T.R.
VAN YÜZÜNCÜ YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF CIVIL ENGINEERING

QUICK DETERMINATION OF THE PERFORMANCE OF EXISTING BUILDINGS IN ERBIL CITY IN BRAYATY QUARTER USING STREET-WALK METHOD

M.Sc. THESIS

Rokhosh KHUDHUR
Supervisor: Assoc. Prof. Dr. Murat MUVAFIK

VAN – 2023

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ACCEPTANCE AND APPROVAL PAGE

This thesis entitled “Quick Determination of the Performance of Existing Buildings in Erbil City in Brayaty Quarter Using Street-Walk Method” presented by Rokhosh KHUDHUR under supervision of Assoc. Prof. Dr. Murat MUVAFIK in the department of Civil Engineering has been accepted as a M.Sc. thesis according to Legislations of Graduate Higher Education on ….../......./.......... with unanimity / majority of votes members of jury.

Chair: Assoc. Prof. Dr. Murat MUVAFIK Signature:

Member: Assoc. Prof. Dr. Barış ERDİL Signature:

Member: Assoc. Prof. Dr. Ercan IŞIK Signature:

This thesis has been approved by the committee of The Institute of Natural and Applied Sciences on ..……../.........../…..….. with decision number of ....

Signature

………………….

Director of Institute

ETHICAL DECLARATION

I declare that all the information in this thesis has been obtained and presented within the framework of ethical behaviour and academic rules, and that in this thesis, which has been prepared in accordance with the thesis writing rules, all kinds of statements and information that do not belong to me have been fully cited.

Signature
Rokhosh KHUDHUR

ABSTRACT

QUICK DETERMINATION OF THE PERFORMANCE OF EXISTING BUILDINGS IN ERBIL CITY IN BRAYATY QUARTER USING STREET-WALK METHOD

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M.Sc. Thesis, Department of Civil Engineering
Supervisor: Assoc. Prof. Dr. Murat MUVAFIK
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In this study the parameters of two methods of Level 1 Walk-Down Procedure, namely FEMA P-154 (1988) and Sucoğlu and Yazgan (2003) are implemented to assess seismic performance of a sample of 867 buildings. The buildings investigated are located in Brayaty Quarter in Erbil City. Two methods were used to collect, classify and analyze required data on the target buildings. The key objective of this study is to assess the seismic performance of the buildings surveyed and to identify whether they are probably safe, unsafe or risky. Another purpose of this study is to determine the seismic safety of the soil on which the buildings in the studied area are built.

The method used to gather data is controlled or structured observation. This method is also utilized to define and record the data on the criteria that determine seismic safety of the buildings. Mixed-methods approaches are utilized in researching into the target buildings. The quantitative data in this research are expressed in numbers and percentages in tables and graphs, while the qualitative data are embodied in the description of phenomena, theories and maps.

This study is of value to designers in vertical irregularity, plan irregularity, short column, overhang, quality of building and soft storey since it provides relevant information about seismic force effect on various types of buildings.

The findings show that the type of the soil in the studied area in Erbil City is class D which is classified as stiff soil and its shear wave velocity is V_s (ft/s) is $1200<V_s\leq2500$.The target buildings are located in high seismicity zone in Iraq. RC buildings are 186 and masonry buildings are 681 in number. 93.54 % of the buildings are safe and6.45% of the buildings are unsafe according to FEMA P-154 (1988). According to Sucoğlu and Yazgan (2003) 87.70% are safe, 6.68% are moderately risky and 5.53% high risky.

Keywords: High seismicity, Low seismicity, Masonry structures, Moderate seismicity, Reinforced-concrete structure

ÖZET

SOKAK TARAMASI YÖNTEMİ KULLANILARAK ERBİL İLİ BRAYATY MAHALLESİN'DEKİ MEVCUT BİNALARIN DEPREM PERFORMANSLARININ HIZLI DEĞERLENDİRİLMESİ

KHUDHUR, Rokhosh Abdalnafi
Yüksek Lisans Tezi, İnşaat Mühendisliği Anabilim Dalı
Danışman: Doç. Dr. Murat MUVAFIK
Haziran 2023, 99 sayfa

Bu çalışmada, 867 binadan oluşan bir örneklemin sismik performansını değerlendirmek için FEMA P-154 (1988) ve Sucoğlu ve Yazgan (2003) olmak üzere iki Birinci Kademe sokak tarama Prosedürü yönteminin parametreleri uygulanmıştır. İncelenen binalar Erbil Şehri'ndeki Brayaty Mahallesi'nde bulunuyor. Hedef binalar hakkında gerekli verileri toplamak, sınıflandırmak ve analiz etmek için iki yöntem kullanılmıştır. Bu çalışmanın temel amacı, incelenen binaların sismik performanslarını değerlendirmek ve muhtemelen güvenli, güvensiz veya riskli olup olmadıklarını belirlemektir. Bu çalışmanın bir diğer amacı da çalışılan alandaki binaların üzerine inşa edildiği toprağın sismik güvenliğini belirlemektir.

Veri toplamak için kullanılan yöntem kontrollü veya yapılandırılmış gözlemdir. Bu yöntem, binaların sismik güvenliğini belirleyen kriterlere ilişkin verileri tanımlamak ve kaydetmek için de kullanılır. Hedef binaların araştırılmasında karma yöntem yaklaşımları kullanılmaktadır. Bu araştırmadaki nicel veriler tablo ve grafiklerde sayı ve yüzdelerle ifade edilirken, nitel veriler olguların, teorilerin ve haritaların tanımında somutlaştırılmıştır.

Bu çalışma, çeşitli yapı tipleri üzerindeki sismik kuvvet etkisi hakkında bilgi vermesi nedeniyle dikey düzensizlik, plan düzensizliği, kısa kolon, çıkıntı, bina kalitesi ve yumuşak katlı tasarımcılar için değerlidir.

Bulgular, Erbil şehrinde çalışılan alandaki toprağın tipinin sert toprak olarak sınıflandırılan D sınıfı olduğunu ve kayma dalgası hızının Vs (ft/s) olduğunu göstermektedir $1200<Vs\leq2500$. Hedef binalar Irak'ta yüksek depremsellik bölgesinde yer almaktadır. RC binaları 186 ve yığma binaların sayısı ise 681'dir. FEMA P-154'e (1988) göre binaların %93.54'ü güvenli, %6.45'i güvensizdir. Sucoğlu ve Yazgan'a (2003) göre %87.70'i güvenli, %6.68'i orta riskli ve %5.53'ü yüksek risklidir.

Anahtar kelimeler: Betonarme yapı, Düşük depremsellik, Yığma yapılar, Orta derecede depremsellik, Yüksek depremsellik

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My special thanks and gratitude should go to my father for his constant support and encouragement.

My love and gratitude are also extended to my family for being patient and supporting me during writing this thesis.

2023
Rokhosh KHUDHUR

DEDICATED

To:
My Father,
Mother,
Husband
And Daughter

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SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this thesis are presented below, along with their descriptions.

Symbols	**Description**
a_g	Ground acceleration
b_h	Hardening ratio of steel
f'_c	Compressive strength of concrete
f_y	Yield strength
S_{min}	Minimum score
S_{L1}	Final level 1 score
V_s	Shear wave velocity

Abbreviations	**Description**
C3	Concrete Frame with Unreinforced Masonry Infill Walls
CQ	Construction Quality
EVRC	Earthquake Vulnerability Reduction for Cities
FEMA	Federal Emergency Management Agency
GLD	Gravity Loads
HPB	High Performance Buildings
IDARC	Inelastic damage Analysis of RC Structures
NEHRP	National Earthquake Hazard Reduction Program
PGA	Peak Ground Acceleration
PML	Probabilistic Maximum Loss
RC	Reinforced Concrete
RVS	Rapid Visual Screening

Abbreviations	**Description**
SEL	Scenario Expected Loss
SSI	Soil-Structure Interaction
SUL	Scenario Upper Loss
TEC	Turkish Earthquake Code
URM	Unreinforced Masonry Bearing-Wall Buildings
W1	Light Wood Frame Single or Multiple Family Dwellings
W1A	Light Wood Frame Multi-Storey Residential Buildings
WHO	World Health Organization

1. INTRODUCTION

1.1 The Topic of the Study

Buildings that may be seismically hazardous have been identified, inventoried, and screened implementing the rapid visual screening (RVS) procedure. Such structures are better to be further examined by a design expert with expertise in seismic design once they have been identified as potentially dangerous to ascertain whether they are actually seismically hazardous. The RVS process employs a method that is founded on a walk-dawn survey of a structure and a Data Collection Form that is filled out by the surveyor based on visual observation of the building's exterior and, if possible, interior. Building identification information, such as its usage and size, can be recorded in the data collection form, together with sketches, a photo of the building, and any relevant information about its seismic performance. A score that indicates the expected seismic building performance is computed. This is based on the information gathered during the survey.

To analyze the performance of buildings three methods are implemented. These methods are in order the Level One, Level Two and Level Three. The first level is street scanning or walk-down procedure to analyze building performances, but it is less precise and less detailed than other levels. First level analysis includes (FEMA 154, 1988; Sucoğlu et al., 2003) procedure and ATC-21(Rapid visual screening) approach. Second level is pre-assessment method, this analysis is more detailed and precise than first level analysis. Third level (detailed evaluation methods) analysis is more detailed and precise than first and second levels of analysis. The techniques used in this level are linear or non-linear dynamic analysis.

In this study, the first level which is Street-Scanning or Walk-Down procedure is implemented to analyze seismic performance of buildings in Brayaty Quarter in Erbil city. To achieve this analysis, data are collected on these criteria: number of storey, vertical irregularity, soft storey, short column, unbraced cripple wall, out-of-plane-setback, split level, plan irregularity, torsion, non-parallel system, reentrant corner, diaphragm opening, beam do not align with column, pre-code, post-benchmark, soil type, heavy overhang, apparent building quality, pounding, topographic effect, wall opening and wall opening type.

1.2 The Problem of the Study

The problem that this study investigates is that in most buildings in the studied area, vertical irregularity is detected, and in some buildings, plan irregularity is identified. These could reduce performance of these buildings and as a result, it increases their vulnerability.

1.3 The Aim of the Study

The purpose of this study is to investigate buildings in the target area. These findings comprise the number and percentages of the buildings which are safe and those of the buildings which are unsafe or risky. The assessment criteria used to determine the extent of the safety of buildings are mentioned before. Another aim of this thesis is to measure the strength of the soil of the area and decide if it is appropriate for the buildings surveyed. According to the data on the soil obtained from previous studies, the strength of the soil is as follows: ZA, ZB, ZC, ZD and ZE. Erbil City soil is classified as Class ZD which is stiff soil.

1.4 The Scope of the Study

This study is restricted to using first level analysis to determine the performance of the existing buildings in Brayaty quarter in Erbil city. It is also restricted to using Street Scanning Method within level 1 analysis. In this research, the second level and third level analysis are excluded. In this study, the performance of buildings and seismicity zones which include very high, high, moderately high, moderate, low seismicity zone will be also investigated. The current study also investigates how to determine seismic forces. Furthermore, this investigation is restricted to high and moderately high seismicity zone since the target area lies between the two zones mentioned above. This study deals with seismic force on structure. It demonstrates the effect of seismic forces on both unsafe buildings and safe buildings and investigates the buildings in Brayaty Quarter in Erbil city with regard to whether they are safe. To decide whether the buildings in the planned area are safe or not depends on number of storey, vertical irregularity, soft storey, short column, unbraced cripple wall, out-of-plane-setback, split level, plan irregularity, torsion, non-parallel system, reentrant corner, diaphragm opening, beam do not align with column, pre-code, post-benchmark, soil type, heavy overhang, apparent building quality, pounding, topographic effect wall opening and wall opening type.

1.5 The Hypothesis

It is hypothesized that:

1. Since soil property of Erbil city is classified by site class D, its shear wave velocity V_s ($^{ft}/_{s}$) is 1200$< V_s \leq$ 2,500 and it is classified as stiff soil. Seismic waves that travel though the ground more moderately through stiff soil.

2. In the buildings surveyed in Brayaty quarter in Erbil, there are vertical irregularities in most reinforced concrete buildings which includes soft storey (weak storey), overhang, unbraced cripple wall, in plan set back and short column. These irregularities increases earthquake damage. A few masonry buildings have split level which is also classified as vertical irregularity.

3. A limited number reinforced concrete buildings in the target area with plan irregularity which might raise the possibility of seismic damage.

4. Appearance quality of buildings mentioned above was moderate it is estimated that they are of moderate seismic performance.

5. The seismic performance of the building surveyed might increase since there are no building constructed on slope site.

1.6 The Value of the Study

The scientific value of this study lies in the fact that it provides basic information about the effect of seismic force on various types of buildings. Vertical irregularity, plan irregularity, short column, overhang, quality of building, and soft storey will be benefited from the recommendations that will come out.

2. LITERATURE REVIEW

2.1 Introduction

Over the past two decades, the construction industry has been compelled to give the notion of "building performance" a lot more consideration due to increased competition, consumer demands, and greater quality requirements in the global environment. As a result, the field of construction management has produced a sizable body of literature on performance and performance measurement. (Akkoyun and Dikbas, 2008)

Building performance studies have been conducted with many different goals in mind, including changing environmental conditions and evolving building requirements. The possibility that a structure will live up to the expectations of its owners, designers, operators, and occupants is very high. Consequently, it is essential to comprehend what is meant by "building performance." (Khalil et al., 2013). In order to identify the components and features of building performance in general and building performance under seismic load in particular investigated in various situations, this literature review illustrates and analyzes the most previous research on performance and performance assessment that has been published in prestigious construction management publications.

The creation of the technique for assessing the earthquake response of buildings has three levels. The first level is street scanning or walk-down procedure which is less precise and less detailed than the other levels, the second level is pre-assessment method which is more detailed and precise than first level analysis and level three is detailed evaluation method. This method is more detailed and precise than levels one and two. This literature review provides a theoretical background for this research and helps to determine the features of this study including the three levels above. It focuses on level one, street scanning/ walk-down procedure. To achieve these goals, a comprehensive survey of journal articles, books and PHD and M.Sc. thesis on building performance associated with seismic activities was conducted.

2.2 Performance of Buildings under Seismic Load

The four distinct performance levels used to describe performance in current-generation operations are Operational, Immediate Occupancy, Life Safety, and Collapse Prevention. These performance standards are evaluated at a certain seismic hazard level and are applied to the components of both structural and nonstructural system. Implementing current-generation processes in reality revealed several limits and exposed the need for improvements, even if they provided a vocabulary and a way for engineers to calculate and explain seismic performance to relevant people, namely clients and other stakeholders. (Applied Technology Council, 2012) Performance levels of buildings against earthquakes are described as follows:

1) Operational Performance Level

This performance level is related to functionality of the structures, namely,

a) Generally, there is only a minor damage to the building.
b) The building remains strong and stiff to large extent.
c) The structure does not go throw permanent drift.
d) Minor cracking occurs in facades, partitions, ceiling and structural elements.
e) Damage to nonstructural component is minor.
f) The minor repairs that the structure requires dos not disrupt the occupants.
g) Lastly, there is access to power and other utilities, might from backup sources (The Constructor, Building Ideas).

2) Immediate Occupancy Performance Level

The characteristics of this performance level are as follows:

a) The building sustains minor damages.
b) There isn't any ongoing drift.
c) The structure still has a good amount of its original stiffness and strength.
d) Minor cracking of structural components as well as facades, walls, and ceilings.
e) Elevators can be restarted.
f) Operating fire protection.
g) It is envisaged that the building's area and systems will be largely functional.

h) However, while the machinery and its contents are typically safe, they could not function well owing to mechanical issues or a lack of utilities.

i) Minor hairline cracking, limited yielding, and no crashes are seen in the concrete frame (strain of concrete less than 0.003).

j) At a few areas, steel moment frames exhibit slight local yielding. There is no fracture, buckling, or visible member deformation (Ibid).

3) Life Safety Performance Level

This level includes:

a) The structure may significantly lose its lateral strength and stiffness from before the earthquake, but the gravity-load bearing parts continue to hold up the structure.

b) Parapet tipping and out-of-plane wall failures are not anticipated, but there will be some permanent drift and some lateral-force resisting system components may experience significant cracking, spalling, yielding, and buckling.

c) Although non-structural parts are fastened and do not pose a risk of collapsing, numerous architectural, mechanical, and electrical systems are harmed.

d) Until repairs are made, the structure might not be safe for occupants to remain in.

e) Although the structure may be repaired, doing so might not be financially advantageous.

f) The intention of code compliance is often based on this performance level (FEMA389-Primer for Design Professionals, N.D.).

4) Collapse Prevention Performance Level or Near Collapse Level

This level is characterized by:

a) The building is severely damaged.

b) The majority of the pre-earthquake stiffness and strength is lost by the mechanism of lateral force resisting.

c) The structure is close to collapsing, yet load-bearing walls and columns are in place.

d) Significant deterioration of structural components takes place, including severe masonry and concrete cracking and spalling as well as steel buckling and fracture.

e) Infills, unbraced parapets, and obstructed exits are all possible outcomes.

f) The structure contains substantial, ongoing slides.

g) Nonstructural elements sustain significant damage and might present a fall hazard.
h) It is dangerous to occupy the structure.
i) It is probably not practical to repair and restore.
j) The most serious life-safety threats are mitigated at a reasonably low cost by using this building performance level as the foundation for mandated seismic restoration regulations adopted by some municipalities (Ibid).

2.2.1 High Performance Buildings

Sam and Hui (2016) point out that high performance buildings (HPB):

a) Are secure, pleasant, and effective.
b) Support owners' and occupiers' pursuit of business objectives.
c) Function consistently with little unexpected downtime and quick recovery.
d) Maintain performance within acceptable limitations over the course of their existence.
e) Improve organization and occupant performance and maintain/increase value. They further state that according to the US Energy Policy Act of 2005, a high performance building is one that combines and maximizes all of the key high-performance building characteristics, such as energy efficiency, durability, life-cycle performance, and occupant productivity. (Ibid)

All structures are vertical cantilevers that extend from the ground surface (Murty et al., N.D.). Therefore, these cantilevers undergo whiplash effects when the earth shakes, especially when the shaking is strong. Therefore, more caution is needed to shield them from this abrupt movement. There are conflicting requirements for earthquake-resistant buildings. Firstly, if a structure is intended to withstand considerable earthquake shaking without being damaged, it becomes pricey. Second, they should be strong enough to avoid being harmed by light earthquake shaking. Thirdly, even during minor earthquakes, they ought to be strong enough to prevent excessive swinging. Fourthly, despite having considerable structural damage, they should not collapse during the anticipated major earthquake shaking. Buildings designed to withstand earthquakes must include four desired qualities to satisfy these conflicting needs.

Murty et al. (N.D.) further argue that the four virtues of earthquake-resistant structures are these qualities, which are as follows:1) Good seismic configuration, with no architectural design decisions that undermine earthquake performance and do not add more complexity to the behavior of the building than the earthquake currently imposes;
2) A minimal amount of lateral stiffness in each of its plan directions (evenly distributed in both plan directions of the structure), to prevent discomfort for building inhabitants and damage to building contents;
3) A minimum of lateral strength in each of its plan directions (equally distributed in both plan directions of the building) to withstand low intensity ground shaking without damaging, as well as a minimum vertical strength to be able to continue supporting the gravity load and thereby prevent collapse under strong earthquake shaking; and
4) It has good overall ductility to support the required lateral deformation between the building's roof and base, as well as the intended mechanism of behavior at the final stage. These four qualities have a major influence on how structures behave during earthquakes. The performance of the facility is anticipated to be poor even if one of these is not guaranteed.

2.2.2 Low Performance Buildings

A survey of earthquakes occurred in Turkey between 1939 and 1999 conducted by Sesigür et al. (2001) displays that low performance building under seismic load resulted from a number of factors. These factors include the following:

1) Contractors utilize poor, inferior materials, as many assume. The authors contend that all parties engaged in the building process, including the owners, the government, and the contractors, must have some degree of responsibility. Poor quality materials used for the load bearing system (reinforced concrete, reinforcing bars, rolled steel profiles, wood, stones, and brick). The construction quality (CQ) is quantified by varying the material and

structural detailing. In Table 2.1, (Rajeev and Tesfamarian, 2011) show that the corresponding variability are categorized into three construction quality CQ levels.

