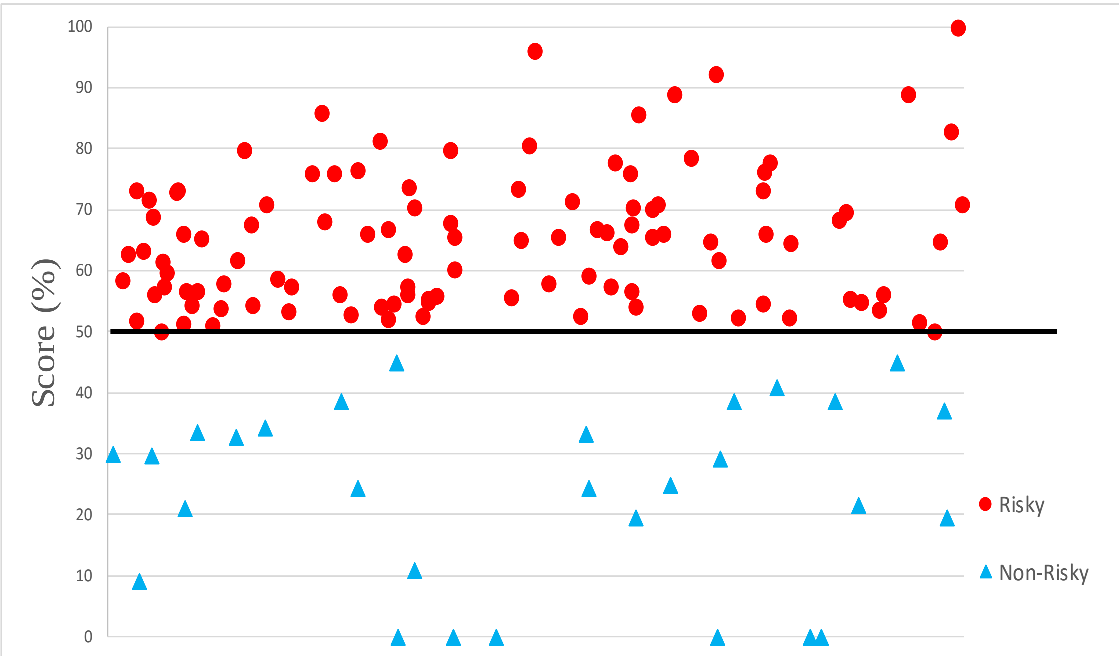

Figure 3.3. Scores of URM Buildings from the Detailed Seismic Assessment in SC3-4

3.1.1. Details of Database in SC1

In SC1, 172 buildings were evaluated. 132 of these buildings are "risky" and 40 of them are "non-risky" according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC1 database are represented in Figures 3.4-3.10.

As is apparent from figures below, the database contains more URM buildings with physical properties common to the construction market to prevent skewing the proposed method. For instance, in SC1, there were more than 150 URM buildings with a typical story height between 2.8 m and 3.2 m, whereas only five had a typical height of more than 3.2 m, as the latter is uncommon in Turkish URM construction.

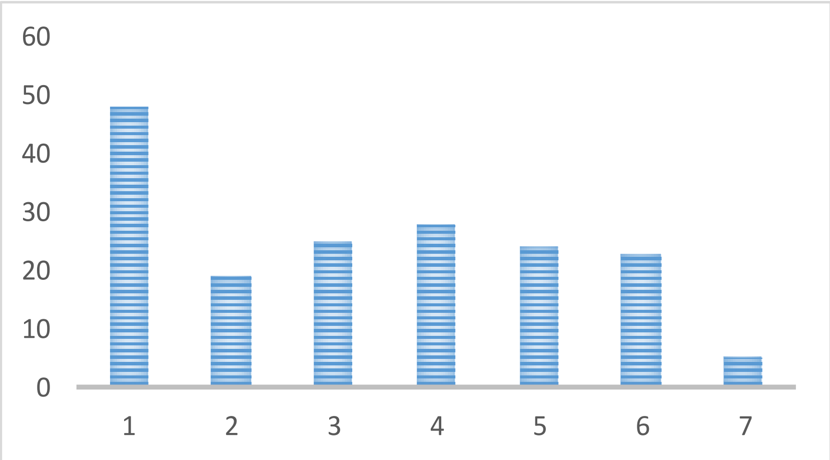

Figure 3.4. Number of Stories in SC1

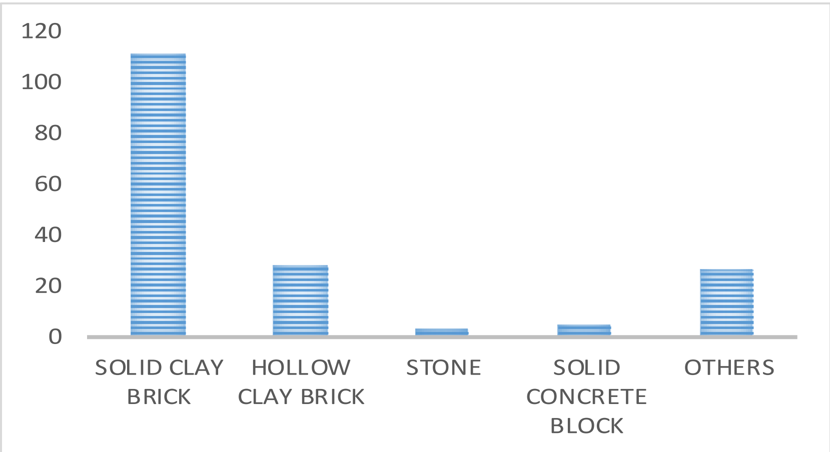

Figure 3.5. Type of Masonry Materials in SC1

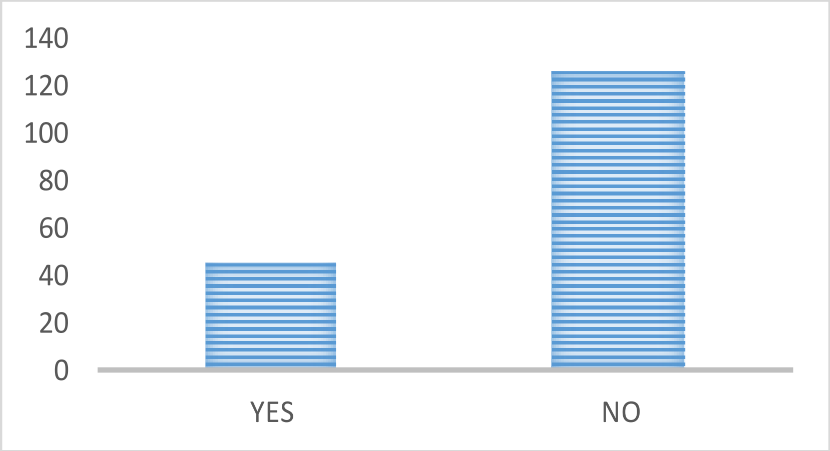

Figure 3.6. Vertical Irregularities in SC1

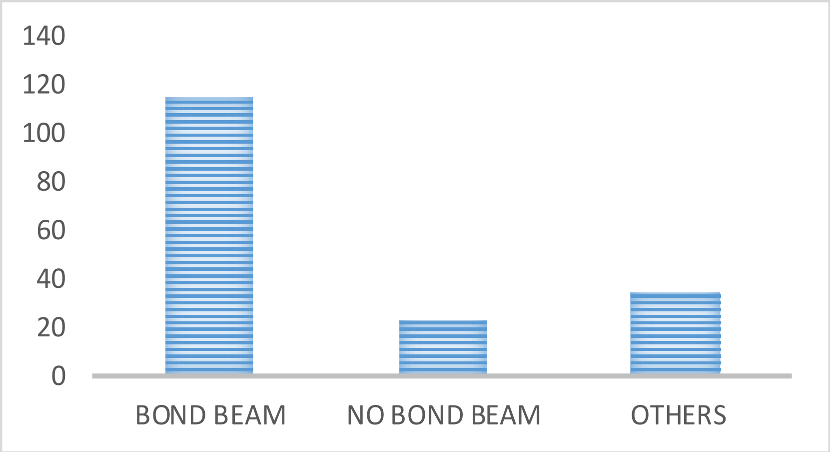

Figure 3.7. Types of Slab Systems in SC1

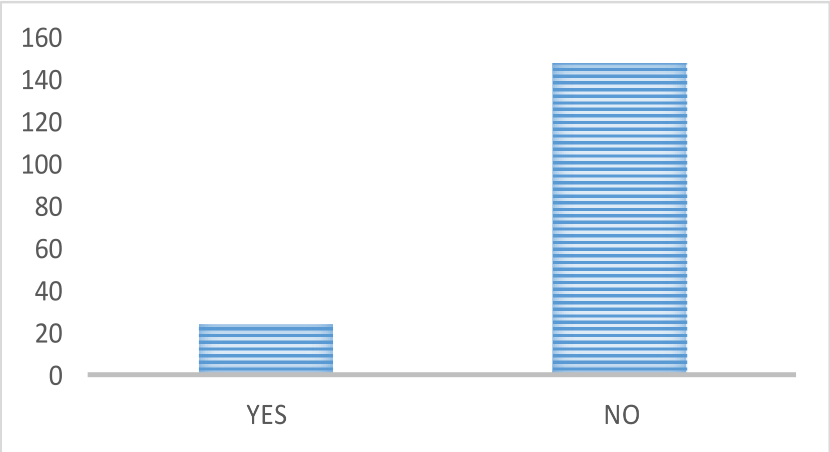

Figure 3.8. Visual Damages in SC1

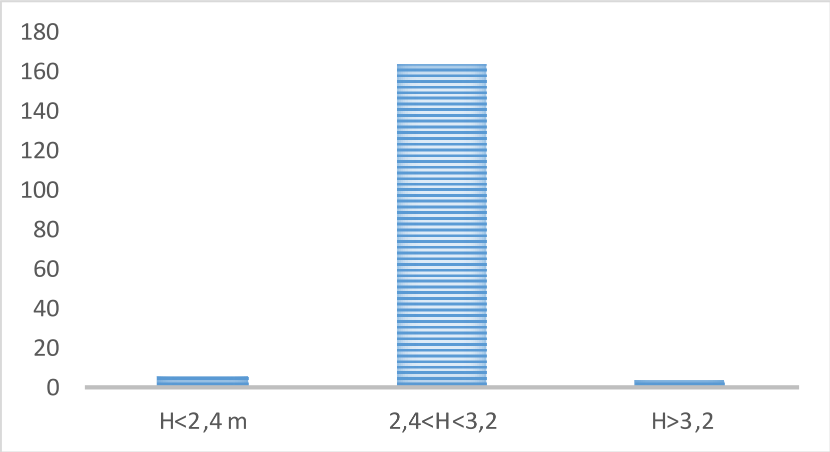

Figure 3.9. Typical Story Heights in SC1

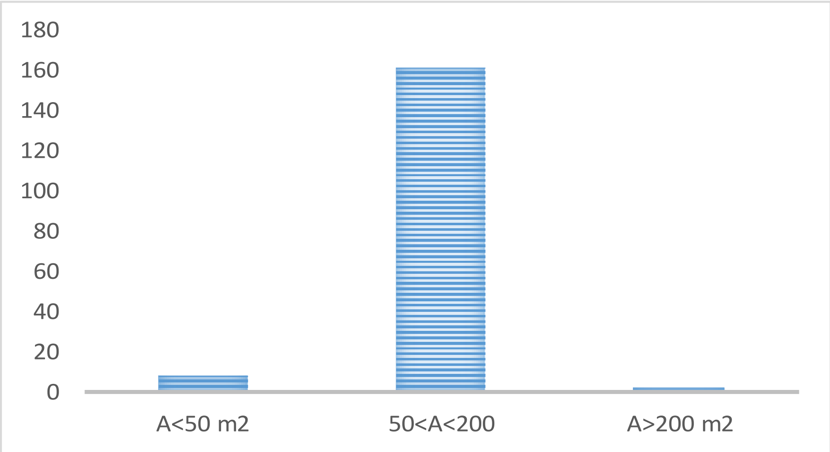

Figure 3.10. Typical Plan Areas in SC1

3.1.2. Details of Database in SC2

In SC2, 133 buildings were evaluated. 107 of these buildings are “risky” and 26 of them are “non-risky” according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC2 database are represented in Figures 3.11-3.17.

