An-Najah National University

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SEISMIC RAPID ASSESSMENT AND STRUCTRAL RETROFITTING STRATEGIES: CASE STUDY OF ESSENTIAL BUILDINGS IN TULKARM CITY

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Dedication

I dedicate my humble message to the soul my soul has longed for, and my limbs have strived to please. I have adhered my prayers to the soul of my beloved father, who, after God, showered me with his wealth, love, efforts, and generosity, inspiring me to earnestly pursue my academic and professional life.

To my dear mother, my beloved refuge, my constant supporter, whose prayers I live by and strive to satisfy.

To my dear brother, my affectionate sisters, to those innocent and pure souls, the source of my energy in this life, my nephews and nieces.

To my second family, my colleagues at work, to my friends, I thank all of you for the moral support that has touched my heart.

To everyone who has had an impact on my life, honorable teachers and educators, to all who have contributed positively to my life, I dedicate this thesis to all of you, seeking God's guidance and success.

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I beseech Allah for His acceptance and favor upon both myself and you, and that our endeavors may be a source of benefit to our community.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

SEISMIC RAPID ASSESSMENT AND STRUCTRAL RETROFITTING STRATEGIES: CASE STUDY OF ESSENTIAL BUILDINGS IN TULKARM CITY

Unless otherwise referenced, I declare that the work provided in this thesis is the researcher's work and has not been submitted elsewhere for any other degree or qualification.

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SEISMIC RAPID ASSESSMENT AND STRUCTRAL RETROFITTING STRATEGIES: CASE STUDY OF ESSENTIAL BUILDINGS IN TULKARM CITY

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Abstract

Recently, the Palestinian territories have been affected by a series of earthquakes that hit neighboring areas. Fortunately, these earthquakes did not result in any human or economic losses or damages. However, they have raised serious concerns about the insufficient preparedness to face more severe earthquakes. This study addresses the urgent need to activate comprehensive earthquake risk management programs and highlights the vulnerability of essential buildings, such as hospitals and schools to this threat. It emphasizes the importance of maintaining their services after earthquakes. To protect such sensitive facilities from seismic events, assessing their readiness to face earthquakes and taking necessary measures to improve their response when needed is necessary. The research was conducted in Tulkarm City in the West Bank and included assessing 134 concrete buildings using RVS procedures based on FEMA P-154 criteria. Multiple parameters were considered, including structural system, building age, height, horizontal and vertical structural irregularities, and soil type. The assessment results revealed concerning indicators, with more than two-thirds of the buildings failing to demonstrate their earthquake capacity and needing detailed and accurate evaluation to enhance their efficiency in the future. It was observed that approximately 60% of the buildings were classified under damage grades 4 and 5 according to the EMS-98 scale. 10 out of 12 healthcare facilities, more than half of educational facilities, and most public buildings and mosques are susceptible to significant structural and non-structural damage in future major earthquakes.

The results confirmed that the age of the building had the most significant impact on increasing its vulnerability due to the lack of proper structural design and insufficient oversight during construction. Additionally, most buildings showed irregularities in both horizontal and vertical design, making them more seismically vulnerable. The study recommends conducting a comprehensive assessment of the performance of critical buildings, preparing risk maps for Tulkarm City, and modifying current emergency response plans. General recommendations include increasing awareness, enforcing seismic design compliance laws, and investing in earthquake risk reduction efforts.

Keywords: Seismic performance; RVS; Vulnerability; Damage grades; Risk reduction.

Chapter One

Introduction and Theoretical Background

Introduction

Disasters are serious disruptions in society's functioning beyond its ability to adapt using resources. Disasters can be caused by natural, technological, and man-made hazards and various factors that affect the fragility of society and its susceptibility. Perhaps the most dangerous of these risks are those related to natural hazards, representing naturally occurring physical phenomena(Al Mougher & Mahfuth, 2021).

Geophysical hazard arising from solid ground (such as earthquakes, landslides, and volcanic activity) is one of the most natural hazards affecting human life and society. It may cause significant damage and risks(Ubeid, 2021).

Like other geographical areas, Palestine is not isolated from the risks caused by earthquakes, landslides, flash floods, winds, snow storms, and other health disasters. This study will discuss the seismic ones as they are the most complex and destructive. Previous studies e.g. (Di Meo et al., 2017, 2018; Grigoratos et al., 2021), indicate that Palestine is exposed to earthquakes and emphasize the need to study this danger and seek to reduce its risks. Since earthquakes are natural phenomena that cannot be prevented or stopped, it is more appropriate to avoid their risks or mitigate their dangers if they must exist. The first thing that comes to mind when a devastating earthquake strike is the sight of destroyed buildings, the resulting rubble, the people who are missing under that rubble, or even those homeless who are fortunate enough to survive. Therefore, this imminent risk calls for an urgent need to regularly, systematically, and continuously inspect buildings.

Suppose this is the reality for ordinary buildings. In that case, the need seems more urgent and necessary in the case of the essential buildings, where the risk of these vital buildings lies as they are important buildings. It is unacceptable that they stop providing their services in emergency cases. For this and more, assessing the vulnerability and seismic performance of the essential buildings was necessary.

1.1 Seismic Hazard

The worst natural disasters that the globe has witnessed are mostly due to earthquakes, which made engineering sciences focus their attention on studying and analyzing those earthquakes in order to find standards and regulations for designing earthquake-resistant facilities (Işık, 2021)

Seismic hazards are numerous, and their outcome varies according to place and time. Perhaps the most dangerous thing happened in 1979, when the world was astonished by the death toll for the year, which amounted to about 650,000 people who were victims of the earthquake in Guatemala, Italy, Indonesia, China, and Turkey. In Guatemala, China, and Italy, earthquakes have occurred during the night while people sleep in their homes that are not resistant to earthquakes. The areas of these earthquakes are crowded with people, which led to these high numbers of victims. The second most fatal recent Port-au-Prince earthquake in Haiti was in 2010. It's reported that 3,000,000 people died as a result.

Seismic tremors are a complex cosmic physical phenomenon, which are random movements of the Earth's crust in the form of trembling, movement, and violent ripple due to the release of huge amounts of energy from the Earth's interior. This energy is generated due to a vertical or horizontal displacement between the Earth's rocks through the cracks that occur due to its constant exposure to contractions. (Posadas et al., 2021). The impact of tremors is magnified in weak lands, especially in newly formed sandy and clay sediments.

Earthquakes range in intensity from minor tremors to violent tremors that crack the Earth's surface, form ridges and landslides, and may destroy buildings, roads, power lines, water, etc.

In general, the causes of earthquakes are divided into natural causes that have nothing to do with humans, and the others result from human activities that cause an imbalance in the Earth's crust. (Zhuang et al., 2021)

Tectonic earthquakes constitute 90% of these earthquakes, and tectonic earthquakes generally arise as a result of the relative movement of the plates (pieces) that make up the Earth's crust; as the continents move away or close to each other, the problem of pressure and tension stresses on each other(Yang et al., 2021). The accumulation of internal stresses begins in the layers of rocks located on the boundaries of the moving plates. Seismic waves form in all directions, and then disaster strikes.

The sit is important in mitigating earthquake risks and designing earthquake-resistant buildings. Therefore, earthquake engineering has taken care of land use policy and seismic intensity maps for each region.

Accordingly, it is always recommended that facilities not be built on geological faults, regardless of their seismic activity. The slightest movement in the Earth's crust on both sides of the faults leads to tangible damage to the installations. (Posadas et al., 2021).

1.2 Seismicity of Palestine and Neighboring Areas

Most of the seismic studies conducted in the Arab region showed possibilities for the region to suffer earthquakes in the future. According to the Richter scale, they are expected not to exceed six and a half degrees. Some studies have shown the possibility of earthquakes reaching seven degrees, especially if the earthquake center is in the Tiberias and Galilee's fingers. It is known that earthquakes do not occur randomly but occur in certain places called seismic belts, usually located within the separating boundaries of tectonic plates (Saudi Geological Survey, 2015). The Arab plate, which includes Iraq, Syria, Lebanon, Jordan, Palestine, Saudi Arabia, and other countries (Al-Dabbeek, 2013), is affected by three types of tectonic boundaries. They are:

1. **Divergent boundaries:** where the Arab plate diverges from the African plate, which leads to the expansion of the area of the Red Sea and the Gulf of Aden at an opening rate of 2 cm per year (Saudi Geological Survey, 2015)
2. **Convergent or collisional boundaries**: It converges with the Eurasian plate at the eastern and northern borders and is represented by the Makran, Zagros, and Taurus mountains.
3. **The (transformational) boundary:** where the Arab plate is bounded from the northwest by a boundary from the left called the Dead Sea Fault ,extends from the northern end of the Red Sea through the Dead Sea to the Taurus Mountains in southern Turkey. (Saudi Geological Survey, 2015).

Because the Arab plate is less thick than the Eurasian plate, it sinks or descends below it, and this pressure movement between the two plates leads to accumulating stresses leading to fracture and, thus, an earthquake (Al-Dabbeek, 2013).

The Arab region is considered a moderate seismic zone since the periods between each earthquake and another are relatively long, with a relatively moderate strength of the earthquakes. (Abu Karki, 2013).

Many earthquakes struck the Arab region and were recorded in history books as devastating earthquakes that caused significant damage and losses to lives and property. Many earthquakes were not recorded or documented because there were no seismic monitoring networks in those areas at that time, or they occurred in uninhabited areas, so no human losses occurred (Al-Dabbeek, 1999)

According to studies conducted by the Earth Sciences and Seismic Engineering Unit at An-Najah National University, the areas in Palestine are classified into potential seismic intensity areas, as they are affected by the locations of geological faults and the length of these faults. The Palestinian region was affected by earthquakes that occurred and were documented in the past two thousand years but in different proportions. (Al-Dabbeek, 2006; Al-Dabbeek, 2010; Palestinian Encyclopedia Authority, 1984; Palestinian Encyclopedia, 2014 .)

Experts base their predictions on the possibility of earthquakes in the future on several factors, the most important of which are the location of the region and its geology, the locations of existing faults and their shapes, the seismic history of the region, and the epicenters of those expected earthquakes, in addition to the seismic activities recorded by the stations, and earthquake monitoring devices. However the probability of an earthquake in the future is based on probabilistic science, and it is not possible through these factors to determine the timing of the earthquake (Al-Dabbeek, 2009).

Since historical events in Palestine showed that it had previously been subjected to high seismic intensity, most Palestinian cities will be affected by varying proportions and seismic intensity, because earthquakes in the past caused losses due to the quality of the buildings and infrastructure (Barakat and Devens, 1997). Knowing the minimum standards and controls for earthquake-resistant buildings was necessary, thus contributing to seismic risk mitigation.

The seismic scenarios conducted by the Earth Sciences and Seismic Engineering Unit at An-Najah University indicated that the exposure of Palestinian cities and villages to an earthquake of 6-6.5 according to the Richter scale could lead to significant losses. Some cities will be exposed to the total and partial collapse of buildings that may exceed a quarter of the existing buildings (Al-Dabbeek, 2009).

Moreover, because of the location of Palestine and the neighboring countries, the possibility of tsunami waves occurring due to earthquakes whose surface centers are located at the bottom of the Mediterranean Sea or the Red Sea is considered possible and expected.

1.3 Disaster Risk Reduction

Risk reduction is the principle and application of diminishing the likelihood and impact of disasters through a methodical examination and control of the factors that contribute to them. This involves minimizing exposure to hazards, mitigating vulnerabilities of individuals and assets, practicing responsible land and environmental management, and enhancing preparedness for critical events. The strategy encompasses four key elements.

1. **Risk identification and assessment**: This stage includes continuous monitoring and risk analysis, as well as vulnerability and determination of risk

2. **Preparedness**: This stage includes initial warning systems, evacuation operations plans, and emergency planning.

3. **Prevention and mitigation:** At this stage, the effort focuses on land-use

4. **Recovery**: This stage includes rehabilitation of buildings, reconstruction, and re-providing the services provided planning, land management, and structural measurements.

1.3.1 Disaster Risk Reduction Strategies and frameworks

From the end of the last century until the current day, and through relevant international institutions, regional and national frameworks, strategies and plans were developed to build the capacities of nations and societies to confront disasters. Including the International Decade for Natural Disaster Reduction (1989), the Yokohama Strategy and Plan of Action for a Safer World (1994), the International Strategy for Disaster Reduction (ISDR) (1999), the Hyogo Framework for Action (HFA), (2005-2015), International Strategy for Disaster Reduction (2009), then Sendai Framework for Disaster Risk Reduction(2015-2030). In conjunction with the Sustainable Development Goals (SDGs), which the United Nations endorsed universally in 2015 to eradicate poverty, safeguard the environment, and ensure that 2030 all people will live in peace and prosperity (UNDP, 2022).

In the Arab world, the League of Arab States has adopted the Arab Strategy for Disaster Risk Reduction - Implementation Framework (2012-2020).

The most important points linked to the topic of this study within these global and Arab strategies can be summarized as follows:

1. Being aware of the fundamentals of disaster planning and devoting efforts to that.

2. Earthquake risk management, which includes the adoption of Seismic Hazard Assessment Mechanisms, production and development of isoseismal maps, the study of the site's soil impact, and the development of land use policy

3. Studying the seismic vulnerability of buildings and the resulting damage and collapses according to the building's architectural and construction considerations and general standards and specifications for earthquake-resistant buildings and adopting the requirements of seismic codes in the design and implementation of facilities

In the Palestinian territories, studies conducted on Palestinian cases indicated a significant shortcoming in the preparedness and ability to face seismic disaster .Whether in terms of preparedness or prevention and mitigation of the risks of these disasters.