Table 2.1 Material uncertainty

Material uncertainty	Unit	Poor	Average	Good
Compressive strength of concrete ($\boldsymbol{f'_c}$)	MPa	25	35	45
Yield strength of reinforcing steel ($\boldsymbol{f_y}$)	MPa	290	345	400
Hardening ratio of steel ($\boldsymbol{b_h}$)	%	1.25	2.00	2.75

2) Sesigür et al. (2001) argue that irregularities in the load bearing system, and the placement of reinforcement in RC buildings are typical causes of structural and nonstructural damages (especially beam-to-column joints), Inadequate element dimensions, short columns and beams, insufficient lateral stiffness (P-Δ effect), soft/weak stories, pounding between neighboring structures, local soil conditions, and the earthquake source parameters. Due to inappropriate, poor soil conditions, liquefaction phenomena was extensively noticed during the Kocaeli earthquake on August 17, 1999, and many structures in Adapazari sustained damage. Figure 2.1, Figure 2.2, Figure 2.3, Figure 2.4 and Figure 2.5illustrate soft-storey, collapse due to soft-storey, pounding type 1 and pounding type 2, and collapse due to pounding respectively:

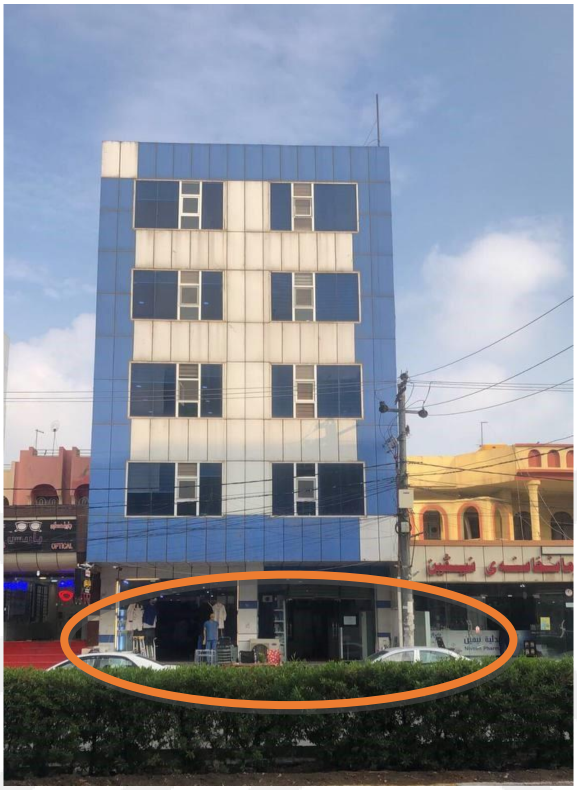


Figure 2.1 Soft-story

Figure 2.2 Examples of Nepal earthquake-related buildings that experienced soft-story collapse

Figure 2.3 Pounding type 1

Figure 2.4 Pounding type 2

Figure 2.5 (a)The intermediate storey collapsed due to the adjacent building pounded against it, and (b) collapse due to extension of the upper storey plan beyond the column grid lines which created vertical irregularity

The Turkish Code divides structural irregularities into two primary categories: irregularities in plans and irregularities in elevation. Torsional irregularity, projections in plan, floor discontinuities, and nonparallel axes of structural components are examples of common plan irregularity. Interstorey stiffness irregularity-soft storey, interstorey strength irregularity-weak storey, and discontinuity of vertical structural parts are three terms used to indicate elevation irregularities (Ibid). The figures 2-6 and Figure 2-7 display vertical and plan irregularity respectively:

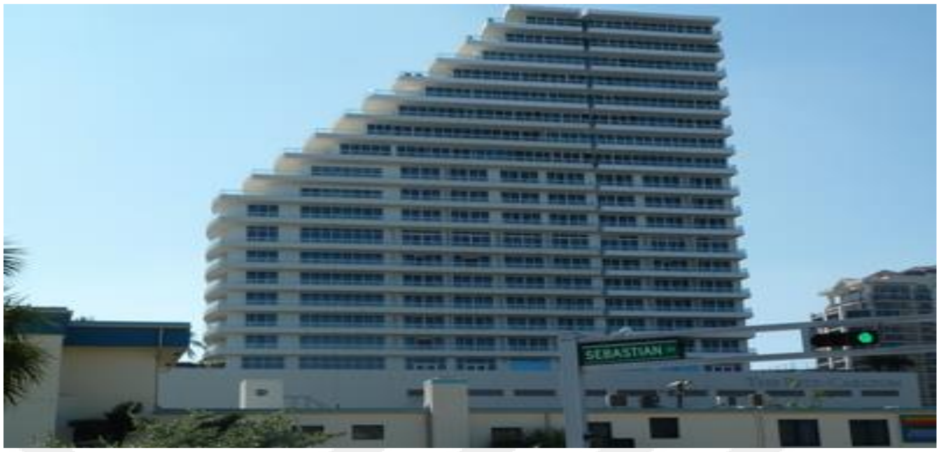


Figure 2.6 Vertical irregularity

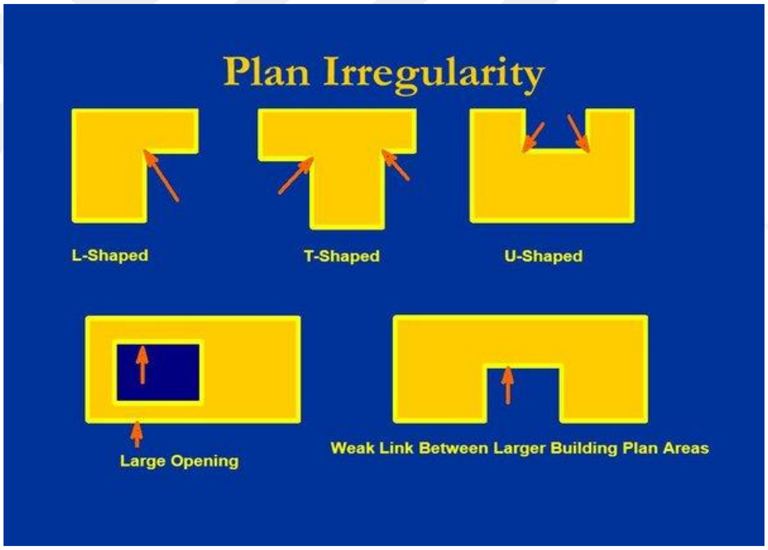


Figure 2.7 Plan irregularity

3) Sesigür et al. (2001) add that short columns that are present or have been formed in quake-prone places almost often cause shear fractures, which significantly reduce the storey yield strength. Although various safety measures can be taken during the phases of building's design and construction, the use of short columns is not advised by the most recent earthquake regulations. In the earthquake zone, it was commonly noted that many of the RC structures that had collapsed or been severely damaged had short columns. Additionally, it was noted that the structural components concrete had a compressive

strength of between 8 to 12 MPa. These values are significantly less than the minimum values that the current and old Turkish Earthquake Codes both recommend. Buildings with short columns saw more catastrophic failure mechanisms in areas where concrete's compressive strength was low. Additionally, other detailed errors were found, including the use of insufficient stirrup and improper anchoring of reinforcements, which caused concrete to spall and longitudinal column reinforcement to buckle. The figures 2-8 and Figure 2-9 below show short column and short column failure in buildings:

Figure 2.8 Short column

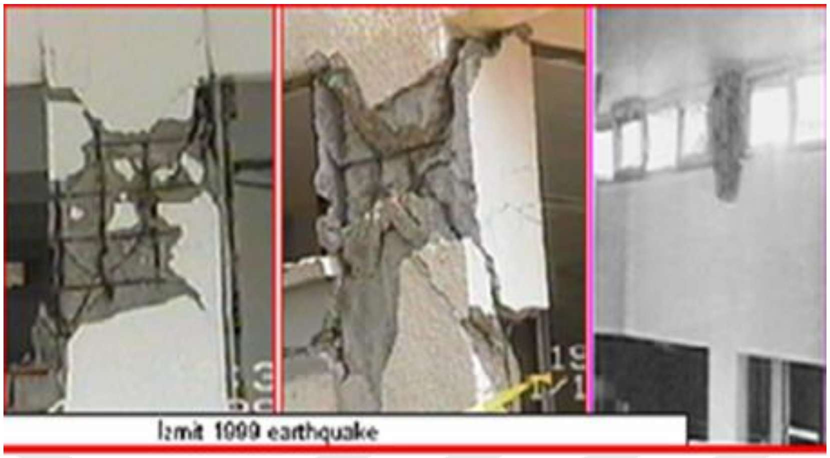


Figure 2.9 Examples of short column failures observed after earthquakes (Isik, 2006)

2.3 Soil Condition under Seismic Load

This part deals with the effect of soil condition on seismic performance of buildings.

2.3.1 General Background

Abdel Raheem et al. (2014) demonstrate soil-structure interaction (SSI) in earthquakes during the past four decades as follows:

There has been significant advancement in the built environment's seismic performance as well as in our understanding of the nature of earthquakes and how they affect structures during the past 40 years. It has been discovered that the impacts of soil-structure interaction (SSI) have a significant influence in determining how building structures behave during modern and historical earthquakes. The fault rupture mechanism, travel path effects, local site effects, and SSI effects can all be considered as contributing factors to the seismic excitation that was experienced. Regardless of the structure, the local soil conditions can have a significant impact on how an earthquake moves from the bedrock to the ground surface by acting as a dynamic filter. As an illustration, consider the 1985 earthquake in Mexico City, where deep soft soils altered the frequency of ground shaking and enhanced ground motion. When the 1989 Loma Prieta earthquake struck, similar behavior was seen, and sections of the Cypress freeway in Oakland collapsed as a result of the motion amplification caused by the soil. After the devastation caused by recent large earthquakes, the seismic soil structure interaction of multi-story structures becomes extremely significant. When a structure is built on the ground, its base will move differently than when it has a fixed basis, because of the structure-soil system's connection. It is true that the analysis is significantly more difficult when the soil is taken into consideration when estimating the structure's seismic reaction. This situation also makes it necessary to estimate additional key parameters, which are difficult to determine, such as the dynamic soil characteristics of site response, radiation damping, and kinematic interaction.

Research on the mechanism by which seismic energy is transferred from soils to buildings is essential for the construction of earthquake-resistant structures and for modernizing existing structures. Thus, there is a greater than ever need for research into issues related to soil-structure interaction (SSI). Furthermore, recent studies indicate that the impacts of SSI may be Un-conservative design that may result in disregarding SSI in analysis, which is damaging to a structure's seismic response. Despite this, the traditional design process typically assumes fixity at the base of the foundation while ignoring the foundation's flexibility, the soil mass compressibility, and ultimately the influence of the foundation settlement on additional bending moment and shear force requirement redistribution. (Ibid)

2.3.2 Types of Soil and Their Characteristics

The site class, or soil type, has a significant impact on the intensity and length of shaking as well as the resulting structural damage. In general, the more severe an earthquake will be, the closer the soil is to the bedrock there. (FEMA P-154, 2015). Six different site classifications were defined by the National Earthquake Hazards Reduction Program (NEHRP) depending on the type of soil and rock in the area and their shear-wave velocity. These types are 1) hard rock (igneous rock), 2) rock (volcanic rock), 3) very dense soil and soft rock (sandstone), 4) stiff soil (mud), 5) soft soil (artificial fill), and 6) soils requiring site-specific evaluations (cited in Nolan, 2022). Nolan (2022) adds that the harder the soil, the earlier in the alphabet it is. Site class A soil is the hardest and has the least amount of wave amplification. Site class E soil is the inverse — the softest soil with the greatest amplification. Site class F may contain a variety of soils, including those prone to failure during an earthquake, peat, and some clays.

Visual approaches used in the field to identify the type of soil are not always successful, according to (FEMA P-154, 2015). The soil type should be determined during the design stage and put into an accessible map format for use during RVS. The correct soil type, indicated by the letters A through F, should be checked on the Data Collection Form during the screening or planning phase in order to record the soil type.

2.3.3 Effect of Soil Conditions on Seismic Forces

Historical earthquakes demonstrate that site conditions have a substantial impact on structure destruction. Studies on earthquakes have virtually always demonstrated that the kind of soil strata supporting the building have a direct impact on the magnitude of the shock. Buildings constructed on firm ground or solid rock usually outperform those constructed on soft ground (IAEE, N.D.). The relationship between soil condition and seismic force affirming that Earth's land surfaces vary; some are covered in hard rock, some in deep soil, and yet others in mud or artificial fill. The distribution of different soil types can vary greatly in small locations, and these differences can have a significant impact on how an earthquake behaves as it passes through the earth. Because of this, two locations that are equally far from an earthquake's epicenter may experience quite different results. Due to geological differences, one place may be comparatively unaffected while another may experience ten times more severely. These discrepancies, sometimes known as "site effects," are generally predicated on two criteria, namely1) softness of the soil or rock and 2) the total thickness of the sediment above the bedrock (Nolan, 2022).

Jha (2018) explains the effect of soil conditions on earthquake waves as follows:

“It is well known that seismic waves travel faster through hard rocks than through soft soil. So, when the earthquake waves (seismic force) pass from a hard rock (high velocity) medium to soft soils (low velocity) medium, they must get bigger in amplitude to carry the same amount of energy. Therefore, resultant shaking is stronger at sites with softer layers compared to rocky layers. This in effect is seen as softer soil amplifying the ground motion. The more the thickness of the soil layer, the more is the slowing down of wave motion which results in more amplification (stronger) of motion."

This was dramatically illustrated by the 1985 Mexico City earthquake, which left soft soils in Mexico City 400 km from the epicenter with significantly more damage than nearby sites. For instance, it was previously known from studies of the Mexico City earthquake of July 28, 1957 that damage to soft soils in the city's center might be five to fifty times greater than to firmer soils nearby (IAEE, N.D.). Another instance was the Tangshan earthquake in 1976 in China, where 50% of the structures on thick soil sites were completely destroyed but only 12% of structures on the rock subsoil close to the mountains. In contrast, rigid masonry structures resting on rock may sustain more severe damage than structures built on soft soil during a near-earthquake, as was the case with the North Yemen earthquake in 1980 and the Koyna earthquake in India in 1967.The images below illustrates the damage to buildings due to type of soil:

Figure 2.10 Soft soil makes Mexico City shake like it was built on jelly

Figure 2.11 The earthquake damage to this building may have been influenced by the type of soil it's sitting on. (Nolan, 2022)

2.4 Seismic Assessment of Building Performance

According to FEMA P-58-1 (2012) Since the publication of ASCE/SEI 31-03, Seismic Evaluation of Existing Buildings (ASCE, 2003), and ASCE/SEI 41-06, Seismic Rehabilitation of Existing Buildings, Engineers and building officials have commonly employed a set of uniform discrete performance levels, referred to as Operational, Immediate Occupancy, Life Safety, and Collapse Prevention, to characterize expected building performance (ASCE, 2007).The acceptable ranges for the strength and deformation demands placed on structural and nonstructural components, as well as the implied qualitative relationships to the possibility of different degrees of damage, casualties, post-earthquake occupancy, and repairs, are used to determine these performance levels.

2.4.1 Building Performance Measures

The preferred performance measures for many financial institutions, including lenders, investment funds, and insurers are Probable Maximum Loss (PML), Scenario Expected Loss (SEL), and Scenario Upper Loss (SUL). These performance measurements constitute quantitative estimates of the expected cost to repair a structure, typically expressed as a percentage of the building's replacement cost. Certain building owners, developers, and tenants have used these performance indicators to estimate seismic performance. (Ibid)

The performance measurements used to express performance as the probable damage and subsequent effects connected with earthquake shaking include:

- Casualties which refer to any fatalities or serious injuries requiring hospitalization that take place inside the building envelope.
- Repair cost indicates the price, in current dollars, required to bring a building back to its pre-quake state or, in the event of total loss, to replace it with a brand-new building with a comparable design.
- Repair time is the time, in weeks, required to restore a damaged structure to its pre-quake state.
- Unsafe placarding means a post-earthquake inspection rating that considers a building, or a building component, damaged to the point that entry, use, or occupancy constitutes immediate risk to safety (FEMA P-58-1, 2012).

2.4.2 Factors Affecting Building Performance

A variety of variables affect the degree of damage a structure undergoes during an earthquake, as well as the consequences of that damage on casualties, repair costs, repair times, and unsafe placarding (FEMA P-58-1, 2012). These variables are:

1) The Intensity of Ground Shaking:

An earthquake's intensity is a number (written as a Roman numeral) that quantifies how severely it affects people, their structures, and the earth's surface. There are other scales, but the Modified Mercalli scale and the Rossi-Forel scale are the two that are most frequently applied in the United States. Contrary to the magnitude, which is a single number for each earthquake, there are various earthquake intensities based on where you are (USGS, N.D.).

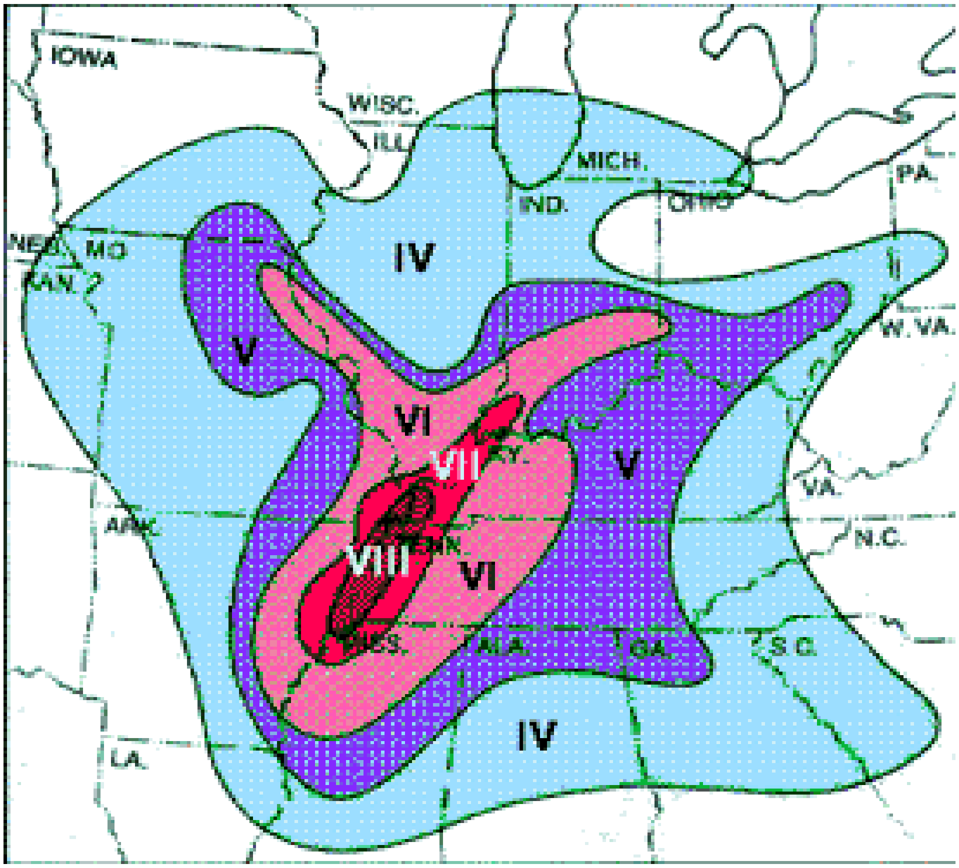


Figure 2.12 Map showing intensity for the New Madrid earthquake (The Central U.S. Earthquake Consortium as cited in USGS Earthquake Glossary)

2) The Building's Response to Ground Shaking:

A building consists of primary components (structural components) and secondary components (nonstructural components). The primary components engage in resisting lateral and vertical loads as load-bearing components. However, although not contributing to load resistance, secondary components nonetheless serve certain crucial functional purposes. These also comprise the equipment and services (Kumar et al., 2011). Another factor that affects building performance is how the building responds to ground shaking and other earthquake effects, as well as the force, deformation, acceleration, and velocity demands that these effects place on the building's structural and nonstructural components, contents, and occupants. (FEMA P-58-1, 2012).

3) The vulnerability of the systems, contents, and building components to damage:

The degree of loss to a particular element at risk, or group of such elements, as a result of an earthquake of a specific size or intensity can also be characterized as vulnerability. This loss is often stated on a scale from 0 (no damage) to 10 (extreme damage) (total loss) (Earthquake Vulnerability Reduction for Cities (EVRC-2, N.D).

4) The Number of People, and the type, Location, and Quantity of Content:

According to (Anon, N.D.) more deaths occur as there are more people. For example, the Indian earthquake in 2001 which occurred in a densely populated area resulted in 20,000 deaths. Furthermore, rural areas have fewer buildings, therefore the size of the disaster is smaller. Regarding building contents, Lin et al. (2013) state that there were buildings with minimal structural damage but severe content damage as a result of the recent Canterbury earthquakes. Examples of this type of incident include:

i. Microwaves moving several meters across rooms.
ii. Heating, ventilation, and air-conditioning HVAC units on the tops of multistory buildings shifting.
iii. Books and computers falling off shelves and tables.
iv. Items sliding over floors. Since sliding or moving items can cause damage and financial loss, it's crucial to quantify them so that they can be taken into account when calculating economic loss or when taking mitigation measures.

5) The Interpretation of Visible Evidence of Damage:

Another factor that affects building performance under seismic load is the interpretation of visible evidence of damage by inspectors performing post-earthquake safety investigations. This evidence is collected from remote sensing (satellite), aerial (pictures taken from aircrafts), omnidirectional imagery, and field survey (gathering raw data and understanding the subject of research in its environment) (Monfort et al., 2019).

The following are a sample of images from the Building Damage Severity dataset, together with their severity (Localizing and quantifying infrastructure damage using class activation mapping approaches).

Slight-damage (0.25) Moderate-damage (0.5) Heavy-damage (0.75) Total-destruction (1)

Figure 2.13 Building damage severity dataset

6) The Specific Details and Methods of Construction Used in Performing Repairs:

“In response to recent past earthquakes in California (CSSC, 1994; Holmes, 1994; Russell, 1994) and in Japan (Sugano, 1996) the affected communities have addressed the challenge of earthquake repair and reconstruction in their own way” (Hanson and Comartin, 2000). Reviewing their experiences reveals a number of general observations, including the following:

i. The execution of strategies for repair and improvement following an earthquake is significantly influenced by the economic effect of the disaster.
ii. The post-earthquake rehabilitation of damaged structures does not have adequate standards.
iii. As the size of the destructive earthquake rises, there is a larger tolerance for damage and lower restoration requirements.

2.4.3 Uncertainty in the Assessment of Building Performance

According to FEMA P-58-1, (2018) "Each factor affecting seismic performance has significant uncertainty in the ability to know or predict specific values. The fault that will produce the next earthquake, where along the fault the rupture will initiate, or the magnitude of shaking that will occur, are all not known with any certainty. Nor is there a complete understanding of the subsurface conditions that seismic waves must pass through between the fault rupture and the building site. As a result, the intensity, spectral shape, or wave form of future earthquake shaking cannot be precisely predicted."

(FEMA P-58-1, 2018) further indicates that models are still imprecise despite advances in the ability to create analytical models of structures. The assumptions of material strength, cross-section geometry, and construction details form the basis of traditional structural models. Rules of thumb are used to estimate damping. The effects of soil-structure interaction, materials made to sustain only gravity stresses, and nonstructural elements have been typically disregarded. The actual response of a building cannot be determined from structural analyses; hence response forecasts are intrinsically uncertain.

However, it's possible that the forces and deformations used in the lab might not be the same as those anticipated by the structural analysis or experienced during a real earthquake. As a result, components tested in a laboratory might not be exactly the same as components in a real structure. Similarly, the time of day or day of the week when an earthquake will occur, the number of people who will be inside the structure at that time, and the kind or quantity of contents and furnishings that are present cannot all be predicted. Once damage is anticipated, it can be challenging to estimate the precise repair methods that will be required to replace damaged parts or the effectiveness of the repairs (FEMA P-58-1, 2018).

2.5 Previous Studies

Bagchi (2001) conducted a PHD thesis with the title, Evaluation of the Seismic Performance of Reinforced Concrete Building. The study's objective is to ensure that structures built in accordance with code requirements can withstand minor earthquakes without structural damage, moderate earthquakes with some non-structural damage, and major earthquakes without collapsing, but with some structural and non-structural damage. According to the methodology, damage states in a structure are often calculated using static push-over analysis and nonlinear dynamic analysis based on how the structure resists an earthquake ground motion. A simplified procedure for building seismic evaluation is also suggested. According to the study, for a given degree of seismic threat, buildings in eastern Canada have a significantly better level of seismic protection. This is due to the following reasons:

a) Building frames in eastern Canada have a longer lifespan than those in western Canada.
b) A building's bare frame model in eastern Canada lasts longer than a corresponding frame model in western Canada.
c) Because there is a larger gap between the design period and the actual period for a building, in eastern Canada the dynamic lateral forces are more significant than in western Canada.
d) It is found out that buildings in western Canada are more vulnerable to the seismic danger there than those in eastern Canada.
e) Good levels of seismic performance are achieved in eastern Canada. The researcher comes to the further conclusion that while wind loads have not been taken into account, the building models under consideration have been constructed and studied for seismic loadings and the accompanying gravity loads.

Rakesh (2018) wrote a PHD dissertation entitled *Seismic Performance Assessment and Strengthening Techniques for Existing Reinforced Concrete Buildings in Nepal.* To conduct this study, six buildings, including non-engineered, pre-engineered, and well-designed structures, were chosen as case studies to illustrate the three contrasting design approaches. In addition to conducting site reconnaissance, in these buildings in-situ tests were performed such as Schmidt hammer and ambient vibration tests. The basic frequencies and accompanying vibration modes could be obtained by ambient vibration experiments, which was essential for calibrating the model. One of the case studies was the calibration of a bare frame model using an unfinished pre-engineered building that just had RC parts. On the basis of adaptive pushover analysis and nonlinear time history analysis, the impact of the distribution of the infill walls on the seismic performance is described in detail for this case. It is concluded that the strength of infilled frame increases by about three to four times compared to the naked frame, while the soft-storey design was found to be significantly more vulnerable than a completely infilled structure.

Abduljaleel (2019), Conducted an M.Sc. thesis entitled Seismic Vulnerability Assessment of Reinforced Concrete Building Structures in Erbil City. To achieve the objectives of the study, the researcher carried out a survey to identify vulnerability in various types of existing RC building structures in Erbil city and analyzed the data collected. The conclusion shows that the building surveyed have low performance towards earthquake, and more vulnerable for seismic excitation. The capacity of building structure of commercial, hotel and residential building with the dynamic analysis is ineffective, the hospital building structure performance is very poor.