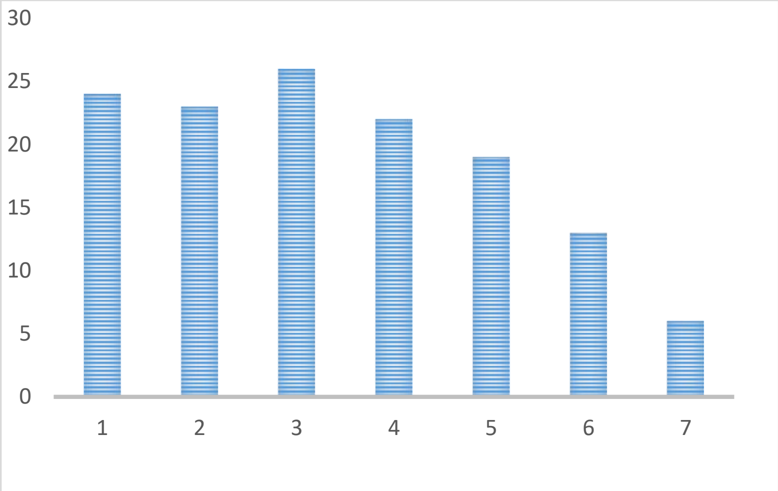

Figure 3.11. Number of Stories in SC2

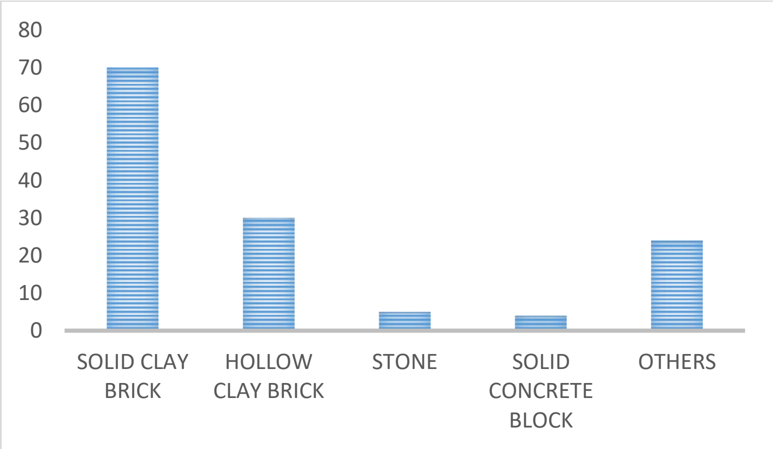

Figure 3.12. Type of Masonry Materials in SC2

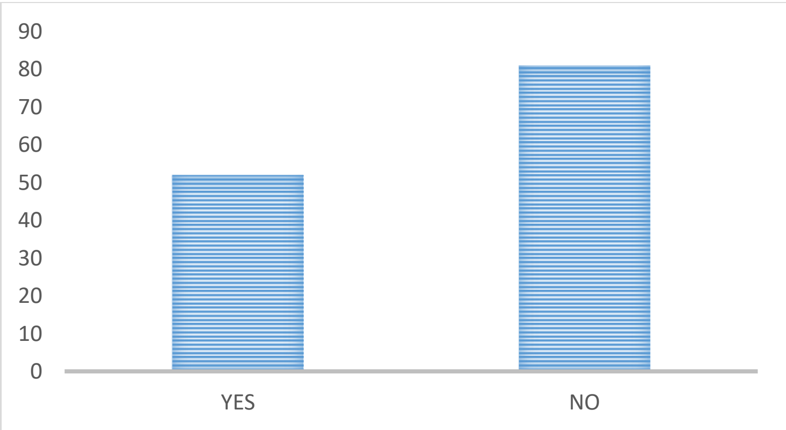

Figure 3.13. Vertical Irregularities in SC2

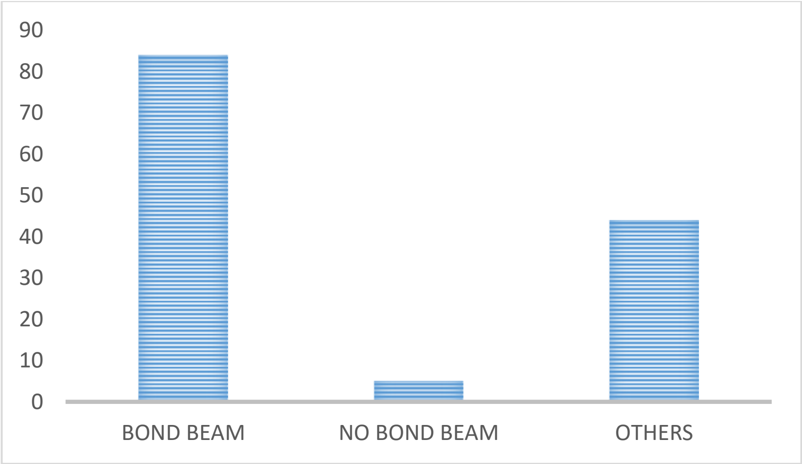

Figure 3.14. Types of Slab Systems in SC2

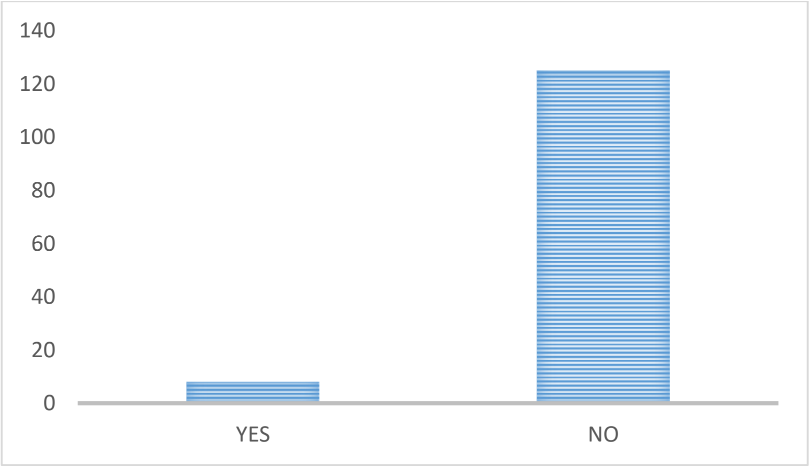

Figure 3.15. Visual Damages in SC2

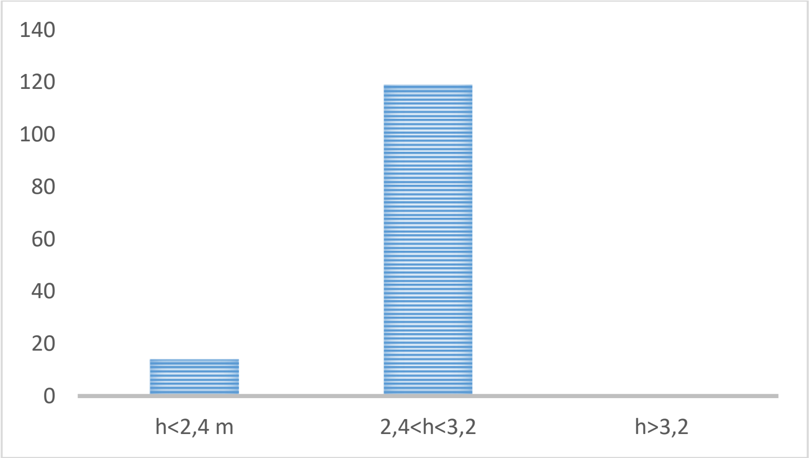

Figure 3.16. Typical Story Heights in SC2

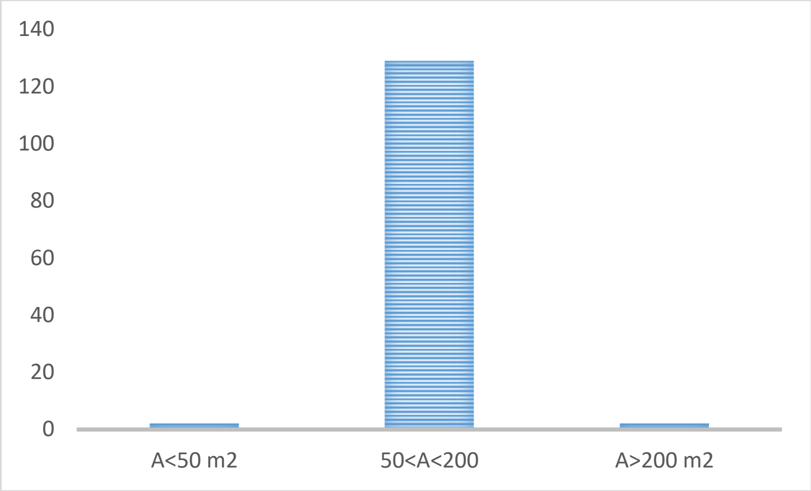

Figure 3.17. Typical Plan Areas in SC2

3.1.3. Details of Database in SC3-4

138 buildings were evaluated together for SC3-4. 109 of these buildings are “risky” and 29 of them are “non-risky” according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC3-4 database are represented in Figures 3.18-3.24.

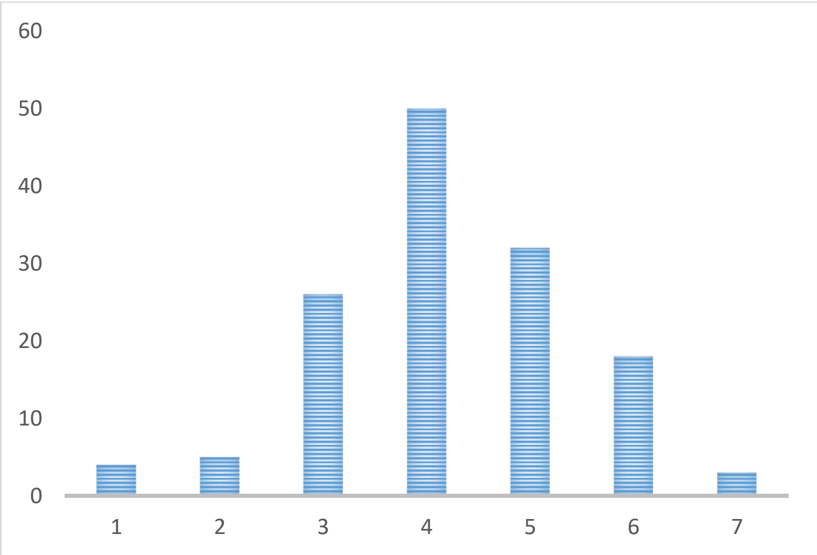

Figure 3.18. Number of Stories in SC3-4

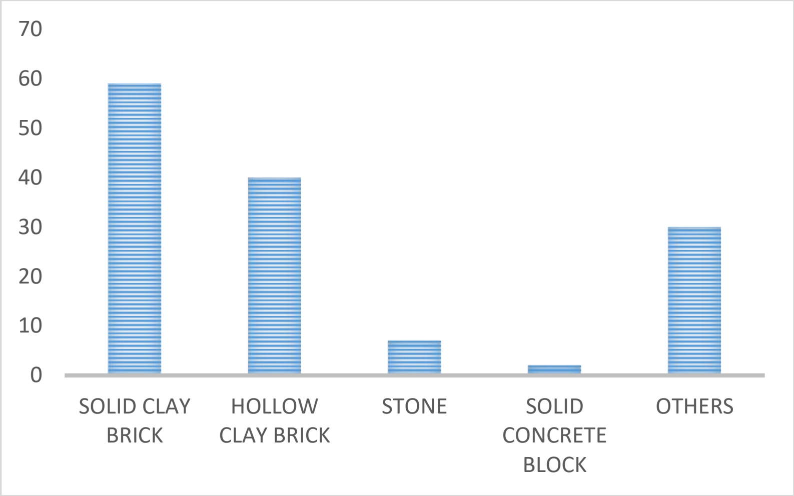

Figure 3.19. Type of Masonry Materials in SC3-4

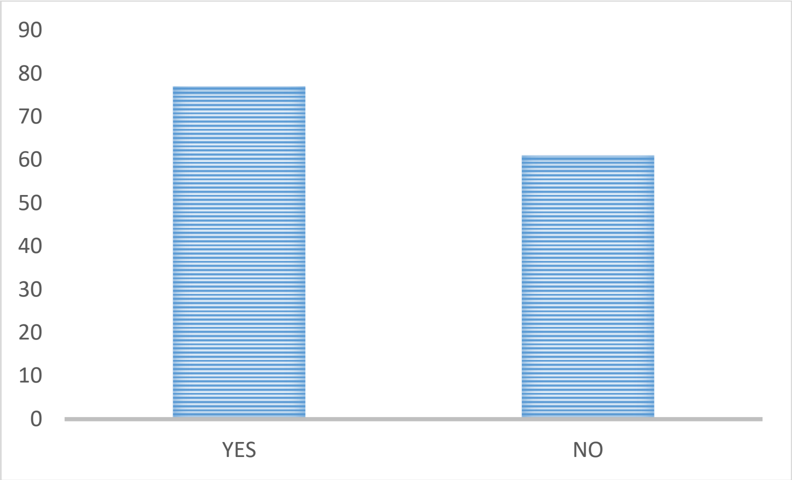

Figure 3.20. Vertical Irregularities in SC3-4

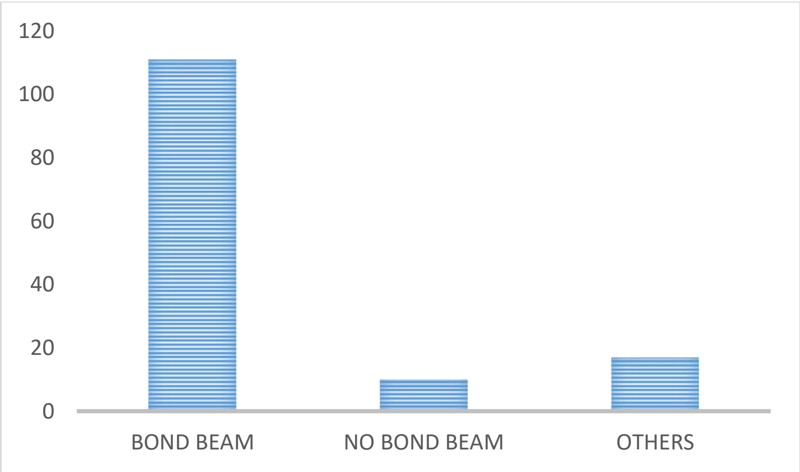

Figure 3.21. Types of Slab Systems in SC3-4

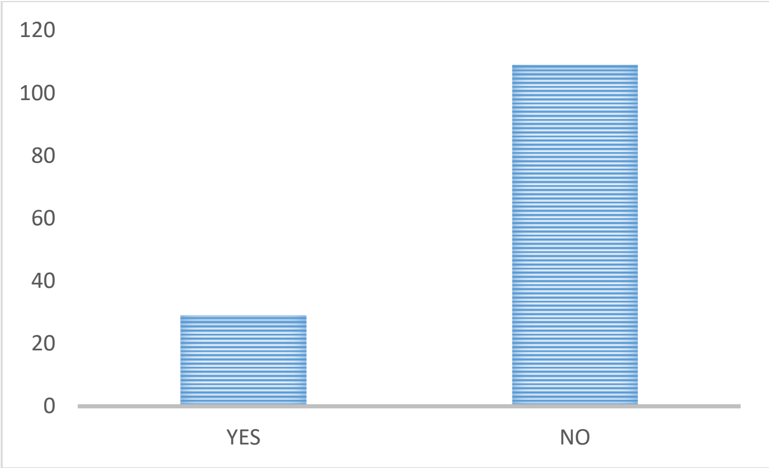

Figure 3.22. Visual Damages in SC3-4

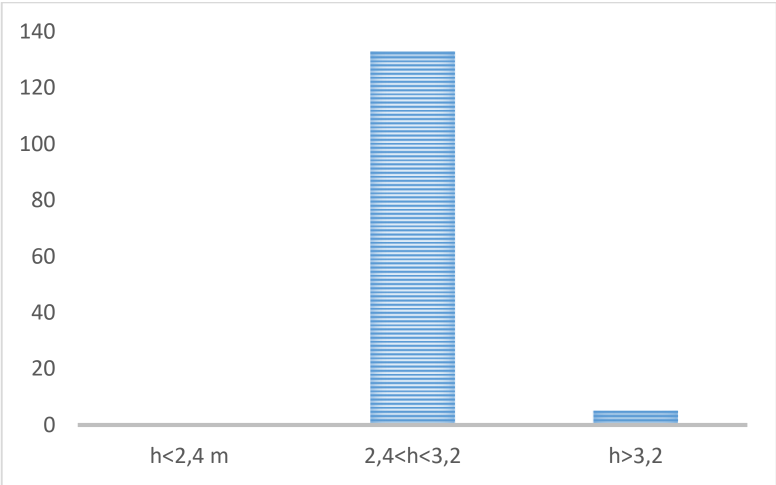

Figure 3.23. Typical Story Heights in SC3-4

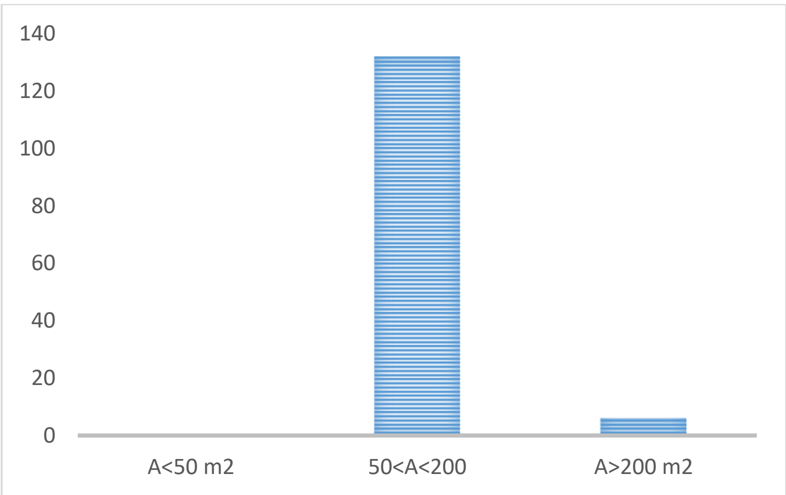

Figure 3.24. Typical Plan Areas in SC3-4

3.2. Details on the performed Statistical Analysis of the Selected Estimation Variables

The database outlined in Section 3.1 was used to generate a new rapid screening method applicable for URM buildings. To this end, the database was transformed into numerical data, as shown in Table 3.2. The risk status of URM buildings in the database is represented by binary data ("risky"=1 and "not-risky"=0) to be compatible with the preferred statistical method, i.e. binary logistic regression [32]. Binary logistic regression is a classification algorithm used to predict binary outcome (i.e. the state of seismic risk) dependent on a set of prediction variables. Binary logistic regression is a subset of linear regression, as the dependent variable in binary logistic regression should be a binary number. In binary logistic regression, a log of the odds of the binary outcome is modeled as a linear combination of the prediction variable (i.e. independent variables). The binary logistic regression expresses the multiple linear regression equation in logarithmic terms in the model, which overcomes the linearity assumption when the dependent variable is categorical [34]. Therefore, the logistic regression is more suitable than the multivariate linear regression for categorical estimation variables.