Earthquake-resistant building standards are still not mandatory in Palestinian areas (Al-Dabbeek and Al-Kalani, 2008), in addition to the fact that many vital and essential buildings, such as hospitals and schools, are still not able to cope with earthquakes that may lead to the disruption of these facilities in times of need, e.g. (El-Betar 2018; Shehada and Shurrab 2017; Ullah et al. 2019; Al-Zaydna, (2016))

In Palestine, many international standards have not been implemented or are below the required level so far.

1.3.2 Seismic hazards mitigation

Earthquakes are violent phenomena that cannot be prevented; however, harmful effects resulting on people can be mitigated. This matter needs to prepare the whole community to cope with this disaster. This is achieved by raising the awareness of the responsible authorities for the importance of this phenomenon and everything about it. and to raise awareness among citizens and prepare them for how to confront it, as it is required for citizens to deal with it with caution and seriousness despite its absence or non-occurrence for some time.

It is very important to know how to act during and after an earthquake; this will help mitigate its after-effects that may outweigh its initial effects. The authorities in any country bear the great responsibility for this role.

Seismic risk mitigation programs are many (Dragomir & Dobre, 2021), for example:

1. Publishing seismic monitoring networks in the country and facilitating the exchange of information with neighboring countries in particular and far away countries in general.
2. Develop seismic maps for the country to determine the value of seismic activity in the different areas.
3. The code (set of principles) included the design of facilities in the country's different regions to resist seismic forces.
4. Designing modern facilities according to the code to increase their earthquake resistance.
5. Strengthen and reinforce old facilities to increase their resistance to earthquakes.
6. Citizens' awareness about seismic hazards, always preparing for earthquakes and guiding them on how to act during and after an earthquake.
7. Training of civil defense personnel on rescue operations after the earthquake.

8. Establishing a permanent national center to confront disasters, including earthquakes.

In the current study, a necessary and fundamental step before developing any of the disaster management programs for buildings was presented. Which is the process of evaluating the seismic vulnerability of the buildings, anticipate the losses and destruction that will be resulted, using the results in the strengthening these existing buildings to raise their seismic efficiency, and coming up with recommendations to prevent problems in new buildings.

It is worth noting that the World Conference on Disaster Risk Reduction, called by the United Nations, held in Kobe, Japan, in 2005, came out with decisions and priorities for action for 2005-2015. The decisions of some axes included a focus on the need to develop basic concepts to mitigate the effects of disasters, and their adoption as curricula for university and school students have been implemented since 1998(Al-Dabbeek, 2009).

1.4 Seismic assessment and retrofitting of essential buildings

The engineering codes have classified the buildings according to their importance within the third and fourth categories. The third building category is: "buildings that represent a substantial hazard to human life in the event of failure". (ASCE code, 2022). Perhaps the most prominent feature for this category is the number of users of the building, for example, buildings where more than 300 people can congregate, daycare facilities with a capacity of more than 150 people, schools with a capacity of more than 250 people, colleges or adult education facilities with a capacity greater than 500 people, health care facilities with 50 or more resident patients (health care facilities without surgery and emergency treatment taking place), jails and detention facilities, power generating stations and other public utility facilities not included in Category IV. Additionally, buildings containing hazardous materials, such as fuels, hazardous chemicals, hazardous waste, or explosives, with sufficient quantities to be a danger to the public, if released should be classified as Category III.

The essential buildings embedded into the fourth category are: hospitals and other health care facilities where surgery and/or emergency treatment is available; water storage and ancillary buildings; fire, rescue, ambulance, and police stations, and garages; designated earthquake, hurricane, or other emergency shelters, all buildings are critical for emergencies and defense. Also, buildings containing extremely hazardous materials, where the quantity exceeds a threshold quantity established by the authority having jurisdiction – should be analyzed with Category IV.

Buildings in these critical sectors include those necessary for providing essential services to communities as they begin to restore functions and get back to normal life, for example, schools, housing, certain retail stores, and banks. (ASCE code, 2022).

The earthquake erupted in Bhoj, India 2001, killing nearly 1,000 school teachers and students. Nineteen thousand children were also killed due to an earthquake in Kashmir, Pakistan 2005. Furthermore, thousands of children in 2008 were killed as an earthquake hit Sichuan that destroyed the school buildings where these students were staying (Achour & Miyajima, 2020).

Devastating earthquakes have hit Southern California over the years. Studies have shown that hospitals in those areas were exposed to damage and failed to provide various forms of health care. Perhaps the most notable is the collapse of unreinforced parts of San Fernando. Due to the damage caused by the 1971 Sylmar earthquake in San Fernando, hospitals killed at least 44 people and stopped providing necessary health services. The Northridge earthquake in 1994 damaged 11 hospitals. Another nine were evacuated in Los Angeles, leading to a shortage in health care. The estimation of losses in the health sector (especially hospitals) was $3 billion.

In 2016, Kumamoto Prefecture in Japan was hit by more than one earthquake, leaving many losses and damages. The worst damage was the loss of approximately 15% of the affected areas' ability to generate health services, as a large number of hospitals or sections of them were evacuated due to the damage caused by the tremors (U.N., 2022)

In 2009, West Sumatra in Indonesia was affected by a devastating earthquake of (7.6) degrees Richter. The earthquake left thousands dead and wounded. Hundreds of thousands of destroyed buildings and total paralysis in the health and education sectors due to the collapse of hospital and school buildings. The buildings of hotels, government offices, shopping centers, and places of worship were not spared, to the extent that a significant obstacle faced the provision of health care on the one hand and the supply of temporary shelters on the one hand. (Domaneschi et al., 2021)

Certainly, the damage and losses in the areas mentioned above were not limited to health and educational facilities without others. The earthquakes that occurred decades ago showed that the losses affect all weak buildings in susceptible sites, regardless of the building material, use, or occupancy rate of these buildings.

1.4.1 Seismic performance of essential buildings

Seismic performance controls a structure's ability to maintain its main functions, such as its integrity and serviceability, during and after earthquakes. A structure is usually considered safe if it does not endanger the life and well-being of the people in or around it through partial or complete collapse. A structure can be considered serviceable if it can fulfill the operational functions for which it was designed(Mucciarelli, 2014). The basic concepts of seismic engineering, implemented in significant building codes, posit that a building must survive a rare and severe earthquake by maintaining significant damage without total collapse. On the other hand, the facility should still operate for more frequent but less severe seismic events. The importance of seismic assessment of essential buildings is shown, for example, in the devastating effects on the health sector, especially hospitals, in several countries in the world during the past decade, namely India (the 2001 earthquake), China (the 2008 earthquake), Chile (the 2010 earthquake) and Haiti (the earthquake in general). 2010)

In India, for example, in 2001, a 7.6-magnitude earthquake struck Gujarat, western India, killing nearly 14,000 people, destroying 1,800 health facilities, partially damaging 3,812 other centers, and disrupting the state's ability to deliver health care in Emergency cases, The ICRC has trained teachers and school students to deal with waterborne injuries and diseases. Health facilities have been repaired, re-equipped, and built closer to communities to enable rapid assessment and triage of patients, and soil tests have been carried out and enforced rules. Building on all health facilities, Water tanks, electrical wires, telecommunications, drug stores, and laboratories was designed to withstand disasters. All health facilities must develop emergency plans and protocols for assessing and triaging patients. As a result of the earthquake's effects on hospitals and the health sector, decentralization was implemented, whereby the top management in hospitals was delegated to take responsibility during emergencies. The 2005 National Disaster Management Act, which created state and local disaster management bodies, was also passed(Joshi et al., 2019; Nilkant, DiNilkant, D., Agarwal, V., & K, P. S. B. (2021). D. Nilkant, V. Agarwal, and P. S. B. K et al., 2021).

On the other hand, a 7.9-magnitude earthquake rocked China's Sichuan Province on May 12, 2008, the deadliest earthquake in the country's history in more than three decades, killing about 87,000 people. The conditions helped contain the healthcare crisis due to the presence of multiple health agencies to respond to emergencies and the country's implementation of the 1997 law on disaster protection and the reduction of its negative effects. Since then, emergency management guidelines have been developed for health authorities, and a national committee composed of experts in emergency response in health has been established(Chen et al., 2010).

The seismic assessment of hospitals and health buildings in Haiti was demonstrated by the earthquake that struck Haiti on January 12, 2010, killing nearly 300,000 people, including health workers, and injuring 250,000 people, of whom 4,000 became amputees. According to Alex Larsen, the country's health minister, the earthquake destroyed or damaged 30 of the 49 hospitals in the affected areas (DesRoches et al., 2011).

The earthquake that struck Chile on February 27 destroyed more than 80,000 homes and killed more than 480 people, 25 percent of whom died in coastal flooding shortly after the earthquake. The quake affected 18 of the 28 health departments it, damaged 33 hospitals and destroyed ten others, according to Mirta Roses-Briago, WHO's regional director for the Americas. Rebuilding the healthcare sector has been estimated at $2.8 billion. In addition, the period of the reconstruction process has been estimated at a decade for some types of hospitals and at least six months for field hospitals(Boroschek et al., 2017).

1.4.2 Seismic Performance Assessment of Essential Buildings

Engineers need to know the quantitative level of actual or prospective seismic performance associated with damage to an individual building subject to specific ground vibration. Such an assessment can be empirically or analytically (Zameeruddin & Sangle, 2016).

Experimental evaluations are costly tests performed by placing the structure's model scale on a vibration table that simulates the ground vibrating and observing its behavior. These types of experiments were first conducted over a century ago. More recently, it has become possible to perform a 1:1 match-size test on whole structures (Jeong et al., 2012).

Over the last few decades, there has been much focus on researching and developing methodologies for quantifying earthquake-related damage to structures. Seismic risk and vulnerability indices have been developed to quantify damage to structural elements or the entire structural system (Kassem et al., 2020).

The seismic performance assessment of essential (lifeline) buildings shows necessary buildings, for example, those devastating seismic effects that appear to educational institutions in general and schools and universities in particular. All seismic performance assessment activities include developing information required for risk assessment, developing hazard distribution maps and risk assessment, and developing maps that show the spatial distribution of the frequency and severity of disasters. Furthermore, developing maps that show the spatial distribution of the elements exposed to risks (exposed elements), the population, the infrastructure, and other elements in the exposed areas. Moreover, developing maps that show the spatial distribution of vulnerabilities of the constituents exposed to risks, in other words, the degree of their vulnerability. Earthquakes in various parts of the world often lead to the collapse of school buildings, leading to the fall of many injuries and deaths among the school system and students (Mitigation, 2014).

When reviewing the damage to schools during some previous earthquakes, for example, the New Zealand earthquake on February 22, 2011, with a magnitude of 6.3 on the Richter scale. The earthquake caused damage to 163 schools, which were closed for three weeks, pending an examination of the extent of the damages. After three weeks, 90 schools were reopened, 24 needed additional evaluation, and 11 needed additional repair or rebuilding due to severe damage(Johnston et al., 2011).

Before that, the New Zealand earthquake that occurred on September 4, 2010, with a magnitude of 7.1 on the Richter scale, was the most powerful earthquake since 1931 to hit the region. Over the past thirty years (especially after 1991 since the issuance of the

Building Safety Decree), the New Zealand government has implemented a program to strengthen and rehabilitate all school buildings to become earthquake-resistant, and 2361 schools have been evaluated and treated within this program. The earthquake mentioned above came as a test of the success of the rehabilitation and strengthening systems and programs that have been adopted over the past three decades. The survey results after the earthquake showed that all schools except for one withstood the earthquake without any significant damage. As for the school that has suffered severe damage, this damage can be attributed to the liquefaction of the soil and not to the building itself (Johnston et al., 2011).

Chile earthquake; the resulting tsunami: The event that occurred on February 27, 2010, with a magnitude of 8.8 on the Richter scale, occurred during the school holidays and led to damages to the infrastructure of the school sector, amounting to 2.1 billion dollars out of total damage amounting to 30 billion dollars (Elnashai et al., 2012).

On January 12, 2010, the Haiti earthquake, with a magnitude of 7 on the Richter scale, destroyed around 80 percent of school buildings on the island. As a result, 4000 students and 7000 teachers were killed.

On the other hand, the earthquake in Italy in the Abruzzo Mountains on April 6, 2009, with a magnitude of 5.8 on the Richter scale, occurred at 3:23 am. This earthquake destroyed about 50 percent of schools, but no deaths occurred because it occurred after midnight. But some buildings in a local university also collapsed, including student dormitories, which led to eleven deaths(Picozzi et al., 2015).

Perhaps the most challenging results are those related to the Bhuj earthquake in Gujarat in India on January 26, 2001, with a magnitude of 6.9 on the Richter scale. This earthquake killed 971 students and 30 teachers and injured 1051 students and 95 teachers. (Ghosh, 2001)

The following are the most common seismic empirical and analytical methodologies**:**

At the outset, we would like to mention that evaluation methods are generally used for all facilities regarding building type or building system. As discussed earlier, it is necessary to use them in evaluating essential buildings in the first place due to their importance.