Toprak (2008) carried out a M.Sc. thesis entitled Code-based Evaluation of Seismic Performance Levels of Reinforced Concrete Buildings with Linear and Non-Linear Approaches. This study uses of the new Turkish Earthquake Code of 2007 (TEC'07) and Eurocode 8 to investigate the code-based procedure of seismic performance assessments of existing buildings and to determine the seismic performance levels of a case study reinforced concrete building that represents the typical existing building stock in Turkey. Additionally, it compares the outcomes of linear static analysis and non-linear static analysis methods. Due to the availability of appropriate analytic tools for non-linear static (pushover) and non-linear dynamic (time history) techniques of analysis, the researcher utilizes a non-linear non-elastic analysis procedure. The conclusion drawn in the thesis indicates that a) The performance levels for the critical storey of the structure are produced by independently using linear and non-linear techniques of analysis using either Eurocode 8 or TEC'07, b)The base shear value according to Eurocode is significantly higher than the Turkish Earthquake Code, while the chosen ground conditions indicate the same features, c) The strains at plastic cross-sections are to be confirmed in accordance with the displacement-based non-linear assessment outlined in TEC'07, however the chord rotations of primary ductile elements must be examined for Eurocode safety verification, and d) Since the ordinate of the horizontal elastic response spectrum for EC8 is higher, it is noticed that rotations using this approach provide higher values than those using TEC'07.

In his study entitled Seismic Performance of Existing R.C. Building, El-Betar (2017), On multi-story In Egypt, the most commonly used type of existing buildings are R.C. framed structures., a comparison between forces due to the Egyptian code for loads

(EC-1994) and (ECP-201, 2012) is conducted. In the methodology, the pushover analysis is carried out on two dimensional reinforced concrete framed by utilizing computer program for inelastic damage analysis of R.C. structures (IDARC version 6). The researchers found that the vulnerability of existing GLD buildings to gravitational loads occurs when ground acceleration (a_g) exceeds0.125g, as predicted by the Egyptian seismic map, whereas buildings designed according to EC-94 (a_g) is equal to 0.2.The reis elasticity more than g, and some damage may occur.

Seismic Performance and Risk Assessment of Traditional Brick-Wood Rural Buildings Based on Numerical Simulation is a study conducted by Chen et al. (2021). In this study, using field surveys and numerical simulations, the seismic performance of traditional brick and wooden houses have been investigated and confirmed in Jiangxi and neighboring areas. Additionally, conventional building methods like the cavity wall and purl in roof are taken into consideration. The focus of this study is on rural low-rise housing in northern China. The building of these houses is different from brick-wood structures in southern china, and the cavity wall has not been considered. It is concluded that the seismic performance of the structure after reinforcement is significantly high, and Improves wall stress concentration.

A New Strategy for the Seismic Assessment of Existing Reinforced Concrete (RC) Buildings conducted by Cozenza et al. (2009) examines the application of this strategy in Catania and the results of this study in urban areas. Characterized by RC structures built in the ’60s and ’70s without seismic provisions. The suggested strategy consists of two steps. In order to define homogeneous classes of buildings that represent typical structures, first surveys of several buildings has been conducted to get an idea of their geometric and mechanical properties**.** This survey is then enhanced with information based on regulations and practical rules used during construction. The results can be applied to the defined classes to produce vulnerability maps in the second step, which is based on the evaluation of the seismic capability of these structures using both revised models and parametric analysis. Application to the City of Catania demonstrates the utility of the method to generate a quantitative assessment of RC seismic capacity under designed structures and concludes that its inadequate capacity in contrast to seismic demand.

Mazılıgüney et al. (2012) undertook the research, Evaluation of Preliminary Assessment Procedures for Reinforced Concrete School Buildings in Turkey. As a result of the unexpectedly poor performance of existing school buildings in Istanbul a comprehensive study was initiated to identify seismic vulnerabilities of existing school buildings in many parts of the country. Regarding methodology, a database of 321 RC school buildings located in Istanbul was collected. The database is used to apply a number of walk-down and preliminary seismic vulnerability assessment processes created for low- to mid-rise reinforced concrete structures. In this study, the results are compared with those of the TEC detailed linear analysis method. A statistical analysis is performed to determine how well each assessment method correlates with the TEC. The damage inducing parameters have been used for walk down and preliminary analysis methods are also analyzed statistically for the database employed. Moreover, the statistical analysis findings of the damage inducing parameters and assessment methodologies, the details of the building statistics, including their material quality, structural, and architectural elements, are supplied. It is concluded that ATC 21 (FEMA 154) seismic vulnerability assessment method is found to be approximately 80% consistent with TEC for reinforced concrete school structures in Turkey.

The study, Seismic risk investigation for reinforced concrete buildings in Antalya, Turkey by Kepenek et al. (2020) aims to conduct a thorough investigation of Antalya's residential buildings. The method put out here can be viewed as an improved version of building survey techniques that were previously identified in the Design Code of Turkey. To understand the vulnerability, the fifth most populous city in Turkey, Antalya, which has a population of over 2.5 million, was researched and divided into sub-regions. In this study, the rapid visual assessment method was used to examine 26,610 reinforced concrete buildings in Antalya that ranged in height between 1 to 7 stories. With the use of statistical techniques applied in the selected sub-region and the second level evaluation, a specific threshold value for the city of Antalya was established. The researchers come to the conclusion that in the micro zonation process, the locations below the threshold value are designated as the priority areas that require in-depth investigation. Since the suggested methodology can be simply calibrated for use, it can be used to establish new threshold values for different cities.

Ateş et al. (2021) conducted research entitled Determination of Regional Soil Structure Earthquake Risk Distribution of Buildings by Street Survey Method: The Sample of Bilecik Province. Buildings made of reinforced concrete and masonry/mixed materials in the province's important locations were examined to see how the earthquake damaged them. the Street Survey Method was employed in this study. A total of 1391 buildings in Bilecik's central areas, including 1021 reinforced concrete and 370 masonry/mixed buildings, were looked at in this regard. The average seismic scores of the masonry/mixed and reinforced concrete buildings in each neighborhood were determined. Conclusion: In terms of reinforced concrete buildings, the neighborhoods of Bahçelievler, Cumhuriyet, Gazipaşa, Ismetpaşa, and Istiklal were found to be at Low Risk for Building Earthquake Safety, whereas the neighborhoods of Beşiktaş, Erturulgazi, and Hürriyet were found to be Safe for Building Earthquake Safety. For earthquake safety, all masonry structures and mixed constructions tested positive.

3. METHODOLOGY

3.1 Introduction

The goal of the research methodology is to outline the procedures that are used to conduct the study linked to the study topic, Quick Determination of the Performance of Existing Buildings in Erbil City in Brayaty Quarter using Street-Walk Method. This chapter discusses the research design, the procedure, instrument, methods of data collection, and data analysis.

3.2 The Research Site

Surveying reinforced concrete buildings, and masonry buildings which include residential and commercial buildings in Brayaty quarter in Erbil city is to demonstrate calculations for assessing seismic performance of these buildings. The houses which consist of two to three storeys are mainly utilized as residential units, while building on the main streets which consist of two to ten storeys are commercial units. These buildings are built on stiff soil which is classified as soil site D. Figure 3-1 illustrates the studied area, Brayaty Quarter in Erbil City.

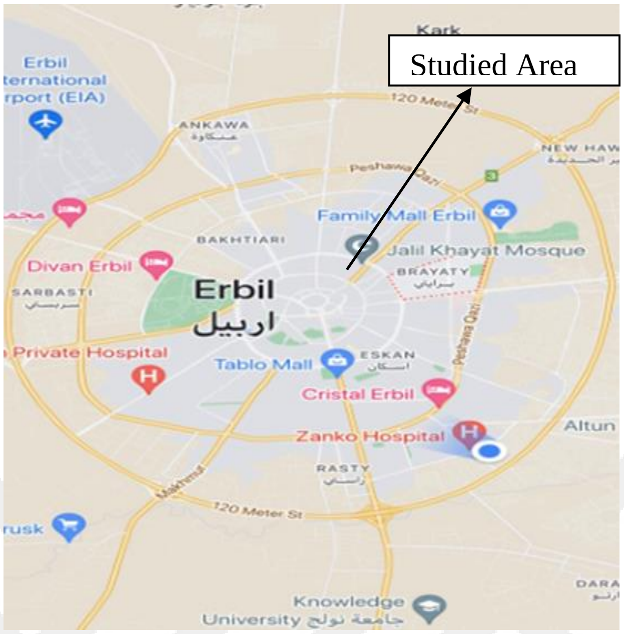


Figure 3.1 Brayaty Quarter in Erbil City

3.3 Instrument

To decide on seismic safety of the buildings in the target area, the researcher chose observation as a tool for collecting required data. Structured or controlled observation was used to define the criteria observed and to record the information gathered. The observation was restricted to visual properties of the buildings.

3.4 Data Collection

To assess the seismic performance of the target buildings, the researcher conducted a field study into the research site collecting required data from the buildings in Brayaty Quarter in Erbil City through controlled observation. According to (FEMA P-154, 1988) and (Sucoğlu and Yazgan, 2003), the data collected and recorded were about the following: situations:

A. According to (FEMA P-154, 1988) procedure, the following are investigated:
   1) Number of storey

2) Vertical irregularity which includes soft storey, short column, unbraced cripple wall, in-plane-setback and split levels.
3) Plan irregularity consisting of torsion, non-parallel system, reentrant corner, diaphragm opening and beam do not align with column.
4) Pre-code
5) Post-benchmark
6) Soil type

B. According to (Sucoğlu and Yazgan, 2003) procedure, the following are researched:

   1. Number of storey
   2. Soft storey
   3. Heavy overhang
   4. Apparent building quality
   5. Short column
   6. Pounding
   7. Local soil condition
   8. Topographic effect
   9. Wall opening
   10. Wall opening type

3.5 Street-Walk Method

Street-Walk method or Walk-down procedures can be defined as the simplest seismic vulnerability assessment procedures, which requires some basic visual properties of buildings collected from a simple street survey and do not require tests or detailed measurements. The aim is to identify the vulnerability level of buildings in a short time. They are not used to assess a single building as they only use the visual properties of buildings rather they are implemented to evaluate the vulnerable buildings in a building stock. (Erdil and Ceylan, 2018). Another definition of the method is presented by (Sucoğlu and Yazgan, 2003) stating that a street survey procedure must start with basic structural and geotechnical data that are observable from the sidewalk. It is anticipated that it will take an observer no longer than 10 minutes to collect data from one building from the sidewalk. This study implements Walk-Down method to assess vulnerability of existing buildings in Brayaty quarter in Erbil city. This method comprises such procedure as (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003), ATC-21 (Rapid Visual Screening) approach and RBT 2019. The procedure used in this study are (FEMA P-154, 1988) level 1 and (Sucoğlu and Yazgan, 2003) level 1. According to Figure 3-2 Iraq seismic hazard distribution Map, Erbil is located in high seismicity zone. This is why (FEMA P-154, 1988) level 1 and (Sucoğlu and Yazgan, 2003) level 1 are used to analyze the data collected from the studied area buildings. To conduct the analysis two separate forms are used as shown in Figure 3-2 and Table 3-1 below.

Table 3.1 Walk-Down procedure- level 1 for RC buildings (Sucoğlu and Yazgan, 2003)

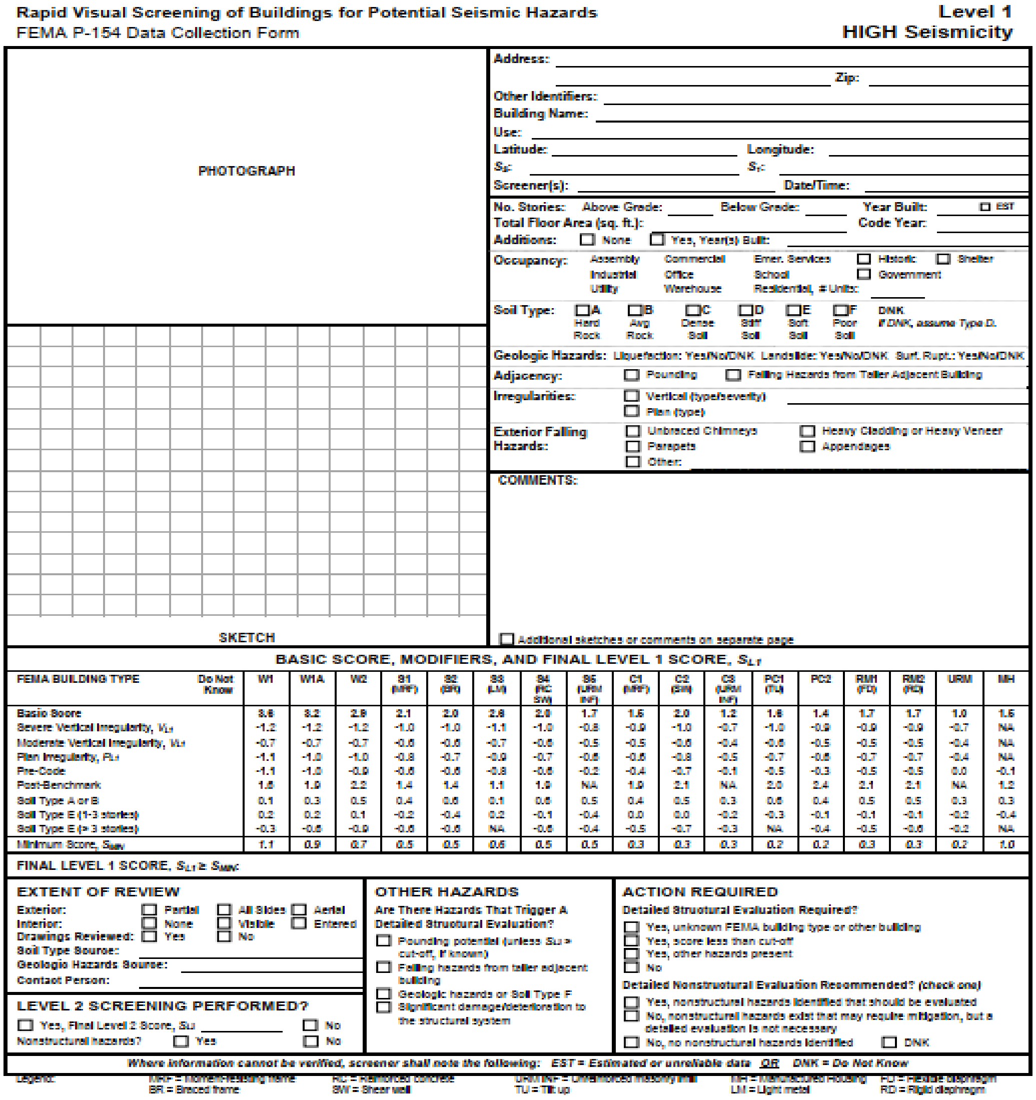
Story #	Zones			Soft Story	Heavy overhangs	Apparent Quality	Short column	Pounding	Topographic Effect
	I	II	III						
1,2	90	125	160	0	-5	-5	-5	0	0
3	90	125	160	-10	-10	-10	-5	-2	0
4	80	100	130	-15	-10	-10	-5	-3	-2
5	80	90	115	-15	-15	-15	-5	-3	-2
6,7	70	80	95	-20	-15	-15	-5	-3	-2

Table 3.2 (Sucoğlu and Yazgan, 2003) level 1 Method table for masonry buildings

Number of storey	Zone I	Building quality	Wall-opening	Pounding effect	Wall-opening type
1-2	100	-10	-5	0	-2
3	85	-10	-5	-3	-5
4	70	-10	-5	-5	-5
5	50	-10	-5	-3	-5

Table 3.3 Priority earthquake scoring in buildings

Building priority	Earthquake score
1. Priority	0-65
2. Priority	66-80
3. Priority	81-100



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

Address:
Zip:
Other Identifiers:
Building Name:
Use:
Latitude: Longitude:
S_S: S_1:
Screener(s): Date/Time:

No. Stories: Above Grade: Below Grade: Year Built: ☐ EST
Total Floor Area (sq. ft.): Code Year:
Additions: ☐ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil DNK If DNK, assume Type D.

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity) ☐ Plan (type)
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer ☐ Parapets ☐ Appendages ☐ Other:

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

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

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW
Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source:
Geologic Hazards Source:
Contact Person:

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? (check one)
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

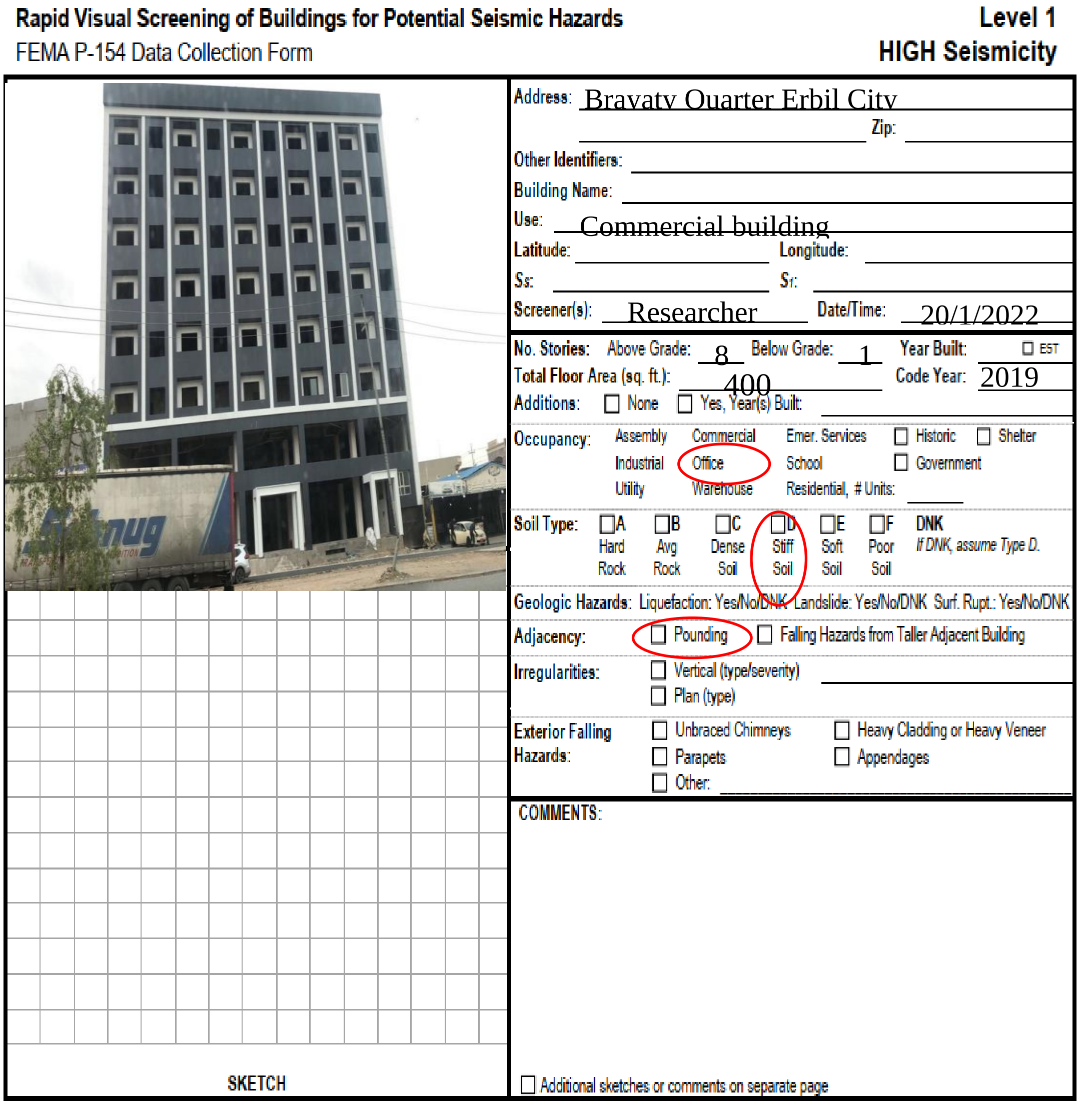
Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame RC = Reinforced concrete URM INF = Unreinforced masonry infill MH = Manufactured Housing FD = Flexible diaphragm
BR = Braced frame SW = Shear wall TU = Tilt up LM = Light metal RD = Rigid diaphragm

Figure 3.2 Data collection form according to FEMA P-154 (1988)

3.6. Data Analysis

The data collected from the buildings in the studied area are classified and analyzed. The objective of analysis the data is to assess the seismic performance of these buildings. The analysis of the data is performed manually on the basis of (FEMA P-154; Sucoğlu and Yazgan, 2003) methods. The following are examples of how the data collected and analyzed.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: Bravaty Quarter Erbil City
Zip:
Other Identifiers:
Building Name:
Use: Commercial building
Latitude: **Longitude:**
Ss: **S1:**
Screener(s): Researcher **Date/Time:** 20/1/2022

No. Stories: Above Grade: 8 Below Grade: 1 **Year Built:** ☐ EST
Total Floor Area (sq. ft.): 400 **Code Year:** 2019
Additions: ☐ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial [✓ Office] School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil [✓ ☐D Stiff Soil] ☐E Soft Soil ☐F Poor Soil DNK *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: [✓ ☐ Pounding] ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity)
☐ Plan (type)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

☐ Additional sketches or comments on separate page

SKETCH

Figure 3.3 A solved example on reinforced concrete building by FEMA P-154 (1988) data collection form

Table 3.4 Basic score, modifiers, and final level 1 score, S_{L1} used for RC buildings