Table 3.2. Numerical Representation of the Selected Estimation Variables

Estimation Variables	Possible Values						
Number of Stories (N)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Type of Slab System (SS)	**1:** RC Slab with RC Bond Beam		**2:** RC Slab without RC Bond Beam		**3:** Others		
Type of Masonry Material (M)	**1:** Solid Clay Brick	**2:** Hollow Clay Brick	**3:** Stone	**4:** Solid Concrete Block	**5:** Others		
Typical Story Height (H)	**1:** ≤ 2.4m		**2:** 2.4 < H ≤ 3.2m		**3:** > 3.2m		
Typical Plan Area (A)	**1:** ≤ 50m²		**2:** 50 < A ≤ 200m²		**3:** > 200m²		
Vertical Irregularities (VI)	**1:** Yes			**0:** No			
Visual Damage (D)	**1:** Yes			**0:** No			

This study proposed a method based on penalty scores (PS_i). Penalty scores for the different weaknesses of URM buildings (i.e. seven different estimation variables) were determined, then a base score (BS) was assigned to each building, depending on its seismic class (SC). Finally, the building risk score (BRS) was calculated as the sum of all penalty scores and the base score (Eq. 1). In this method, URM buildings with a BRS value of less than zero were classified as vulnerable to seismic risk or "risky." Other buildings were categorized as non-vulnerable to seismic risk or "non-risky."

$$BRS = BS + \sum_{i=1}^{7} PS_i \tag{3.1}$$

After converting the data into a form compatible with the selected statistical method, the database was filtered according to the Seismic Class (SC). Each filtered database was then used separately to conduct binary logistic regression [32]. All analyses were performed in the SPSS [32] program. In these analyses, number of stories (N), type of slab system (SS), vertical irregularities (VI), visual damage (D), type of masonry material (M), typical story height (H) and typical plan area (A) were selected as basic estimation variables. From each binary logistic regression analysis for different Seismic Class, Cox and Snell R^2 and Nagelkerke R^2 terms and the Omnibus Test results [35] were obtained (Table 3.3). The accuracy of the statistical models for each seismic class was examined using the Cox and Snell R^2 values, Nagelkerke R^2 values and Chi-square values of the Omnibus Tests (i.e. likelihood-ratio chi-square test) of the variables [32]. From Table 3.3, it could easily be inferred that the significance values were below 0.05, implying that the statistical model outscored the null model. More importantly, the Nagelkerke R^2 values were very close to 1 for the seismic classes SC1 and SC2 whereas the Nagelkerke R^2 value was 0.689 for SC3-4. This indicated that the proposed statistical models are adequately representative of the database, especially for seismic classes with large seismic demands, i.e. SC1 and SC2.

Table 3.3. Statistical Test Results for Models for Different Seismic Classes

	Seismic Class		
	SC1	**SC2**	**SC3-4**
Cox and Snell R^2	0.665	0.688	0.456
Nagelkerke R^2	0.968	0.979	0.689
Chi-square – degree of freedom (df) - Significance (p)	118.01 – 7 – 0.001	35.593 – 7 – 0.001	11.410 – 7 – 0.048

Binary logistic regression analysis was used to obtain the best estimates for the coefficients of the selected variables and the significance levels of the selected estimation variables (Table 3.4). In addition, the constant term determined from the regression analysis was considered the base score (BS). The best estimates of the coefficients (penalty scores) and the constant terms (base score) are presented in Table 3.4, rounded to result in more practical values (Table 3.4). These rounded coefficients are considered the penalty scores.

In Table 3.4, the selected estimation variables indicate whether the estimation variable is statistically significant enough to predict output score. A significance level close to zero implies a significant relationship between the independent variable and the dependent variable, whereas a level close to unity means a weak relationship. Therefore, number of stories and typical story height are significant prediction variables in SC1 and SC2, while typical story height lost its significance in SC3-4.

Table 3.4. Best Estimates of the Coefficients and the Constant Term for Different Seismic Classes

	SC1			SC2			SC3-4		
	Best Estimate	**Significance Level**	**Penalty Score**	**Best Estimate**	**Significance Level**	**Penalty Score**	**Best Estimate**	**Significance Level**	**Penalty Score**
Number of Stories (N)	-18.32	0.009	-18	-18.18	0.010	-18	-14.99	0.013	-15
Type of Slab System (SS)	-0.89	0.084	-1	-0.86	0.081	-1	-9.87	0.084	-10
Type of Masonry Material (M)	-2.16	0.049	-2	-1.15	0.049	-1	-4.96	0.044	-5
Typical Story Height (H)	-15.31	0.026	-15	-1.86	0.027	-2	-5.08	0.999	-5
Typical Plan Area (A)	-35.18	0.052	-35	-0.95	0.079	-1	-5.25	0.087	-5
Vertical Irregularities (VI)	-15.48	0.086	-15	-15.19	0.089	-15	-10.14	0.052	-10
Visual Damage (D)	-20.29	0.700	-20	-15.18	0.840	-15	-19.98	0.520	-20
Base Score (BS)	79.70	0.999	80	35.04	0.999	35	34.94	0.900	35

According to the coefficients listed in Table 3.4, Building Risk Score Tables (Table 3.5, 3.6 and 3.7) were formed for all Seismic Classes with specified parameter coefficients.

Table 3.5. Building Risk Score Table with Penalty Scores for SC1

BUILDING RISK SCORE TABLE (Seismic Class 1)								
Base Score=80								
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score
Number of Stories (P1)	1	-18	Masonry Material (P2)	Solid Clay Brick	-2	Slab Type (P3)	Bond Beam	-1
	2	-36		Hollow Brick	-4		No Bond Beam	-2
	3	-54		Stone	-6		Others	-3
	4	-72		Solid Concrete Block	-8			
	5	-90		Others	-10			
	6	-108				Parameter	Parameter Value	Penalty Score
	7	-126				Visual Damage (P4)	Yes	-20
							No	0
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score			
Typical Story Height (P5)	h<2,4 m	0	Plan Area (P6)	A<50 m2	0	Parameter	Parameter Value	Penalty Score
	2,4<h<3,2	-15		50<A<200	-35	Vertical Irregularity P(7)	Yes	-15
	h>3,2	-30		A>200 m2	-70		No	0

Table 3.6. Building Risk Score Table with Penalty Scores for SC2

BUILDING RISK SCORE TABLE (Seismic Class 2)								
Base Score=35								
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score
Number of Stories (P1)	1	-9	Masonry Material (P2)	Solid Clay Brick	-1	Slab Type (P3)	Bond Beam	-1
	2	-36		Hollow Brick	-2		No Bond Beam	-2
	3	-54		Stone	-3		Others	-3
	4	-72		Solid Concrete Block	-4			
	5	-90		Others	-5			
	6	-108				Parameter	Parameter Value	Penalty Score
	7	-126				Visual Damage (P4)	Yes	-15
							No	0
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score			
Typical Story Height (P5)	h<2,4 m	0	Plan Area (P6)	A<50 m2	0	Parameter	Parameter Value	Penalty Score
	2,4<h<3,2	-2		50<A<200	-1	Vertical Irregularity P(7)	Yes	-15
	h>3,2	-4		A>200 m2	-2		No	0

Table 3.7. Building Risk Score Table with Penalty Scores for SC3-4

BUILDING RISK SCORE TABLE (Seismic Class 3 and 4)								
Base Score(SC3=25 ; SC4=35)								
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score
Number of Stories (P1)	1	-15	Masonry Material (P2)	Solid Clay Brick	0	Slab Type (P3)	Bond Beam	-1
	2	-30		Hollow Brick	0		No Bond Beam	-2
	3	-45		Stone	0		Others	-3
	4	-60		Solid Concrete Block	0			
	5	-75		Others	0			
	6	-90				Parameter	Parameter Value	Penalty Score
	7	-105				Visual Damage (P4)	Yes	-20
							No	20
Parameter	Parameter Value	Penalty Score	Parameter	Parameter Value	Penalty Score			
Typical Story Height (P5)	h<2,4 m	5	Plan Area (P6)	A<50 m2	10	Parameter	Parameter Value	Penalty Score
	2,4<h<3,2	0		50<A<200	5	Vertical Irregularity P(7)	Yes	-10
	h>3,2	-5		A>200 m2	0		No	10

3.3. Results of the Proposed Method

After generating the proposed rapid screening method, risk estimations of the proposed method for URM buildings in the database were determined (Figures 3.25 - 3.27). Figures 3.25 – 3.27 use the same visualization strategy as Figure 3.1 - 3.3. Buildings classified as "risky" from the detailed seismic assessment analysis are shown as circles and "non-risky" buildings are represented by triangles. The scores, as presented in y-axis were determined using the proposed method. In Figures 3.25 - 3.27, whenever a building represented by a circle falls below the zero-line or whenever a building represented by a triangle is above zero-line, it means the estimation of the proposed method was correct. Anything else indicates the proposed method generated the wrong estimation.

Figures 3.25 - 3.27 show that the proposed method was able to estimate the state of risk with good accuracy, and more importantly, could dissociate "risky" buildings from "non-risky" ones, as is apparent from the clustered "risky" and "non-risky" estimations.

A comparison of the number of "risky" and "non-risky" buildings from the detailed seismic assessment and the proposed method is presented in Table 3.8. Percentage errors in the estimations appear in Table 3.9. Table 3.8 and 3.9 show that the total number of "risky" buildings was 132 and 127 for SC1, based on the detailed analysis results and the estimations of the proposed method, respectively. Thus, the proposed method failed to correctly estimate the risk state of five non-risky buildings in SC1, resulting in a 3.78% error rate. Estimation performance of the proposed method was similar for SC2, with a percentage error around 7%. The proposed method predicted the risk state of the "risky" buildings in seismic class SC3-4 with a similar error rate of around 7%. However, the estimation performance of the proposed method for the non-risky buildings in the seismic class SC3-4 was lower at approximately 35%.

From all these results, it can be seen that the method will be very useful in estimating seismic danger of URM buildings of a field with large number of buildings. For example, if we consider how long it would take to perform detailed seismic analysis of each buildings in an area with approximately 400 buildings, as in the method, the risk analysis of such an area can be performed in a very short time with this method with acceptable error rates mentioned above.

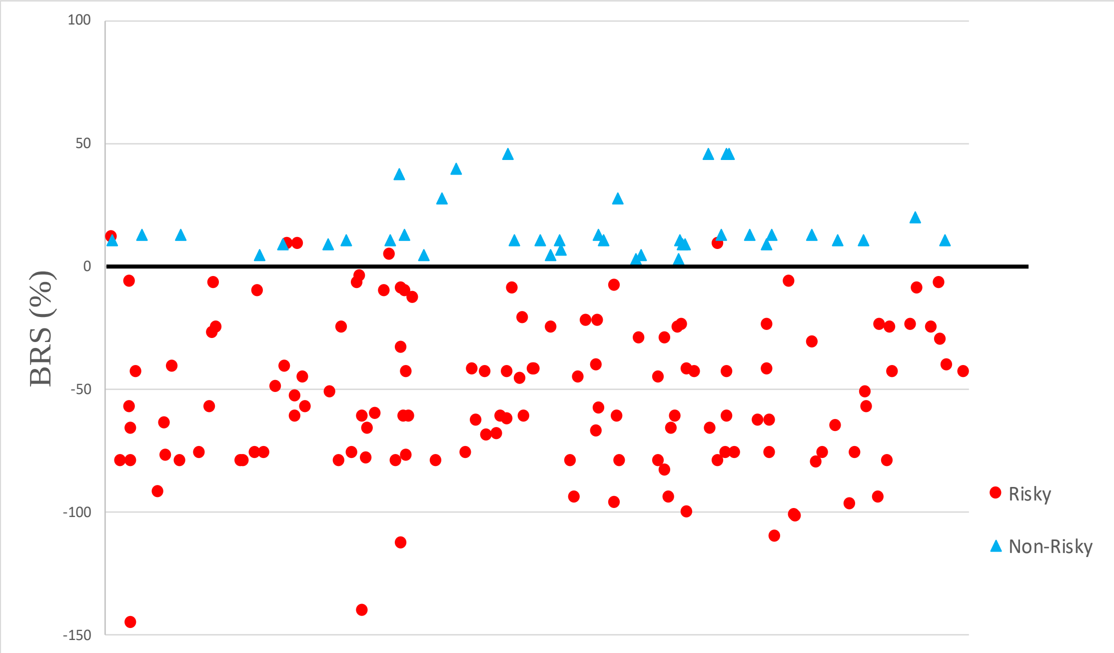

Figure 3.25. Comparison of the Risk State Estimations of the Proposed Method with the Detailed Seismic Assessment Results in SC1

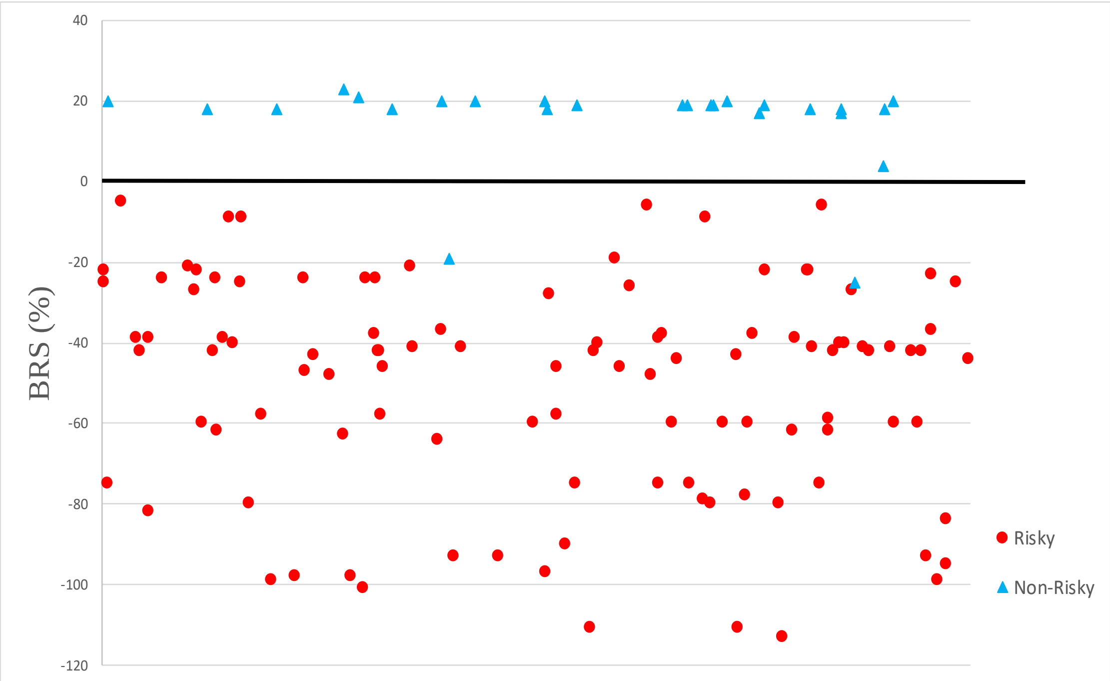

Figure 3.26. Comparison of the Risk State Estimations of the Proposed Method with the Detailed Seismic Assessment Results in SC2

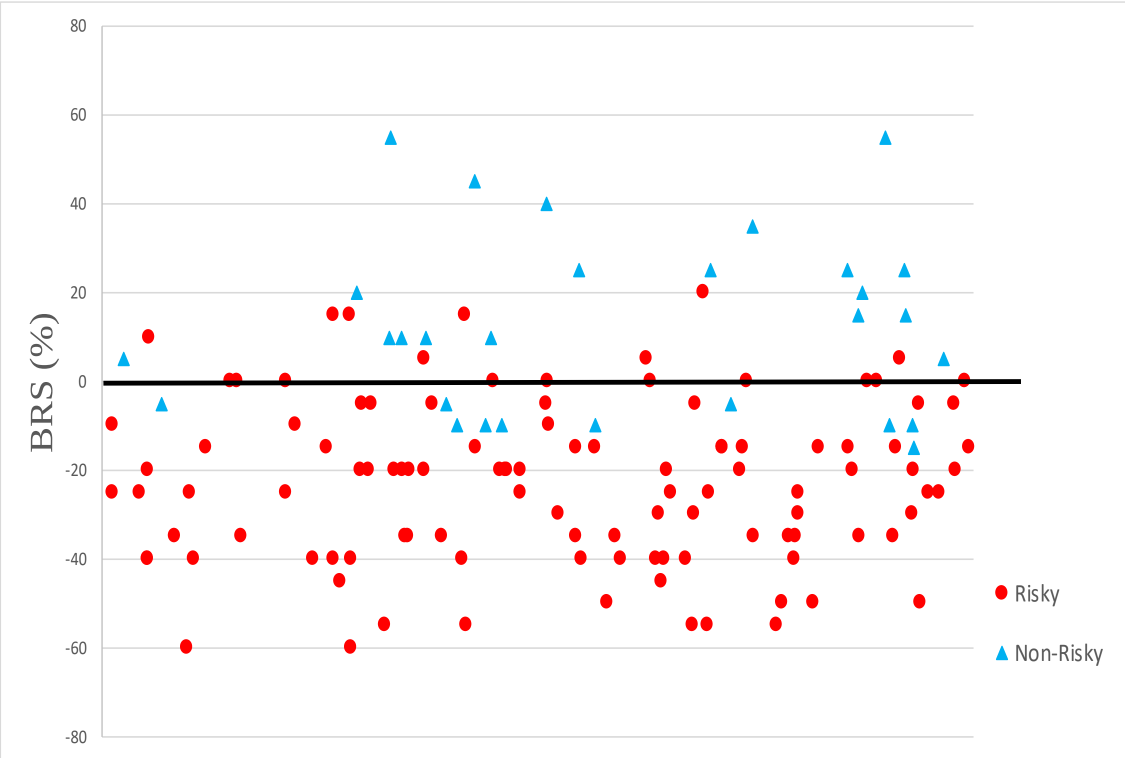

Figure 3.27. Comparison of the Risk State Estimations of the Proposed Method with the Detailed Seismic Assessment Results in SC3-4

Table 3.8. Number of "Risky" and "Non-Risky: Buildings from the Detailed Seismic Assessment and the Proposed Method

Number of Buildings	Detailed Assessment Result			Estimation of the Proposed Method		
	SC1	**SC2**	**SC3-4**	**SC1**	**SC2**	**SC3-4**
Risky	132	107	109	127	109	111
Non-risky	40	26	29	45	24	27
Total	172	133	138	172	133	138

Table 3.9. Performance of the Proposed Method to Estimate the State of Risk

Number of Buildings	Estimations of the Proposed Method (Correct - Incorrect)			Percentage Error (%)		
	SC1	**SC2**	**SC3**	**SC1**	**SC2**	**SC3**
Risky	127- 5	107 - 0	101 - 8	3.78	0.0	7.34
Non-risky	40 - 0	24 - 2	19 - 10	0.00	7.69	34.48
Total	167 -5	131 - 2	120 - 18	2.91	1.50	13.04
Overall	418 - 25			5.64		

These results show that overall errors of the proposed method were lower for seismic classes with larger seismic demands (i.e. SC1 and SC2). The proposed method predicted the state of risk of 418 buildings correctly and 25 buildings incorrectly, with a percentage error of approximately 5%. Overall percentage errors were within acceptable engineering limits for a rapid screening method. More importantly, Table 3.8 and 3.9 show that the proposed method is better for the most seismic-prone regions (i.e. SC1). These observations have increased confidence in the proposed method. However, it should still be blind-tested with a new database to test whether the method memorized the database or not.