Analytical assessment approach

Seismic performance assessment or seismic structural analysis is a powerful earthquake engineering tool used in detailed structure modeling with structural analysis methods better to understand the seismic performance of buildings and non-building structures. Furthermore, this method is the concept of the current building codes, and this development is relatively recent (Di Sarno & Pugliese, 2020).

Generally, four procedures are available for numerical seismic analysis and assessment of buildings: two are linear, and the others are nonlinear. The nonlinear procedures include the nonlinear static procedure (NSP) and the nonlinear dynamic procedure (NDP). NSP's are deemed efficient tools to assess the nonlinear seismic performance of structures. On the other hand, NDPs require detailed input data, and it is very time-consuming, which is a relevant drawback in design offices, where the deadlines are restrictive. Also, this method does not exist in Palestine and many European countries without local earthquake records or powerful specialized programs for NDP. This makes the NSP the best choice for the practical assessment of buildings using the numerical method (Finite Element**).**

Empirical assessment approach

In empirical vulnerability methods, the scale of the damage was used as an inquiry approach to develop the post-event data that comes with statistics studies as the content of building damages (Kassem et al., 2020; Maher et al., 2019).

Many models and criteria depend on the impressionistic seismic assessment, and among these methods, we mention:

A. The Vulnerability Index Method (VIM) takes into account the five non-null damage states and defines the action in terms of macro seismic intensity and the seismic quality of the building using a vulnerability index. Semi-empirical functions measure the estimated damage degree. These approaches include:

1. **The National Group of Defense from Earthquakes approach (GNDT** methodology was developed in Italy in turn is classified into two levels "GNDT level I," which classifies the typologies of the buildings and defines the vulnerability classes (A, B, and C). The methodology of "GNDT level II." In this approach, many

damaged survey data and information needed to be collected. The field survey is to build a clear vision to understand the most fundamental parameters influencing and controlling the structural vulnerability of the building. For instance, plan layout and elevation configurations, footing, material, and quality. There were eleven parameters in total, and one of the qualification coefficients, Ki or Cvi, was distributed into four vulnerability classes (A, B, C, and D).

2. **European Macro-Seismic (EMS) approach (RISK-UE):** Another approach developed for the vulnerability assessment purpose in Europe with The primary goal of integrating an overall seismic risk assessment methodology in European countries. This approach is based on the building typology classification distributed into six vulnerability classes (A to F), from most vulnerable to least vulnerable typologies. Such buildings are classified into four typologies: masonry, reinforced concrete, steel, and wooden. Besides that, it categorized the scale of damage into five grades denoted by D1, D2, D3, D4, and D5, from slightly damaged to fully collapsed (Kassem et al., 2020).
3. **Combined GNDT and macro-seismic approaches:** Another type of vulnerability index is a combined approach. The first problem that should be addressed is finding a correlation between these two methods. This can be proposed and expressed to define the damage grade (DG) as a vulnerability function.

Rapid Visual Screening Assessment Methods:

There are several rapid assessment methods; the street screening procedure is the most straightforward rapid assessment approach. Rapid Visual Screening (RVS), as a qualitative estimation procedure, can be used on a large building stock to classify the vulnerability of the structures. It is built on observations made from the building exterior without considering the building inside. This visual survey can be done in less than 30 minutes (Kassem et al., 2020).

The rapid evaluation process is a statistical method for determining the seismic resistance of a group of structures, and it is based on Visual observation of external changes in the building and its structural system (no need to enter the building); in some cases, general information from structural plans was used. Generally, the results obtained from this method represent an essential indicator for engineers' decisions concerning the entire group of structures (not for individual structures)(Cerchiello et al., 2018).

RVS can be utilized on a large building stock as a qualitative evaluation process to classify the susceptibility of the structures.

Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security whose purpose is to coordinate efforts to respond to disasters that afflict the United States and exceed the resources and powers of the affected state. The state must officially declare a state of emergency. Furthermore, demand from the federal government to respond to the disaster(Cornell et al., 2002).

This method is a precursor indicator of more thorough assessments of buildings based on their materials and structural systems. It is simply a pavement survey technique that focuses on detecting and monitoring construction factors and calculating the basic structural performance score to assess construction risk priorities.

FEMA created a set of guidelines for seismic risk assessment and building renovation:

1. FEMA 154, issued in 1989 and updated in 1992
2. FEMA 154 2002 was developed as a second edition.
3. In January 2015, the third revised version of FEMA 154 was for rapid visual screening of structures.

FEMA 154 has been widely employed in the United States, Europe (Greece), and Asia (India).

FEMA P-154 Third Edition, published in January 2015, was applied in this study.

During the sidewalk survey, a data collection form was filled out by visually inspecting the building from the exterior or inside, if possible. Depending on the levels of seismicity classification, an appropriate form must be chosen. The classification is based on the spectral response acceleration values.

There are five Level 1 and 2 Data Collection Form varieties, each reflecting a distinct seismicity zone. Very high, high, moderately high, moderate, and low(Harirchian, 2020; FEMA P-154. 3d Edition.,2015).

Indicators affecting the seismic behavior of buildings**:**

According to FEMA P-154 forms for RVS assessment, seven indicators were put into consideration during an assessment, which affect the seismic performance of the building:

- Building type
- Building height.
- Plan Irregularities.
- Vertical Irregularities.
- Soil classification.
- Post-benchmark (whether the facility was built before the seismic codes were approved).
- Pre-Code, (whether the structure was built before the initial seismic codes were approved).

In chapter two of this study, RVS evaluation using FEMA P-154 procedure will be addressed in detail.

1.5 Seismic Retrofitting

It is a structural modification process applied to existing buildings to increase their ability to resist seismic activities, landslides, and other ground motions resulting from earthquakes. Before contemporary seismic codes appeared in developed countries, many structures were designed without sufficient detail and reinforcement to protect against earthquakes.

Since the current practice of seismic retrofitting is mainly concerned with structural improvements to reduce seismic risks of using structures, it is also necessary to reduce risks and losses from non-structural elements. It is also important to remember that there is no such thing as a -resistant earthquake structure. However, proper initial design or subsequent modifications can significantly improve seismic performance.

The most important goal, which all designers and engineers aspire to achieve, is to preserve the safety of the building and its occupants during and after a seismic disaster.

For the new buildings, design according to seismic code requirements ensures their readiness to resist earthquakes in the event of exposure. While the existing buildings must be assessed to identify weaknesses and risks of their structural elements they must be rehabilitated by adopting retrofitting policies that raise their efficiency to face potential earthquakes. (Shehadah, 2017)

1.5.1 Seismic Retrofit Strategies and Techniques

Different retrofitting methods mainly aim to improve the seismic performance of existing structures. Many points must be considered before applying these methods. Some of them are related to the external shape of the building, and the availability of carrying out these works in the best and most efficient way, the costs of these works and the time available to complete them. The other part depends on the level of desired structural strength of these works, the materials used in the structural elements, the condition of the existing foundations ,how they will affected by the strengthened works and many other details that must be taken into consideration.

Two main Strategies are used to increase the seismic performance for existing buildings. One is at the whole retrofit level of the structure, while the other is an element-level approach by increasing the seismic capacity of the vulnerable components.

The first approach includes global changes to the existing structure. Common such general modifications include the addition of steel braces, structural walls, or base insulators. On the other hand, element-level retrofits such as concrete, steel, and reinforced polymer (FRP) jackets are added to columns for confinement. This method is more economically efficient. (Bai & Hueste, 2003).

In order to increase both the stiffness and the strength of structures, especially for concrete frame structures, different of intervention techniques using to achieve this purpose, some of the most common valuable techniques are:

Adding shear walls: It is the most popular method for strengthening a building in our reign, added shear walls start from the foundation level (shear wall strap footing) and continues throughout the building. They are placed on both the width and length of the building to keep the center of rigidity and center of mass as close as possible. Good links must be provided between the existing building and the added shear wall. This method enhances the overall stiffness of the structure, increasing base shear. Seismically, it is effective for controlling lateral drifts, in addition to the mitigation of structural frame member damage.(Bai & Hueste, 2003)

Column jacketing: As columns are key structural parts, they must be sufficiently strong. They are subjected to axial, shear, and flexure forces. Columns jacketing is a strengthening technique employed to ensure their resistance and prevent severe damage. This method can be applied to both single and group of structural elements. It may be of concrete, steel, or Fiber –fiber-reinforced polymer (FPR). It is effective to increase the shear of columns, thus preventing their damage from exposure to seismic forces.

Concrete Jacketing: Used in case of insufficient sections of structural elements to bear loads or if the existing concrete covers are damaged. The principle of this method is based on enclosing the structural element (especially columns) of new steel bars, stirrups, and concrete, thus, increasing the strength, stiffness, and ductility of the member.

Steel jacketing: It confines RC columns with a steel cover (jacket), thus improving its ability to resist seismic shear forces. It is an easy-to-implement method; it also prevents concrete spalling. It is used when the stresses on the column will be raised while expanding the cross-sectional area is not allowed. Steel Jacketing increase strength, stiffness, and ductility of the columns.

FRP: It has a tensile strength that can be up to five times that of iron. This method used without causing any distortions in the shape of the structure, on the other hand, it is a cost method, and it is typically used in important facilities or in cases where using iron for reinforcement is difficult due to space limitations. (Bai & Hueste, 2003; Shehadah, 2017)

Many other techniques have been detailed in many studies and applied on the ground around the world, such as, base isolation, supplemental energy dissipation, epoxy injection method, and many others.

1.6 Literature Review

This section gives a brief introduction to the methods and tools used in seismic rapid assessment for different types of existing R.C. buildings:

Some of the studies were conducted for schools, such as (El-Betar, 2018; Shehada and Shurrab, 2017; Ullah et al., 2019; Al-Zaydna, (2016)), and others ,for example, study (Cardenas et al., 2020) study was conducted in Peru 2020; the necessity of assessing the seismic risks of essential buildings such as schools in the region was emphasized because the city was located in a high seismicity area, besides the effective role of these buildings in post-disaster phase. Therefore, the researchers used FEMA P-154 method for seismic vulnerability evaluation, which was applied to 30 public schools -205 buildings- belonging to Lima city in Peru. The results showed that 80% of the buildings didn't meet the minimum seismic design requirements and needed appropriate measures to strengthen and improve them. The evaluation steps were detailed for two different schools in the city, resulted that one of them safe to resist seismic forces. In contrast, the other school has a high seismic vulnerability, and a detailed structural evaluation must be conducted.

Another study conducted by (Khan et al., 2019) in Malak in Pakistan, investigated a sample of buildings with different use, including schools. It was carried out using the RVS procedure of FEMA P-154. RVS sheets were used to calculate structural scores, and likely seismogenic damage is depicted as a function of damage grades of the EMS Scale of the building stock inspected. It was observed that almost half of the buildings fall in damage grades 4 and 5, implying a strong probability of heavy structural and non-structural damages in the case of future earthquake occurrence. Government school buildings were found to be less vulnerable than their private counterparts. Most commercial buildings were not constructed according to building code, making them highly susceptible to damage. Based on the results, the article recommended the implementation of building codes which can lead to a decrease in infrastructural damages and economic losses in the wake of a future seismic event.

Furthermore, the (Domaneschi et al., 2021) study introduces a new approach to the seismic assessment of existing school buildings. Based on the EMS-98 scale and a modified rapid survey of architectural and structural elements of existing school buildings. Sixty-four selected public schools Gaza Strip. The results showed that 50% of the surveyed schools are classified as Vulnerability class B. While 20 % are classified as Vulnerability Class A. The researchers recommended to take appropriate actions related to enhancing seismic performance of Gaza Strip schools against seismic activities since these school buildings not only host about 450,000 students and teachers but they also serve as emergency shelters for those who lose their homes as a result of political instabilities in the region.

(Zayadneh & Armouti, 2014) with a study titled "Seismic Assessment of Selective Retrofitting Technologies for Typical School Buildings in Jordan", in addition to applying the seismic assessment using structural analytical methods, the study showed the effectiveness of constructing new shear walls in reducing the local seismic demands on deficient elements. Local modifications using CFRP-strengthening show a good alternative for enhancing the shear resistance of columns and drop beams with almost no contribution to increasing the deformation capacity through confinement due to the high aspect ratio effect. The study in addition emphasizes the shortcomings of using steel plates as a long-term retrofitting scheme in the case study. The study also outlin**ed** problems when applying steel plates to rectangular-shaped elements that need special care in welding and bonding with the existing surface raising their tendency to buckle.

(El-Betar, 2018) in 2016, with more detailed steps, the researcher applied a qualitative assessment using the FEMA P-154 form for only two school buildings. One of them was old designed to resist gravity loads only. The other was newly constructed, considering the seismic design requirements according to the Egyptian code. The result of the rapid assessment confirmed the efficient seismic performance of the newest one. While the old school needed a more detailed structural assessment, because of its low structural score. Moreover, the researcher applied the push-over analysis using (ASCE 41-13) methodology as a quantitative evaluation procedure to evaluate the seismic vulnerability of the two schools, which confirmed the same result of the rapid visual evaluation. The researcher confirmed the two methods' effectiveness, which indicated that the rapid method is ideal for a large stock of buildings, while the other (quantitative) is for individual cases. On the other hand, researchers have applied the seismic performance assessment for hospitals, for example, (Clemente et al., 2020) conducted a rapid assessment of 26 hospital buildings in the capital of the Philippines (Manila), using FEMA P-154 procedure. Six hospitals only have passed the requirements of rapid evaluation, while the others showed different levels of potential damage, which means that urgent improvement measures must take into consideration. The researchers indicated that the building age factor significantly impacted these results, as 17 hospitals were built before the adoption of seismic codes and vertical asymmetry aspects, which came in the second place. Additional factors such as horizontal asymmetry and others were also observed.