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{l1}

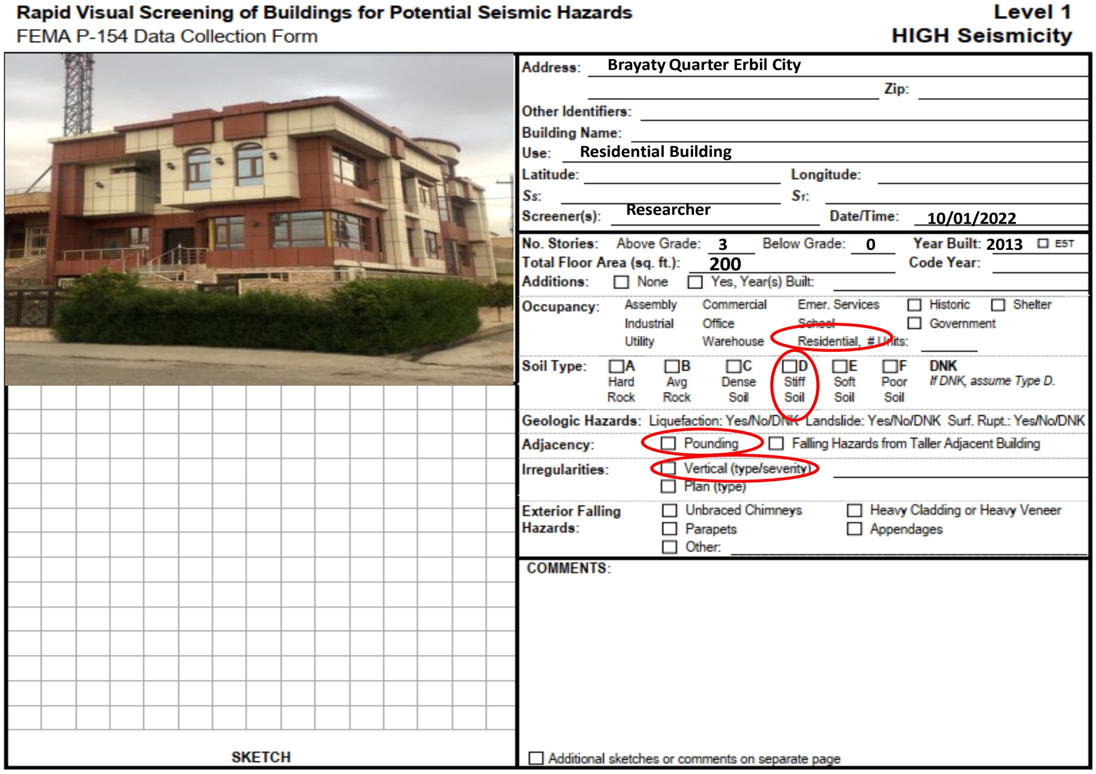
FEMA BUILDING TYPE	W1	W1 A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM NF)	C1 (MRF)	C2 (SW)	C3 (URM NF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (FD)	URM	MH
Basic Score	3.6	3.2	2.9	2.1	2.0	2.6	2.0	1.7	1.5	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical irregularirt, V_{l1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-0.1	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical irregularity, V_{l1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{l1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil type E (1-3 Stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil type E (>3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minnimum Score, S_{MIN}	1.1	0.9	0.7	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0
FINAL LEVEL 1 SCORE, $S_{l1} \geq S_{MIN}$																	

S_{min}Minimum score for the reinforced concrete building (C3) is 0.3 and Basic score is 1.2

S_{L1}= 1.2-0.7= 0.5 >0.3 S_{min} (minimum score) the building is safe

S_{min}Minimum score

S_{L1}Final level 1 score



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: Brayaty Quarter Erbil City
Zip:
Other Identifiers:
Building Name:
Use: Residential Building
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): Researcher **Date/Time:** 10/01/2022

No. Stories: Above Grade: 3 Below Grade: 0 **Year Built:** 2013 ☐ EST
Total Floor Area (sq. ft.): 200 **Code Year:**
Additions: ☐ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse [✓ Residential, # Units:]

Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil [✓ ☐D Stiff Soil] ☐E Soft Soil ☐F Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: [✓ ☐ Pounding] ☐ Falling Hazards from Taller Adjacent Building

Irregularities: [✓ ☐ Vertical (type/severity)]
☐ Plan (type)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

☐ Additional sketches or comments on separate page

SKETCH

Figure 3.4 Data collection form according to FEMA P-154 (1988)

Table 3.5 Basic score, modifiers, and final level 1 score, S_{L1} used for masonry buildings

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{l1}																	
FEMA BUILDING TYPE	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM NF)	C1 (MRF)	C2 (SW)	C3 (URM NF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (FD)	URM	MH
Basic Score	3.6	3.2	2.9	2.1	2.0	2.6	2.0	1.7	1.5	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical irregularirt, V_{l1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-0.1	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical irregularity, V_{l1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{l1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil type E (1-3 Stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil type E (>3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minnimum Score, S_{MIN}	1.1	0.9	0.7	0.5	0.5	0.6	0.5	0.5	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	1.0
FINAL LEVEL 1 SCORE, $S_{l1} \geq S_{MIN}$																	

S_{min}Minimum score for the masonry building (URM) is 0.2 and Basic score is 1.0

S_{L1}= 1.0-0.7= 0.3 =0.3S_{min} (minimum score) the building maybe safe

S_{min}Minimum score

S_{L1}Final level 1 score

Figure 3.5 Sample of reinforced concrete building in Brayaty Quarter, solving by (Sucoğlu and Yazgan, 2003) method

Table 3.6 Level 1 Method table for RC building (Sucoğlu and Yazgan, 2003)

Story #	Zones			Soft Story	Heavy overhangs	Apparent Quality	Short column	Pounding	Topographic Effect
	I	II	III						
1,2	90	125	160	0	-5	-5	-5	0	0
3	90	125	160	-10	-10	-10	-5	-2	0
4	80	100	130	-15	-10	-10	-5	-3	-2
5	80	90	115	-15	-15	-15	-5	-3	-2
6,7	70	80	95	-20	-15	-15	-5	-3	-2

Basic score

ZONE I has been chosen because Erbil City is located in High seismicity zone Number of storey for the reinforced concrete building in figure 3-5 is 6 storeys The building has soft storey

Heavy overhang also seen in the building

The quality of building is moderate

Short column is exist because of the unbraced cripple wall in the basement

Pounding effect is exist because the building is end building

No topographic effect

Minimum score=50

Vulnerability Score = Basic Score + Σ PMF*V

Vulnerability Score = 70+(-20*1-15*1-5*1-3*1)=27<50 the building is high risky

4. SEISMIC ASSESSMENT OF EXISTING BUILDINGS ACCORDING TO STREET-WALK METHOD

4.1 General Background

Rapid street screening is a quick and efficient way to check for potential seismic hazards. The process is used to identify, list, and rank the buildings in a given location that are most likely to sustain damage from an impending earthquake. The used methodology is based on observations and assigning scores for the chosen buildings while taking into account a few particular street walking factors. (FEMA P-154, 1988, Sucoğlu and Yazgan, 2003) are implemented to assess the seismic performance of the existing buildings in Brayaty Quarter in Erbil City. In addition, to achieve the assessment, a number of factors are taken into account. These factors comprise tectonic setting of Iraq, faults in Iraq, seismic zone of Erbil City and the negative parameters identified by the two methods mentioned above.

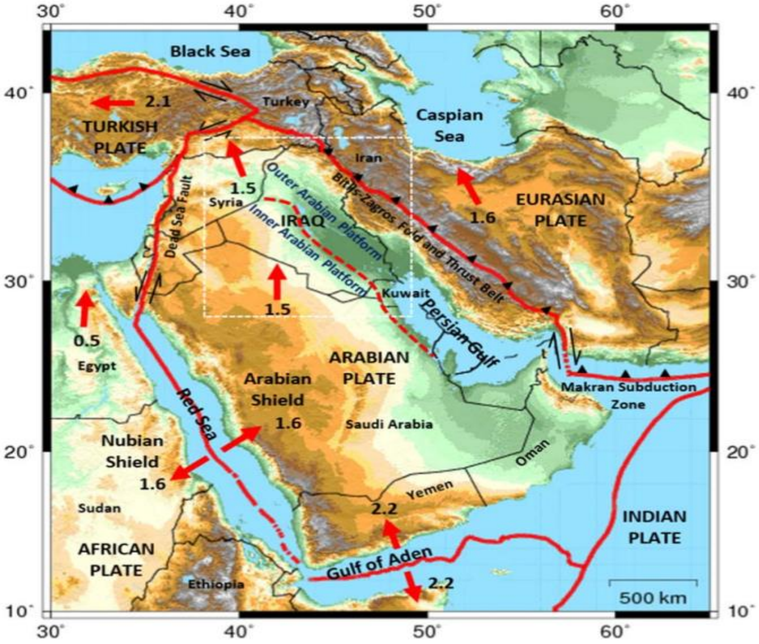


Figure 4.1 Tectonic setting of Iraq and environs (red arrows indicate plate motions in cm/year)

4.1.1 Tectonic Setting of Iraq and Environs

Iraq is located in the northwestern region of the Arabian Plate, close to the convergent tectonic boundary between the Eurasian and Arabian plates, as depicted in Figure 4-1. The Bitlis-Zagros Fold and Thrust Belt in northern and eastern Iraq produces strong earthquake activity; the rest of Iraq, which is primarily on the Arabian Platform and far from major plate boundaries, experiences less seismic activity. (Abdulnaby et al., 2020)

4.1.2 Seismic Zone

Although the terms "seismic zone" and "seismic hazard zone" are frequently used interchangeably, they actually refer to two distinct concepts. A location where earthquakes frequently occur is referred to as a seismic zone, like the New Madrid Seismic Zone in the Central United States. A region having a certain degree of earthquake risk is referred to as a seismic hazard zone. In general, a lower seismic hazard zone is located further away from a seismic zone and a high seismic hazard zone is closest to one where there are more earthquakes. (USGS, science for a changing world, N.D.)

4.1.3 Seismic Hazard Zone of Iraq

According to World Health Organization (WHO) (N.D.) Iraq is divided to five seismic hazard zones. As in figure 4-2 below, these zones range from lowest seismic hazard zone to highest seismic hazard zone with Peak Ground Acceleration (PGA, m/s^2) values as follows:

1) Very low seismic hazard zone with PGA (0-0.2)
2) Low seismic hazard zone with PGA (0.2-0.8)
3) Medium seismic hazard zone with PGA (0.8-2.4)
4) High seismic hazard zone with PGA (2.4-4)
5) Very high seismic hazard zone with PGA (>4)

Also, according to the Figure 3-2 below, the area surveyed in Erbil city is located within high seismic hazard zone with PGA (2.4-4).

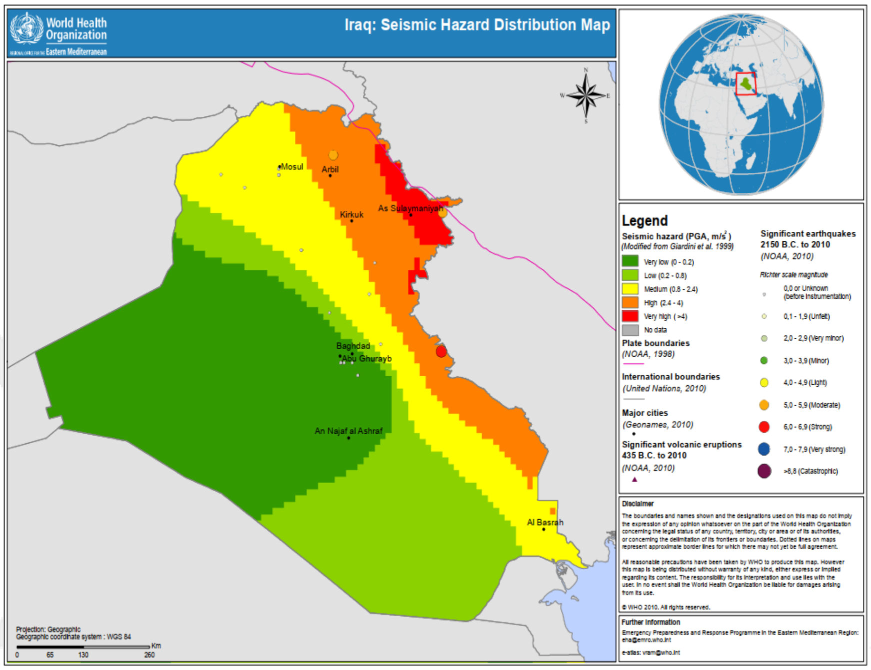


Figure 4.2 Iraq: seismic hazard distribution map

4.1.4 Faults Location in Iraq

Erbil city is usually under the influence of the possibility of the Zagros Fold-Thrust Belt. In addition, there are also extensional activities taking place along faults. Figure 4-3shows some clear examples of these faults near the City of Erbil, the studied area. These examples include Kirkuk fault (system of NW-SE Najd), Hadhar-Bekhme, and Anah-QalatDizeh fault (system of NE-SW/E-W Transverse), and (system of N-S Nabitah) (Jassim and Goff, 2006; Abdul Jaleel and Taha, 2019), the common stress pattern defined by strike-slip (normal) faulting (Abdulnaby et al., 2014a; Abdul Jaleel and Taha, 2019).

4.1.5 Earthquakes in Iraq

Based Since 1900, Erbil has experienced 15 earthquakes with a magnitude of 5.0 or higher and 171 earthquakes between 4.0 and 5.0, according to data from Volcano Discovery. According to Ministry of Transportation and Communication-General Directorate of Meteorology and Seismology -Erbil, the following tables illustrate seismic data on earthquakes occurred in Iraq in the years 2019, 2020 and 2021. The data obtained are about location, latitude, longitude, date, time of earthquake and earthquake magnitude according to Richter scale.

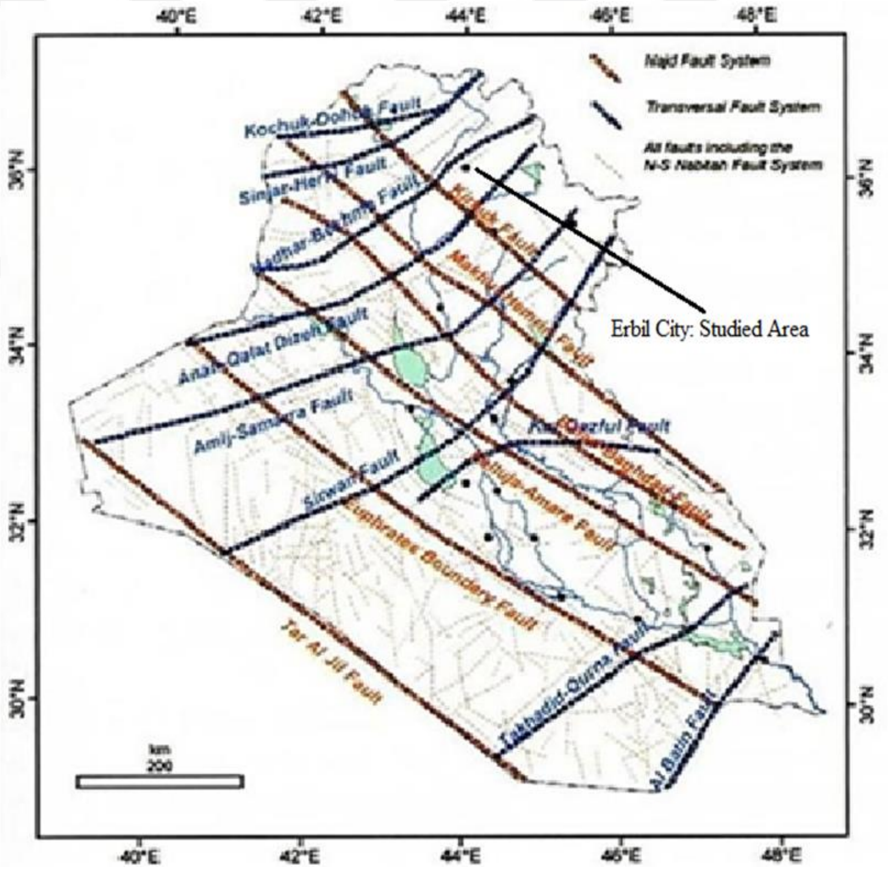


Figure 4.3 Faults location in Iraq (Jassim and Goff, 2006)

Table 4.1 Earthquakes in Iraq in 2019

No.	Date	Time of earthquake	Earthquake magnitude according to Richter scale	Latitude	Longitude	location
1	1/1/2019	12:37:22	3.5	33.8129	46.688	Iraq-Iran border
2	1/1/2019	13:14:01	3.4	33.3071	46.196	Southeast of Khanaqin
3	4/1/2019	22:01:16	3.8	34.2138	45.924	27 km to the east of Kalar
4	6/1/2019	13:55:08	4	42.2600	45.7000	South of khanaqin
5	6/1/2019	15:38:4	3.3	33.9026	45.901	Iraq-Baaquba(Dyala) near Dhulu'iyya
6	6/1/2019	16:40:02	3.3	34.4286	45.3500	Kalar-Kareem village
7	7/1/2019	19:31:10	3.3	33.9644	45.809	Northeast of Kalar
8	8/1/2019	11:31:43	3.5	34.2687	45.35	Northeast of Khanaqin
9	8/1/2019	19:58:10	3.4	33.9996	45.795	Iraq-near Mandali
10	8/1/2019	20:00:39	3.5	33.8435	45.4140	West of Hamrin lake
11	9/1/2019	2:26:36	3.5	34.1105	45.897	South of Khanaqin
12	8:57:56	3.3	36.1732	43.789	Erbil Kaniqrzhala	

Table 4.2 Earthquakes in Iraq in 2020

No.	Date	Time of earthquake	Earthquake magnitude according to Richter scale	Latitude	Longitude	Location
1	5/12/2020	23:45:29	2.4	35.9583	44.199	Erbil Azyan
2	5/12/2020	23:45:29	2.4	35.9583	44.199	Erbil-Azyan
3	8/12/2020	20:50:18	3.3	35.0485	45.9198	Halabja-Grna
4	11/12/2020	22:50:43	2.2	36.1752	44.5041	Erbil-Koya- Sektan
5	12/12/2020	6:30:50	2.3	36.3476	44.5164	Erbil-Shaqlawa-Balisan
6	17/12/2020	0:00:59	2.3	36.5662	44.8468	Erbil-Choman-Galala
7	18/12/2020	14:48:54	3.2	35.8848	44.0773	Erbil-Koya-Grdlanga village
8	27/12/2020	17:43:52	2.4	35.8907	44.1975	Erbil-Qushtapa
9	30/12/2020	4:13:40	3.1	35.9578	44.3175	Erbil-Koya

Table 4.3 Earthquakes in Iraq in 2021

No.	Date	Time of earthquake	Earthquake magnitude according to Richter scale	Latitude	Longitude	Location
1	2/12/2021	16:47:48	2	35.7264	44.9067	Chamchamal-Mutlija
2	2/12/2021	17:26:24	2.8	35.6856	44.8968	Chamchamal-Shexwais
3	2/12/2021	18:06:32	3.5	35.7038	44.9054	Chamchamal-Mutlija
4	2/12/2021	21:20:40	2.2	35.7107	44.9101	Chamchamal-Mutlija
5	3/12/2021	1:24:52	2.3	36.5734	44.925	Erbil- Choman
6	10/12/2021	18:28:38	2.2	36.2729	44.4779	Erbil-Shaqlawa Hiran
7	13/12/2021	21:18:24	2.7	35.9545	44.1231	Gumagdri-Erbil

4.2 Parameters for Assessing Seismic Performance of Existing Buildings in Brayaty Quarter in Erbil city

Two categories of parameters are used in the assessment of vulnerability of the aforementioned buildings. These categories are (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003) parameters.

4.2.1 FEMA P-154 (1988) Parameters

These parameters are:

1. Number of Storey

This criterion deals with measuring number of storeys above and below grades. Above grade indicates that the portion of a building is above the ground, while below grade refers to the portion of a building below the ground. Figure 4-4 is an example the building has four storeys above grade and one storey below grade in Brayaty Quarter in Erbil City.

Figure 4.4 Four storey building example in Brayaty Quarter in Erbil City

2.Vertical Irregularity on Slopping Site

The building's slope is more than one storey from one side to the other. It is evaluated as severe irregularity for W1(Light wood frame single- or multiple-family dwelling) buildings as shown below in Figure 4-5 (a); for all other building types, it is rated as moderate, as indicated below. In Figure 4-5 (b).

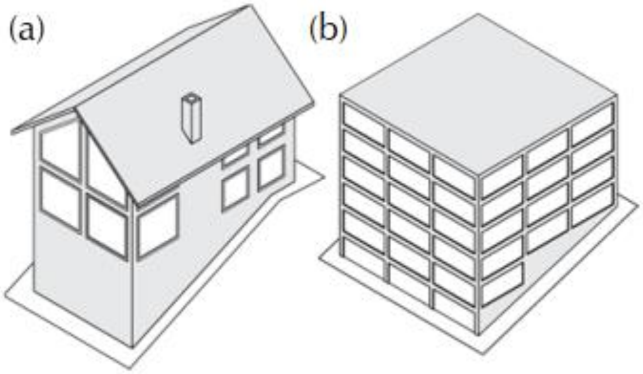


Figure 4.5 Vertical Irregularity

3. Sever Vertical Irregularity

a) Weak or/ Soft Storey:

Figure 4.6 (a) shows an example of a W1house with a garage with an occupied space above it and short or low walls on either side of the garage entry. For a W1A (light wood frame multi-story residential buildings with plan area on each floor of greater than 3,000 square feet), building with an open front at the ground storey, (such as for parking), see Figure 4-6 (b) and Figure 4-6 (c), when one story has fewer columns or walls than the others (usually the bottom story). Figure 4-6 (d) illustrates that one story is taller than the rest (usually the bottom story). (FEMA P-154, 2015)

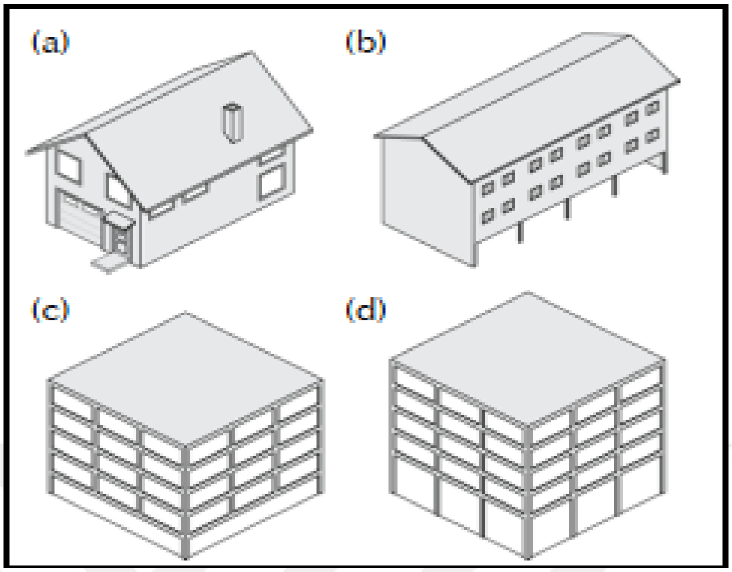


Figure 4.6 Sever vertical irregularity weak/ soft storey

b) Out-of-Plane Setback

"If the walls of the building do not setback stack vertically in plan. This irregularity is most severe when the vertical elements of the lateral system at the upper levels are outboard of those at the lower levels as shown in Figure 4-7 (a). The condition in Figure 4-7(b) also triggers this irregularity. If nonstacking walls are known to be nonstructural this irregularity does not apply (FEMA P-154, 2015).

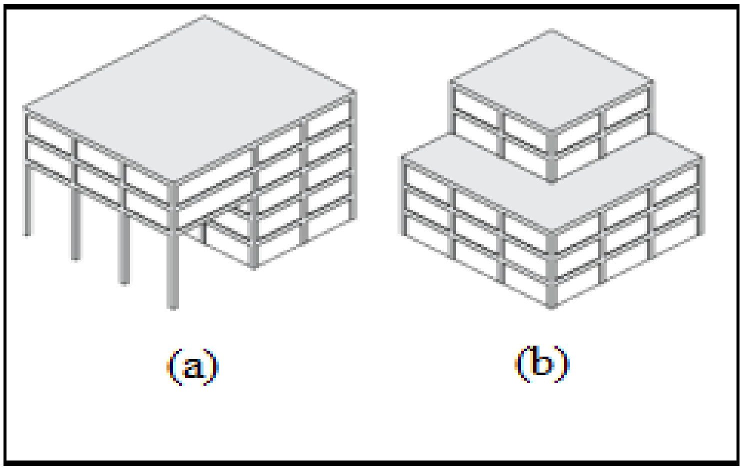


Figure 4.7 Sever vertical irregularity out-of-plane setback

c) Short column

Figure 4.8 (a) shows that some columns in a same are substantially shorter than the average columns. Figure 4-8 (b) explains that compared to the depth of the beams, the columns are narrow. Figure 4-8 (c) indicates infill walls that shorten the column's clear height.