3.4. Test of the Proposed Method

The performance of the proposed method was examined by comparing estimations of the proposed method with the detailed seismic assessment results. For this purpose, a new test database of 100 URM buildings in different seismic classes was formed. Properties of URM buildings in the test database are listed in Figures 3.28-3.48, showing that it covered a very wide range of the selected estimation variables.

3.4.1. Details on the Test Database for SC1

In SC1, 22 buildings were evaluated for testing the purposed method. 17 of these buildings are “risky” and 5 of them are “non-risky” according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC1 test database are represented in Figures 3.28-3.34.

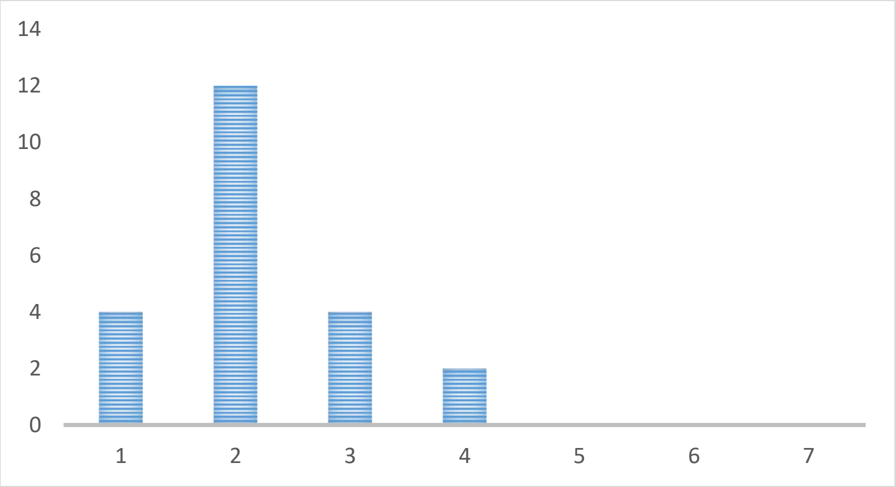

Figure 3.28. Number of Stories in SC1 Test Data

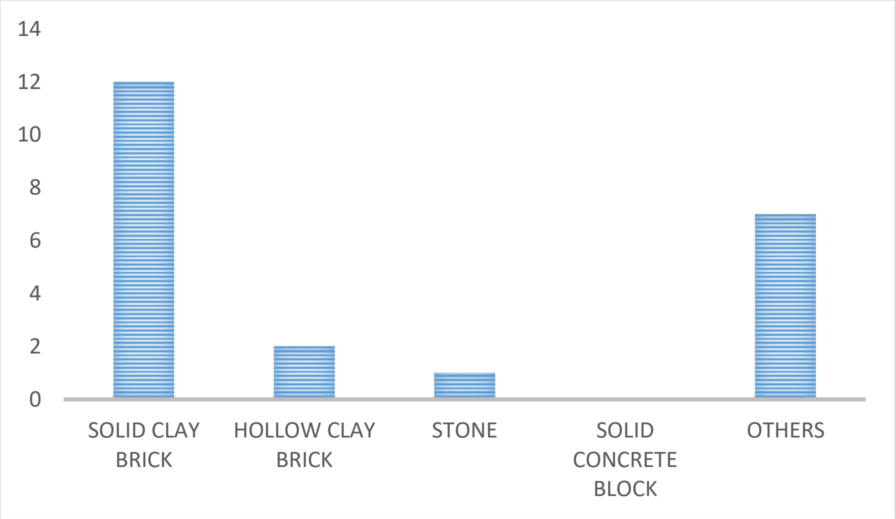

Figure 3.29. Type of Masonry Materials in SC1 Test Data

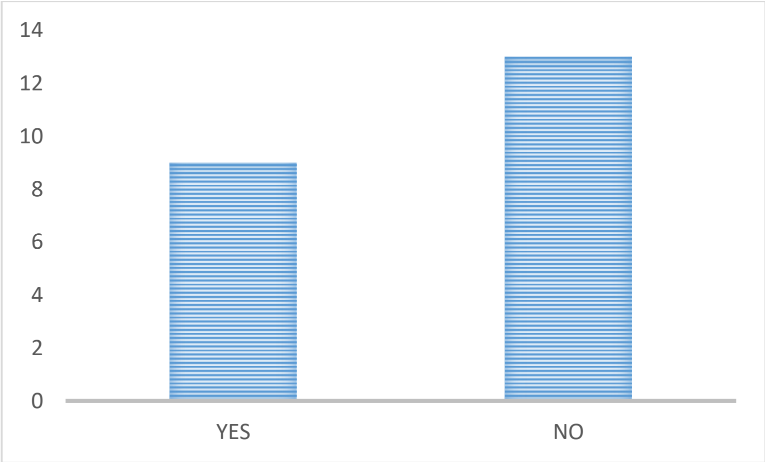

Figure 3.30. Vertical Irregularities in SC1 Test Data

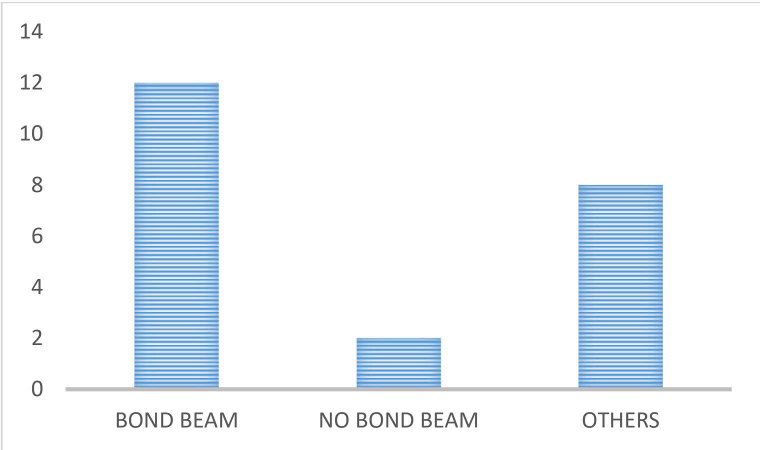

Figure 3.31. Types of Slab Systems in SC1 Test Data

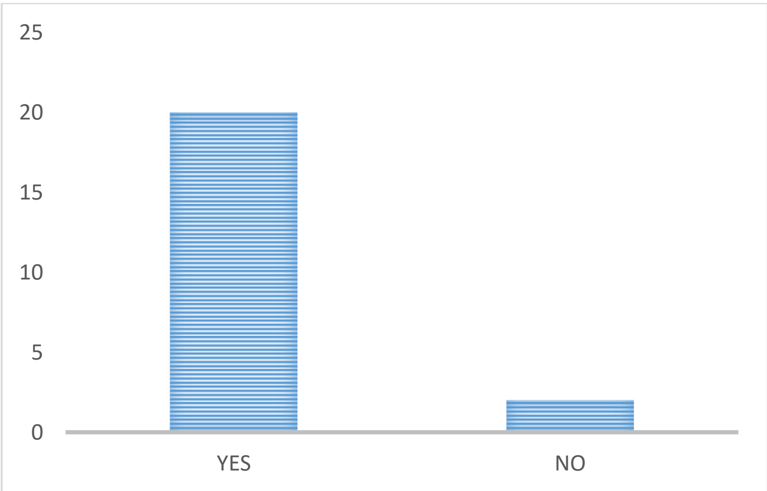

Figure 3.32. Visual Damages in SC1 Test Data

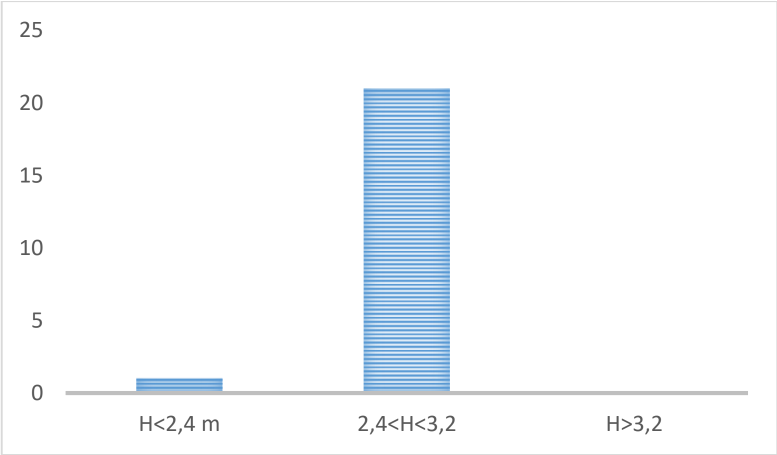

Figure 3.33. Typical Story Heights in SC1 Test Data

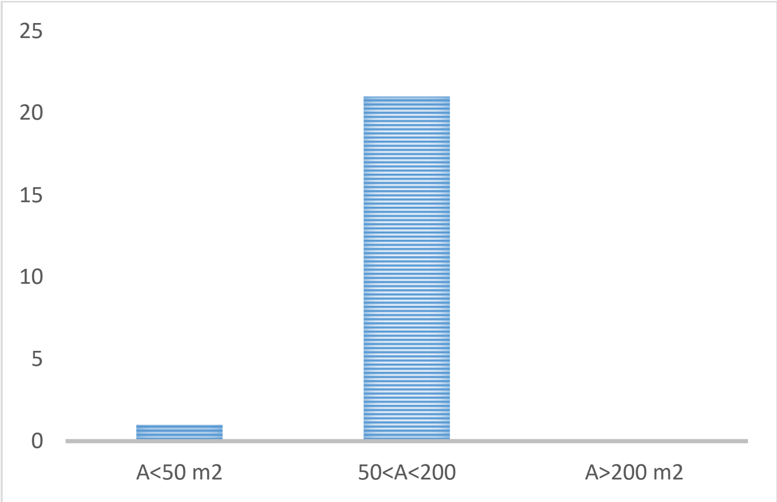

Figure 3.34. Typical Plan Areas in SC1 Test Data

3.4.2. Details on the Test Database for SC2

In SC2, 38 buildings were evaluated for testing the purposed method. 30 of these buildings are "risky" and 8 of them are "non-risky" according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC2 test database are represented in Figures 3.35-3.41.