A rapid assessment of the architectural design of some government hospitals was applied by(Habboub, 2014). It was conducted as a complement to a previous study carried out by the Center for Urban Planning and Disaster Risk Reduction at An-Najah National University to identify the extent of seismic vulnerability to government hospitals. The descriptive and analytical, and the deductive approach were adopted to achieve this goal, including interviews with stakeholders were used, in addition to visits and field surveys. The study concluded that one hospital has a medium seismic potential among the governmental hospitals, two are high, and the rest are very high, as most of the hospitals under study were considered seismically unsafe.

Most of the studies discussed above concern with essential buildings, especially hospitals and schools, which are the most vital and necessary buildings to sustain in seismic emergencies.

In Palestine, several studies dealt with rapid seismic assessment of buildings, came up with effective results and recommendations related to the safe seismic design of buildings; from these studies:

(Salah's, 2018) study discussed the impact of the architectural and construction organization on the seismic behavior of common building patterns in Hebron city in Palestine, by conducting a rapid visual seismic assessment. The study aimed to encourage offices, engineering companies, and related institutions to adhere to the standards of earthquake-resistant buildings in the design and implementation of the proposed buildings and pay attention to the seismic rehabilitation of existing buildings.

Results demonstrated that there is a clear impact of the architectural and construction body on the seismic behavior of any building, Concurrently with a clear absence of seismic design with common mistakes in most buildings in the city Hebron. Also, through a survey of a group of engineers, it was found that there is an absence of a scientific plan taught in universities for students of the Faculty of Engineering or that this plan does not allocate enough space for awareness in the field of seismic design.

To determine the area’s most vulnerable to earthquakes and forecast losses in the future, (Di Meo et al., 2018) conducted a study with the main purpose of proposing a framework for integrated seismic risk assessment in Palestine, where earthquake-induced risk awareness still at an early stage. A methodology was proposed to combine an existing state-of-the-art hazard model with new vulnerability and exposure models, specifically built upon local field surveys and national data collection. The study's outcome the identified the regions that are more vulnerable to earthquakes, and predicted the future loss at the regional scale.

Another study was done by (Salahat, 2014), dealt with evaluating the seismic performance of existing reinforced concrete buildings in the Palestinian territories, then determining the induced damages and losses in order to propose the appropriate retrofitting system if needed. In addition, the researcher evaluated the common structural design practice and methods in the study area, and their ability to meet the requirements of dynamic design. The study also showed that adding shear walls as a retrofitting system is sufficient to enhance the structure’s seismic capacity.

(Al-Dabbeek and Al-Kilani, 2008) applied a study in 2008 in an evaluation of camp buildings entitled: "Rapid Assessment" of Seismic Vulnerability in Palestinian Refugee Camps". It included an estimate of the percentage of damages and losses in the buildings of certain Palestinian camps such as Al-Amari camp, Balata and Deheisheh, and an assessment of the vulnerability categories of the buildings according to the FEMA and EMS-98. They focused on camp's buildings in terms of the building materials used, and the architectural and structural configurations. The results showed that significant structural and non-structural damages and losses will occur, that many buildings will suffer damage from Class 4 and 5. Due to the poor quality of the buildings in terms of design, implementation, adhesion of buildings, and inappropriate width of roads, this will certainly increase the seismic vulnerability of buildings under the influence of Strong or moderate predicted earthquakes.

Another study for Al-Dabbeek at 2007, entitled: "Vulnerability and the Expected Seismic Behavior of Buildings in the West Bank, Palestine" included conducting seismic scenarios for some areas in Palestinian cities as a sample. The assessment of buildings was done by determining the size and proportions of mistakes in building practices, and thus finding of the collapses and potential damage for different building styles, If they exposed to seismic forces. The study also included a presentation of the most important architectural and construction patterns and formations in Palestinian buildings that do not meet the seismic safety requirements. A general exploratory evaluation methodology was adopted, where a quick field assessment was conducted for several areas in 7 Palestinian cities. The results showed that the susceptibility to seismic injury was high in many buildings, with a possibility that some of these areas will be exposed to major damages and total and partial collapses and the high possibility of disabling and closing many roads in these areas. (Al-Dabbeek, 2007)

An old and worthy study for the same researcher in1999 entitled: "Seismic Risk Mitigation in Palestine," aimed to prepare a Peak Ground Acceleration Map for Palestine. In addition, the study focused on the impact factor of the soil of the site (site effect) with a general overview about the expected seismic behavior of common building in Palestine. (Al-Dabbeek, 1999)

From the previous studies, it is clear that various seismic assessment methods have been applied, including rapid (qualitative methods), which are suitable for application in the case of study samples that include a large number of buildings, and other (quantitative) methods with more accurate results, suitable for individual buildings and useless in cases that need to evaluate a large stock of buildings. In addition, most studies the evaluation results have been linked to the EMS ratings to determine the expected degrees of damage for each building. This facilitates understanding of how the expected building performs when exposed to seismic forces. Some researchers discussed solutions to raise the seismic efficiency of weak and vulnerable buildings. Reinforcement and consolidation works were applied to prove their efficacy in solving the problems of weak buildings.

Based on these studies and others, In this research, FEMA P-154 as one of the rapid visual survey methods has been adopted to assess the seismic vulnerability of buildings, then linkage the results with the EMS-98 ratings scale to represent the expected degrees of damager, Moreover, 3D dynamic analysis will apply for one building as a representative case study, in order to evaluate its seismic efficiency, and propose the appropriate retrofitting system if need.

This study will apply for a vital category of buildings that have an effective impact in the face of disasters, the essential buildings in the study area.

1.7 Problem Statement

Earthquakes can be occurred from many sources such as points, lines, and areas. Many line sources, i.e., faults, locate in Palestine like the Dead Sea - Jordan river, the Wadi-araba, the North East Gaza faults, and others. This makes Palestine vulnerable to earthquakes.

"*In a developing country with limited resources and investments concentrated in seismic areas, the consequences of a major earthquake should be feared as much as the phenomenon itself"*.(Ambraseys, 2015)

In Palestine, like other developing countries, the majority of existing buildings according to their current conditions, are expected not to meet the minimum requirements of seismic codes, as part of them are old buildings that were built using traditional ways, or most of them were designed under the influence of gravity loads only, without any seismic considerations.

Numerous studies have shown that the fact that seismic history of Palestine due to its geographical location, and the human behavior and random building patterns, and emphasized the need to mitigate the risks of earthquakes. Unfortunately, it still lacks to the preparedness and awareness required to face the consequences of such disasters.

Therefore, it is necessary to consider the risks associated with earthquake phenomena, and to employ all efforts to reduce them.

In general, disaster risk reduction strategies have been identified under three drivers:

- Avoid creating any new risks.
- Addressing pre-existing risks.
- Risk sharing and transfer to prevent other development outcomes from absorbing disaster losses and creating more poverty.

According to the second strategy concerning to existing buildings, in addition to the fact that earthquake risks are more destructive in the case of essential buildings.(Cardenas et al., 2020) ,as these buildings have special and unique occupancy, such as hospitals and schools, as well their post-disaster effective role. For these and other reasons, essential buildings require special attention regarding seismic performance.

Therefore, there is a need to study rapid seismic assessment and retrofitting strategies for essential buildings, in order to enhance their performance against seismic activities.

1.8 Aims of study

The main goal of this study is to evaluate the seismic performance of essential buildings in the city of Tulkarm, and to prioritize the intervention for seismic efficiency improvements.

The current study also seeks to achieve the following sub-objectives:

- Enhancing the awareness among individuals and groups regarding the vulnerability of buildings, and thus exposing them to danger.
- To produce a risk map for the essential buildings in the city, to contribute in preparation of effective emergency plans, or to upgrade the existing plans, in addition to determining the possible locations of shelters and evacuation routes and others.

1.9 The importance of study

The importance of the current study lies in the following set of points:

- The result of this study is the application of an important risk mitigation tool (risk assessment) which is an effective step in the disaster management cycle.
- Informing officials in government institutions of the importance of adopting procedures for rapid earthquake assessment and making recommendations for the design of essential buildings such as schools, government institutions, mosques, etc., and taking the necessary measures to implement them before earthquakes occur, and to increase their readiness to resist earthquakes.
- General clarification to officials about the importance of developing national plans to develop the readiness of the essential buildings, mitigate the impact of the earthquake and reduce the dangers to citizens.
- Finding proposals to improve the condition of the essential buildings, through Seismic Rapid Assessment and Retrofitting Strategies of the authority.
- Assisting engineers in charge of designing the essential buildings on how to plan appropriately designed to be more earthquake resistant.
- Giving specialists a glimpse of the importance of selection of suitable location to construct new essential buildings, so that the negative results of the site effect are avoided, and therefore the prevention or mitigation of severity seismic losses.

Chapter Two

Methodology

Risk assessment is an essential tool for the disaster risk management process and the beginning from which the series of steps to mitigate the risks of any disaster underlies. The evaluation of seismic hazards is centered on three major components: hazard, exposure, and vulnerability. Seismic vulnerability of buildings is the probability of the various damages to these buildings, their infra-structure, and its affiliated services, as well as much more that result from the earthquake. The seismic vulnerability of a building refers to its seismic capacity also.

Since seismic vulnerability is one of the main components used to evaluate seismic risk, controlling its levels and minimizing it greatly contributes to the risk reduction of the anticipated earthquakes.(Khan et al., 2019)

In this chapter, seismic evaluation was applied to particular buildings whose degrees of damage were determined so that they can be utilized later in the risk reduction strategies of the seismic disaster in the area.

2.1 Study design

In order to achieve the main purpose of this research, which includes taking radical steps in the project of disaster risk mitigation, particularly the seismic ones, and since the earthquakes do not kill but rather the unsafe buildings, which are the main cause of destruction and loss of both lives and properties. (Al-Dabbeek, 2007).

Therefore, conducting this integrated study is necessary to inspect the seismic efficiency of buildings, their resilience to the seismic disaster, and the ensuring of its operation in the post-disaster phase.

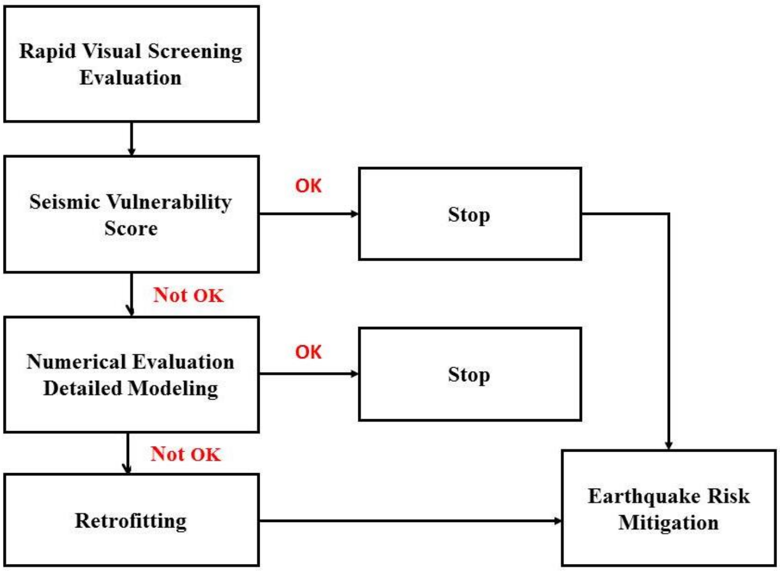
Figure 1 illustrates through the sequence of steps the strategy pursued in this study to manage the seismic risks of existing buildings. Hence the evaluation of the seismic performance process for buildings is established by applying one of the most popular assessment methods. The rapid assessment methodology is a fast way of evaluation, low-cost, easy to implement, and suitable for a large stock of buildings without the need to make any structural calculations to evaluate the seismic vulnerability.

RVS outcomes are numerical results that indicate the seismic capacity of buildings based on certain features, which are studied for each structure separately. These values are interpreted using global standards to represent the various levels of potential damage to buildings. Accordingly, interventions are prioritized so that needed measures and actions can be taken to raise the capacity and efficiency of seismically fragile buildings.

As for the buildings with low evaluation Scores, thus high and unacceptable degrees of seismic damage, the next step is considered by resorting to more detailed analysis and evaluation using linear or nonlinear numerical analyses. These ways require modeling of buildings using one of the finite element soft wares in order to confirm RVS results. In case a building is proven to have a structural weakness in seismic resistance, a need is emerged to strengthen it by providing propositions around the structure rehabilitation in the fourth step. It will increase the seismic efficiency of the most affected buildings and reduce their susceptibility.

Figure 1

Strategy of work



Upon completion of the evaluation process, the buildings that were examined are divided into two categories; the first one has a low seismic vulnerability and a low to moderate degree of damage. In case of exposure to seismic forces, minor and low-cost adjustments are sufficient so that it is reused immediately in the disaster response phase.