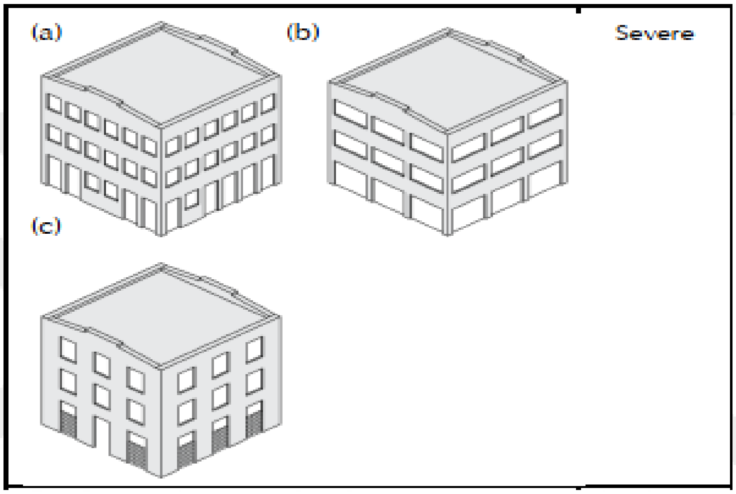


Figure 4.8 Sever vertical irregularity short column

4. Moderate vertical irregularity

a) Unbraced Cripple Wall

In the building's crawlspace, unbraced cripple walls may be seen, see Figure 4-9. This applied to W1buildings. If the basement is occupied, this situation must be considered as a soft story.

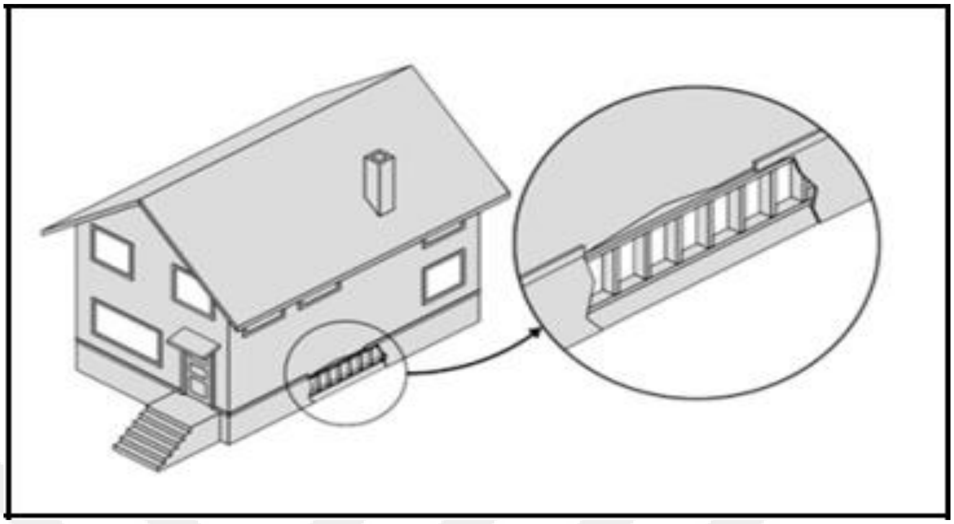


Figure 4.9 Unbraced cripple wall

Figure 4.10 Unbraced cripple wall in the building in Brayaty Quarter in Erbil City

b) In-Plane-Setback

There is moderate severity if the lateral system has an in-plane offset. This is typically visible in braced frame as shown in Figure 4-11 (a), and Figure 4-11 (b) shows shear wall structures. (FEMA P-154, 2015).

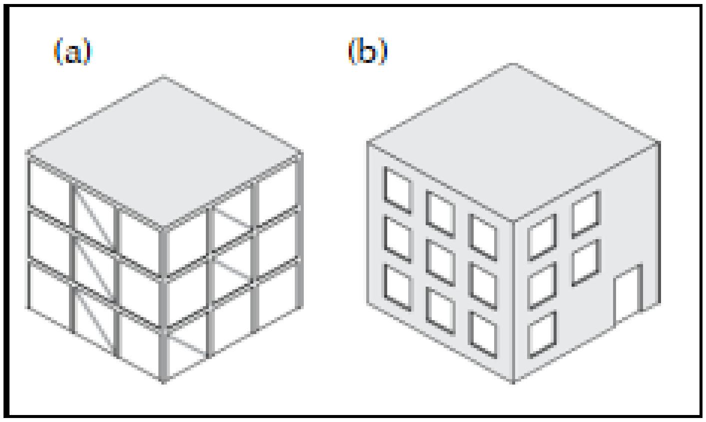


Figure 4.11 In-plane-set back

c) Split levels

Split levels are buildings where the floors are not parallel or have a stepin the roof level. Another definition is that a building has a room or rooms higher than others by less than a whole storey as in Figure 4-12.

Figure 4.12 The two red lines illustrate split level in a building in Brayaty Quarter in Erbil City

5. Plan irregularity

a) Torsion

The existence of eccentric stiffness in the plan is known as torsion as in Figures 4-13(a) and (b) in which the buildings have walls with a lot of openings on one side and solid walls on two or three sides, which is known as torsion, which is when in one direction, there is good lateral resistance, but not in the other.

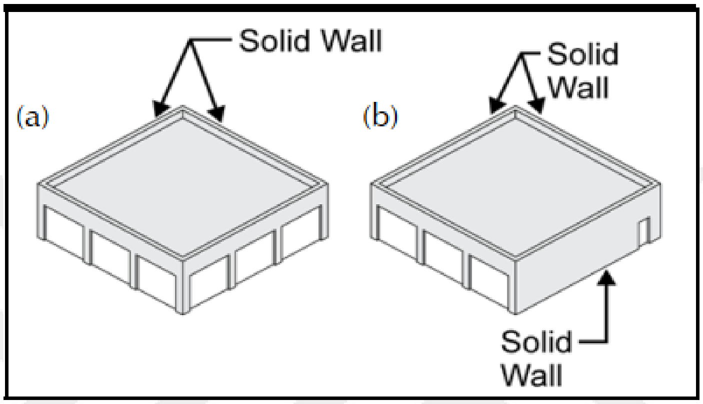


Figure 4.13 Torsion

b) Non-Parallel system

This criterion can be defined as the building's sides don't meet at 90 degrees as in the figures 4-14. and 4-15.

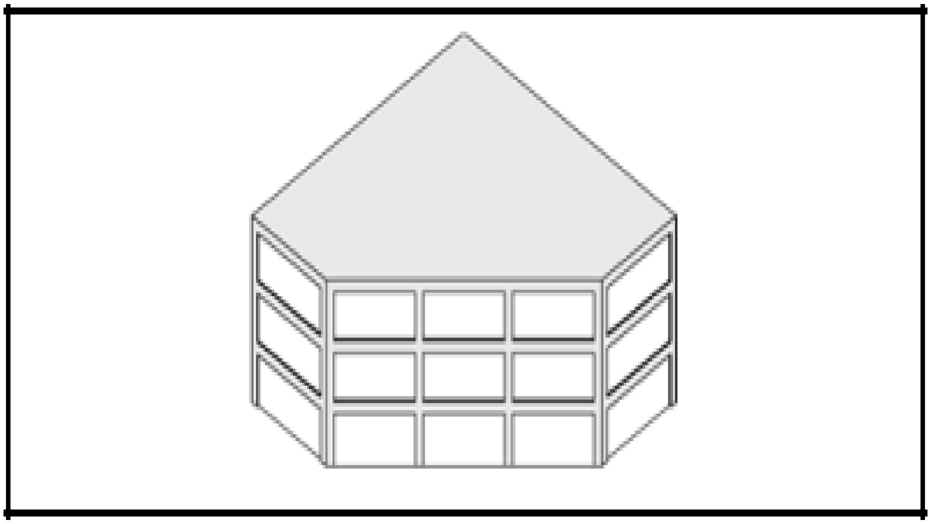


Figure 4.14 Non-parallel system

Figure 4.15 The front of the building and the side on the right do not form 90-degree angles in Brayaty Quarter in Erbil City

c) Reentrant corner

A reentrant corner refers to the structure has projections of more than 20 feet and is L, U, T, or + shaped. Check to determine if there are any seismic separations where the wings connect, if at all possible. In that case, check for pounding. The Figure 4-16 below shows that reentrant corners with the L, U, T shapes.

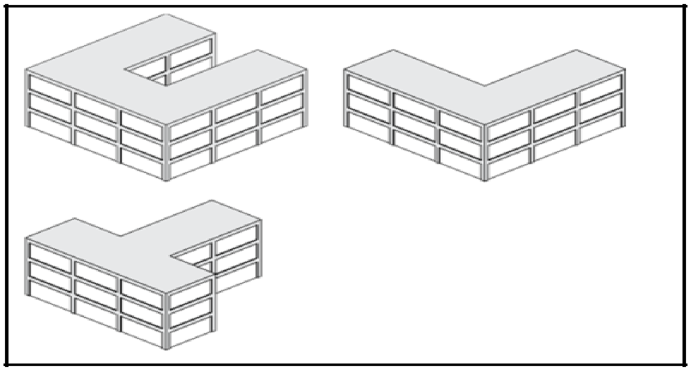


Figure 4.16 Reentrant corner, L, U, T shaped buildings

d) Diaphragm opening

At any level, there is an opening with a width greater than half the diaphragm's width as shown in Figure 4-17 below.

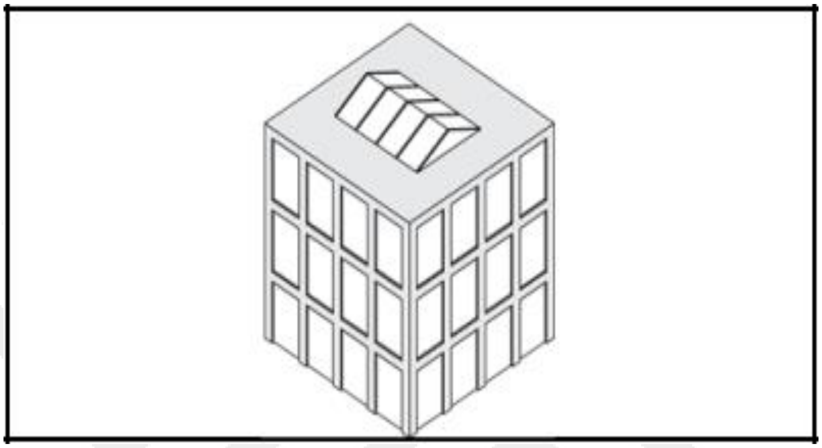


Figure 4.17 Diaphragm opening

e) Beam do not align with column

The outside beams and columns are not lined up in the plan. This criterion typically holds true for concrete structures where the perimeter columns are located outboard of the perimeter beams. The perimeter columns are outside of the beam perimeters, as shown in Figure 4-18.

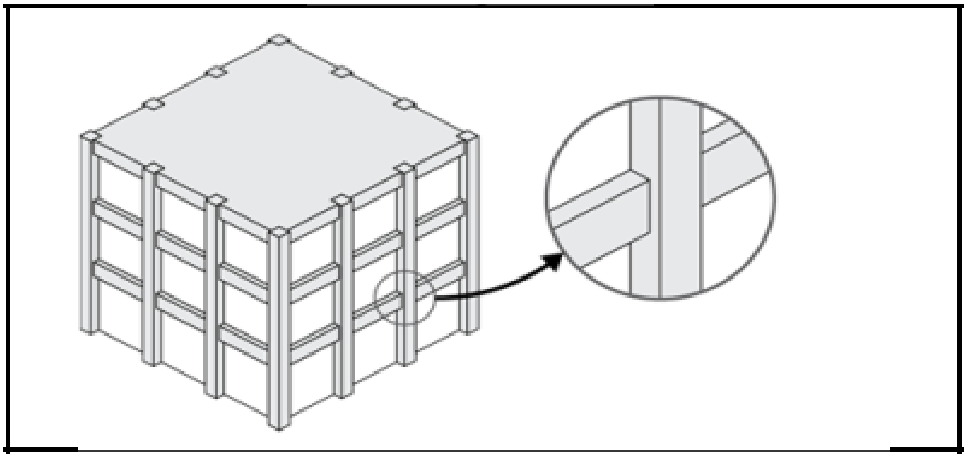


Figure 4.18 Beam do not align with column

6. Pre-Code

"Buildings designed prior to year in which the seismic codes were adopted and implemented in the relevant jurisdiction. It is noteworthy that pre-code years are not applicable in regions with low seismicity" (FEMA P-154, 2015).

7. Post-Bench Mark

Post-Bench mark can be defined as "building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction."(FEMA P-154, 2015)

8. Soil Type

In terms of seismic performance soil can be classified in to six categories, namely, soil type (A)is a hard rock, soil type (B) defined as average rock, soil type (C) is dense soil, soil type (D) is stiff soil, soil type (E) is soft soil and soil type (F) defined as poor soil, if the soil type is unknown assume soil type D.

4.2.2 Sucoğlu and Yazgan (2003) Parameters

In Sucoğlu and Yazgan, parameters are chosen to indicate building vulnerability (2003) Walk-Down procedure- level 1. Each parameter, on a variable scale, reflects a negative feature of the building system under seismic excitations. The selected parameters include the following:

1. The number of stories above the ground (one to seven)

The number of stories and the severity of building damage are significantly correlated, according to field measurements made following the 1999 Kocaeli and Düzce earthquakes. Such a distribution would not occur if all buildings complied with contemporary seismic design rules, and a uniform distribution of damage would be anticipated. Seismic forces increase linearly with the increasing of number of storeys, however the seismic resistances do not follow in acceptable proportions if the majority of the buildings in the quake area lack this fundamental quality. As a result, damage grows roughly linearly stories are added. Based on the number of stories, the damage distribution for each of the 9685 buildings in Düzce following the two quakes in 1999 is computed. The results are shown in Figure 4-19 below, which normalizes the number of damaged buildings to the total number of structures at a given story level. Damage grades shift linearly with the number of stories, as in Figure 4-19 The percentage of undamaged and lightly damaged buildings declines continuously as the number of stories rises, but the ratio of moderately and severely damaged structures rises in the opposite direction. This shows clearly that the number of stories is an important factor-possibly the most important one-in determining how seismically vulnerable Turkish multistory concrete buildings are (Sucoğlu and Yazgan, N.D.).

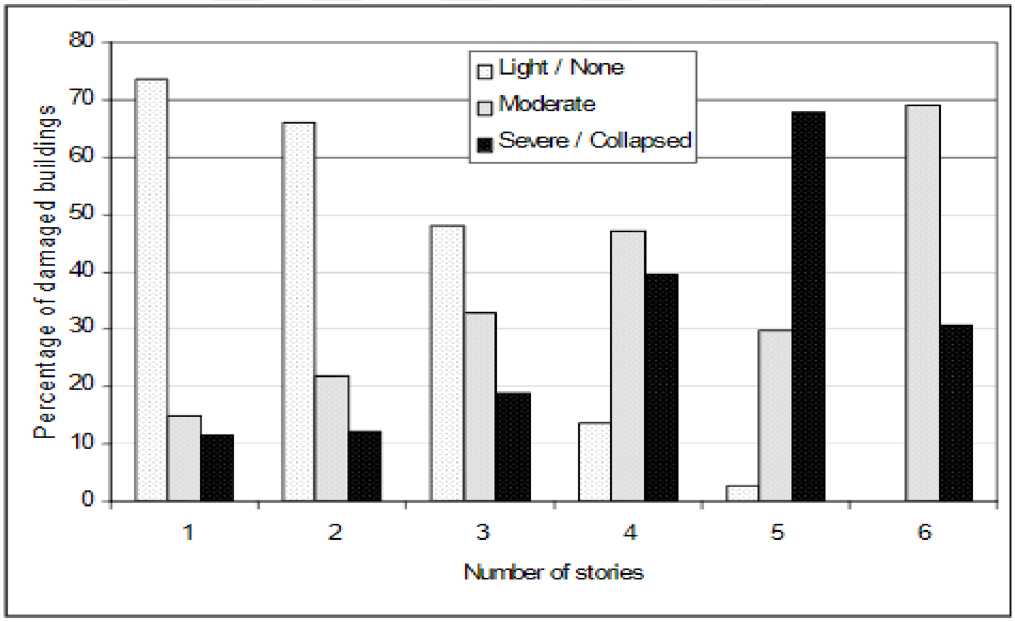


Figure 4.19 Percentage of damaged buildings in Düzce after the 1999 earthquakes, with respect to the number of stories (Sucoğlu and Yazgan, N.D.)

2. Soft Storey

When the ground floor of a building is less stiff and strength compared to the upper stories, it is said to have a soft story. This problem typically occurs in buildings that are situated alongside a main street. While the higher stories are occupied by homes, the bottom storeys, which have level access from the street, are used as a storefront or other commercial space. The commercial space at the bottom is mainly left open between the frame elements, allowing for customer mobility, while these top stories benefit from the increased rigidity and strength that many partition walls provide. Additionally, the ground stories may have irregularity due to taller clearances and a different axis system. From the standpoint of earthquake engineering, the cumulative effect of all these negative parameters is referred to as a soft story. During previous earthquakes around the world, it was observed that many structures with soft stories collapsed as a result of a soft story that had pancaked. (Sucoğlu and Yazgan, N.D.). Figure 4-20 is an example of soft storey:

Figure 4.20 Illustrates presence of a soft storey in the building in Brayaty Quarter in Erbil City

In the figure 4-20 the ground floor is considered as a soft storey. This is because the height of the ground floor is less than the height of the upper floors. Besides, in the ground storey there is commercial space left open between the frame elements, while the upper stories are residential units which have more partitions and less space between the partitions. These weaknesses result in increasing the vulnerability of the ground floor which in turn, decreases the seismic performance of the building.

3. Heavy overhangs

In multistory reinforced concrete buildings, heavy balconies and overhanging levels shift the mass center upward, increasing seismic lateral stresses and overturning moments during earthquakes. In comparison to conventional structures in elevation, buildings with balconies with enormous overhanging cantilever spans encased with massive concrete parapets suffered greater damages during the recent earthquakes in Turkey. This building feature is included in the parameter set because it is simple to see during a walk-down survey. (Sucoğlu and Yazgan, N.D.) Figure 4-21 indicates presence of heavy overhang in a building in Brayaty Quarter in Erbil city.

Figure 4.21 Shows presence of heavy overhang

This building consists of a ground floor and eight overhanging floors. Overhanging levels shift the mass center upward, increasing seismic lateral stresses and overturning moments during earthquakes. This negative feature might increase the possibility of damage of buildings during earthquakes.

4. Apparent building quality (Good, Moderate or Poor)

The apparent quality of a structure is reflected in the quality of the materials and workmanship as well as the attention paid to its maintenance. A well-trained observer can roughly classify a building's apparent quality as good, moderate, or poor. During the recent earthquakes in Turkey, a strong correlation between the visible quality and the actual damage was seen. One can anticipate that a building with poor apparent quality will have weak material strengths and insufficient detailing. (Sucoğlu and Yazgan, N.D.) Figure (4-22) below illustrates three types of apparent building quality.

Good quality Moderate quality Poor quality

Figure 4.22 Shows three types of apparent building quality inBrayaty Quarter in Erbil City

5. Presence of short columns

Short columns are found in structures built on slopes, and some RC frame columns may be significantly less in height than other columns in the same story. When there are different height columns inside a one story of RC frame buildings, the shorter columns typically suffer more damage than the taller columns. Short columns are stiffer and need more force to bend by the same amount as higher, more flexible columns. The short columns typically sustain significant damage as a result of this increased force (Murty et al., 2006).

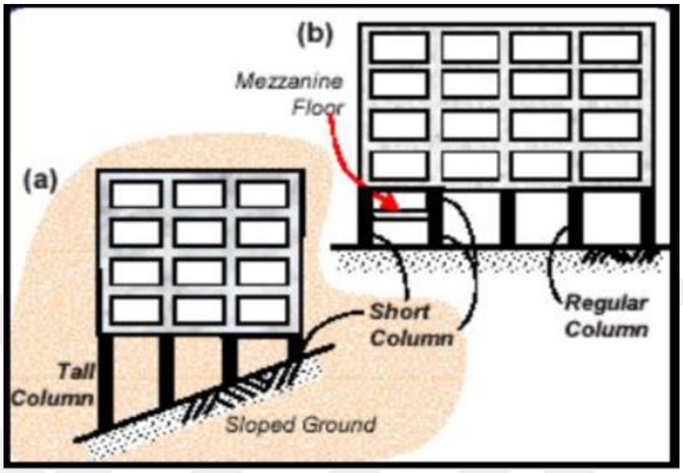


Figure 4.23 Examples of common building types with short columns (Murty, 2005)

The Figure 4-23 shows two different types of short columns. The figure on the left represents a structure built on a slope site in which the column on the right is the short column. In the figure on the right the four short columns are on the left and there are different height columns inside a one story of RC frame building.

Figure 4.24 Presence of short column in Brayaty Quarter in Erbil City

In the figure above, upper parts of the front columns of the basement are above the ground level for an opening. This opening is called unbraced cripple wall. The upperparts of these columns in the unbraced cripple wall are short columns. Therefore, these short columns are the weakest columns in the building. This in turn could increase the seismic vulnerability of the building and decreases its seismic performance.

6. Pounding between adjacent buildings

In pounding, two buildings strike due to their lateral movement caused by lateral forces (Raheem, 2013, as cited in Noman et al., 2016). It can also be defined as seismic pounding refers to the quake-related collision of nearby structures (Khatiwada and Butterworth, 2011, as cited in Noman et al., 2016). Due to the various dynamic characteristics of adjacent buildings, which cause their out of phase vibration during earthquakes, pounding of adjacent buildings can be extremely dangerous. Damage as a result of inadequate energy dissipation systems or gaps that are too small to account for the relative motion of these buildings. (Noman et al., 2016) Figure 4-25and Figure 4-26are respectively examples of pounding end building and pounding where one building rises above the other by two or more stories in Brayaty Quarter in Erbil City. Figure 4-27an example of pounding damage observed in Christchurch CBD, 2011.

Figure 4.25 Pounding end building

Figure 4.26 Pounding one building is two or more stories taller than the other

Figure 4.27 Pounding damage observed in Christchurch CBD, 2011 (Noman et al., 2016)

7. Local soil conditions (Stiff or Soft)

One of the main elements that makes ground motions more intense is site amplification. Even though it can be difficult to get precise data during a street survey, an expert observer can distinguish between the stiff and soft soils in the area. For identifying the local soil conditions in urban settings, local authorities' geotechnical information is a reliable source. (Sucoğlu and Yazgan, 2003)

8. Topographic effects

Topographic amplification is another factor that could amplify the ground motion on top of hills. Furthermore, buildings constructed on steep slopes (steeper than 30 degrees) typically have stopped foundations, which are unable to evenly distribute ground distortions to structural members above. Therefore, these two characteristics must be taken into account while assessing seismic risk. Both factors can be easily observed during a street survey. (Sucoğlu and Yazgan, 2003)

Figure 4.28 Building a house on a sloped land

5. RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the results of the analysis of the data on Brayaty Quarter buildings in Erbil City collected through a rapid visual screening. The first part of this chapter shows the number and percentage of reinforced concrete buildings, mix and masonry buildings. The second part demonstrates the results obtained from the evaluation ofthe buildings in terms of negative parameters based on (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003) methods. These parameters include number of storey, vertical irregularity, soft storey, short column, unbraced cripple wall, in-plane-setback, split level, plan irregularity, torsion, non-parallel system, reentrant corner, diaphragm opening, beam do not align with column, pre-code, post-benchmark, soil type, heavy overhang, apparent building quality, pounding, topographic effect, wall opening and wall opening type. The third component presents whether the buildings surveyed are safe or unsafe according to (FEMA P-154, 1988) method. The fourth part shows the buildings' extent of being risky according to (Sucoğlu and Yazgan, 2003) method.