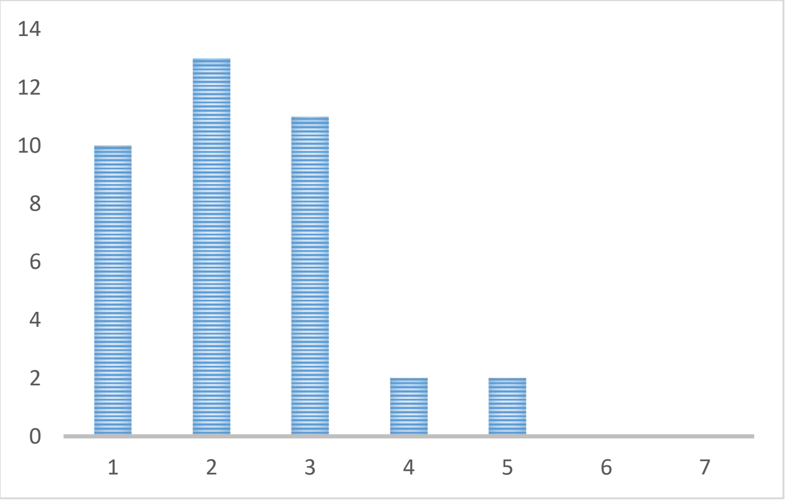

Figure 3.35. Number of Stories in SC2 Test Data

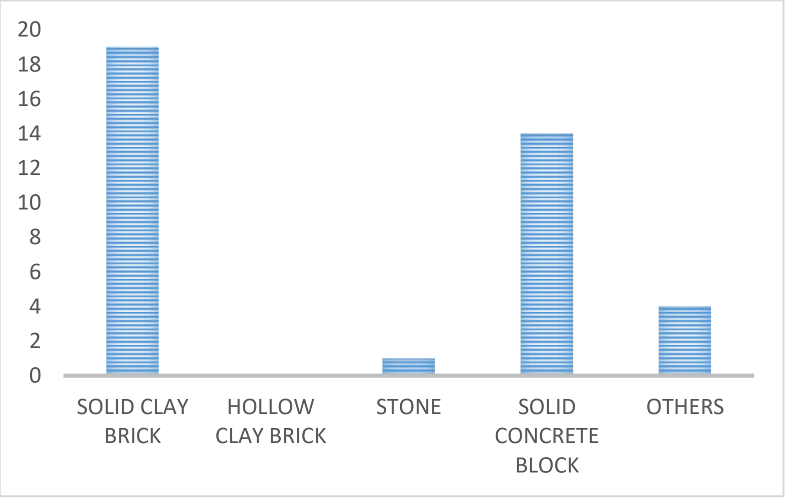

Figure 3.36. Type of Masonry Materials in SC2 Test Data

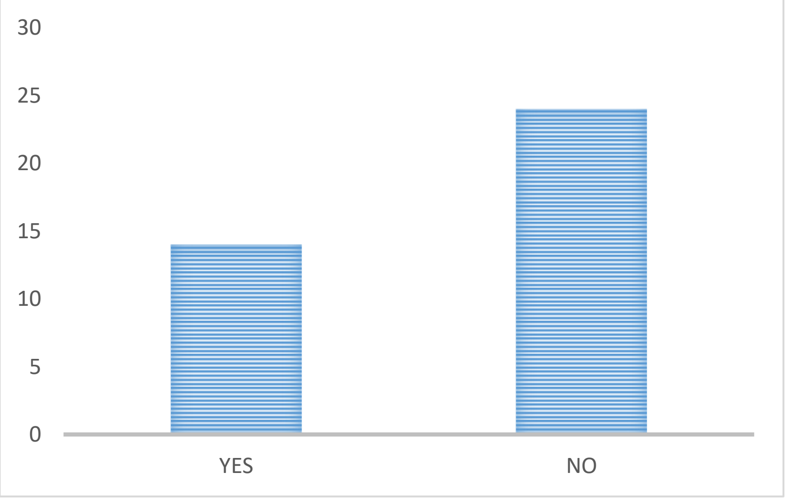

Figure 3.37. Vertical Irregularities in SC2 Test Data

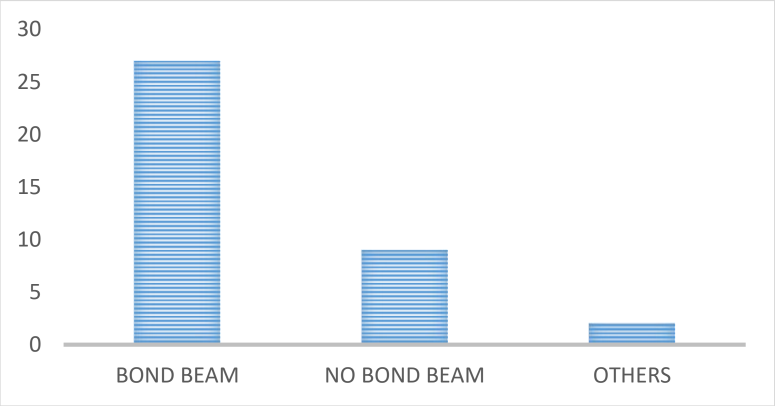

Figure 3.38. Types of Slab Systems in SC2 Test Data

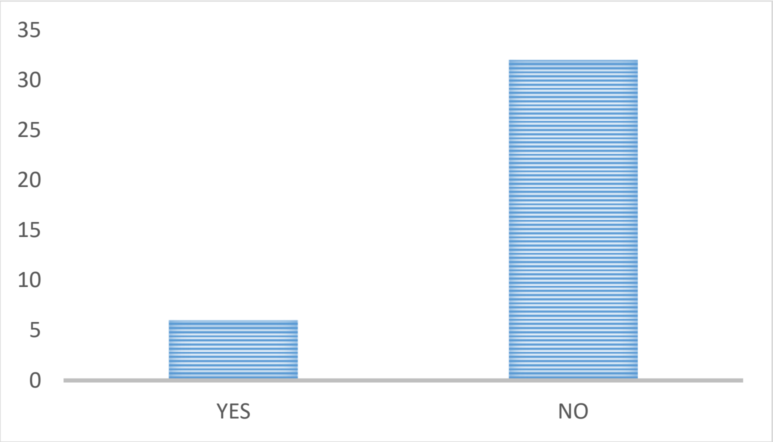

Figure 3.39. Visual Damages in SC2 Test Data

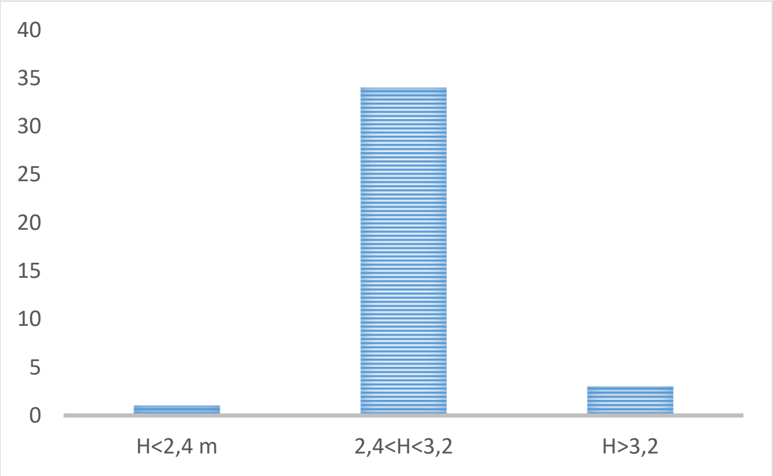

Figure 3.40. Typical Story Heights in SC2 Test Data

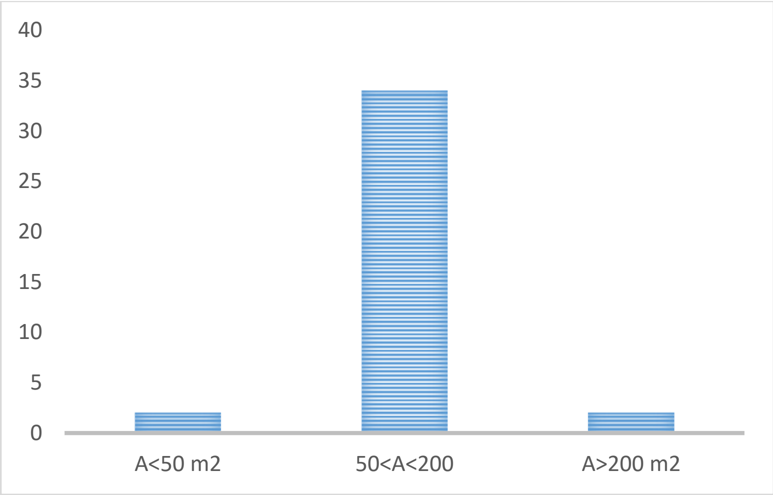

Figure 3.41. Typical Plan Areas in SC2 Test Data

3.4.3. Details on the Test Database for SC3-4

In SC3-4, 40 buildings were evaluated for testing the purposed method. 11 of these buildings are “risky” and 29 of them are “non-risky” according to GABHR 2013. The details about number of stories, type of slab system, type of masonry material, typical story height, typical plan area, vertical irregularities and visual damage in SC3 and 4 test database are represented in Figures 3.42-3.48.

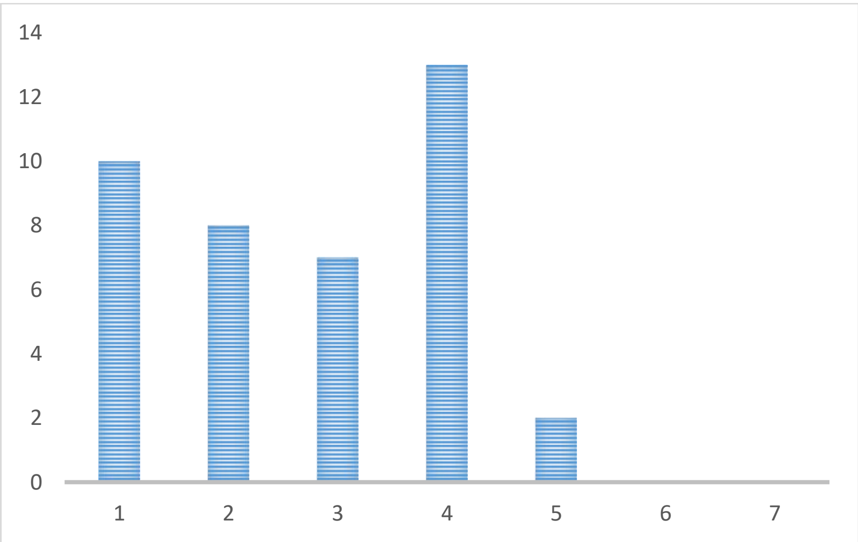

Figure 3.42. Number of Stories in SC3-4 Test Data

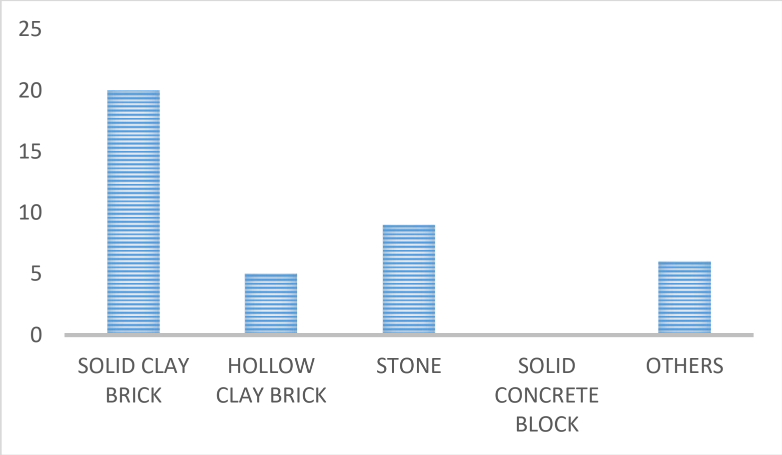

Figure 3.43. Type of Masonry Materials in SC3-4 Test Data

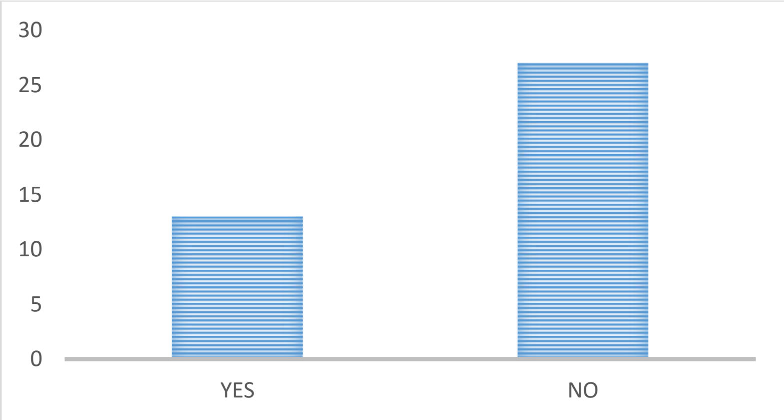

Figure 3.44. Vertical Irregularities in SC3-4 Test Data

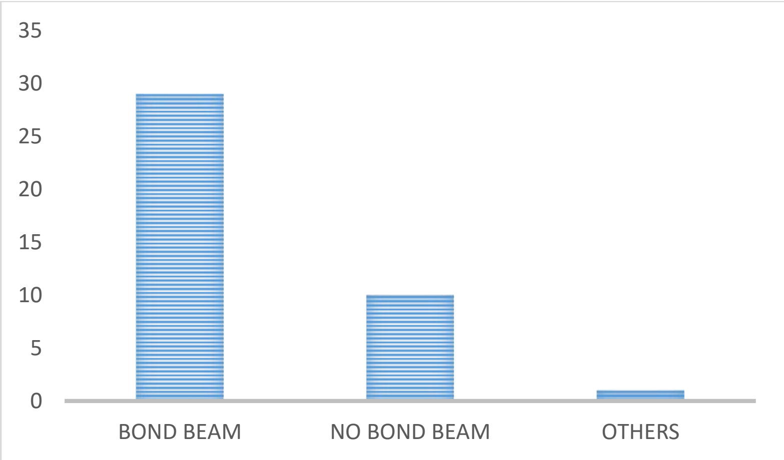

Figure 3.45. Types of Slab Systems in SC3-4 Test Data

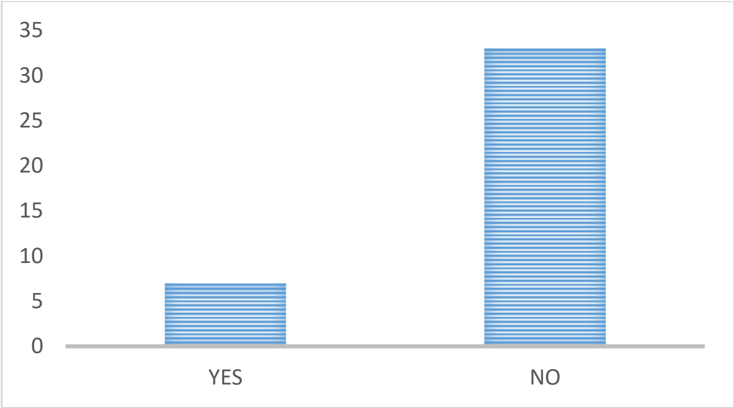

Figure 3.46. Visual Damages in SC3-4 Test Data

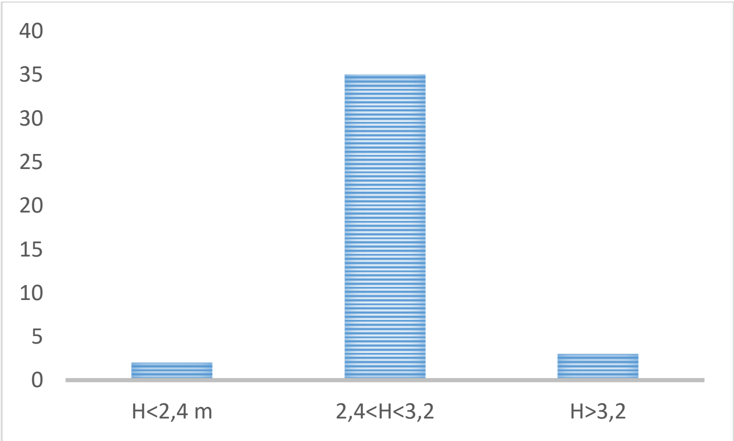

Figure 3.47. Typical Story Heights in SC3-4 Test Data

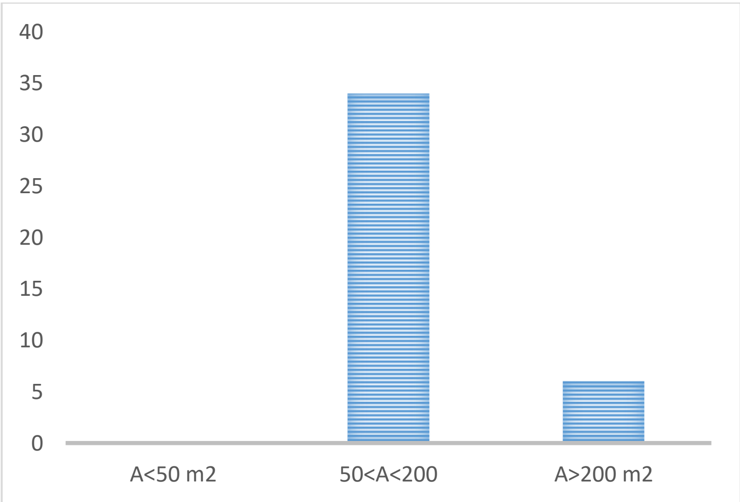

Figure 3.48. Typical Plan Areas in SC3-4 Test Data

Building risk scores (BRS) of URM buildings in the test database were calculated and the state of risk of each building was determined (i.e. BRS≥0 means “non-risky”). BRS scores are plotted in Figure 3.49, with “risky” buildings shown as circles and “non-risky” ones as triangles. Percentage errors in the estimations are shown in Table 3.10. Figure 3.49 shows that the 86% risk state of the total number of test buildings was estimated correctly by the proposed method, and that the method had a good estimation performance for all SCs with a maximum percentage error of less than 30%.

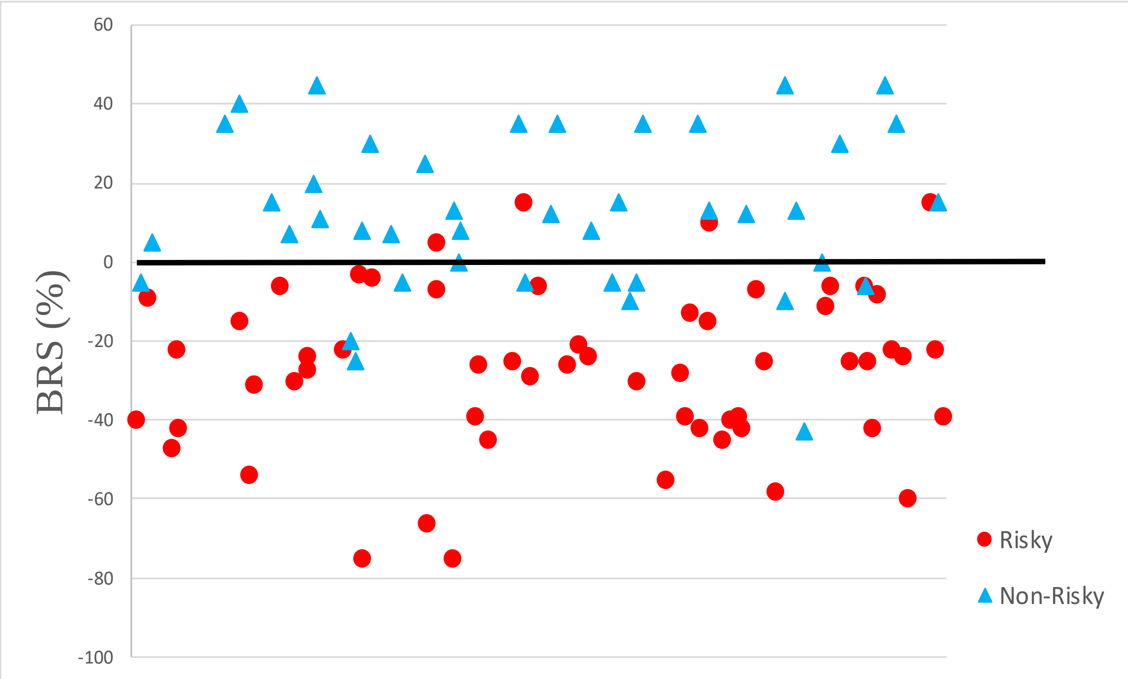

Figure 3.49. Comparison of the Risk State Estimations of the Proposed Method with the Detailed Seismic Assessment Results for the Test Database

Table 3.10. Performance of the Proposed Method to Estimate the State of Risk of URM Buildings in the Test Database

Number of Buildings	Estimations of the Proposed Method (Correct - Incorrect)			Percentage Error (%)		
	SC1	**SC2**	**SC3-4**	**SC1**	**SC2**	**SC3-4**
Risky	16 – 1	30 - 0	8 - 3	5.88	0.00	27.28
Non-risky	4 - 1	7 - 1	21 - 8	20.00	12.50	27.59
Total	20 - 2	37 - 1	29 - 11	9.10	2.63	27.50
Overall	86 - 14			14.00		

3.5. Evaluation of a Sample Building with BRS Method

In this section, a sample building in SC1 will be evaluated according to BRS method (Figure 3.50).