The other has a high seismic vulnerability, and its structural elements are expected to either be affected or partially collapse. It needs structural retrofitting to mitigate its susceptibility and thus raise its seismic capacity.

Consequently, this study is an integrated, realistic, and efficient method to evaluate the susceptibility of buildings to potential seismic hazards and generate sufficient information for decision-makers, stakeholders, and supporting bodies. Accordingly, the evaluation methodology will be employed as the main tool to determine priorities in disaster risk management.

2.2 Study population

2.2.1 Essential buildings

Evaluating the seismic susceptibility of buildings is important for all existing buildings that are exposed to the possibility of facing an earthquake without exception, regardless of their location, area, construction costs, or others. As long these buildings are inhabited or if they provide humans with vital services. Keeping people alive is the first aim and the highest demand that should not be condoned at any time, even in times of public emergency.

Buildings in the vital sectors should perhaps be prioritized for evaluating seismic vulnerability. They provide services crucial for immediate response in emergencies, such as hospitals, emergency centers, police and fire stations, etc. Another example of vital buildings is those that offer communities basic services in the response phase to restore jobs and return to normal life. Most of them have large gatherings such as schools, housing, banks, etc.(UNISDR, 2013) ; they are called essential facilities, which must have the capacity to resume providing their services immediately after the disaster. Moreover, if earthquakes cause damage, a simple repair of some non-essential components will be sufficient to restore operations instantly.

The circle of critical and essential buildings for any area may widen to include every building that can be obviously and largely relied upon after the disaster. Some supermarkets, warehouses, large retail stores, pharmacies, and banks have proven their effective role by providing plentiful supplies and basic services such as food, water, medical supplies, and money in a number of the affected areas after the incidence of disasters around the world. If these facilities are unsafe, it is expected to be damaged. The loss will not be limited to their construction structures only. Due to the loss of supplies and any other materials stored inside these facilities, a major obstacle will impede the community's post-disaster recovery. (Oregon Seismic Safety Policy Advisory Commission (OSSPAC), 2013)

But in this research, the focus was on the essential buildings that have a vital role in response and rehabilitation processes. Perhaps the most prominent buildings that received "special" attention from the relevant authorities are hospitals and schools. Hospitals awakened interest because of the sensitivity of their services, which need to be sustainable without any interruptions. Schools sparked interest because there are large numbers of students and staff. Moreover, there has been a concern about ensuring the unimpeded education process, maintaining its quality, and employing school buildings in response and hospitalization operations.

"*People in unsafe schools, hospitals, and health facilities are at the greatest risk of losing their lives when a disaster strikes.*"

Representative of the United Nations Secretary-General for Disaster Reduction, Margareta Wallström, April-2010. https://www.un.org

This is why it is needed to focus and direct attention to the Essential buildings more than others and evaluate them to determine their susceptibility to EQ effect and their ability to withstand when exposed to seismic forces. This data must be put in the hands of decision-makers and specialists to prioritize intervention for the strengthening and rehabilitation procedures for these buildings. Furthermore, to contribute fundamentally and effectively to formulating and preparing evacuation and sheltering plans in both response and recovery phases.

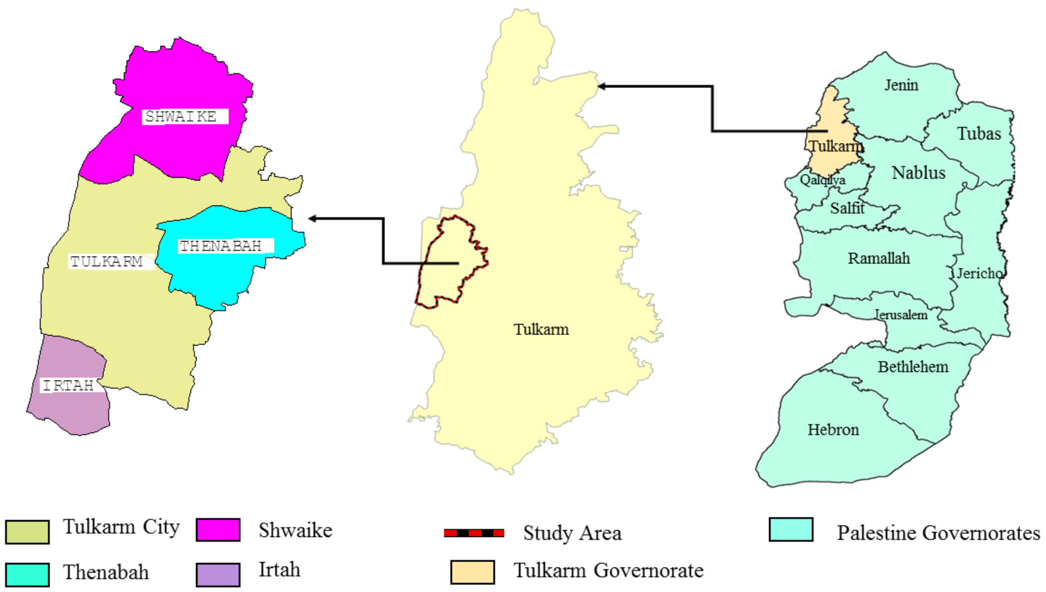
Consequently, all the essential buildings in the study area were viewed as the total population of the study from which a representative sample will be chosen.

2.2.2 Study area

The study area was limited to the area located within the boundaries of the Tulkarm municipality. It consists of the city of Tulkarm and its affiliated neighborhoods, which are the neighborhood of Thenabah to the east, Irtah to the south, and Shwaike to the north, which is called (the Tulkarm city assembly). The city of Tulkarm was selected in this study due to its significance that it is the third-largest city on the West Bank, and it has a vital and strategic location in the West Bank.

Figure 2

Geographic location of study area



Geographical location: The city of Tulkarm is located in the western part of natural Palestine, in the north of the West Bank. It is about 15 km from the Mediterranean coast and about 90 km from Jerusalem, the capital of Palestine. The elevation of the city ranges from 65 to 120 meters above sea level. It is situated north of the equator, at latitude (9-532), and east of Greenwich on longitude (1-535). Figure 2 shows the location of the study area with the governorates of the West Bank and Tulkarm Governorate.

Area and population: In reliance on the master plan -2019 for the city of Tulkarm, the study area covers an area of approximately 13790.351Dunams. The population of the city of Tulkarm will reach 68,712 people by the end of 2021, as estimated by the Palestinian Central Statistical Organization.

The urban structure of the city: The city of Tulkarm, like other cities on the West Bank, adopts the pattern of the central city in terms of urban planning. Buildings are concentrated in the city center and diverge on the outskirts, forming residential clusters. They contain several villages surrounding the city from all sides except for the side adjoining the separation wall. These communities are directly linked to the business center of the city. The buildings in the city center extend vertically. At the same time, buildings with a height of two to three floors extend horizontally; this spread in most parts of the city, such as residential neighborhoods consisting of detached houses and residential villas with one or two floors at most, as with school buildings whose height does not exceed three floors mostly. Because of the random planning and its impact on many geographical and humanitarian factors, it is observed that there are many adjoined buildings as the building shares one or more of its facades with the building adjacent to it, and this type is evident in commercial buildings. Moreover, it is noted that new upper floors have been constructed with modern designs over the existing old floors, which are executed traditionally. Buildings are divided according to their usage into single-use buildings (such as villas and residential houses), multi-use buildings such as commercial buildings, and some residential buildings that employ the ground floor as commercial stores (Jamil, 2009).

Soil: Figure B.1 illustrates the general types of soil in the study area. There are three types of soil. The first is the Grumusols soil, which is between red and yellow, with a high clay content, which increases its water permeability. The second type is the pink-red soil Terra Rossa which covers most of the West Bank and is formed from limestone and dolomite rocks. Third, the Rend Zina soil is found in high areas formed from chalk stone, called (whiteness). This is mainly because of the city's location in the semi-coastal region, which increased the depth and fertility of the soil from the western side. Accordingly, this escalates its vulnerability to seismicity.

Agricultural value: The city of Tulkarm depends mainly on agriculture. It is the main profession through which the city's inhabitants make a living. The agricultural lands are widely distributed, whether of the city's high, medium, or low agricultural value. Figure B.2 shows that the study area falls into the areas of low agricultural value

Water: The water level in the city is high compared to other cities due to the abundance of rain and groundwater. Accordingly, moisture of the soil rises, which leads to the spacing of its particles and hence the increase in the possibility of seismic amplification. The severity of the seismic impact on the city will rise as well. Figures B.3 and B.4 shows the rainfall in millimeters, and catchments in the study area respectively.

Seismicity of the area: The study area is situated in Tulkarm, north of the West Bank. The seismic foci are distributed in Palestine from north to south. Because of the presence of active faults, as in the Fara'a-Carmel, north of Tiberius, the Dead Sea, and others, the fracture in the ground layer of each of these foci or faults is renewed at a certain periodic time. Therefore, the Fara'a-Carmel earthquake is renewed every 200-300 years, while the Dead Sea earthquake is renewed every 100 years, according to the periodic time of each seismic focus. Fortunately, the city of Tulkarm is considered relatively far from these seismic foci, which makes it less affected by seismic intensity than other cities such as Nablus and Jericho. (ESSEC),(Hawajri, 2016) .

Based on the seismic macro-zonation map prepared by ESSEC, Tulkarm is located within the seismic zone = 2A, See figure B.5. It is symbolized by the symbol Z: the seismic zone coefficient and its value are 0.15, a considerably low value compared to other cities in the east of the West Bank. Consequently, it is classified among the areas of moderate seismicity.

2.3 Study sample

In this study, rapid seismic vulnerability evaluation procedures were applied to a sample of 134 existing construction buildings, considered the most essential to be more resilient in the case of an earthquake in the city of Tulkarm.

As mentioned before, the significance of these structures stems from the need to keep them safe, in addition to ensure the continuity of providing the desired services during and after seismic crises.

The evaluation sample was represented in any facility that provides health services, whether includes surgical facilities and ambulatory treatment or not, such as hospitals and health centers. Additionally, educational facilities in the city, such as schools and universities, were adopted in this sample. The importance of this category derives from the fact that, on the one hand, they have a basic occupancy of more than 250 people (IBC code). On the other hand, these facilities are usually used to accommodate those affected in the post-disaster stage. The governmental public facilities that directly host the security authorities and any other party specialized in crisis and disaster management or emergency preparedness were also included in the study. These buildings may contain the administration of significant operations and groups or individuals expected to contribute to all stages of disaster risk management, especially both response and recovery.

In the name of public buildings, club buildings, multi-purpose venues, and other public buildings with huge areas that provide the opportunity to be used as shelters or warehouses for storing aid materials and others were taken into account in the evaluation process. For the same reasons stated above, some mosques were evaluated in different neighborhoods of the study area because of their moral value (Sanctity) and the feeling of safety that it gives in emergencies that cause panic and distress.

It is important to emphasize that even if these buildings are not used as shelter centers, their yards or dependencies will be exploited in the response and recovery phase. Therefore, it was crucial to include them within this sample.

This study sample contained the buildings mentioned in the emergency response plan for the city of Tulkarm. It was prepared by the Civil Defense Directorate in the city, which is associated with the General Directorate of Civil Defense - the Ministry of Interior. These buildings were proposed as primary or alternative centers for housing people or transferring some of them to field hospitals, Annex to the Emergency Response Plan - Tulkarm 2019-2020. Appendix A.1

The study sample is not representative of all the buildings in Tulkarm since it was confined to most of the essential buildings in the city without other residential and commercial buildings. Following the completion of this study, it will be possible to disseminate the findings to similar buildings in terms of the construction system and occupancy, even done locally at the whole governorate level or nationwide.

Figure 3 demonstrates the geographical distribution of essential buildings in the study area. The sample size totaled 134 reinforced concrete, existing buildings of the most important buildings in Tulkarm city. They are located within the boundaries of Tulkarm municipality and distributed over four areas: Tulkarm - the city assembly - Shwaike in the north, Thenabah in the east, and Irtah south of the city of Tulkarm. The sample buildings were divided and grouped into three categories according to their use and the services they bestow as follows:

Educational Facilities

It includes the buildings of schools and universities in the study area. They are 73 buildings belonging to 53 educational facilities. Schools, whether governmental, private, or under the supervision of UNRWA, in addition to the buildings of the Al-Quds Open University (POQ) and Palestine Technical University (PTU) Kadoorie, Some schools, and universities consist of two or more buildings. Educational structures represent the largest share and most widespread part of other important buildings because of the services they provide for significant groups of individuals, young people and youth, and others, and being an option usually included when locating accommodations centers –shelters - in disaster response plans.

It is worth mentioning that 273 classroom comprising 17170 students in the schools evaluated in this study, regardless of universities. (Supplement to the Schools Framework in the West Bank 2021-2022 Appendix A.2

A classroom with several students, used daily for education, may have to be considered a temporary shelter for a family in case of emergency. For these reasons, the focus was more on educational buildings, especially schools. All the schools in the study area were evaluated.

Health Facilities

They are governmental and private hospitals and health centers distributed in the entire study area. They are 12 buildings that provide emergency and non-emergency medical and health services, 7 of which are located in the same city, while five are in the surrounding areas (suburbs). Only 3 of the health buildings are major hospitals that provide full health services and have critical surgical facilities.