5.2 Distribution of 867Reinforced Concrete and Masonry Buildings in Brayaty Quarter in Erbil City

Total building stock in Brayaty Quarter is 867 units, with 681 masonry buildings and 186 reinforced concrete buildings as shown in the figure below. The percentage of masonry buildings is 78.55% and that of reinforced concrete buildings is 21.45%

5.3 Evaluation of Negative Parameter Values of Concrete and Masonry Buildings

The negative parameter values used to assess seismic performance of structures mentioned previously in Chapter4.1. highlight the seismic vulnerability of the target buildings. Based on the assessment of the buildings, most buildings showed lack of negative aspects of vulnerability, while a less number of buildings indicated that these negative parameters were applied to them. This analysis indicates that the number of the buildings classified as safe is much more than the buildings classified as unsafe according to both methods, (FEMA P-154 (1988; Sucoğlu and Yazgan, 2003).

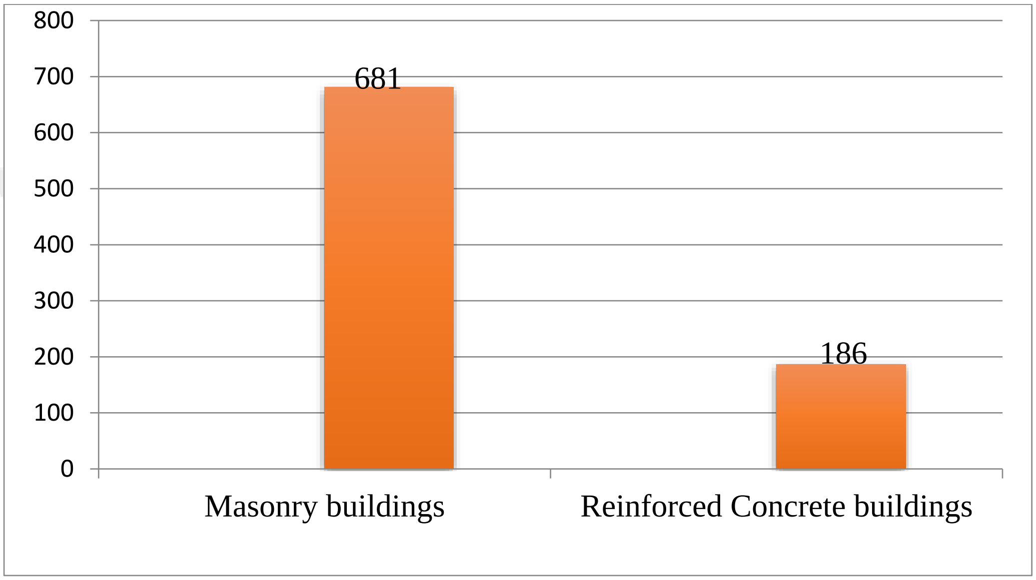


Figure 5.1 Distribution of structural systems of 867 buildings in Brayaty Quarter in Erbil City

5.3.1 Evaluation of Number of Storeys of Reinforced and Masonry Buildings

Figure 5.2 below demonstrates that the analysis of the data on one storey buildings and more than one storey buildings and percentage of each category are shown in the Table 5.1.

Table 5.1 Percentage of each category of buildings with regard to number of storey

Number of storey	Number of buildings	Percentage of buildings %
1	134	15.45%
2	566	65.28%
3	82	9.45
4	33	3.80%
5	27	3.11%
6	16	1.84%
7	4	0.46%
8	1	0.11%
9	2	0.23%
10	2	0.23%

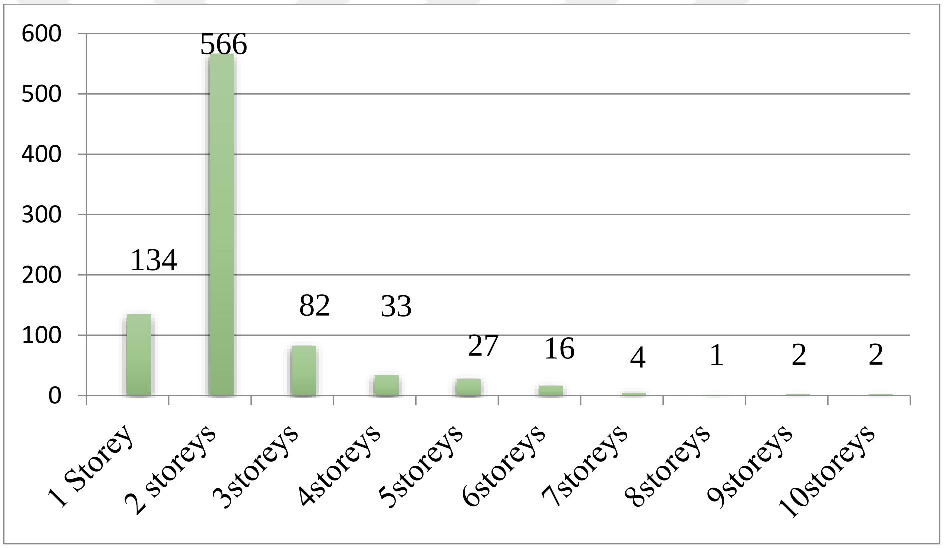


Figure 5.2 Number of storeys of 867 buildings in Brayaty Quarter

5.3.2 Evaluation of Soft Storey of Reinforced and Masonry Buildings

As mentioned in 4.2.1. and 4.2.2, soft storey or weak storey is the weakest floor in a building with more than one storey. Soft storey are seen in reinforced concrete buildings built in commercial areas and are also used as shops on the ground floor and apartments on the upper floors. Shops and workplaces are higher than other upper floors. The buildings with soft storey are 184 in number which constitute 21.22% of total buildings, while the number of buildings without soft storey is 683 which represents78.77% as in Figure 5-3 below.

Figure 5.3 Number of buildings with soft storey and buildings without soft storey in the target area

5.3.3 Evaluation of Heavy Overhang of Reinforced and Masonry Buildings

As mentioned in 4.2.2., in multistory reinforced concrete buildings, heavy balconies and overhanging levels shift the mass center upward, increasing seismic lateral stresses and overturning moments during earthquakes. The increase in the use of the building on the upper storeys increases the demand of existing overhang. The number of the building with overhang is 100 and that of without overhang is 767 which respectively represent 11.53% and88.47% of total buildings as shown in Figure 5-4.

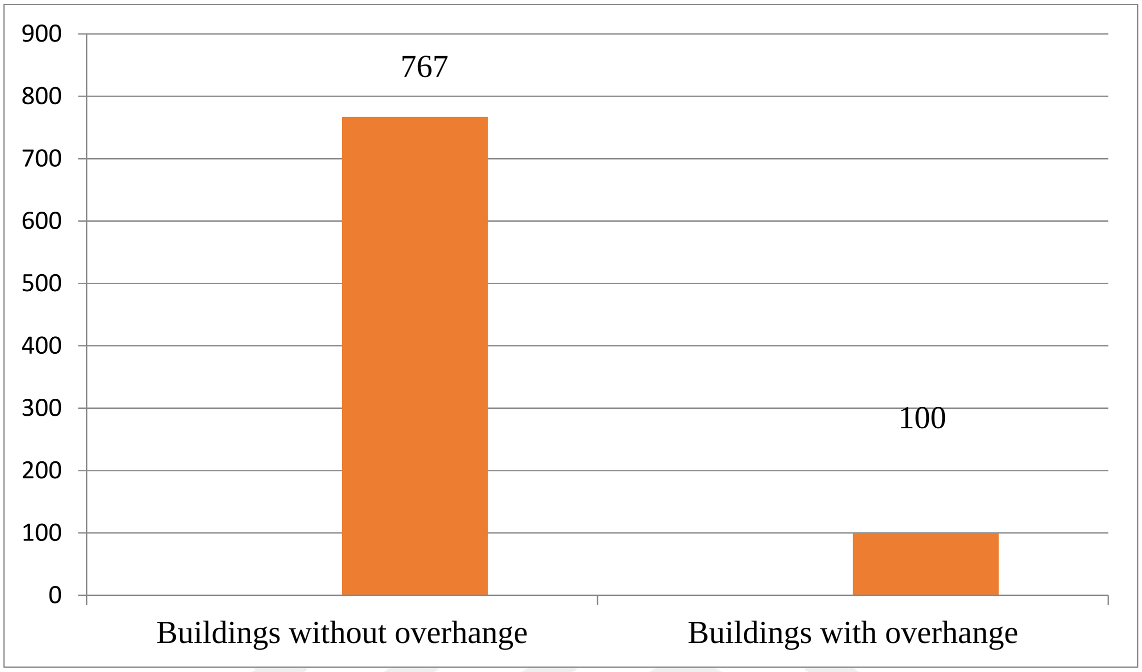


Figure 5.4 Distribution of buildings with overhang and without overhang

5.3.4 Evaluation of Quality of Reinforced and Masonry Buildings

The aforementioned definition of the quality of a structure is that it is reflected in the quality of the materials and workmanship as well as the attention paid to its maintenance. A building's apparent quality can be classified as good, moderate, or poor. According to Figure 5-5, 559 buildings are of good quality, 234 buildings are in moderate quality and 74 buildings are of poor quality and their percentages are 64.47%, 26.98% and 8.5% respectively.

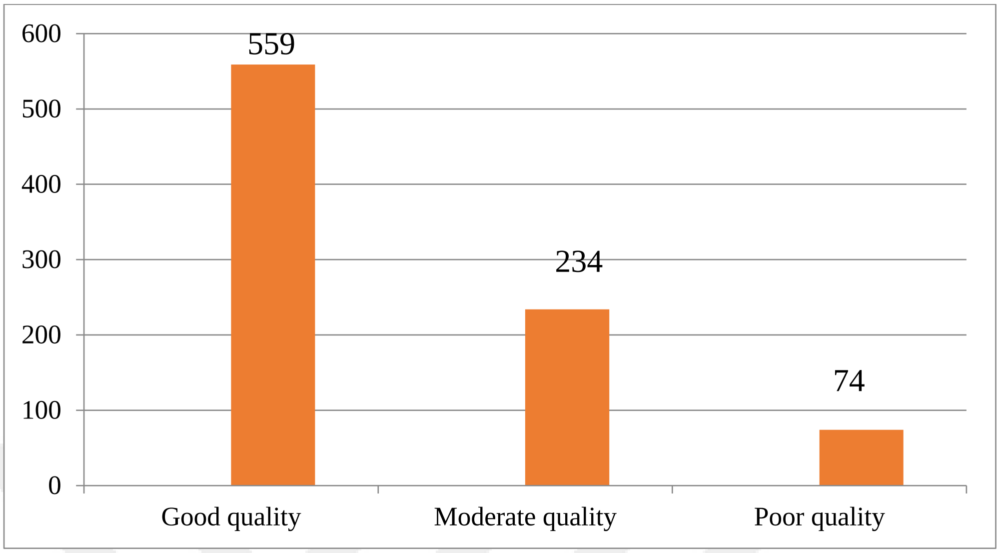


Figure 5.5 Number of buildings in good, moderate and poor quality

5.3.5 Evaluation of Pounding of Buildings

As mentioned previously**,** the pounding effect occurs intensely in adjacent buildings and the possibility of pounding also increases in end buildings. 305 of the buildings represent pounding and 562of them are without pounding in the target area. That is, (35.17%) of them have pounding and (64.82%) are without it as shown in Figure 5-6.

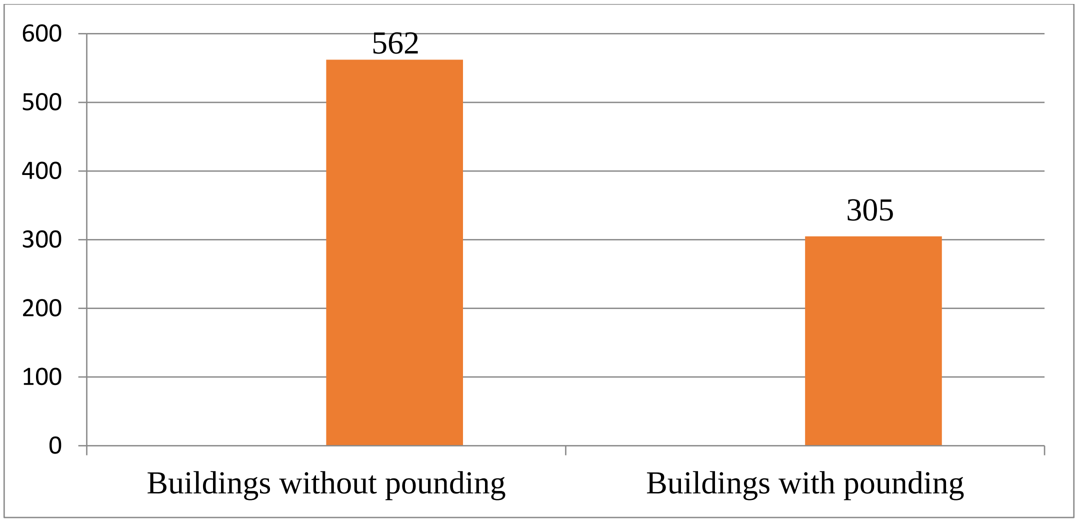


Figure 5.6 Number of buildings with pounding and without pounding

5.3.6 Evaluation of Split level of Reinforced and Masonry Buildings

In 4.2.1.a split level is defined as a that building has a room or rooms higher than others by less than a whole storey. The analysis in Figure 5-7 indicates that 838 buildings with percentage of 96.65% are not split level structures and 29 buildings with percentage of 3.34% are split level structures.

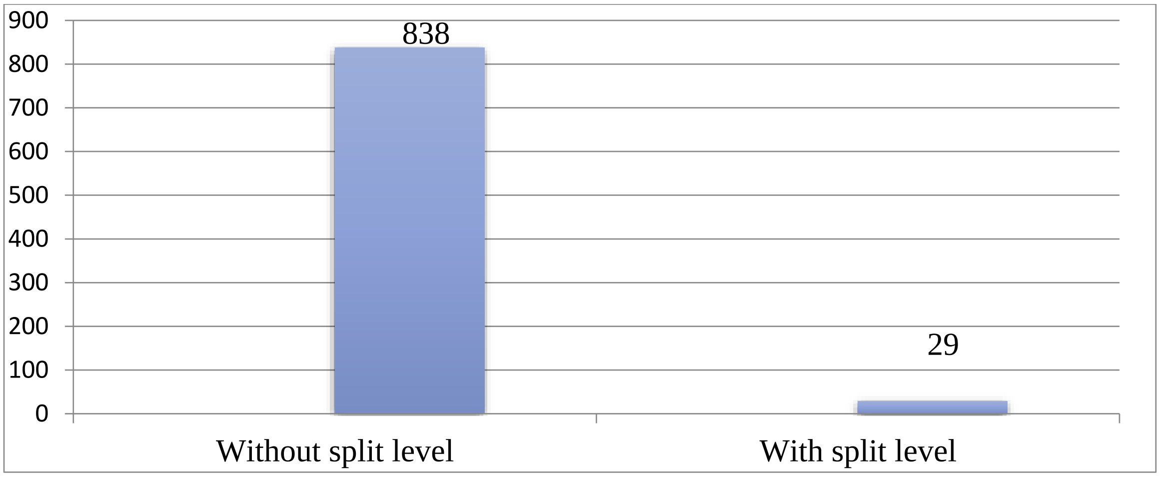


Figure 5.7 Number of buildings with and without split level

5.3.7 Evaluation of Torsion in Reinforced Concrete and Masonry Buildings

As mentioned in 4.2.1, buildings having solid walls on two or three sides and walls with large openings on the other sides, or with high lateral resistance in one direction but not the other, which is sometimes referred to as torsion.814 of reinforced concrete and mix and masonry buildings that represent 93.88%do not have this negative parameter, while 53 of them representing 6.11% are characterized by torsion irregularity as shown in Figure 5-8 below.

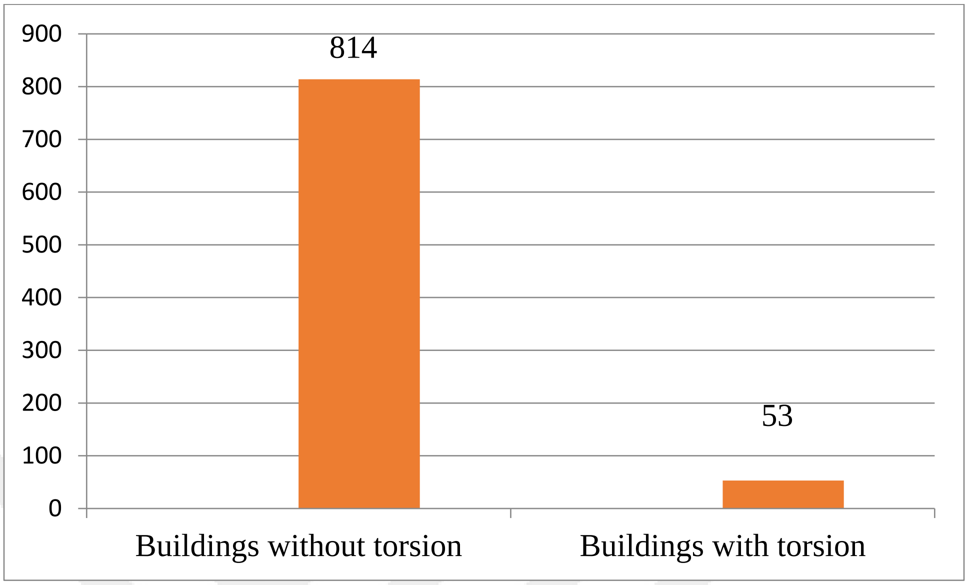


Figure 5.8 Distribution of buildings with and without torsion

5.3.8 Evaluation of Short Column of Reinforced and Mix and Masonry Buildings

As mentioned earlier, short columns are found in structures built on slopes, and some RC frame columns may be significantly less in height than other columns in the same story. The shorter columns typically suffer more damage than the taller columns.756ofthe buildings are classified as being without short column effect and 111 of them possess the characteristic of the negative parameter short columns and the percentages are 87.19% and 12.28% of total buildings in order as shown in Figure 5-9 below.

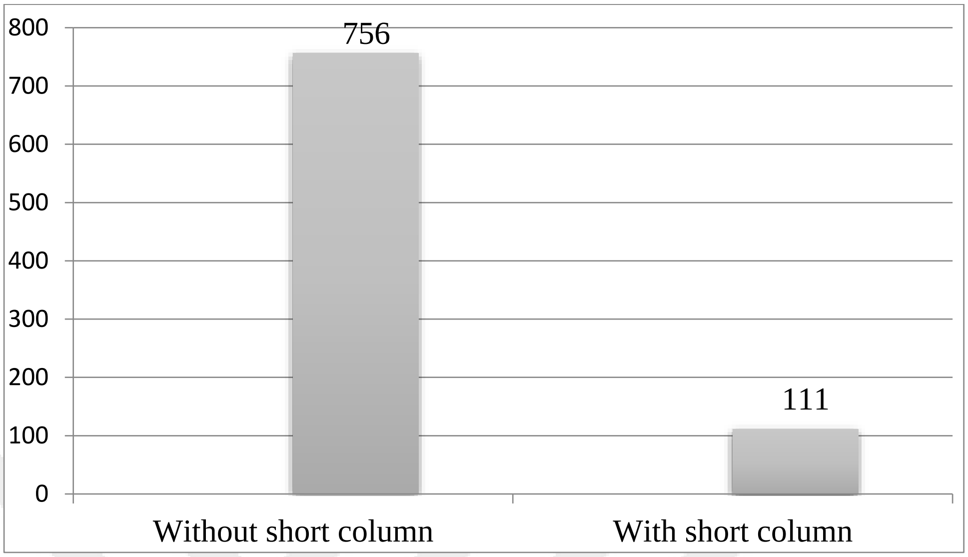


Figure 5.9 Distribution of the number of buildings with short column

5.3.9 Evaluation of Out-of-Plane Setback of Reinforced and Mix and Masonry Buildings

As mentioned in 4.2.1. the definition of Out-of-Plane Set back as when the lower levels' vertical parts of a lateral system are outboard of the upper levels', this irregularity is at its most severe. The analysis performed in Figure 5-10 shows that 801 buildings that form 92.38% of total buildings are not characterized by the negative aspect, out-of-plane setback and 66 buildings that form 7.61% possess the characteristics of out-of-plane setback.

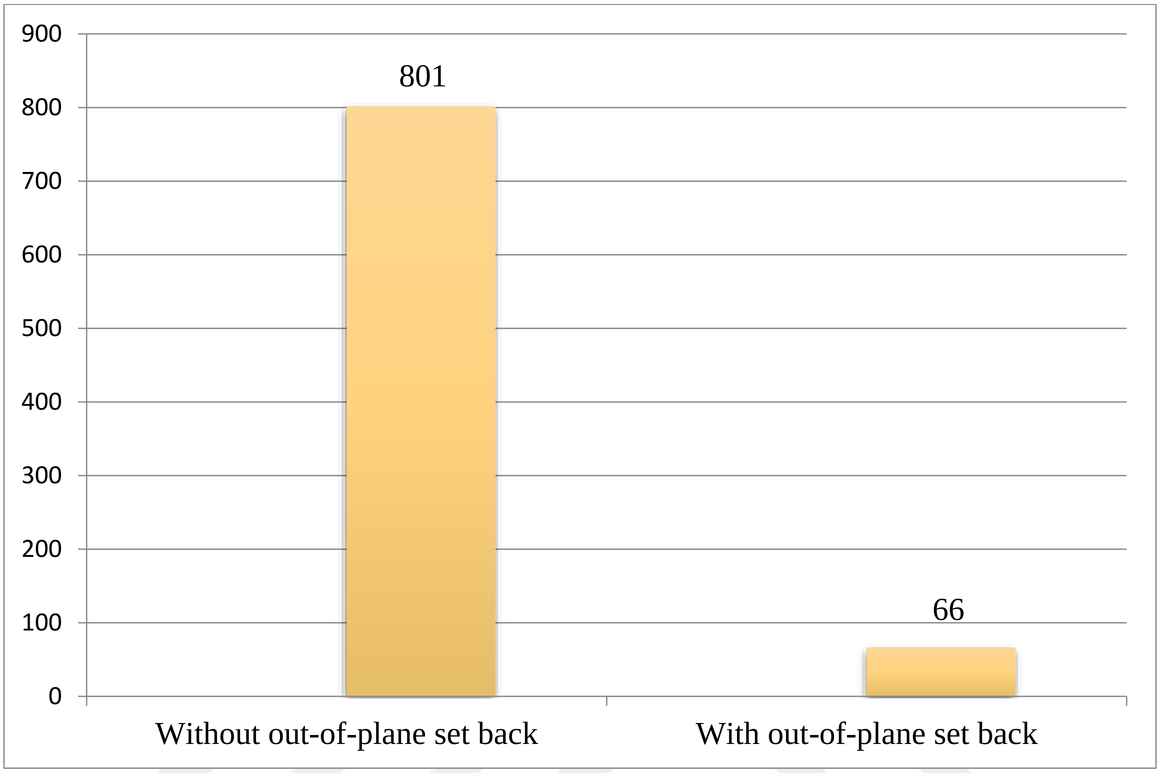


Figure 5.10 Number of buildings with and without out-of-plane set back

5.3.10 Evaluation of Reentrant Corner of Reinforced and Masonry Buildings

A reentrant corner refers to the structure has projections of more than 20 feet and is L, U, T, or + shaped.863 buildings are without reentrant corner and only 4 buildings have reentrant corner which constitute 99.5% and 0.5% respectively as shown in Figure 5-11.