BUILDING RISK SCORE DATA COLLECTION FORM
(For Seismic Class 1)

Adress: Yalı Mahallesi, Egemenlik Caddesi, No:46
Erdek/BALIKESİR

Block: 32
Plot: 83
Layout: 17
Coordinate: 40,397617 ; 27,792495

Review Date: 01/08/2019

Notes:

NUMBER OF STORIES (PS1)

1:	2:	3:	4:	5:	6:	7:
-18	-36	-54	-72	-90	-108	-126

MASONRY MATERIAL (PS2)

Solid Clay Brick:	Hollow Brick:	Stone:	Solid Concrete Block:	Other:
-2	-4	-6	-8	-10

SLAB TYPE (PS3)

Bond Beam:	No Bond Beam:	Other
-1	-2	-3

VISUAL DAMAGE (PS4)

No:	Yes:
0	-20

VERTICAL IRREGULARITY (PS5)

No:	Yes:
0	-15

TYPICAL STORY HEIGHT (m) (PS6)

H≤2,4:	2,4<H<3,2:	H≥3,2m:
0	-15	-30

PLAN AREA (m2) (PS7)

A≤50:	50<A<250:	A≥250:
0	-35	-70

$$BRS = BS + \sum_{i=1}^{7} PS_i$$ (BS=80)

BRS= 80-36-2-2-15-35= **-10**

Figure 3.50. Evaluation of a Sample Building with BRS Method

The properties and analysis results about the building are listed below:

- **Earthquake Zone:** 1
- **Number of Stories:** 2
- **Masonry Wall Material:** Solid clay brick
- **Rc Beam:** No
- **Visual Damage:** No
- **Vertical Irregularity:** No
- **Typical Story Height:** 2,52 m
- **Plan Area of the Building:** 124 m^2
- **Risk Status According to Detailed Seismic Analysis:** Risky
- **Building Risk Score (BRS): -**10 (Risky)

4. CONCLUSION

The seismic risk of an URM building stock could only be determined by using rapid screening methods as detailed seismic assessment methods (FEMA 356, Eurocode 6, TEC 2019, GABHR 2019, etc.) require both too many skilled staff and too much time. However, rapid screening methods should be accurate enough as the result of the rapid screening is generally used to filter buildings with severe seismic vulnerabilities from the large building stock. To this end, a new rapid screening method for URM buildings is proposed in this study.

In this study, an attempt was made to propose a new rapid screening method based on detailed seismic assessment results. To this end, a database of 543 URM buildings located in Turkey was obtained from the Ministry of Environment and Urbanization. For each building in the database, the scores from the detailed seismic assessment analysis were calculated by utilizing the assessment method given by GABHR (2019). In this method, the linear assessment of URM buildings were implemented under the effect of seismic actions. The seismic actions were considered by using response spectrum analysis (i.e. modal analysis Chopra 2012). Then, the shear force demands on each URM wall were compared with the available shear capacities. The URM walls with insufficient shear capacities were classified as collapsed. And, the score of the building was calculated by taking the ratio of the total shear forces carried by the URM walls with insufficient capacities to the total base shear. If the score of the building was over 50%, then the building was deemed to be susceptible to collapse (i.e. risky). In other case, the building was classified as “non-risky”.

The method (BRS) is completely based on the results of detailed seismic assessment of a URM building database. The database was formed in order to represent a wide range of possible URM buildings. The rapid screening is based on penalty scores obtained from a large database of URM buildings with available detailed seismic assessment results (543 buildings). A total of 443 buildings from the database were used to generate penalty scores and 100 buildings were reserved for testing of the proposed method. After investigating the database, number of stories (N), type of slab system (SS), vertical irregularities (VI), visual damage (D), type of masonry material (M), typical story height (H) and typical plan area (A) were determined as the most influential variables on the seismic risk. The database was classified according to different seismic classes, and binary logistic regression analysis was performed separately for each seismic risk category in order to determine the penalty scores for the selected basic estimation variables.

443 buildings were firstly classified according to the level of seismicity based on spectral response acceleration parameter at short periods (SDS). In this study, there were four seismic classes in order to be compatible with TEC2019. Sites with SDS values greater than or equal to 0.75g was the first Seismic Class (SC1), sites with SDS values between 0.50g and 0.75g belonged to the second Seismic Class (SC2), sites with SDS values between 0.25g and 0.50g were classified as the third Seismic Class (SC3) and sites with SDS values less than 0.25g were named as Seismic Class (SC4). Due to insufficient data in SC3 and SC4, these seismic classes were decided to be combined during the statistical model formation. Consequently, the number of buildings in SC1, SC2 and SC3-4 are 172, 133 and 138, respectively. After completing the conversion of the data into a compatible form with the selected statistical method, the database was filtered according to the Seismic Class (SC). Then, each filtered database was separately used to conduct binary logistic regression (SPSS 2006).

The proposed method matched well with the results of the overall database, with an overall percentage error of approximately 5%. Finally, the performance of the proposed method was examined by using another test database composed of 100 URM buildings. Comparing the estimated states of risk determined by the proposed method with detailed seismic assessment results yielded an overall percentage error of 14%, proving that the proposed rapid screening method can result in accurate enough estimations to filter large building stocks composed of URM buildings.

If we compare BRS method with Simplified Method in Appendix of GABHR 2019 (SM) which has explained in detail in Section 2.3.1.; BRS method predicts the risk status of the building, while SM does not and if we look at the parameters considered by SM, it is obvious that the evaluation of any building will take quite a long time whereas a building can be evaluated within 2-3 minutes by BRS method.

Since GABHR2019 has just been released at the time when this study finished, the database used in this method is only based on the results of seismic analysis done according to GABHR2013. It is possible to develop this purposed method by investigating a large database containing the results of seismic analysis made according to GABHR2019.

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APPENDICES

APPENDIX A – Data Collection Forms for the Proposed RVS Method

BRS

BUILDING RISK SCORE DATA COLLECTION FORM
(For Seismic Class 1)

PHOTO OF THE BUILDING	**Adress:**
	Block: **Plot:** **Layout:** **Coordinate:**
	Review Date:
	Notes:

NUMBER OF STORIES (PS1)

1:	2:	3:	4:	5:	6:	7:
-18	-36	-54	-72	-90	-108	-126

MASONRY MATERIAL (PS2)

Solid Clay Brick:	Hollow Brick:	Stone:	Solid Concrete Block:	Other:
-2	-4	-6	-8	-10

SLAB TYPE (PS3)

Bond Beam:	No Bond Beam:	Other
-1	-2	-3

VISUAL DAMAGE (PS4)

No:	Yes:
0	-20

VERTICAL IRREGULARITY (PS5)

No:	Yes:
0	-15

TYPICAL STORY HEIGHT (m) (PS6)

H≤2,4:	2,4<H<3,2:	H≥3,2m:
0	-15	-30

PLAN AREA (m2) (PS7)

A≤50:	50<A<250:	A≥250:
0	-35	-70

$$BRS = BS + \sum_{i=1}^{7} PS_i \quad (BS=80)$$

BRS=

Figure A.1. Building Risk Score Data Collection Form for Seismic Class 1

BUILDING RISK SCORE DATA COLLECTION FORM
(For Seismic Class 2)

PHOTO OF THE BUILDING	**Adress:**
	Block: **Plot:** **Layout:** **Coordinate:**
	Review Date:
	Notes:

NUMBER OF STORIES (PS1)

1:	**2:**	**3:**	**4:**	**5:**	**6:**	**7:**
-9	-36	-54	-72	-90	-108	-126

MASONRY MATERIAL (PS2)

Solid Clay Brick:	**Hollow Brick:**	**Stone:**	**Solid Concrete Block:**	**Other:**
-1	-2	-3	-4	-5

SLAB TYPE (PS3)

Bond Beam:	**No Bond Beam:**	**Other**
-1	-2	-3

VISUAL DAMAGE (PS4)

No:	**Yes:**
0	-15

VERTICAL IRREGULARITY (PS5)

No:	**Yes:**
0	-15

TYPICAL STORY HEIGHT (m) (PS6)

H≤2,4:	**2,4<H<3,2:**	**H≥3,2m:**
0	-2	-4

PLAN AREA (m2) (PS7)

A≤50:	**50<A<250:**	**A≥250:**
0	-1	-2

$$BRS = BS + \sum_{i=1}^{7} PS_i$$ (BS=35)

BRS=

Figure A.2. Building Risk Score Data Collection Form for Seismic Class 2

BUILDING RISK SCORE DATA COLLECTION FORM
(For Seismic Class 3)

PHOTO OF THE BUILDING	**Adress:**
	Block: **Plot:** **Layout:** **Coordinate:**
	Review Date:
	Notes:

NUMBER OF STORIES (PS1)

1:	**2:**	**3:**	**4:**	**5:**	**6:**	**7:**
-15	-30	-45	-60	-75	-90	-105

MASONRY MATERIAL (PS2)

Solid Clay Brick:	**Hollow Brick:**	**Stone:**	**Solid Concrete Block:**	**Other:**
0	0	0	0	0

SLAB TYPE (PS3)

Bond Beam:	**No Bond Beam:**	**Other**
-1	-2	-3

VISUAL DAMAGE (PS4)

No:	**Yes:**
+20	-20

VERTICAL IRREGULARITY (PS5)

No:	**Yes:**
+10	-10

TYPICAL STORY HEIGHT (m) (PS6)

H≤2,4:	**2,4<H<3,2:**	**H≥3,2m:**
+5	0	-5

PLAN AREA (m2) (PS7)

A≤50:	**50<A<250:**	**A≥250:**
+10	+5	0

$$BRS = BS + \sum_{i=1}^{7} PS_i$$ (BS=25)

BRS=

Figure A.3. Building Risk Score Data Collection Form for Seismic Class 3

BUILDING RISK SCORE DATA COLLECTION FORM
(For Seismic Class 4)

PHOTO OF THE BUILDING	**Adress:**
	Block: **Plot:** **Layout:** **Coordinate:**
	Review Date:
	Notes:

NUMBER OF STORIES (PS1)

1:	2:	3:	4:	5:	6:	7:
-15	-30	-45	-60	-75	-90	-105

MASONRY MATERIAL (PS2)

Solid Clay Brick:	Hollow Brick:	Stone:	Solid Concrete Block:	Other:
0	0	0	0	0

SLAB TYPE (PS3)

Bond Beam:	No Bond Beam:	Other
-1	-2	-3

VISUAL DAMAGE (PS4)

No:	Yes:
+20	-20

VERTICAL IRREGULARITY (PS5)

No:	Yes:
+10	-10

TYPICAL STORY HEIGHT (m) (PS6)

H≤2,4:	2,4<H<3,2:	H≥3,2m:
+5	0	-5

PLAN AREA (m2) (PS7)