This sample did not contain private health clinics, radiology centers, and pharmacies, for most of them do not represent a separate building in itself, but rather a part on a particular floor of a multi-story building, which may be residential or commercial, and was not designed to provide these services in the first place.

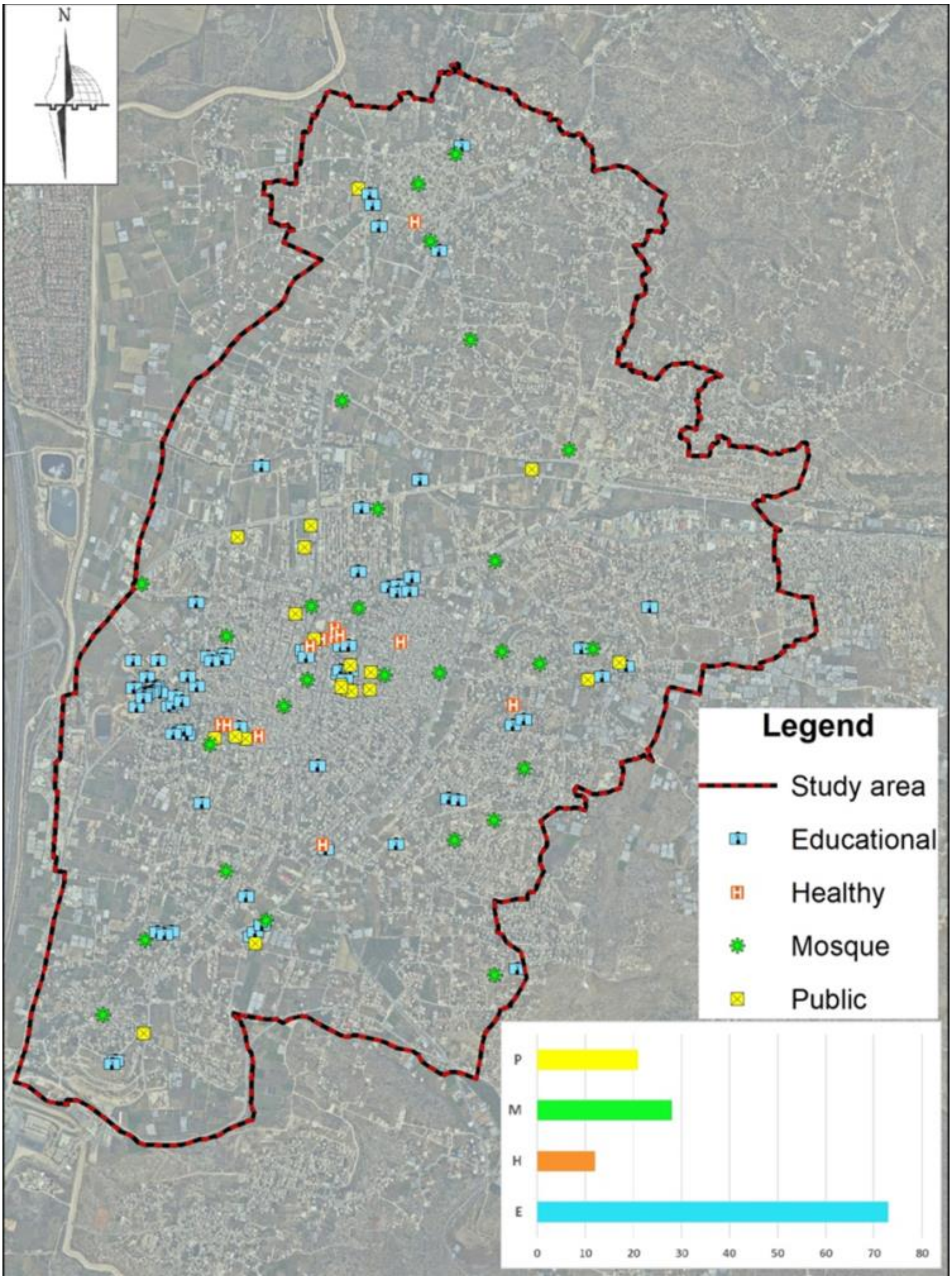
Significant public facilities

They include governmental public buildings such as the county, police, national security, and ministries. They also contain sports clubs and multi-purpose venues (halls), which were established under the supervision of competent authorities (Tulkarm Municipality) or donors and financiers such as (CHF). Part of the large mosques in the region is considered important public facilities. The number of public buildings was 49, mosques included.

For more details and better comparisons through analysis and discussions, mosques were separated from other public buildings in some parts of this study as a separate category.

Figure 3

The geographical distribution of buildings investigated in the study area



2.4 Instruments of study

Many tools were deployed in this research in order to obtain its purpose.

- **FEMA P-154 Data Collection Form as adscription tool**

FEMA P-154 Data Collection Form for RVS of buildings for potential seismic hazards: The Level 1 form for moderate seismicity zones was adopted.

- **ETABS as analytical tool**

ETABS 2016 version 16.0.2: Engineering software is especially used to analyze and design multi-story buildings. This study was used to apply seismic analysis and re-design for the study case.

- **Microsoft Excel as analytical and storage tool**

Spreadsheet software was a powerful tool for data storage, organization, analysis, and visualization. It was used to codify and regulate the key information about the buildings before and after the visual survey stage and to make simple calculations to achieve the results after the evaluation. Additionally, it was used to interpret the findings and illustrate them through expressive and conceptual graphs.

- **Geographic Information System (GIS) software, as mapping tool**

(ArcGIS 10.8, ESRI) The software was used to deal with different data types for the buildings. Creating, managing, analyzing, and mapping these data. GIS is an effective tool for linking location data with several forms of descriptive data.

The GIS is required for data preparation and mapping spatial linkages between natural hazard occurrences and the elements under concern.

2.5 Study procedures

The seismic vulnerability of buildings depends on several factors. They manifest in the area's seismicity, site effect (soil conditions), type of the structural system, and the architectural and construction elements and their distribution.

The best way to evaluate the seismic weakness of buildings is to conduct nonlinear finite element analysis; thus, accurate results are obtained with the least error rate(Khan et al., 2019).

Since the study sample, which was approved to represent the essential buildings in Tulkarm, consists of 134 buildings, it is challenging to analyze each structure separately due to the large sample size. This will require experience in modeling, linear and nonlinear analysis, and more time and increased effort. Therefore, a rapid visual assessment is a viable alternative to other analysis methods. This process is implemented for a large stock of buildings with minimal time, effort and cost, in addition to its uncomplicated procedures.

This evaluation process was based on visually inspecting the buildings in a short time of no more than 30 minutes. The building was inspected mainly from the outside, from the inside if possible. During that, specific observations were recorded about some of its architectural and structural features, which may increase the seismic capacity of buildings or reduce them because it directly influences the performance of the buildings when facing seismic forces.

By conducting a simplified calculation process, a numerical value is reached for each building, which expresses the vulnerability of each building without the need for any complex structural calculations.

In this study, (the FEMA P-154) Procedure, which is one of the most important, widespread rapid visual evaluation methods, was applied to 134 important buildings in the city of Tulkarm. Moreover, 3D dynamic analysis was conducted to investigate the seismic vulnerability of a building as a detailed evaluation case study.

Structural strengthening strategies were also applied to the study case building to raise its seismic efficiency.

2.5.1 RVS assessment (Qualitative method)

Rapid visual inspection of potential seismic hazards for buildings using FEMA P-154

As implied earlier, the rapid assessment process is implemented in three phases, as follows:

The First stage: Pre-field stage:

It is called the planning stage of evaluating and processing all data before going to the field and inspecting the buildings. It can be summarized in the following steps:

Selection of Data Collection Form

To begin with, the first step after adopting the sample is determining the evaluation form suitable for the study area (the city of Tulkarm). FEMA P-154 provides five samples that differ according to the seismic zone in which the evaluation will be implemented (very high, high, and medium to high, medium, low seismic activity).

With reference to the seismic map of Palestine, figure B.5 and table C.1.

based on that, the value of Z, Ss, and S1 are constant values of the study areas as follows:

Z=0.15 (from Palestinian seismic map)

0.375 =Ss = 2.5* Z

=٠,١٨٧٥ S1=1.25* Z

The Palestinian territories fall within the moderate seismic zone. Therefore, the form of moderate seismicity areas was adopted to evaluate buildings for the potential seismic risks.

The form consists of two levels of evaluation. Level 1 is fundamental and sufficient to evaluate the seismic ability of the building. (Its output is a structural score (S.S) which demonstrates the seismic ability of buildings). The second (level 2)is optional and focuses on additional structural properties more than the first. Unlike the first level, the second requires time and effort, and experience in seismic assessment and design. In this study, applying the first level as an evaluation form was sufficient. Figure C.1.

Documentation of Pre-Screening Data needed for the evaluation

To facilitate the research process and compile information on sites and buildings, the study area was divided into four geographical areas: the city of Tulkarm, each of the suburbs of Shwaike, Irtah, and Thenabah. The essential buildings (the subject of the study) were classified according to their usage and services into three educational groups: schools, universities, and libraries, symbolized by the symbol (E). The health ones include government and private hospitals and health centers, symbolized by the symbol (H). Finally, public facilities, which include government buildings, mosques, police stations, and other buildings that provide public services, were symbolized by (P).

Maximum information about these buildings (Pre-field data) was compiled, documented, and scheduled in an Excel sheet Appendix A.3, Among this initial information:

- The numbers of land parcels and the basins in which these buildings are located.
- The use of the building (occupancy).
- Year of construction , if possible.
- Soil classification for each region.
- Area of some buildings, if possible.

This information and others were obtained by communicating with the authorities in charge of these buildings, both institutions, and individuals, such as the Palestinian Ministry of Education, particularly the National Center for Educational Research and Development (NCERD), the Education Directorate in Tulkarm (Buildings and Projects Department), Tulkarm City Municipality (Engineering Department, Licensing Department, and Surveying Department).

The city's structural plan was also examined. Licensing documents and engineering design plans for buildings were used, in addition to contacting engineering offices that designed and supervised some buildings. Part of the information was gathered from previous studies which were conducted on these buildings or buildings in nearby areas.

A major step which is necessary to examine the possibility of any geological threats the study area may be exposed to, such as Liquefaction, Landslide as well as Surface fault rupture. as the presence of one of these dangers at least requires a more detailed study, Due to the inefficiency of rapid assessment in these cases. in Due to the nature of the plain area in the study area (in Tulkarm), it has not experienced any of the above-mentioned threats.

To determine the geographical location of the buildings, the geospatial information system of the Palestinian Ministry of Local Government (Geomolg) was utilized. Initial maps were prepared based on the city's aerial photographs along with its master plan in order to facilitate reaching the build during the field visit. Additionally, these maps provided a rough sketch for the horizontal plan of each building, comparing and auditing it on the field.

Determining key dates and values adopted for the screened area

The evaluation form includes specific ruling numbers and dates that influence the final value S.S of the building negatively or positively. It is essential to determine these values for the study area before starting the actual evaluation process, which are:

Seismic code adoption dates, and Benchmark years for the area being screened

On 26-11-2015 Engineering Bureaus Board in the Palestinian Engineering Association - Al-Quds Center- issued a decision confirming the urgency to adopt the seismic code within the requirements that must be met in the engineering plans of public buildings and those with a height of more than seven floors in the Palestinian territories and the Gaza Strip. Appendix A.5, Figure A.1

The law required seismic structural design, which considers all the requirements of the seismic codes, was approved in late 2015. However, it was officially implemented and enforced in a wide and comprehensive manner until the beginning of 2017. That was after holding several workshops and intensive training courses in a seismic design targeting all relevant parties. They include engineers of the engineering offices that implement the structural design drawings, the engineers of municipalities, and other bodies that manage the engineering supervision operations on the buildings.

Memorandum of understanding agreements was signed between the Syndicate of Engineers, the Ministries of Local Government and Works, and An-Najah University, represented by ESSEC. It aimed at approving seismic design and monitoring to apply it correctly. Thus, 2012 was considered the year in which seismic codes were initially adopted, while the year 2017 was adopted as a benchmark year. which means that every building that has been constructed after 2017 was considered after the (benchmark) within the rapid screening evaluation. Therefore, it was a positive point for it that raised its final S.S value.

As for educational facilities, such as schools and universities, there was a "special" situation concerning seismic design since all the buildings constructed since 2005 have had their structural plans audited and the seismic code applied in the design in particular. This occurred due to official approval from ESSEC in cooperation and coordination with the Engineers Association.

For this reason, 2005 was adopted to be the year of the seismic code for only schools and universities (ESSEC), add that 2008 was adopted to be the benchmark year for them (An interview with Haj Qasem ,Head of building dep., Tulkarm,2021)

Cut-off score to be used in

According to FEMA P-154, (2.0) is a logical value worth using as a cut-off score. Because adopting a value higher than two guarantees a more conservative situation and, therefore, higher costs and greater effort in the options for maintenance, consolidation, and rehabilitation. On the other hand, a value less than 2 for (cut-of-score) reduces costs during the evaluation or rehabilitation processes before the disaster. But that equates to an increase in the region's seismic risk and greater uncertainty.