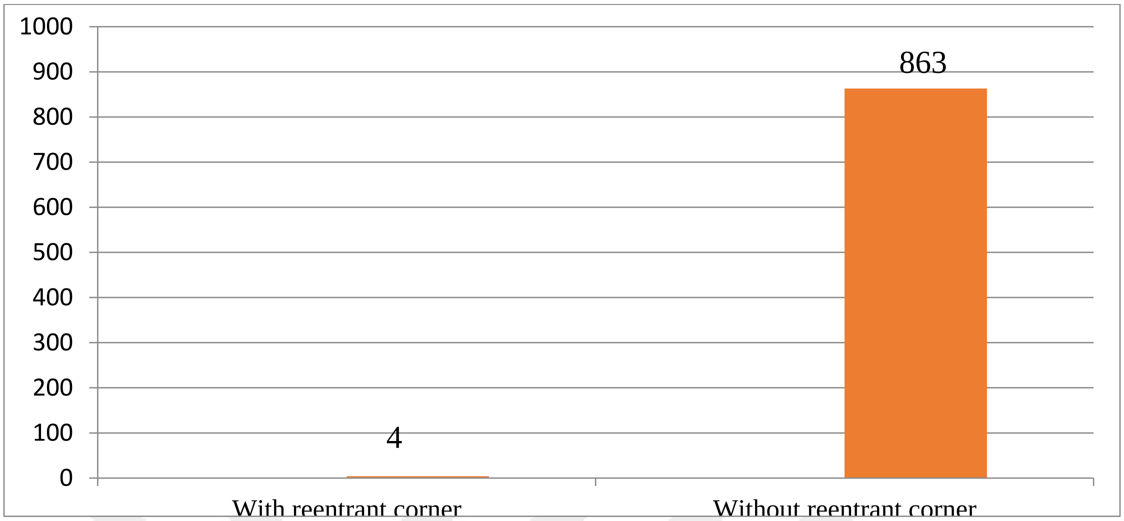


Figure 5.11 Distribution of buildings with and without reentrant corner

5.3.11 Evaluation of Non-parallel System

As mentioned in 4.2.1 this criterion is defined as the building's sides don't meet at 90 degrees, 34 buildings that form 3.92% of total buildings are characterized by the negative aspect, 833 buildings that form 96.07% are not characterized by the negative aspect as shown in Figure 5-12 below.

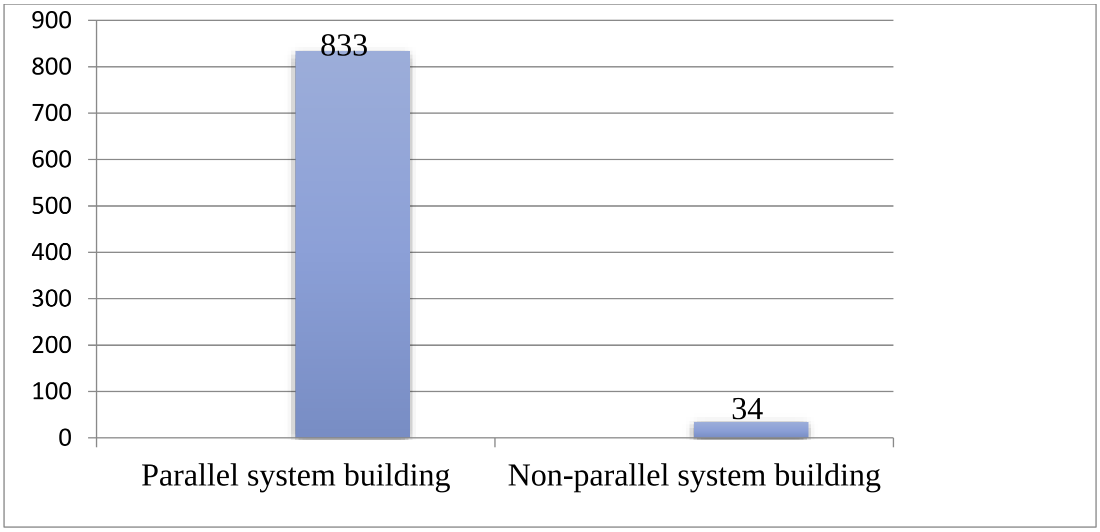


Figure 5.12 Parallel and non-parallel system

5.3.12 Summary of the Results

The analysis in Table 5-2 indicates that 21.45% of the buildings surveyed in Brayaty Quarter in Erbil City are reinforced concrete buildings and 78.54% are mix and masonry buildings. It also shows that 79.38% of the buildings do not have the negative aspects measured by the ten negative parameters of (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003) methods. 20.62% of them have negative parameters which highlights the vulnerability of this percentage of the buildings.

Table 5.2 Analysis of data on reinforced concrete and masonry buildings according to (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003) methods

Distribution of structural system	Number of buildings	Percentage
Reinforced concrete buildings	186	21.45%
Masonry buildings	681	78.54%
Parameters Number of storey	Number of buildings #	Percentage
1	134	15.45%
2	566	65.28%
3	82	9.45%
4	33	3.80%
5	27	3.11%
6	16	1.84%
7	4	0.46%
8	1	0.11%
9	2	0.23%
10	2	0.23%
Buildings with soft storey	184	21.22%
Buildings without soft storey	683	78.77%
Buildings with overhang	100	11.53%
Buildings without overhang	767	88.47%
Good quality buildings	559	64.47%
Moderate quality buildings	234	26.98%
Poor quality buildings	74	8.5%
Buildings with pounding	305	35.17%
Buildings without pounding	562	64.82%
Buildings with split level	29	3.34%
Buildings without split level	838	96.65%
Buildings with torsion	53	6.11%
Buildings without torsion	814	93.88%
Non-parallel system	34	3.92%
Parallel system	833	96.07%
Buildings with reentrant corner	4	0.5%
Buildings without reentrant corner	863	99.5%
Buildings with short column	111	12,28%
Buildings without short column	756	87.19%
Buildings with Out-of-Plane setback	66	7.61%
Buildings without Out-of-Plane setback	801	92.38%
Soil condition	0	0%
Topographic effect	0	0%
Beam do not align with column	0	0%
Buildings with negative parameters	178.77	20.62%
Buildings without negative parameters	688.22	79.38%

5.4. Safe and Unsafe Buildings According to FEMA P-154 (1988) Approach

17 buildings which form 9.14% of total RC buildings are unsafe and 169 buildings, namely 90.86% of RC buildings are safe. 39 buildings which constitute 5.72% of total

masonry buildings are unsafe and 643 buildings which are 94.28% of total masonry buildings are safe as shown in Figures 5-13, Figure 5-14 and Figure 5-15.

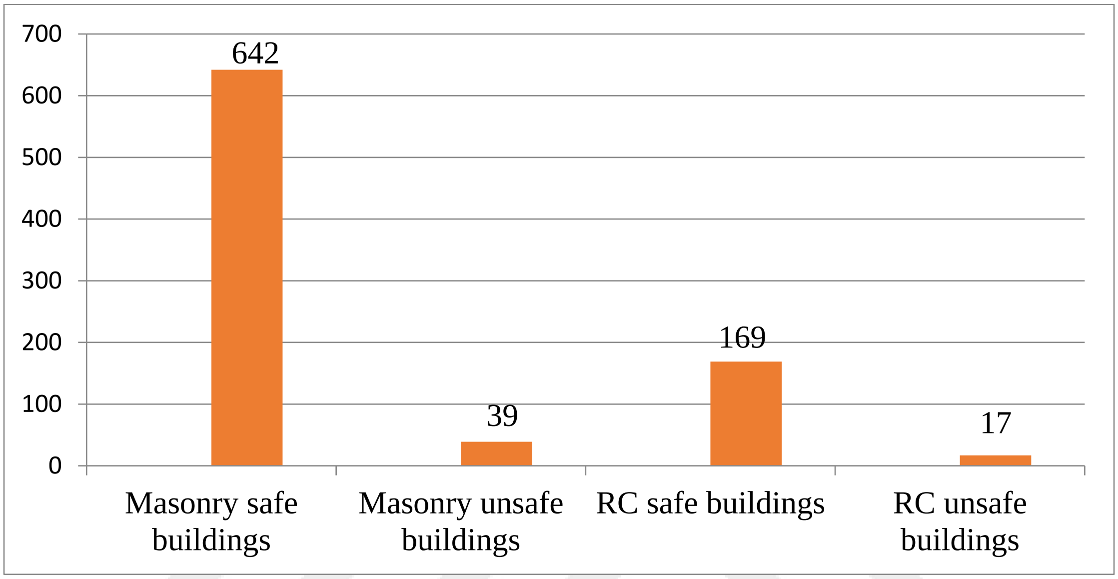


Figure 5.13 RC and masonry safe and unsafe buildings according to FEMA P-154 (1988) method

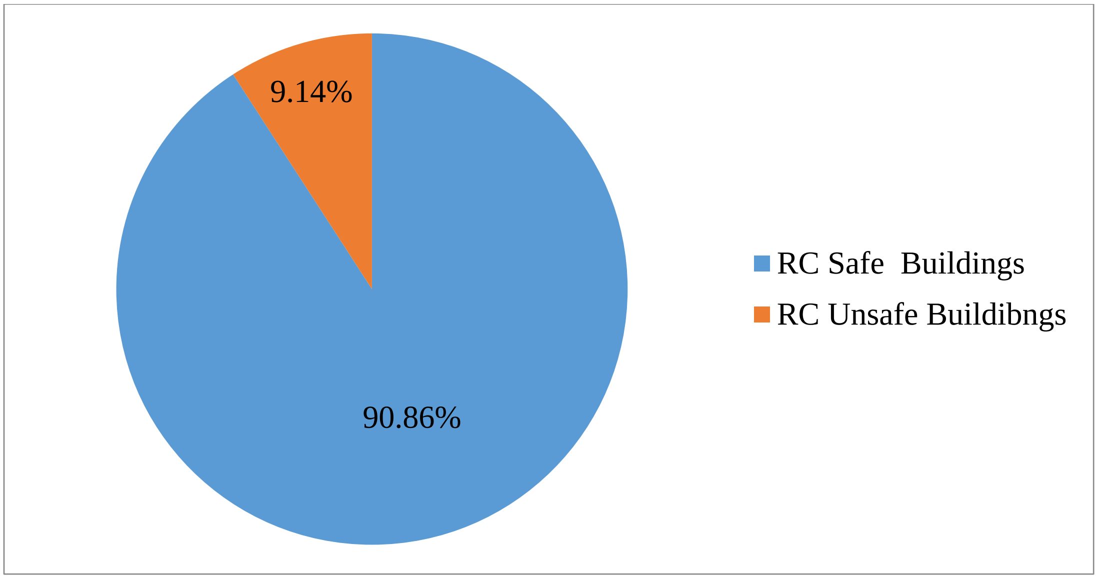


Figure 5.14 Percentage of safe and unsafe RC buildings based on FEMA P-154 (1988) method

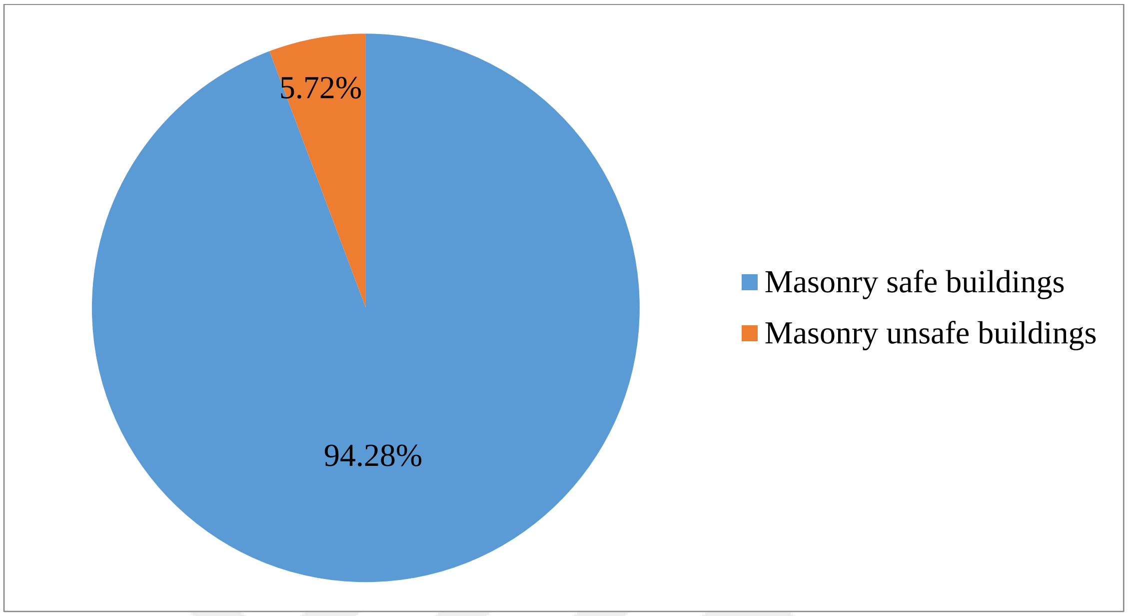


Figure 5.15 Percentage of safe and unsafe masonry buildings for (FEMA P-154, 1988)

5.5 Safe and Risky Buildings on the Basis of Sucoğlu and Yazgan (2003) Method

Five reinforced concrete buildings are not included in the calculation in (Sucoğlu and Yazgan, 2003) Method, because they are with more than seven storeys, (Sucoğlu and Yazgan, 2003) is only used for one to seven storey buildings.22 buildings which form 12.15% of total RC buildings are moderate risky, 48 buildings namely 26.51% of total RC buildings are high risky buildings and 111 buildings which form 61.32% of RC buildings are safe.645 which form 94.71% of masonry buildings are safe and 36 buildings namely 5.28% are moderate risky.

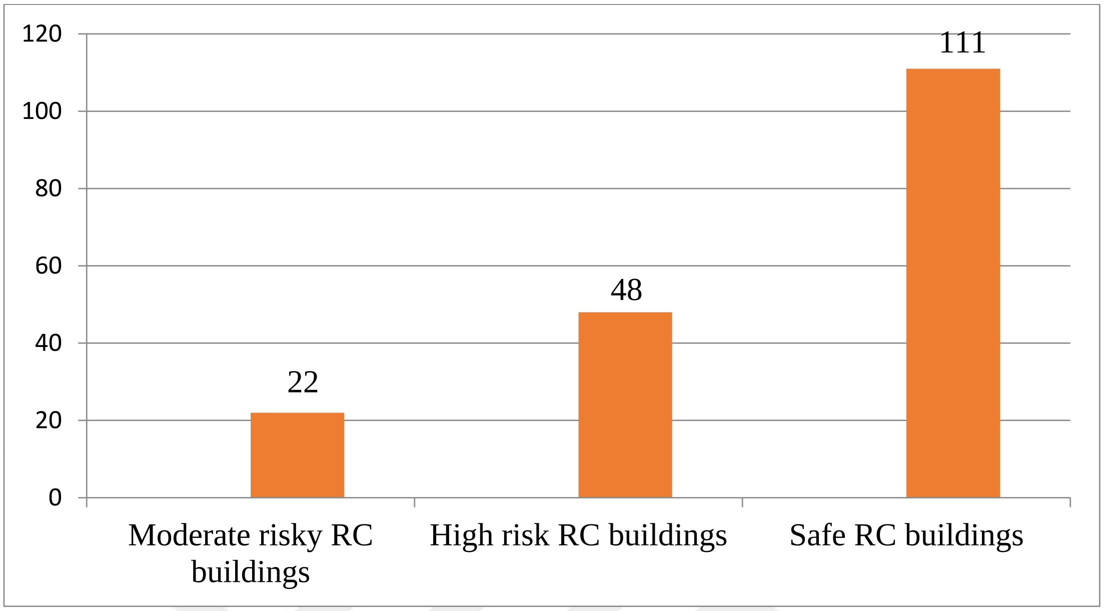


Figure 5.16 Number of moderate, high risky and safe RC buildings

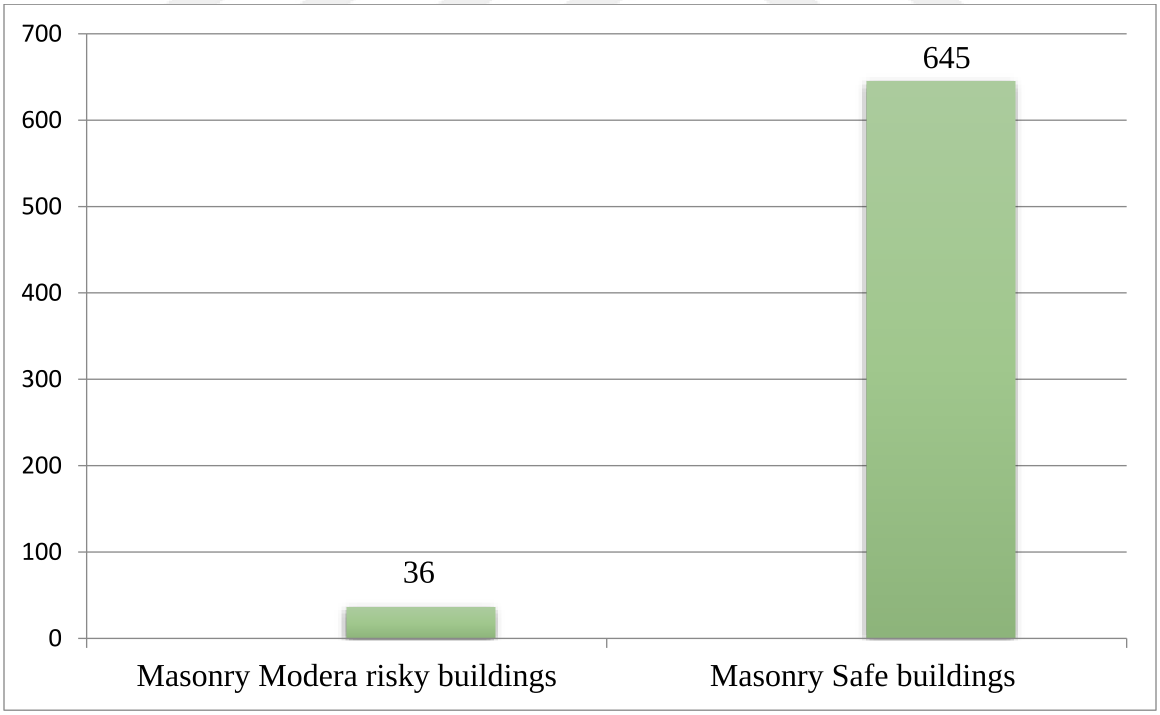


Figure 5.17 Moderately, risky and safe masonry buildings

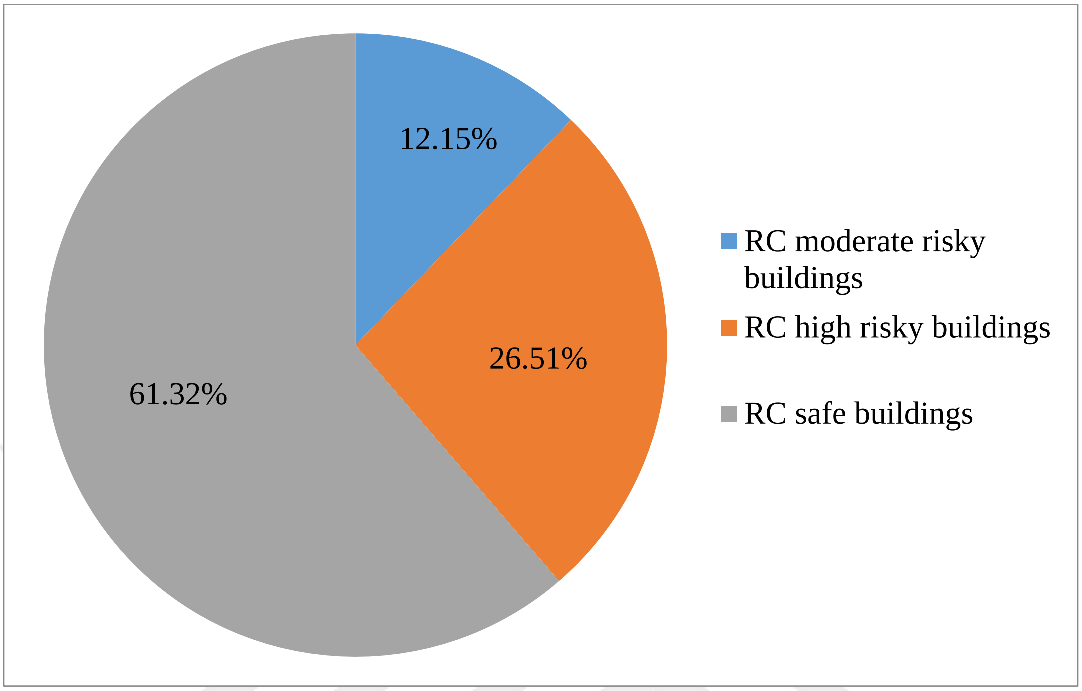


Figure 5.18 Percentage of moderate risky, high risky and safe RC buildings in (Sucoğlu and Yazgan, 2003) method

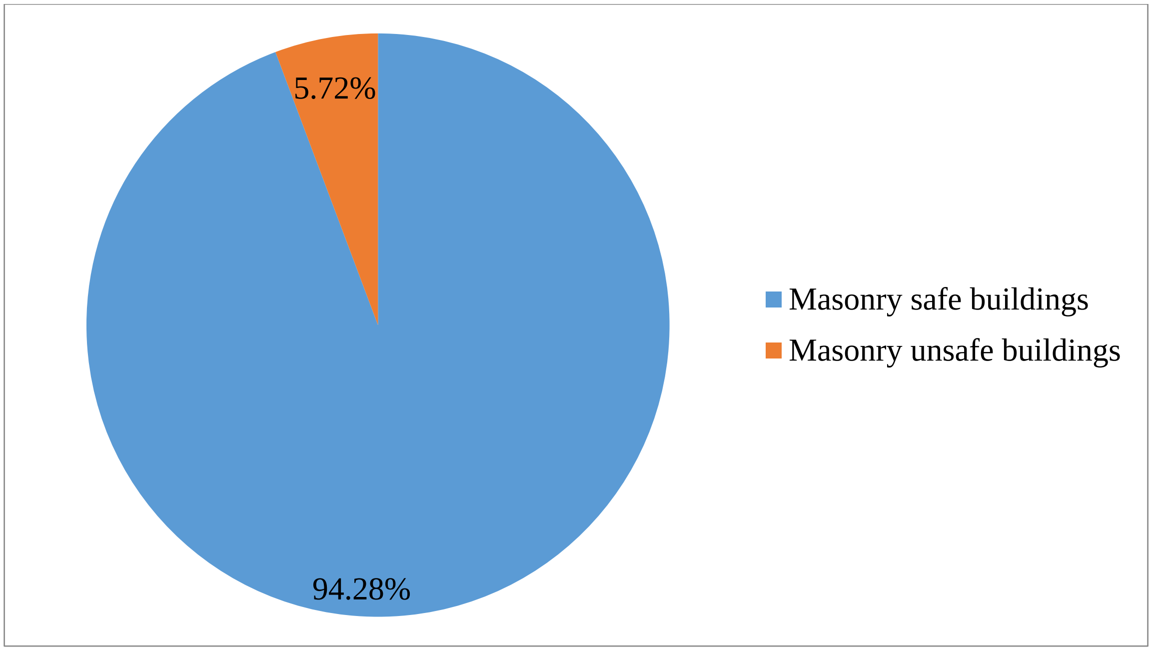


Figure 5.19 Percentage of moderate risky and safe masonry buildings by (Sucoğlu and Yazgan, 2003) method

6. CONCLUSIONS AND SUGGESTION FOR FURTHER STUDY

6.1 Conclusions

In the light of the analysis carried out in the previous chapters, several conclusions can be drawn as follows:

The key aim of conducting this study is to assess the seismic safety of existing buildings. To realize this aim, the study researched into the buildings in Brayaty Quarter in Erbil City. The buildings in the studied area are built on soil class D which is categorized as stiff soil. Seismic waves travel though the ground more moderately through stiff soil and its shear wave velocity is V_S (ft/s) is $1200<V_S\leq2500$. The buildings investigated are within high seismicity zone in Iraq.