A≤50:	50<A<250:	A≥250:
+10	+5	0

$$BRS = BS + \sum_{i=1}^{7} PS_i \qquad (BS=35)$$

BRS=

Figure A.4. Building Risk Score Data Collection Form for Seismic Class 4

APPENDIX B – Building Database used to generate the proposed RVS Method

Table B.1. Selected Database of the Proposed Method

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
1	1	7	3	0	0	4	1	1	Risky	-101	Risky	1
2	1	7	1	0	0	5	1	2	Risky	-140	Risky	1
3	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
4	1	6	3	0	0	4	1	1	Risky	-83	Risky	1
5	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
6	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
7	1	1	3	0	0	2	1	0	Non-Risky	46	Non-Risky	1
8	1	6	1	1	0	5	1	1	Risky	-102	Risky	1
9	1	1	3	0	0	5	1	0	Non-Risky	40	Non-Risky	1
10	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
11	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
12	1	1	1	0	0	2	1	1	Non-Risky	9	Non-Risky	1
13	1	6	1	1	0	2	1	1	Risky	-96	Risky	1
14	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
15	1	6	3	1	0	5	1	1	Risky	-100	Risky	1
16	1	1	1	0	0	5	1	1	Non-Risky	3	Non-Risky	1
17	1	6	3	0	0	2	1	1	Risky	-79	Risky	1
18	1	2	1	1	0	5	0	0	Non-Risky	20	Non-Risky	1
19	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
20	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
21	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
22	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
23	1	1	1	0	0	2	1	1	Non-Risky	9	Non-Risky	1
24	1	6	3	1	0	1	1	0	Risky	-57	Risky	1
25	1	1	1	0	0	5	1	0	Non-Risky	38	Non-Risky	1
26	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
27	1	6	3	0	0	1	1	1	Risky	-77	Risky	1
28	1	1	1	0	0	2	1	1	Non-Risky	9	Non-Risky	1
29	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
30	1	1	3	0	0	4	1	1	Non-Risky	7	Non-Risky	1
31	1	1	3	0	0	5	1	1	Non-Risky	5	Non-Risky	1
32	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
33	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
34	1	1	1	0	0	2	1	1	Non-Risky	9	Non-Risky	1
35	1	1	1	0	0	2	1	1	Non-Risky	9	Non-Risky	1
36	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
37	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
38	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
39	1	1	3	0	0	2	1	0	Non-Risky	46	Non-Risky	1
40	1	6	1	1	0	1	1	1	Risky	-94	Risky	1
41	1	6	1	1	0	1	1	1	Risky	-94	Risky	1
42	1	1	3	0	0	2	1	1	Non-Risky	11	Non-Risky	1
43	1	7	1	0	0	1	1	1	Risky	-97	Risky	1
44	1	6	3	1	0	1	1	1	Risky	-92	Risky	1
45	1	1	1	0	0	5	1	1	Non-Risky	3	Non-Risky	1
46	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
47	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
48	1	1	1	0	0	1	1	0	Non-Risky	46	Non-Risky	1
49	1	1	3	0	0	2	1	1	Non-Risky	11	Non-Risky	1
50	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
51	1	7	3	1	0	1	1	1	Risky	-110	Risky	1
52	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
53	1	1	3	0	0	5	1	1	Non-Risky	5	Non-Risky	1
54	1	1	3	0	0	5	1	1	Non-Risky	5	Non-Risky	1
55	1	1	3	0	0	2	1	0	Non-Risky	46	Non-Risky	1
56	1	6	1	1	0	1	1	1	Risky	-94	Risky	1
57	1	1	1	0	0	1	1	1	Non-Risky	11	Non-Risky	1
58	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
59	1	1	3	0	0	1	0	1	Non-Risky	28	Non-Risky	1
60	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
61	1	1	3	0	0	1	0	1	Non-Risky	28	Non-Risky	1
62	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
63	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
64	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
65	1	6	1	0	0	1	1	1	Risky	-79	Risky	1
66	1	1	3	0	0	5	1	1	Non-Risky	5	Non-Risky	1
67	1	6	2	1	1	1	1	1	Risky	-113	Risky	1
68	1	4	3	0	0	5	1	1	Risky	-49	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
69	1	4	3	0	0	1	1	1	Risky	-41	Risky	1
70	1	7	3	0	0	1	2	2	Risky	-145	Risky	1
71	1	5	1	0	0	5	1	1	Risky	-69	Risky	1
72	1	5	2	0	0	1	1	1	Risky	-60	Risky	1
73	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
74	1	5	2	0	1	1	1	1	Risky	-80	Risky	1
75	1	4	2	1	1	2	1	1	Risky	-79	Risky	1
76	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
77	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
78	1	4	2	1	1	1	1	1	Risky	-77	Risky	1
79	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
80	1	5	1	0	0	4	1	1	Risky	-67	Risky	1
81	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
82	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
83	1	5	1	1	0	2	1	1	Risky	-78	Risky	1
84	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
85	1	4	1	1	0	5	1	1	Risky	-66	Risky	1
86	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
87	1	4	2	1	0	1	1	1	Risky	-57	Risky	1
88	1	4	1	0	1	1	1	1	Risky	-63	Risky	1
89	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
90	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
91	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
92	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
93	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
94	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
95	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
96	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
97	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
98	1	4	1	1	0	5	1	1	Risky	-66	Risky	1
99	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
100	1	4	1	0	1	1	1	1	Risky	-63	Risky	1
101	1	4	1	0	0	5	2	1	Risky	-66	Risky	1
102	1	4	2	1	0	1	1	1	Risky	-57	Risky	1
103	1	4	1	0	1	2	1	1	Risky	-65	Risky	1
104	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
105	1	4	1	1	0	1	1	1	Risky	-58	Risky	1
106	1	4	1	1	0	1	0	1	Risky	-43	Risky	1
107	1	4	1	0	1	1	1	1	Risky	-63	Risky	1
108	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
109	1	3	2	0	0	1	1	1	Risky	-24	Risky	1
110	1	3	1	0	1	1	1	1	Risky	-45	Risky	1
111	1	3	1	1	1	2	1	1	Risky	-62	Risky	1
112	1	3	1	0	1	1	1	1	Risky	-45	Risky	1
113	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
114	1	4	2	0	0	1	1	1	Risky	-42	Risky	1
115	1	4	1	0	0	5	1	1	Risky	-51	Risky	1
116	1	4	2	0	0	1	1	1	Risky	-42	Risky	1
117	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
118	1	4	2	1	0	1	1	1	Risky	-57	Risky	1
119	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
120	1	4	1	0	0	5	1	1	Risky	-51	Risky	1
121	1	4	1	0	0	1	1	1	Risky	-43	Risky	1
122	1	3	1	0	1	1	1	1	Risky	-45	Risky	1
123	1	3	2	0	1	2	1	1	Risky	-46	Risky	1
124	1	4	1	1	0	5	1	1	Risky	-66	Risky	1
125	1	3	1	1	0	1	1	1	Risky	-40	Risky	1
126	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
127	1	3	2	0	0	1	1	1	Risky	-24	Risky	1
128	1	3	1	1	1	5	1	1	Risky	-68	Risky	1
129	1	3	1	0	0	5	1	1	Risky	-33	Risky	1
130	1	2	2	0	0	1	1	1	Risky	-6	Risky	1
131	1	2	3	0	0	5	1	1	Risky	-13	Risky	1
132	1	2	1	1	0	1	1	1	Risky	-22	Risky	1
133	1	2	1	0	0	1	1	1	Risky	-7	Risky	1
134	1	2	1	0	0	2	1	1	Risky	-9	Risky	1
135	1	2	1	0	0	2	1	1	Risky	-9	Risky	1
136	1	2	1	0	0	1	1	1	Risky	-7	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
137	1	2	2	0	0	1	1	1	Risky	-6	Risky	1
138	1	3	1	1	0	1	1	1	Risky	-40	Risky	1
139	1	2	2	1	1	1	1	1	Risky	-41	Risky	1
140	1	2	1	1	0	5	1	1	Risky	-30	Risky	1
141	1	2	2	0	0	1	2	1	Risky	-21	Risky	1
142	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
143	1	2	1	1	1	1	1	1	Risky	-42	Risky	1
144	1	3	1	0	0	2	1	1	Risky	-27	Risky	1
145	1	3	1	1	0	2	1	1	Risky	-42	Risky	1
146	1	3	2	0	0	1	1	1	Risky	-24	Risky	1
147	1	1	1	0	0	2	1	1	Risky	9	Non-Risky	0
148	1	3	1	0	0	1	0	1	Risky	-10	Risky	1
149	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
150	1	1	2	0	0	1	1	1	Risky	12	Non-Risky	0
151	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
152	1	1	2	0	1	2	1	1	Risky	-10	Risky	1
153	1	1	2	0	1	1	1	1	Risky	-8	Risky	1
154	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
155	1	3	1	1	1	3	1	1	Risky	-64	Risky	1
156	1	5	1	1	0	1	1	1	Risky	-76	Risky	1
157	1	1	1	0	0	2	1	1	Risky	9	Non-Risky	0
158	1	2	1	0	1	3	1	1	Risky	-31	Risky	1
159	1	3	2	0	0	1	1	1	Risky	-24	Risky	1
160	1	5	1	0	0	1	1	1	Risky	-61	Risky	1
161	1	1	3	0	0	5	1	1	Risky	5	Non-Risky	0
162	1	2	1	0	0	1	1	1	Risky	-7	Risky	1
163	1	3	1	0	0	3	1	1	Risky	-29	Risky	1
164	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
165	1	2	1	0	0	2	1	1	Risky	-9	Risky	1
166	1	1	1	0	0	2	1	1	Risky	9	Non-Risky	0
167	1	3	1	0	1	5	1	1	Risky	-53	Risky	1
168	1	2	1	0	1	2	1	1	Risky	-29	Risky	1
169	1	2	1	1	0	1	1	1	Risky	-22	Risky	1
170	1	1	2	0	1	2	1	1	Risky	-10	Risky	1
171	1	2	1	1	1	1	1	1	Risky	-42	Risky	1
172	1	1	1	1	0	1	1	1	Risky	-4	Risky	1
173	2	7	3	1	0	1	1	1	Risky	-113	Risky	1
174	2	7	3	0	0	1	1	1	Risky	-98	Risky	1
175	2	1	3	0	0	1	1	1	Non-Risky	19	Non-Risky	1
176	2	1	3	0	0	1	1	1	Non-Risky	19	Non-Risky	1
177	2	7	3	0	0	1	1	1	Risky	-98	Risky	1
178	2	1	1	0	0	2	0	0	Non-Risky	23	Non-Risky	1
179	2	1	1	0	0	2	1	1	Non-Risky	20	Non-Risky	1
180	2	1	1	0	0	5	1	1	Non-Risky	17	Non-Risky	1
181	2	1	3	0	0	1	1	1	Non-Risky	20	Non-Risky	1
182	2	1	1	0	0	3	0	1	Non-Risky	21	Non-Risky	1
183	2	1	1	0	0	2	1	1	Non-Risky	20	Non-Risky	1
184	2	1	3	0	0	1	1	1	Non-Risky	19	Non-Risky	1
185	2	1	3	0	0	2	0	1	Non-Risky	20	Non-Risky	1
186	2	1	1	0	0	2	1	1	Non-Risky	20	Non-Risky	1
187	2	1	1	0	0	3	1	1	Non-Risky	19	Non-Risky	1
188	2	1	3	0	0	3	1	1	Non-Risky	17	Non-Risky	1
189	2	1	3	0	0	2	1	1	Non-Risky	18	Non-Risky	1
190	2	1	3	0	0	2	1	1	Non-Risky	18	Non-Risky	1
191	2	1	3	0	0	3	0	1	Non-Risky	19	Non-Risky	1
192	2	1	1	0	0	4	1	1	Non-Risky	18	Non-Risky	1
193	2	2	1	1	0	1	0	1	Non-Risky	-19	Risky	0
194	2	1	3	0	0	2	1	1	Non-Risky	18	Non-Risky	1
195	2	6	3	1	0	5	1	1	Risky	-99	Risky	1
196	2	6	3	1	0	5	1	1	Risky	-99	Risky	1
197	2	6	3	0	0	5	1	1	Risky	-84	Risky	1
198	2	6	1	0	0	5	1	1	Risky	-82	Risky	1
199	2	6	3	0	0	1	1	1	Risky	-80	Risky	1
200	2	6	1	1	0	1	1	1	Risky	-93	Risky	1
201	2	1	3	1	0	1	1	1	Non-Risky	4	Non-Risky	1
202	2	6	1	1	0	5	1	1	Risky	-97	Risky	1
203	2	1	3	0	0	1	1	1	Non-Risky	19	Non-Risky	1
204	2	6	1	0	0	1	1	2	Risky	-79	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
205	2	6	3	0	0	1	1	1	Risky	-80	Risky	1
206	2	6	1	1	0	1	1	1	Risky	-93	Risky	1
207	2	2	1	1	0	5	1	1	Non-Risky	-25	Risky	0
208	2	6	1	1	0	1	1	1	Risky	-93	Risky	1
209	2	1	3	0	0	2	1	1	Non-Risky	18	Non-Risky	1
210	2	6	3	0	0	1	1	1	Risky	-80	Risky	1
211	2	4	1	1	0	2	1	1	Risky	-58	Risky	1
212	2	4	1	1	0	2	1	1	Risky	-58	Risky	1
213	2	4	1	0	0	1	0	1	Risky	-40	Risky	1
214	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
215	2	6	3	1	0	1	1	1	Risky	-95	Risky	1
216	2	4	3	1	0	5	1	1	Risky	-63	Risky	1
217	2	4	1	0	0	5	1	1	Risky	-46	Risky	1
218	2	4	1	0	0	5	1	1	Risky	-46	Risky	1
219	2	1	3	0	0	2	1	1	Non-Risky	18	Non-Risky	1
220	2	1	3	0	0	5	1	1	Non-Risky	20	Non-Risky	1
221	2	4	1	0	0	5	1	1	Risky	-46	Risky	1
222	2	7	1	1	0	1	1	1	Risky	-111	Risky	1
223	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
224	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
225	2	4	3	0	0	1	1	1	Risky	-44	Risky	1
226	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
227	2	4	3	0	0	1	1	1	Risky	-44	Risky	1
228	2	7	1	0	0	5	1	2	Risky	-101	Risky	1
229	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
230	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
231	2	5	1	0	0	1	0	1	Risky	-58	Risky	1
232	2	2	1	0	0	4	1	1	Risky	-9	Risky	1
233	2	2	3	1	0	1	1	1	Risky	-23	Risky	1
234	2	2	3	1	0	2	1	1	Risky	-24	Risky	1
235	2	2	1	1	0	2	1	1	Risky	-22	Risky	1
236	2	2	3	0	0	1	0	1	Risky	-6	Risky	1
237	2	2	3	1	0	5	1	1	Risky	-27	Risky	1
238	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
239	2	3	1	1	0	2	1	1	Risky	-40	Risky	1
240	2	3	1	1	0	5	1	1	Risky	-43	Risky	1
241	2	3	1	1	0	2	1	1	Risky	-40	Risky	1
242	2	2	1	0	0	1	1	0	Risky	-5	Risky	1
243	2	2	1	0	0	1	1	1	Risky	-6	Risky	1
244	2	2	1	1	0	5	1	1	Risky	-25	Risky	1
245	2	2	1	1	0	2	1	1	Risky	-22	Risky	1
246	2	2	1	1	0	2	1	1	Risky	-22	Risky	1
247	2	5	3	0	0	1	1	1	Risky	-62	Risky	1
248	2	5	1	0	0	5	1	1	Risky	-64	Risky	1
249	2	5	3	0	0	1	1	1	Risky	-62	Risky	1
250	2	5	3	0	0	1	1	1	Risky	-62	Risky	1
251	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
252	2	3	3	1	0	1	1	1	Risky	-41	Risky	1
253	2	3	1	1	0	1	0	1	Risky	-37	Risky	1
254	2	1	1	0	0	4	1	1	Non-Risky	18	Non-Risky	1
255	2	3	1	0	0	1	1	1	Risky	-24	Risky	1
256	2	2	3	0	0	2	1	1	Risky	-9	Risky	1
257	2	2	1	1	1	2	1	1	Risky	-37	Risky	1
258	2	3	3	1	0	1	1	1	Risky	-41	Risky	1
259	2	3	1	1	0	2	1	1	Risky	-40	Risky	1
260	2	2	3	1	0	2	1	1	Risky	-24	Risky	1
261	2	2	3	0	0	2	1	1	Risky	-9	Risky	1
262	2	2	1	0	1	1	1	1	Risky	-21	Risky	1
263	2	2	1	0	1	1	1	1	Risky	-21	Risky	1
264	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
265	2	2	3	1	0	5	1	1	Risky	-27	Risky	1
266	2	4	3	0	1	1	1	1	Risky	-59	Risky	1
267	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
268	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
269	2	4	2	0	0	5	1	1	Risky	-47	Risky	1
270	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
271	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
272	2	4	3	0	0	5	1	1	Risky	-48	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
273	2	4	1	0	0	1	1	1	Risky	-42	Risky	1
274	2	2	1	1	0	1	0	1	Risky	-19	Risky	1
275	2	4	3	0	0	5	1	1	Risky	-48	Risky	1
276	2	2	1	1	0	2	1	1	Risky	-22	Risky	1
277	2	2	1	1	0	2	1	1	Risky	-22	Risky	1
278	2	7	1	0	1	1	1	1	Risky	-111	Risky	1
279	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
280	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
281	2	5	1	0	1	1	1	1	Risky	-75	Risky	1
282	2	5	1	1	0	4	1	1	Risky	-78	Risky	1
283	2	5	1	1	0	1	1	1	Risky	-75	Risky	1
284	2	5	1	1	0	1	1	1	Risky	-75	Risky	1
285	2	5	1	1	1	1	1	1	Risky	-90	Risky	1
286	2	5	1	0	1	1	1	1	Risky	-75	Risky	1
287	2	5	1	0	0	1	1	1	Risky	-60	Risky	1
288	2	5	1	1	0	1	1	1	Risky	-75	Risky	1
289	2	3	1	1	0	3	1	1	Risky	-41	Risky	1
290	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
291	2	3	2	1	0	2	1	1	Risky	-41	Risky	1
292	2	3	1	0	0	5	1	1	Risky	-28	Risky	1
293	2	3	2	1	0	2	1	1	Risky	-41	Risky	1
294	2	3	1	0	0	1	1	1	Risky	-24	Risky	1
295	2	3	1	0	0	2	1	1	Risky	-25	Risky	1
296	2	3	1	0	0	1	1	1	Risky	-24	Risky	1
297	2	3	1	1	0	2	0	1	Risky	-38	Risky	1
298	2	3	1	1	0	5	1	1	Risky	-43	Risky	1
299	2	3	2	1	0	1	0	1	Risky	-38	Risky	1
300	2	3	1	0	0	5	0	1	Risky	-26	Risky	1
301	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
302	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
303	2	3	1	1	0	2	0	1	Risky	-38	Risky	1
304	2	3	2	0	0	1	1	1	Risky	-25	Risky	1
305	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
306	3	5	1	0	0	5	1	1	Risky	-15	Risky	1
307	3	5	1	0	0	2	1	1	Risky	-15	Risky	1
308	3	6	1	0	0	1	1	1	Risky	-30	Risky	1
309	3	5	1	1	0	5	1	1	Risky	-35	Risky	1
310	3	5	1	1	0	1	1	1	Risky	-35	Risky	1
311	3	5	1	0	0	1	1	1	Risky	-15	Risky	1
312	3	5	1	0	0	5	2	1	Risky	-20	Risky	1
313	3	5	3	0	0	1	1	1	Risky	-15	Risky	1
314	3	3	3	0	0	2	1	1	Risky	15	Non-Risky	0
315	3	5	3	1	0	5	1	1	Risky	-35	Risky	1
316	3	3	3	1	0	1	1	1	Risky	-5	Risky	1
317	3	3	1	1	0	5	1	1	Risky	-5	Risky	1
318	3	5	1	1	0	2	1	1	Risky	-35	Risky	1
319	3	3	3	0	0	1	1	1	Non-Risky	15	Non-Risky	1
320	3	5	1	0	0	5	1	1	Risky	-15	Risky	1
321	3	1	1	0	0	5	1	1	Non-Risky	45	Non-Risky	1
322	3	5	1	1	0	5	1	1	Risky	-35	Risky	1
323	3	5	1	0	0	5	1	1	Risky	-15	Risky	1
324	3	4	1	1	0	3	1	1	Risky	-20	Risky	1
325	3	4	1	1	0	5	1	1	Risky	-20	Risky	1
326	3	4	1	0	0	1	1	1	Risky	0	Risky	1
327	3	4	3	1	0	2	1	1	Risky	-20	Risky	1
328	3	4	1	1	0	2	1	1	Risky	-20	Risky	1
329	3	5	3	1	0	1	1	1	Risky	-35	Risky	1
330	3	4	1	0	0	5	1	1	Risky	0	Risky	1
331	3	4	3	0	0	1	1	1	Risky	0	Risky	1
332	3	4	1	0	0	2	1	1	Risky	0	Risky	1
333	3	5	1	1	0	5	1	1	Risky	-35	Risky	1
334	3	4	1	0	0	5	1	1	Risky	0	Risky	1
335	3	4	1	0	0	2	1	1	Risky	0	Risky	1
336	3	5	1	0	0	2	1	1	Risky	-15	Risky	1
337	3	5	3	0	0	5	1	1	Risky	-15	Risky	1
338	3	4	1	1	0	1	1	1	Risky	-20	Risky	1
339	3	4	1	0	0	2	1	1	Risky	0	Risky	1
340	3	4	1	1	0	4	2	1	Risky	-25	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
341	3	4	1	1	0	4	1	1	Risky	-20	Risky	1
342	3	4	3	0	0	5	1	1	Risky	0	Risky	1
343	3	4	1	1	0	1	1	1	Risky	-20	Risky	1
344	3	4	1	0	0	5	2	1	Risky	-5	Risky	1
345	3	4	1	0	1	1	1	1	Risky	-40	Risky	1
346	3	4	1	0	1	2	1	1	Risky	-40	Risky	1
347	3	4	1	1	1	2	1	1	Risky	-60	Risky	1
348	3	4	1	0	0	2	1	1	Risky	0	Risky	1
349	4	7	1	1	0	1	1	1	Risky	-55	Risky	1
350	4	5	1	0	0	1	1	1	Non-Risky	-5	Risky	0
351	4	2	1	0	0	1	1	1	Non-Risky	40	Non-Risky	1
352	4	6	1	1	0	2	1	1	Risky	-40	Risky	1
353	4	4	3	0	0	1	1	1	Non-Risky	10	Non-Risky	1
354	4	5	1	0	0	1	1	2	Non-Risky	-10	Risky	0
355	4	4	3	1	0	1	1	1	Non-Risky	-10	Risky	0
356	4	7	1	1	0	5	1	1	Risky	-55	Risky	1
357	4	3	1	1	0	5	1	1	Non-Risky	5	Non-Risky	1
358	4	6	1	0	0	1	1	1	Risky	-20	Risky	1
359	4	5	1	0	0	5	1	1	Non-Risky	-5	Risky	0
360	4	2	1	1	0	1	1	1	Non-Risky	20	Non-Risky	1
361	4	1	1	0	0	2	1	1	Non-Risky	55	Non-Risky	1
362	4	4	1	0	0	1	1	1	Non-Risky	10	Non-Risky	1
363	4	3	1	0	0	2	1	1	Non-Risky	25	Non-Risky	1
364	4	3	1	0	0	2	1	1	Non-Risky	25	Non-Risky	1
365	4	2	3	1	0	2	1	1	Non-Risky	20	Non-Risky	1
366	4	3	1	0	0	2	1	1	Non-Risky	25	Non-Risky	1
367	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
368	4	4	1	1	0	1	2	1	Non-Risky	-15	Risky	0
369	4	5	1	0	0	1	1	1	Non-Risky	-5	Risky	0
370	4	6	3	0	0	5	1	1	Risky	-20	Risky	1
371	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
372	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
373	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
374	4	6	1	0	0	1	1	1	Risky	-20	Risky	1
375	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
376	4	4	1	0	0	5	1	1	Non-Risky	10	Non-Risky	1
377	4	6	1	1	0	1	1	2	Risky	-45	Risky	1
378	4	4	1	1	0	5	1	1	Non-Risky	-10	Risky	0
379	4	4	1	1	0	1	1	1	Non-Risky	-10	Risky	0
380	4	1	1	0	0	1	1	1	Non-Risky	55	Non-Risky	1
381	4	2	1	1	0	1	1	2	Non-Risky	15	Non-Risky	1
382	4	1	1	1	0	2	1	1	Non-Risky	35	Non-Risky	1
383	4	4	3	1	0	5	1	1	Non-Risky	-10	Risky	0
384	4	4	1	1	0	1	1	1	Non-Risky	-10	Risky	0
385	4	4	1	0	0	1	1	1	Non-Risky	10	Non-Risky	1
386	4	3	1	1	0	1	1	1	Non-Risky	5	Non-Risky	1
387	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
388	4	6	1	0	0	1	1	1	Risky	-20	Risky	1
389	4	3	1	0	0	1	1	1	Non-Risky	25	Non-Risky	1
390	4	7	1	1	0	5	1	1	Risky	-55	Risky	1
391	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
392	4	5	1	1	0	2	1	1	Risky	-25	Risky	1
393	4	5	1	0	0	1	1	1	Risky	-5	Risky	1
394	4	6	1	1	0	1	1	1	Risky	-40	Risky	1
395	4	5	1	0	0	2	1	1	Risky	-5	Risky	1
396	4	5	1	1	0	1	1	1	Risky	-25	Risky	1
397	4	4	1	1	0	2	1	1	Risky	-10	Risky	1
398	4	4	1	1	1	1	2	1	Risky	-55	Risky	1
399	4	4	3	1	0	5	1	1	Risky	-10	Risky	1
400	4	5	1	1	0	1	1	2	Risky	-30	Risky	1
401	4	5	1	1	0	1	1	1	Risky	-25	Risky	1
402	4	6	1	1	0	1	1	2	Risky	-45	Risky	1
403	4	4	1	1	0	2	1	1	Risky	-10	Risky	1
404	4	5	1	0	0	5	1	1	Risky	-5	Risky	1
405	4	5	1	0	0	1	1	1	Risky	-5	Risky	1
406	4	5	1	1	0	2	1	1	Risky	-25	Risky	1
407	4	5	1	1	0	5	1	1	Risky	-25	Risky	1
408	4	5	1	1	0	1	1	1	Risky	-25	Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
409	4	6	1	0	0	2	1	1	Risky	-20	Risky	1
410	4	5	1	1	0	5	1	1	Risky	-25	Risky	1
411	4	6	1	0	1	1	1	1	Risky	-60	Risky	1
412	4	3	3	1	0	3	1	1	Risky	5	Non-Risky	0
413	4	3	1	0	1	1	1	1	Risky	-15	Risky	1
414	4	2	1	1	1	3	1	1	Risky	-20	Risky	1
415	4	3	2	1	1	2	1	1	Risky	-25	Risky	1
416	4	3	1	1	1	3	1	1	Risky	-35	Risky	1
417	4	3	2	1	1	1	1	1	Risky	-25	Risky	1
418	4	3	1	1	1	1	1	1	Risky	-35	Risky	1
419	4	3	1	1	0	2	1	1	Risky	5	Non-Risky	0
420	4	4	2	1	1	2	1	1	Risky	-40	Risky	1
421	4	4	2	0	1	1	1	1	Risky	-20	Risky	1
422	4	4	1	1	1	1	1	2	Risky	-55	Risky	1
423	4	4	1	0	0	1	1	1	Risky	10	Non-Risky	0
424	4	4	1	1	1	2	1	1	Risky	-50	Risky	1
425	4	4	1	0	1	1	1	1	Risky	-30	Risky	1
426	4	4	2	1	1	1	1	1	Risky	-40	Risky	1
427	4	4	1	1	1	1	1	1	Risky	-50	Risky	1
428	4	3	2	1	0	3	1	1	Risky	15	Non-Risky	0
429	4	4	1	1	1	2	1	1	Risky	-50	Risky	1
430	4	3	1	1	1	5	1	1	Risky	-35	Risky	1
431	4	4	1	0	1	2	1	1	Risky	-30	Risky	1
432	4	3	1	0	1	2	1	1	Risky	-15	Risky	1
433	4	3	1	0	1	3	1	1	Risky	-15	Risky	1
434	4	3	1	1	1	2	1	1	Risky	-35	Risky	1
435	4	4	2	0	0	2	1	1	Risky	20	Non-Risky	0
436	4	3	2	1	0	2	1	1	Risky	15	Non-Risky	0
437	4	3	1	0	1	2	1	1	Risky	-15	Risky	1
438	4	4	2	0	1	2	1	1	Risky	-20	Risky	1
439	4	4	2	1	0	3	1	1	Risky	0	Risky	1
440	4	4	1	1	1	5	1	1	Risky	-50	Risky	1
441	4	3	1	1	1	2	1	1	Risky	-35	Risky	1
442	4	4	1	0	1	2	1	1	Risky	-30	Risky	1
443	4	3	1	1	0	2	1	1	Risky	5	Non-Risky	0