After this stage was completed, 134 copies of the adopted evaluation data collection form were provided to fill in the confirmed information, such as the name of the building, address, and other information verified from the sources as mentioned above. Accordingly, this stage, with its three steps, is the guide and the main pulse for what follows the evaluation steps. Moreover, it advances the reduction of the total time needed to complete the evaluation process and may provide an opportunity to ensure the reliability and accuracy of the data gathered in the field.

The second stage -field Observation

RVS methodology operates within a logical framework, which is broken down (the framework) into technical parameters. They represent the characteristics of the building, then used the determine building SS.

At this stage, the visual survey was applied by visiting the buildings in the field, inspecting each one separately, collecting the required information, and reviewing and confirming what was previously collected. The buildings were approached using maps and aerial photographs prepared in the previous stage. The four parts of the study area, the city of Tulkarm, Shwaike, Irtah, and Thenabah, were visited. Each building was considered and examined from all sides outside. The inside of the ones that would have been possible to enter was also examined. The process of recording observations was carried out using a separate data collection form for each building.

The following are the steps of Practical Implementation of the evaluation process, by sequence in the data collection form:

The evaluation process started with reviewing the building identifiers, the building name, its address in detail, and any other identifier to locate the site easily, in addition to the usage of the building and the screening's date. The ZIP code of the building was replaced by registering (the number of land parcels/the number of basins) as a code that facilitates access to the building and the location's data. Moreover, the building's code was referred to in the preparatory schedule in the auxiliary excel sheet prepared in the stage before screening, which was the number of building in the sample, along with the first letter of its use, E, H, P, or M, as was mentioned earlier.

General information about the building

They are the building's general and obvious characteristics, which can be seen simply walking around it. They are obtained without the need to enter the building and without complication. They are:

Number of stories: what is underground (basement) and above it were determined. The buildings ranged from 1 to 7 stories, with an average height of 3 stories, see figure D.1 This is mainly because they were public buildings. Most screening buildings were schools due to their spread compared to other buildings. Their height usually ranges between 2 and 3 floors to facilitate teachers and students' moving between classrooms. Moreover, Tulkarm is a plain area whose lands are somehow level. Most buildings in study area were constructed above the ground without basements, contrary to other sloping areas in the city.

Year of construction**:** Although a large part of this information was documented in an earlier stage, but it was completed in field, by inquiring from the trustworthy people in the evaluated buildings. Usually, the date of construction for buildings may be written on the identification boards at the entrances of public ones.

The shape of the building was previewed, and a rough sketch of the building was drawn rapidly (Plan view, elevation) in the space designated for that. Among the information reviewed and confirmed after visiting the site, the soil classification and the possibility of geological hazards were mentioned in form (Liquefaction, Landslide, Surface rupture). Figures D.2 and D.3 show the soil types for the screened buildings, and their distribution according to year of built respectively.

Additions: It was indicated in the data collection form that whether additional units for the building was implemented or not, it is possible in our country that construction works can be carried out in stages or to make additions to the building later. These additions may be vertically by adding an upper floor above an existing one, or horizontally by adding a building Adjacent to the current one, many cases of horizontal additions have been dealt with according to the reference guide shown in Table C.3. In contrast to vertical additions, where the building is considered single unit without any terms, if the upper floor is identical to the one below it, otherwise a detailed evaluation is the option.

Photography of buildings: To avoid any confusion in the evaluation process, several pictures were taken for each building and linked with the evaluation form for each one with a specific number and code. These images may be used to confirm the identity of the building in case this data is used for any later study or research goals and any later reference.

Pictures of all the buildings evaluated in this study were delivered (as a soft copy) to the professor supervising the thesis.

Occupancy**:** It refers to determining the occupancy and documenting the use of buildings. They are divided into educational, healthy, or public buildings that have a post-disaster vital role. As shown in figure 3.Educational buildings constitute the highest percentage in the study sample because of the spread of educational facilities, especially schools, more widely than others. 54.5% of the total buildings were educational. Public buildings come in the second category, which include government buildings, mosques, and other buildings used in the various stages of seismic disaster management, and they were 36.5% of the building.

Because the study sample was limited to hospitals and health centers that provide medical services only and did not include auxiliary facilities such as private clinics and pharmacies for the reasons mentioned previously, the health facilities constituted only 9% of the sample size (12 out of 134 buildings). Figure D.4 shows the distribution of buildings according to their use in the four parts of study areas.

Adjacency examination

The possibility of a collision between two buildings during seismic tremors rises when they are adjacent with the absence of an expansion joint separating them or in case of the presence of it with insufficient distance.

In this study, considering the city of Tulkarm is of moderate seismicity, the minimum distance in inches separating two adjacent buildings should not be less than 1/2 inch, which is equivalent to (1.27 cm) per story.

Minimum separation =1/2" x (No. of stories in the shorter building) Eq. (1)

Being the distance less than that minimum increases the susceptibility to risk of collision. However, according to code FEMA, when the insufficient separation distance between two buildings combines with one of the three conditions mentioned in Table C.4, so the danger of collision (pounding) is considered. Accordingly, a more detailed study is required.

In addition, the possibility of any dangers falling from the adjacent high buildings was also examined, such as hanging blocks, tank walls, banners, and so on. Precautions must be taken because they may fall and cause damage to the building being examined or block its main entrances and exits. These conditions were applied to all the adjacent buildings in the study sample. Fortunately, a very small percentage of the buildings in the surveyed sample were at risk of pounding or falling hazards.

The plan and vertical irregularity

There is no doubt that most buildings are irregular in shape in general, and the same applies to the buildings evaluated within our study. Accordingly, asymmetry in both horizontal plan and vertical elements of these buildings was noticed, due to aesthetic architectural reasons, functional purposes, the area of the land the building is located on, or the licensing conditions in the region, and much more.

The asymmetry affects the seismic performance of the building negatively. It weakens it and increases its susceptibility. This is evident in the evaluation form, where the irregularity has negative score modifiers for the various types of buildings mentioned in both the vertical and horizontal directions. Figure D.6 shows in general, the percentage of irregularities in the buildings.

Plan irregularities

Buildings with simple shapes and devoid of angles in their horizontal plans, as well as their symmetrical distribution of structural elements, have better seismic performance than those that take shapes with angles and irregular edges such as U- and L-shaped buildings and many others. (Nanda & Majhi, 2014)(Khan et al., 2019)

Indicators of horizontal asymmetry were examined, as mentioned in the reference guide, see table C.5. Some buildings contained more than one indicator, noting that the evaluation does not depend on the type of defect in the lack of symmetry; it is enough to notice one of them in order to adopt the negative value in the evaluation process.

Torsion as one of plan irregularities is caused by the irregularity of the horizontal position of the buildings, resulting in the eccentricity between the center of mass for the structure and its center of stiffness. This indicator appeared in most of the buildings that were inspected.

In addition, this modifier is affected by the fact that the building has reentrant corners as in L and U shapes buildings, and non-parallel systems in sharp edges (wedges and triangles) buildings. Plan asymmetry also has been adopted as a negative modifier in buildings with large openings in the ceilings or floors, specifically in mosques, due to its effect on transferring seismic loads process.

In most of schools, it was noted that the outside columns do not align with the exterior beams based on them. The outer columns protrude, and therefore the centers of the column and the beam do not apply, which negatively affects the structure's seismic performance. This case is also indicative as one of plan irregularity of the buildings in the evaluation process.

Figure D.5 shows that nearly 80% of the screened buildings have one or more of plan irregularity indicators.

Vertical Irregularities

As in the plan asymmetry case, the vertical elements' symmetry is more important because of their crucial role in the transmission of seismic loads.(Yön et al., 2017) Consequently, regular buildings in their vertical configurations are less affected compared to those that contain any of the parameters which cause an interruption in this formation, thus inhibits the continuity of the lateral load resisting system for the structure.

The evaluation form is based on seven indicators of vertical irregularity that negatively affect the performance of buildings when exposed to seismic shear forces. According to the reference guide shown in table C.6, appendix C, this study examined six of these indicators, divided in to two categories based on their severity, as follows:

- Sloping Site
- Weak/Soft story
- Out-of plane setback
- In- plane setback
- Short columns
- Split levels

The seventh one (un-braced cripple walls) was ignored because it’s restricted to wooden buildings while this study was conducted on concrete ones.

It was noted that the formation of short columns which is considered the most sever phenomenon, either because of window openings in public buildings or the presence of corridors in hospitals and schools. High-impact violations were also recorded due to the presence of a soft story in several buildings, due to a significant difference between the stiffness and the lateral load resistance of one of the floors of a building and the rest of them.

Also, in-plane setbacks were monitored, which were formed because the vertical elements of the seismic resistance system in the building (columns and Shear Walls) in the upper floor or floors, are shifted from their counterparts on the lower floors.

This weakens the resistance of horizontal beams that join these displaced elements. This was observed in buildings consisting of shear walls due to the change in the locations of the openings between floors.

The out of plane setback irregularities differ that were resulted when the seismic resisting system of one floor is not aligned with the same system on the floor above or vertically below it. Cantilevers (a protrusion in the ceiling without any support below it) are also a form of out of plane setback.

The score modifier within the evaluation form, that has the highest effect on the final score of each building , is for the sever vertical irregularity item .On the other hand, it is mentioned that the number of vertical irregularities were observed more than the plan irregularities in the sample buildings as shown in figure D.5

Identifying any potential exterior falling hazards

In the seismic assessment, the non-structural elements are not less important than the structural ones. This is due to the danger it poses to the safety of people if it is not installed properly in the building. The form prepared by FEMA mentioned some of the most common non-structural elements in buildings, such as chimneys, appendages, heavy cladding, parapets, and other brick canopies, as well as heavy metal panels.

In this study, most of the evaluated buildings contained non-structural elements regardless of their use. 108 out of 134 buildings showed that they are likely to be susceptible to external falling hazards (non -structural) for several reasons. Perhaps the most prominent reason is that the common building system in the region consists of stone facades or of concrete bricks, with architectural decorations to beautify the exterior and stone protrusions to decorate those facades. Moreover, some buildings are in danger of external falling hazards, just like the parapets. These elements are not usually installed correctly because the buildings are not designed according to seismic codes. Another example of this, water tanks installation on metal stands without a tight fixation on the roofs of buildings, which makes it possible for them to fall, and many other reasons.

The possibility of these non-structural hazards must be clarified and documented in the evaluation, even if the structural system of the building is seismically suitable.

More than 80% of buildings are exposed to such dangers, a percentage that cannot be ignored. Rather, it is a cause for concern, as it undoubtedly poses a danger to the building occupants. Furthermore, this information may later be used to develop a risk mitigation program.

Building type definition according to FEMA P-154

The type of construction was determined for a part of the buildings before examining them in the preparatory stage, either by reviewing the engineering design plans or by inquiring from the relevant authorities, which are: (the supervising engineering office, Tulkarm municipality, engineers of the Directorate of Health and engineers of the Directorate of Education). For the other part, the type of building, the system based on a gravity system, the type of building material, and the seismic force-resisting system were determined. Narrowing the 16 types of buildings listed in FEMA to one or two types was continued, which suits the system of the building to be evaluated. Table C.7 in appendix C, describes types of buildings according to FEMA.

All surveyed buildings are concrete buildings; therefore, the available options mentioned in the evaluation table are only three as follows:

C1: moment-resisting frame, with B.S= 2.1

C2: shear wall, with B.S= 2.5

C3: unreinforced masonry infill, with B.S=٢,٠

It was not easy to classify the buildings in the study into the three categories mentioned above because part of the buildings is very old, and most of the buildings combine more than one structural system (dual system).

Other buildings with structural frames consisting of columns and beams that resist seismic forces were classified as category C1, whereas those built with just reinforced shear walls were classified as category C2. Finally, category C3 consisted of buildings of concrete frames with unreinforced masonry infill walls.

Ancient buildings that were unsuitable for any building type in FEMA, were considered seismically weak, and the category took the symbol DNK (do not know).

In case there was uncertainty about the type of building and its confinement between the two categories C1 & C3, it was classified under the category of buildings of type C3 as the worst possibility. Figure D.6 shows the buildings Distribution by building system type.

The third stage - Post field stage

It is the last stage in the evaluation after completing the inspection and filling out the evaluation form. It is the compilation of all data, reviewing it, confirming its documentation, and completing the missing ones.

The evaluation table indicates the probability of collapse by a Basic Structural Score (BSH)، which is calculated using the Technical Manual's building fragility and capacity curves. It represents an average score for the structures in each class utilized in large-scale economic research. Additional factors and specifications of the building known as Score Modifiers (SMs) may boost or lower the BSH value, resulting in the final S.S.

$S.S = BSH \pm SMs$ Eq. (2)

SMs for each structure have been circled, and SS values for all the buildings have been calculated, which means that the evaluation process RVS has been completed.

Building's Data Mapping

After accomplishing the rapid evaluation in all its stages for all 134 sample buildings, the standard paper assessment forms (hard copies) were sorted, and the final results were compiled. Then, using the geographic information system (Arc GIS), the locations of the buildings were mapped, and shape files were produced. These data were linked to the locations of the buildings. By referring to the building, it is possible to access its descriptive data, which are as follows:

- Building ID
- Year of construction
- Building use
- Number of stories
- Type of soil
- Presence of vertical irregularities
- Presence of plan irregularities
- Building type
- Structural score (the result of RVS)
- Presence of other hazards
- The pre-code status
- After benchmark status.