The contributing factors of seismic vulnerability of buildings comprise number of storey, vertical irregularity, soft storey, short column, unbraced cripple wall, out-of-plane-setback, split level, plan irregularity, torsion, non-parallel system, reentrant corner, diaphragm opening, beam do not align with column, heavy overhang, apparent building quality, pounding, topographic effect, wall opening and wall opening type.

The percentage of the buildings with negative parameters are 20.62% while 79.28% of total buildings do not have these negative parameters.

The percentage of each negative parameter is as follows:
soft storey 21.22%, overhang 11.53%, pounding 35.17%, split level 3.34%, torsion 6.11%, non-parallel system 3.92%, reentrant corner 0.5%, short column 12.28% and out-of-plane set back 7.61%.

Level 1 of (FEMA P-154, 1988; Sucoğlu and Yazgan, 2003) methods are used to assess the seismic performance of the buildings in the target area.

The total number of buildings surveyed is 867, 186 of which are RC buildings and 681 are masonry buildings. It is concluded that the assessment of seismic performance of the target buildings according to FEMA P-154 (1988) criteria shows that 90.86% of RC buildings are safe and 9.14% are unsafe and 94.28% masonry buildings are safe and 5.4% are unsafe.

Seismic performance of the total of 862 of same buildings above were also assessed by (Sucoğlu and Yazgan, 2003) criteria. RC buildings are 181 and masonry are 681 in number. It was concluded that 61.32% of RC buildings were safe, 12.15% were moderately risky and 26.51%were highly risky. Also, according to (Sucoğlu and Yazgan, 2003), 94.71% of masonry buildings were safe and 5.28% were moderately risky.

The percentage of vulnerability of RC buildings are higher than that of masonry buildings according to both methods.

6.2 Suggestions for Further Study

Further study may include:

Further study is required to research into the existing buildings using the parameters of other methods in Street Scanning or Walk-Down Procedure (Level 1) such as ATC-21 (Rapid visual screening).

Methods used in levels 2 known as Pre-Assessment Method and Level 3 known as Detailed Evaluation Methods are more accurate than those in level 1. More studies should be conducted based on the methods in level 2 such as (Hassan and Sözen, 1997; FEMA 310, 1998; Otani, 2000; JBDPA, 2001) methods, (Sucoğlu and Yazgan, 2003; Yakut, 2004) and level 3 such as Linear Elastic Calculation Methods and Linear Non-Elastic Calculation Methods.

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EXTENDED TURKISH SUMMARY

(GENİŞLETİLMİŞ TÜRKÇE ÖZET)

SOKAK TARAMASI YÖNTEMİ KULLANILARAK ERBİL İLİ BRAYATY MAHALLESİN'DEKİ MEVCUT BİNALARIN DEPREM PERFORMANSLARININ HIZLI DEĞERLENDİRİLMESİ

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Haziran 2023, 99 sayfa

Bu çalışmada, Erbil kenti Brayaty bölgesinde; sismik olarak tehlikeli görülen binalar ele alınarak, mevcut binaların envanteri çıkarılmış ve hızlı görsel tarama (HGT) prosedürü uygulanarak taranmıştır. Nitekim bu tür yapıların, potansiyel olarak tehlikeli olanların öncelik sıraları belirlendikten sonra, yapılması gerekli olan işlem, bu binaların gerçekten sismik açıdan tehlikeli olup olmadıklarını belirlemektir. Bunun için de bu binaların sismik tasarım konusunda uzman bir tasarım uzmanı tarafından daha ayrıntılı olarak incelenmesi gerekebilmektedir. HGT süreci, bir yapının araştımacı tarafından binanın dışının ve mümkünse içinin görsel olarak gözlemlenmesine dayalı olarak doldurulan bir Veri Toplama Formu'na dayanan bir yöntemdir. Bu süreçte, verilerin kullanımı, boyutu gibi bina tanımlama bilgileri ile eskizler, binanın bir fotoğrafı ve sismik performansıyla ilgili her türlü bilgi ile birlikte veri toplama formuna kaydedilebilir (FEMA P-154, 1988).

Bu çalışmanın amacı, hedef bölgedeki binaları araştırmaktır. Bu bulgular, güvenli olan ve güvensiz veya riskli olan binaların sayı ve yüzdelerini içermektedir. Bununla beraber, bölgedeki zeminin mukavemetini ölçmek ve incelenen binalar için uygun olup olmadığına karar vermekte diğer bir hedef olarak bu çalışmanın kapsamındadır.

Bu çalışmada, 867 binadan oluşan bir örneklemin sismik performansını değerlendirmek için (FEMA P-154, 1988; Sucoğlu ve Yazgan, 2003) olmak üzere iki adet birinci kademe sokak tarama prosedürü yönteminin parametreleri uygulanmıştır. Hedef binalar hakkında gerekli verileri toplamak, sınıflandırmak ve analiz etmek için iki yöntem kullanılmıştır. Bu noktada çalışmanın temel amaçları içindeki en önemli hedef, incelenen binaların sismik performanslarını değerlendirmek ve güvenli-güvensiz veya riskli olup olmadıklarını belirlemektir. Buna bağlı olarak çalışılan alandaki binaların üzerine inşa edildiği zeminin sismik güvenliğini verilerle ortaya koymaktır.

Erbil şehrinin Brayaty semtindeki konut ve ticari binaları içeren betonarme binalar ve yığma binaların etüdü, bu binaların sismik performansını değerlendirmek için hesaplamaları göstermek içindir. İki ila üç kattan oluşan konutlar, ağırlıklı olarak konut olarak değerlendirilirken, iki ila on kattan oluşan ana caddelerdeki binalar ticari üniteler olarak kullanılmaktadır. Bu binalar, yerel zemin sınıfı D olarak sınıflandırılan sert toprak üzerine inşa edilmiştir (Abduljaleel, 2019)

Veri toplamak için kontrollü veya yapılandırılmış gözlem yöntemi kullanılmıştır. Bu yöntem, binaların sismik güvenliğini belirleyen kriterlere ilişkin verileri tanımlamak ve kaydetmek için de kullanılır. Hedef binaların araştırılmasında karma yöntem yaklaşımları kullanılmaktadır. Bu araştırmadaki nicel veriler tablo ve grafiklerde sayı ve yüzdelerle ifade edilirken, nitel veriler olguların, teorilerin ve haritaların tanımında somutlaştırılmıştır. Bu çalışma, çeşitli yapı tipleri üzerindeki sismik kuvvet etkisi hakkında bilgi vermesi nedeniyle dikey düzensizlik, plan düzensizliği, kısa kolon, çıkıntı, bina kalitesi ve yumuşak katlı tasarımcılar için değerlidir.

Birinci kademe sokak tarama prosedürleri, binaların basit bir sokak araştırmasından toplanan bazı temel görsel özelliklerini gerektiren, testler veya ayrıntılı ölçümler gerektirmeyen en basit sismik hasar görebilirlik değerlendirme prosedürleri olarak tanımlanabilir. Bu yöntemde temel amaç, binaların hasar görebilirlik düzeylerinin kısa sürede tespit edilmesidir. Binaların sadece görsel özelliklerini kullandıkları için tek bir binayı değerlendirmek için kullanılmazlar, bunun yerine bir bina stoğundaki hassas binaları değerlendirmek için yöntem bütün binaların aynı anda değerlendirmeye tabi tutulmasını da içermektedir.(Erdil ve Ceylan, 2018).

Sucuoğlu Seviye-1 yöntemi 7 kata kadar olan betonarme yapılar için geliştirilen bir yöntemdir. Bu yöntemde sokakta dolaşılarak 10 dk içinde basitçe yapılabilen bir yöntem olarak bilinir. Binalar için ele alınan olumsuzluk parametreleri; kat sayısı, ağır çıkma, zayıf kat, görüntü kalitesi, çarpma etkisi, tepe-yamaç etkisi, kısa kolon, zemin değerleri ve deprem etkisi gözlemlerini içerir. Bu yöntem Haluk Sucuoğlu tarafından oluşturulmuştur (Sucuoğlu, 2007).

WHO (Dünya Sağlık Örgütü)’a göre Irak, beş sismik tehlike bölgesine ayrılmıştır,

PGA (Hız Bölgesi) ile çok düşük sismik tehlike bölgesi (0-0.2)

PGA (Hız Bölgesi)'lı düşük sismik tehlike bölgesi (0.2-0.8)

PGA (Hız Bölgesi)'lı (0.8-2.4) orta sismik tehlike bölgesi

PGA (Hız Bölgesi) (2.4-4) ile yüksek sismik tehlike bölgesi

PGA (Hız Bölgesi) ile çok yüksek sismik tehlike bölgesi (>4)

Araştırmacı hedef binaların sismik performansını değerlendirmek için kontrollü gözlem yoluyla Erbil Şehrindeki Brayaty Mahallesi'ndeki binalardan gerekli verileri toplayarak araştırma sahasında bir çalışma yürütmüştür. FEMA P-154, 1988; Sucoğlu ve Yazgan'a, (2003) göre toplanan ve kaydedilen veriler aşağıdaki verileri içerecek şekilde kaydedilmiştir: Bu veriler ise, kat sayısı, düşeyde düzensizlik, yumuşak kat/zayıf kat, kısa kolon, çarpma etkisi, plan düzensizliği, burulma, paralel olmayan sistem, yerel zemin sınıfı, ağır çıkma, görünen kalite, kısa kolon, tepe/yamaç etkisi, duvar boşluğu, duvar boşluk düzeni gibi verilerdir. İncelenen toplam bina sayısı 867 olup, bunların 186'sı betonarme, 681'i yığma binadır. Bu yöntemle değerlendirildiğinde Erbil şehrinde bulunan Brayaty Mahallesi, PGA (Hız Bölgesi) (2.4-4) yüksek sismik tehlike bölgesinde yer almaktadır denilebilir.

Erbil şehri Brayaty Mahallesi çalışmasında kat sayısı, bodrum, zemin, ara kat, normal kat ve teras, binaların değerlendirilmeye alındığı veriler olarak ele alınmıştır. Temel üzerindeki her kat hesaplanmaya dahil edilmiştir. Bir binada birden fazla kat varsa, en yüksek kat dikkate alınmıştır. Kaçak yapılaşmanın artması nedeniyle, proje dışında bir çatı katında çelik konstrüksiyondan kat eklentisi yapıldığı da yapılan tespitler arasında yer almaktadır. Bu kat, bina deprem yükünün artması, deprem etkisiyle mevcut durumdan farklı davranması ve kat adedi arttıkça depremde oluşacak hasar oranının artması nedeniyle riskli yapıların tespitinde hesaba katılmalıdır. Sokak taraması formunda eklenti parametresi ve olumsuzluk puanı olmadığından toplam kat sayısı parametresine dahil edilmiştir (Sucuoğlu, 2007). Çalışma alanında 134 adet tek katlı, 566 adet iki katlı, 82 adet üç katlı, 33 adet dört katlı, 27 adet beş katlı, 16 adet 6 katlı, 4 adet 7 katlı, 1 adet 8 katlı, 2 adet 9 katlı ve 2 adet 10 katlı yapı bulunmaktadır.

Yumuşak kat/zayıf kat, binaların zemin kat seviyeleri normal kat seviyelerine göre daha yüksektir. Çünkü bu binalardaki zemin katlarının genellikle mağaza veya alışveriş merkezi olarak kullanıldığı tespit edilmiştir. Brayaty Mahallesi’nde, faaliyete girmeyen kat duvarlarının örülmediği görülen bazı yapılar zayıf kat olarak kabul edilir. (Sucuoğlu, 2007). Araştırma alanındaki tüm binaların % 21.22'sini (184 bina) yumuşak katlı binalar, % 78.77'ini (683 bina) yumuşak katlı olmayan binalardan meydana geldiği tespit edilmiştir.

Kısa kolon: Betonarme yapılarda çoğunlukla dış cephelerde kısa kolon durumu vardır. Kolonların yarı yükseklikte duvarlar ile örülmesi, merdiven sahanlıklarında ara kirişler kullanılması, bant pencere oluşturulması kısa kolon oluşmasının asıl nedenlerindendir. Kısa kolonlu yapılar depremlerde genellikle ağır hasar görürler (Deprem Şurası, 2004). Çalışma alanındaki toplam yapı sayısının kısa kolon etkisi olmayan bina sayısı ve yüzdesi 756 ve % 87.19, negatif parametreli kısa kolon etkisine sahip bina sayısı 111 oran olarak % 12.28'dir.

Çarpma etkisi/ yapı nizamı gibi olumsuz parametrenin nedeni, bitişik nizamlı yapılardır. Tek doğrultulu elastoplastik davranışlı çarpma etkisi, bitişik nizamlı yapıların döşeme hizaları farklıysa ortaya çıkabilmektedir. Binaların kenarda aynı görünmesine ragmen diğer yanlarda farklı veya ortada farklı düzeyde bitişik nizamlı olması çekiçleme nedeni olarak ele alınmıştır (Özçebe, 2004). Brayaty Mahallesi’nde incelenen binaların 305 adetinde çarpma etkisine, 562 adet binada ayrık nizam durumuna rastlanmıştır.

Yerel zemin sınıfı: Zemin sınıflarına göre ZA, ZB, ZC, ZD, ZE ve ZF şeklinde sınıflandırılmıştır. Erbil şehri yerel zemin sınıfı ZD olarak sınıflandırılan sert toprak üzerine inşa edildiği tespit edilmiştir.

Ağır çıkma, çok katlı betonarme binalarda ağır balkonlar ve sarkan döşemeler kütle merkezini yukarı kaydırır. Buna bağlı olarak deprem sırasında sismik yanal kuvvetleri ve devrilme momentlerini arttırabilmektedir. Türkiye'de son depremlerde ağır beton parapetlerle çevrelenmiş geniş konsol açıklıklı balkonlara sahip binalar, normal yüksek binalara göre daha ağır hasar görmüştür. Bu bina özelliği, bir yüzey araştırması sırasında kolayca gözlemlenebileceğinden, bu çalışmadaki örneklemde parametre setine dahil edilmiştir (Sucuoğlu, 2007).

Bina görsel kalitesi, bir yapının görünen kalitesi, malzeme ve işçiliğin kalitesine olduğu kadar, bakımına gösterilen özene de yansır. İyi eğitimli bir gözlemci, bir binanın görünen kalitesini kabaca iyi, orta veya kötü olarak sınıflandırabilir. Nitekim görünür kalite ile gerçek hasar arasında güçlü bir ilişki görülmüştür. Görünür kalitesi düşük olan bir yapının malzeme dayanımlarının zayıf olacağı ve detaylandırmanın yetersiz olacağı tahmin edilebilir (Deprem Şurası, 2004). Brayaty Mahallesi'nde incelenen binalarda 559 adet bina iyi, 234 adet bina orta, 74 adet bina kötü görüntü kalitesine sırasıyla % 64.47, % 26.98 ve % 8.5 oranlarıyla değerlendirilmiştir.

Tepe/yamaç etkisi, topografik yükseltme, tepelerin üzerindeki yer hareketini artırabilecek başka bir faktördür. Ayrıca, dik yamaçlarda (30 dereceden daha dik) inşa edilen binalar tipik olarak, zemin bozulmalarını yukarıdaki yapısal elemanlara eşit şekilde dağıtamayan inşa edilmiş temellere sahiptir.

Planda düzensizlik, kolonların düzensiz yerleştirilmesi ve planın geometrik olarak simetrik olmadığı durumlar olarak tanımlanır. Yapıda burulmaya neden olabilecek plan düzensizlikleri de ele alınmalıdır (FEMA P-154, 1988).

Yapısal sistem türü, betonarme binaların tasarımı betonarme çerçeve ve perde, betonarme çerçeve şekilde karşımıza çıkmaktadır. Betonarme çerçeveli perde sistemler, betonarme çerçeveli sistemlere oranla süneklikleri daha az ve enerji sönümleme kuvvetleri daha fazladır. Analizi neticesinde yer değiştirmeleri daha azdır.

Düşeyde düzensizlik, düşey yükseklikte değişen kat alanlarının ve devam etmeyen çerçeve etkisini yansıtmak için dikkate alınır. Yapı yüksekliği boyunca kesilen kolonlar veya perdeler düşeyde düzensizlik oluşturabilmektedir (FEMA P-154, 1988).

Yapının tahmini yaşı, betonarme binalar için sokak taraması yönteminde kullanılan diğer önemli bir parametrededir. Yapının tahmini yaşının tespitinde taşınmazın bulunduğu belediyeden alınan ruhsat bilgileriyle öğrenilebilir. Fakat kaçak yapıların yapı ruhsatlarına ulaşılamayacağı ve çok sayıda binanın tespitinde pratik olmadığından hızlı değerlendirme yönteminde kullanılmamıştır. Yalnız ruhsatsız yapılara ulaşılamayacağından ve çok sayıda kaçak yapının olduğu durumda binanın görseline bakılarak ve çevreden yardım alınarak tahmin edilebilir.

Bu çalışma kapsamında Erbil ilinin Brayaty Mahallesindeki 186 adet betonarme ve 681 adet yığma bina olmak üzere toplamda 867 adet bina Sucoğlu ve Yazgan (2003) ve (FEMA P-154, 1988) yöntemleri riskli binaların tespitine İlişkin sokak taraması yöntemiyle incelenerek ele alınmıştır.

FEMA P-154 (1988) prosedüründe güvenli ve güvensiz binalar: Toplam betonarme binaların % 9.14'ünü oluşturan 17 bina güvensiz ve 169 bina, yani betonarme binaların %90,86'sı güvenlidir. Toplam yığma binaların % 5.72'sini oluşturan 39 bina güvensiz ve toplam yığma binaların % 94.28'ini oluşturan 643 bina güvenli olarak tespit edilmiştir.

Sucoğlu ve Yazgan (2003) yönteminde güvenli ve riskli binalar: Toplam betonarme binaların % 12.15'ini oluşturan 22 bina orta riskli, toplam betonarme binaların % 26.51'ini oluşturan 48 bina yüksek riskli ve betonarme binaların % 61.32'sini oluşturan 111 bina güvenli olarak kayıt altına alınmıştır. 645 yığma binanın % 94.71'ini oluşturan kısmı güvenli; 36 bina yani % 5.28'i orta derecede riskli olarak değerlendirilmiştir.

Hedef bölgedeki binaların sismik performansını değerlendirmek için birinci kademe sokak tarama prosedürü olarak FEMA P-154 (1988) ile Sucoğlu ve Yazgan (2003) yöntemleri kullanılmıştır. Her iki yönteme göre de betonarme binaların hasar görebilirlik yüzdesi yığma binalara göre daha yüksek bulunmuştur.

Erbil kenti Brayaty bölgesinde yerel zemin sınıfı D sınıfı olduğunu ve bu sınıftaki zeminin kayma dalgası hızına 1200 ft/s $<Vs\leq 2500$ ft/s hız aralığı karşılık gelmektedir.

Betonarme yapıların olumsuzluk parametrelerinin tespitinde en yanıltıcı parametre görüntü kalitesi parametresi olarak değerlendirmektedir. Nitekim binalarda dışardan yapılan gözlem neticesinde değerlendirilen bu parametre estetik kalitesinden çok taşıyıcı sistemlerdeki malzeme kalitesi ve işçiliğe bakılarak karar verilmelidir. Dış cephe giydirmesi yapılan binaların taşıyıcı sistemindeki kalite grubu tespitine karar verme konusunda ikilemler oluşabilmektedir. Bu nedenle yapıların görsel kalite olumsuzluk parametresi ya farklı bir parametreyle değiştirilmeli ya da tespitinin belirlenmesinde netlik kazandırılmalıdır.

Bu yüksek lisans tezi Erbil ili Brayaty Mahallesi için birinci aşama değerlendirme yöntemi kullanılarak yapılan ilk ve şu an için tek saha araştırması olma özelliğine sahiptir. Erbil ili genelinde var olan binaların birinci aşama değerlendirme modeli ile yapılacak çalışmalara örnek olacağı umulmaktadır. Bu ve benzeri çalışmaların ülke geneline yaymaya çalışılması elzemdir. Çünkü ikinci derece deprem bölgesinde bulunan Kuzey Irak'ın yapı stoku hem fazla hem de bu yapılar deprem yönetmeliklerine uygun yapılmayan yapılardan meydana gelmektedir.

Brayaty Mahallesinde birinci aşama değerlendirme modeliyle bina risk puanları çözümlenen çok riskli, riskli betonarme ve yığma yapıların ikinci ve üçüncü aşama değerlendirme modelleriyle de incelemeler yapılarak deprem performansı sonucunda riskli olan yapılar ya güçlendirilmeli ya da yıktırılmalıdır. Aksi durumda olası bir şiddetli depremde büyük hasarlar ile karşı karşıya kalınabilir.

Ayrıca unutulmamalıdır ki sokak tarama yönteminden elden edilen sonuçlar bir kesinlik vermemekte ve betonarme ile yığma binaların, deprem yönetmeliğine göre inşa edilip edilmediği kesin olarak tespit edilememektedir. Bazen parametreler yanıltıcı olabilmekte ve bazen de incelemeyi yapan kişiye göre tespitler değişebilmektedir. Sokak tarama yönteminin amacı binalar hakkında hızlı veri elde edebilmek ve bu verilerle risk sıralaması yapabilmektir. Bu tez çalışması, riskli yapıların belirlenmesi için bir ön hazırlıktır. Bu çalışmanın daha sonra yapılacak çalışmalara önayak olarak Kuzey Irak'ın tamamı için bir risk haritasının elde edilmesinde katkı sağlaması temenni edilmektedir.

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