APPENDIX C – Building Database used to test the proposed RVS Method

Table C.1. Database of Test Buildings

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
1	2	2	1	0	0	1	1	1	Risky	-6	Risky	1
2	2	3	1	0	0	1	2	2	Risky	-27	Risky	1
3	2	2	1	0	0	1	2	0	Risky	-7	Risky	1
4	2	3	1	1	1	1	1	1	Risky	-54	Risky	1
5	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
6	2	2	1	0	0	3	1	1	Risky	-8	Risky	1
7	2	4	1	0	0	5	1	2	Risky	-47	Risky	1
8	2	2	1	1	0	1	1	1	Risky	-21	Risky	1
9	2	2	2	0	0	5	1	1	Risky	-11	Risky	1
10	2	3	1	1	0	1	1	1	Risky	-39	Risky	1
11	2	3	2	0	0	1	1	1	Risky	-25	Risky	1
12	2	1	2	0	1	1	1	1	Risky	-4	Risky	1
13	2	5	1	1	0	1	1	1	Risky	-75	Risky	1
14	2	2	1	0	1	5	1	1	Risky	-25	Risky	1
15	1	4	1	1	0	5	1	1	Risky	-66	Risky	1
16	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
17	1	2	3	0	0	5	1	1	Risky	-13	Risky	1
18	1	2	1	1	0	5	1	1	Risky	-30	Risky	1
19	1	2	3	1	0	5	1	1	Risky	-28	Risky	1
20	1	2	1	0	0	5	1	1	Risky	-15	Risky	1
21	1	2	1	1	0	1	1	1	Risky	-22	Risky	1
22	1	3	3	0	0	5	1	1	Risky	-31	Risky	1
23	1	2	1	0	1	5	0	0	Risky	15	Non-Risky	0
24	1	2	1	1	0	3	1	1	Risky	-26	Risky	1
25	1	2	1	1	0	1	1	1	Risky	-22	Risky	1
26	1	3	1	0	0	1	1	1	Risky	-25	Risky	1
27	2	3	1	1	0	4	1	1	Risky	-42	Risky	1
28	2	2	1	1	0	4	1	1	Risky	-24	Risky	1
29	2	2	1	1	0	4	1	1	Risky	-24	Risky	1
30	2	2	1	1	0	4	1	1	Risky	-24	Risky	1
31	2	3	3	0	0	4	1	1	Risky	-29	Risky	1
32	2	2	1	0	0	4	1	1	Risky	-9	Risky	1
33	2	3	1	1	0	4	1	1	Risky	-42	Risky	1
34	2	3	1	1	0	4	1	1	Risky	-42	Risky	1
35	2	1	1	0	0	4	2	1	Non-Risky	7	Non-Risky	1
36	4	4	1	0	0	5	1	2	Non-Risky	-5	Risky	0
37	4	3	1	0	0	1	1	1	Non-Risky	15	Non-Risky	1
38	4	4	1	0	0	1	1	2	Non-Risky	-5	Risky	0
39	4	4	1	0	0	1	1	2	Non-Risky	-5	Risky	0
40	4	4	1	0	0	1	1	1	Non-Risky	0	Risky	0
41	4	4	1	0	0	1	1	1	Non-Risky	0	Risky	0
42	4	3	1	1	0	1	1	1	Non-Risky	5	Non-Risky	1
43	4	4	1	0	0	1	1	2	Non-Risky	-5	Risky	0
44	4	4	1	0	0	1	1	2	Non-Risky	-5	Risky	0
45	1	1	3	0	0	2	1	1	Non-Risky	11	Non-Risky	1
46	2	2	1	0	0	1	1	1	Non-Risky	-6	Risky	0
47	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
48	2	1	3	0	0	4	1	1	Non-Risky	7	Non-Risky	1
49	2	1	1	0	0	1	1	1	Non-Risky	12	Non-Risky	1
50	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
51	1	1	3	0	0	1	1	1	Non-Risky	13	Non-Risky	1
52	2	1	1	0	0	1	1	1	Non-Risky	12	Non-Risky	1
53	1	4	3	0	0	2	1	1	Non-Risky	-43	Risky	0
54	3	1	1	0	0	2	1	1	Non-Risky	35	Non-Risky	1
55	3	1	1	0	0	1	1	1	Non-Risky	35	Non-Risky	1
56	4	2	1	1	0	5	2	1	Non-Risky	25	Non-Risky	1
57	3	1	3	0	0	1	2	1	Non-Risky	40	Non-Risky	1
58	2	4	2	1	0	1	1	1	Risky	-58	Risky	1
59	2	3	2	0	0	1	0	0	Risky	-22	Risky	1
60	2	2	2	1	0	5	1	1	Risky	-26	Risky	1
61	4	1	1	0	0	2	1	1	Non-Risky	45	Non-Risky	1
62	4	1	2	0	0	2	1	1	Non-Risky	35	Non-Risky	1
63	4	3	1	0	0	1	1	1	Non-Risky	15	Non-Risky	1
64	4	2	1	1	0	3	1	1	Non-Risky	20	Non-Risky	1
65	4	1	1	0	0	3	1	1	Non-Risky	45	Non-Risky	1
66	4	1	2	0	0	3	1	1	Non-Risky	35	Non-Risky	1
67	4	1	1	0	0	2	1	1	Non-Risky	45	Non-Risky	1

Building ID	Seismic Class	Number of Stories	Slab Type	Vertical Irregularities	Visual Damage	Masonry Material	Typical Story Height	Plan Area	Seismic Analysis Result	Method Score	Method Result	Check
68	4	3	2	1	0	3	0	1	Non-Risky	-10	Risky	0
69	4	4	2	1	0	5	1	1	Non-Risky	-20	Risky	0
70	4	2	2	0	0	2	0	1	Non-Risky	15	Non-Risky	1
71	4	1	2	0	0	3	1	1	Non-Risky	35	Non-Risky	1
72	4	5	2	0	0	5	1	1	Non-Risky	-25	Risky	0
73	4	1	2	0	0	3	1	1	Non-Risky	35	Non-Risky	1
74	4	4	1	1	0	3	1	1	Non-Risky	-10	Risky	0
75	4	2	1	0	0	3	1	1	Non-Risky	30	Non-Risky	1
76	4	2	1	0	0	3	1	1	Non-Risky	30	Non-Risky	1
77	2	1	2	0	0	4	1	1	Non-Risky	8	Non-Risky	1
78	2	1	2	0	0	4	1	1	Non-Risky	8	Non-Risky	1
79	2	1	2	0	0	4	1	1	Non-Risky	8	Non-Risky	1
80	1	2	2	0	0	1	1	1	Risky	-6	Risky	1
81	1	2	1	0	0	1	1	1	Risky	-7	Risky	1
82	1	2	1	1	1	1	1	1	Risky	-42	Risky	1
83	1	3	2	1	0	1	1	1	Risky	-39	Risky	1
84	1	2	1	1	0	1	1	1	Risky	-22	Risky	1
85	2	1	1	0	1	4	1	1	Risky	-6	Risky	1
86	2	2	1	0	0	1	1	1	Risky	-6	Risky	1
87	2	3	1	0	1	1	1	1	Risky	-39	Risky	1
88	2	1	1	0	1	1	1	1	Risky	-3	Risky	1
89	2	5	1	1	0	1	1	1	Risky	-75	Risky	1
90	3	3	1	1	1	1	1	1	Risky	-45	Risky	1
91	3	4	1	1	1	1	1	1	Risky	-60	Risky	1
92	3	3	1	1	1	5	1	1	Risky	-45	Risky	1
93	3	2	1	1	0	1	2	1	Risky	15	Non-Risky	0
94	3	2	2	0	0	5	1	1	Risky	10	Non-Risky	0
95	4	4	1	0	1	1	1	1	Risky	-40	Risky	1
96	4	3	1	1	0	1	1	1	Risky	5	Non-Risky	0
97	4	4	1	0	1	1	1	1	Risky	-40	Risky	1
98	4	5	1	0	0	1	1	1	Risky	-15	Risky	1
99	4	2	2	1	1	1	1	1	Risky	-30	Risky	1
100	4	4	1	1	1	1	1	2	Risky	-55	Risky	1

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