Consequently, the spatial data of the sample buildings were finalized, with the aim of producing different maps and taking them out, with the possibility of altering the descriptive data at any time. These files form the basis for the initiation of extracting, analyzing, and discussing the findings (in the last chapter of this thesis).

All GIS data, shape files, attribute data, and the maps produced were submitted (as a soft copy) to the doctor supervising the thesis.

2.5.1.1 RVS evaluation far a case study

In this section, the RVS evaluation was applied to one of the study sample buildings. The model (FEMA P-154) for moderate seismic zones was employed in order to get a value that represents the extent of its seismic susceptibility

Description of the building

Al-Quds Girls' Elementary School is a primary governmental school with 522 students, in addition to the administrators and the staff.

The school consists of three stories, each of which has an area of (528) m^2, and a floor height of (3.25) m. The horizontal plan of the building is L-shaped. The building was divided into two systematic parts, including an expansion joint with a width of 3 cm. The ground floor of the school was first designed and built in 2003. Later on, the upper floors were built, in accordance with the existing basement. In the school there are two staircases, the first in the middle was built earlier with the ground floor. Then, another staircase was added (at the east end) adjacent to the existing building, without any space to mitigate students' rush, facilitate communication and reduce the time needed to move between floors. Figure D.7 shows the horizontal plan of the and an aerial photo of the school.

Application RVS Evaluation

For the purpose of assessment, all the related data has been collected using a form specially prepared for that purpose as shown Figure 4. Part of the data was collected before visiting the site in the planning stage, and the other part after inspecting the building. Perhaps the most prominent of the collected data are the following:

- Building name, address, height of building (stories No.), use and date of construction, in addition to the date and name of assessor (researcher).
- Vertical additions were discovered (first and second floors), but they were fully matched with the existing ground floor, so it was screened as a single building.
- Total area of the school =1584m^2
- A plan view and elevation for the school were depicted.
- Photographs were taken of the school.
- Type of soil in site is C. (Bearing Capacity B.C=250 KN/m^2). Table C.2

- No adjacent buildings were observed.
- Parapet was defined as exterior falling hazard, for the year of construction is before benchmark year.
- System of building was considered to be a concrete frame with unreinforced masonry infill (C3). Base Score (B.S) = 2.0
- Short Columns deformation was considered as severe vertical irregularity.
- No plan irregularities were noticed.
- School building was made before the obligation of seismic design (in 2003). Pre code modifier was considered.

The result was that S.S = 0.7, which is less than Cut-off score value of 2. Therefore, the School building has required a detailed evaluation.

The data contained in the evaluation form was linked with the geospatial data of the building using the GIS tool.

Figure 4

Final RVS Form for Al-Quds Girls Elementary School

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

Level 1
MODERATE Seismicity

Address: Tulkarm- Ezbet Al- Jarrad E-35
Near Ibrahim Al-khawaja Girl's **Zip:** 12-8182
Other Identifiers: Palestinian Military Intellegence Building
Building Name: Al- Quds Girl's Elementary School
Use: School
Latitude: **Longitude:**
S_S: 0.375 **S_1:** 0.1875
Screener(s): Isra' **Date/Time:** 12.Jan.2021

No. Stories: Above Grade: 3 Below Grade: **Year Built:** 2003 ☐ EST
Total Floor Area (sq. ft.): 17050 ft^2 = 1584 m^2 **Code Year:** UBC97
Additions: ☐ None ☒ Yes, Year(s) Built: DNK .

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

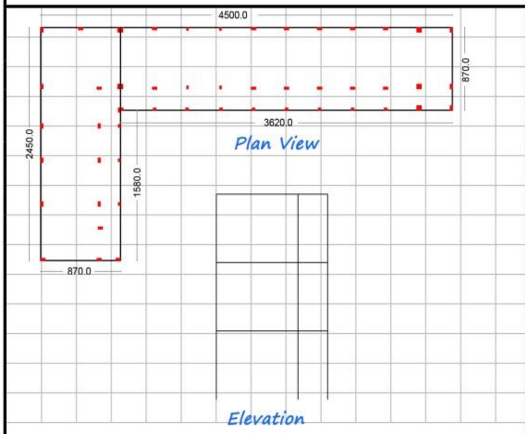
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☒ Vertical (type/severity) Short columns - Severe
☐ Plan (type)

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

COMMENTS:

- Material : Bricks.
_ Vertical Addition : Fully matched with Exsisting Floors.
_ No adjacent building.
_ Expansion joint is observed (not reentrant corner).
_ Per level 1 pounding Reference Guide . required gap is 3*0.5'' = 1.5 inch = 4.5'' = 3.81 cm > Existing gap = 3 cm
Pounding potential exists



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		**5.1**	**4.5**	**3.8**	**2.7**	**2.6**	**3.5**	**2.5**	**2.7**	**2.1**	**2.5**	**2.0**	**2.1**	**1.9**	**2.1**	**2.1**	**1.7**	**2.9**
Severe Vertical Irregularity, V_{L1}		-1.4	-1.4	-1.4	-1.2	-1.2	-1.4	-1.1	-1.2	-1.1	-1.2	-1.0	-1.1	-1.0	-1.1	-1.1	-1.0	NA
Moderate Vertical Irregularity, V_{L1}		-0.9	-0.9	-0.9	-0.8	-0.7	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.7	-0.6	-0.7	-0.7	-0.6	NA
Plan Irregularity, P_{L1}		-1.4	-1.3	-1.2	-1.0	-0.9	-1.2	-0.9	-0.9	-0.8	-1.0	-0.8	-0.9	-0.8	-0.8	-0.8	-0.7	NA
Pre-Code		-0.3	-0.5	-0.6	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.5
Post-Benchmark		1.4	2.0	2.5	1.5	1.5	0.8	2.1	NA	2.0	2.3	NA	2.1	2.5	2.3	2.3	NA	1.2
Soil Type A or B		0.7	1.2	1.8	1.1	1.4	0.6	1.5	1.6	1.1	1.5	1.3	1.6	1.3	1.4	1.4	1.3	1.6
Soil Type E (1-3 stories)		-1.2	-1.3	-1.4	-0.9	-0.9	-1.0	-0.9	-0.9	-0.7	-1.0	-0.7	-0.8	-0.7	-0.8	-0.8	-0.6	-0.9
Soil Type E (> 3 stories)		-1.8	-1.6	-1.3	-0.9	-0.9	NA	-0.9	-1.0	-0.8	-1.0	-0.8	NA	-0.7	-0.7	-0.8	-0.6	NA
Minimum Score, S_{MIN}		*1.6*	*1.2*	*0.9*	*0.6*	*0.6*	*0.8*	*0.6*	*0.6*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*	*0.2*	*1.5*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: Sl 1 = 0.7 < 2 needs more detailed evaluation

EXTENT OF REVIEW

Exterior: ☐ Partial ☒ All Sides ☒ Aerial
Interior: ☐ None ☒ Visible ☐ Entered
Drawings Reviewed: ☒ Yes ☐ No
Soil Type Source: Design Drawings
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; BR = Braced frame; RC = Reinforced concrete; SW = Shear wall; URM INF = Unreinforced masonry infill; TU = Tilt up; MH = Manufactured Housing; LM = Light metal; FD = Flexible diaphragm; RD = Rigid diaphragm

2.5.2 Detailed Structural Analysis (Quantitative evaluation)

The result of the rapid assessment showed the need for a more detailed study to evaluate the seismic performance of the building, and to determine its safety in the event of exposure to seismic forces. Therefore, in this part of the study, one of the numerical analysis methods (RSA) Response-spectrum analysis, which is a linear-dynamic one, was applied to examine the seismic efficiency of the building. Retrofitting techniques were recommended and implemented.

It should be noted that structural calculations are not required to be a primary objective of this study. However, to make this study as realistic as possible, and to obtain indicators of a quantitative nature in the seismic performance assessment of existing buildings, the following steps have been adopted in the detailed evaluation process:

- Check of the structure behavior under the influence of gravity loads only.
- Check of its behavior in case of exposure to seismic forces.
- Re-design the structure to resist seismic load, taking into account the seismic design requirements according to IBC 2015 and ASCE7-16 codes.
- Comparison between the actual design of the existing building and the proposed seismic one.
- Adoption of one or more methods of seismic rehabilitation.

This study's findings will be extremely valuable in risk reduction strategies (risk mitigation and emergency response plans, and others).

3D Dynamic Analysis

Structural details of the case study building

The structure was previously defined in Section 2.5.1 for the purpose of RVS evaluation. It was indicated that it is a three-story school building with two portions (Block A and Block B), separated by 3 cm Expansion joint as shown Figure E.1

Referred to the structural design drawing system of the school is made up of one-way ribbed slabs of 32 cm thickness as shown in Figure E.2, supported by a network of beams resting on columns.

It should be noted that the available engineering drawings were used, along with the screened data through the external inspection of the building. Therefore, any unknown data was imposed, so that this case is as close as possible to reality, and thus achieve the goal of this study.

Materials properties:

All structural elements in school are made of concrete having a strength (f'_c) =24 MPa, and the steel is (F_y)= 420 MPa strength. These values were assumed as per the design drawings.

Loads on the building:

- Dead load (DL): The own weight of the structure elements, calculated by Etabs.
- Super imposed dead load (SID): As indicated in Table E.1
- Live load (LL): Loads from the occupancy of the building, it was estimated of 5 KN/m^2 according to IBC 2018 .

Modeling:

Etabs computer software (version 16.0.2) was used for modeling and analysis. Two separate models were created for the two blocks of the building.

After reviewing the available design drawings, it is found that the structural system can be considered as Intermediate moment resisting frames. Figures E.3 and E.4 illustrate the structural models A and B for the two blocks of the building, respectively.

Structural analysis for gravity load

Check of compatibility:

Figures E.5 and E.6 show the deformed shape of the structure under the effect of gravity loads. It is evident that the deformed shape is compatible.

Check of deflection:

This check was passed for both blocks A and B; since Max. deflection < Allow. Deflection.

Table 1

Check of deflection results

	Max. Deflection (mm)	Allowable Deflection (mm)	Reference	Check
Block A	25	L/240=26	Figure E.7	25<26 OK
Block B	15.3	L/240=26	Figure E.8	15.3<26 OK

* L: Length of span

Check of structural elements under gravity loads effect

All structural elements were modeled as they are in reality, and the results were safe under the influence of gravity loads; all columns and beams were safe. Figures E.9 and E.10.

Structural analysis for seismic lateral load

Since the building is located in Tulkarm, the peak ground acceleration Z= 0.15 according to the seismic acceleration map in Palestinian.

Earthquake load:

It is defined in Etabs by response spectrum method. Table 2, shows the seismic input data.

Table 2

Seismic parameters for original building

Parameter	Value	Resource
Z	0.15	From seismic map, 10% accel.
Risk category	III	IBC code 2015/ Table 1604.5
Site classification	C	IBC code 2015/ Table 20.3-1
I (importance factor)	1.25	IBC code 2015/ Table 1.5-2
Seismic force resisting system	IMRF	IBC code 2015/Table 12.2-1
R (Response Modification coe.)	5	IBC code 2015/Table 12.2-1
Ώ (Over strength Factor)	3	IBC code 2015/Table 12.2-1
Cd (Deflection amplification factor)	4.5	IBC code 2015/Table 12.2-1
Ss	0.375	Ss= 2.5*Z
S1	0.1875	S1=1.25*Z
Fa (Short Period Site coefficient)	1.3	IBC code 2015/Table 11.4-1
Fv (Long-Period site coefficient)	1.5	IBC code 2015/Table 11.4-2
SMS	0.4875	SMS=Fa*Ss
SM1	0.28125	SM1=Fv*S1
SDS	0.4875	SDS=SMS
SD1	0.28125	SD1=SM1
Seismic design category	D	Least value from(Table 11.6-1 & Table 11.6-2)

* Details of seismic analysis is given in Appendix E.

Check of Structural elements under seismic loads

As a result of the seismic analysis for the existing school structure; both models A and B proved their seismic incapacity. Where most columns were structurally unsafe as shown in figures E.14 and E.15. On the other hand, the allowable story drift for block A was exceeded in two directions based on the recorded results in tables E.4-E.7, as well as the story drift was induced by the effect of P-Delta , as shown in tables E.15-E.18.

The Final Result of structural analysis of the school building

The results of the analysis showed that the building was designed to resist the gravity loads only, while its structural elements were not capable of resisting other seismic loads.

This means that the structure needs to be strengthened, in order to prevent or reduce the expected damages in the event of an earthquake, by improving and modifying structural elements that would resist seismic forces, i.e. there is a need to retrofit this school building.

2.6 Seismic Rehabilitation for the Case Study Building

Seismic retrofitting is considered as one of the most effective procedures to improve the seismic performance of existing structures.

In order to enhance the seismic performance of the structure of the case study, two retrofitting techniques were chosen to apply including the addition of shear walls, and RC column jacketing.

To increase the seismic resistance of the structure, Building Frame System BFS was considered as aseismic force resisting system. Hence, the columns and beams resist the gravity loads, while additional shear walls resist the seismic load. The shear walls were added in the middle distances between the existing columns, to avoid footings overlap. In addition, they were distributed in such a way that achieves symmetry as much as possible.

In this procedure the structure was re-designed according to the seismic requirements, to enable it to withstand the potential seismic forces. The new models of the structure including the added shear walls and improved columns are shown in figures E.18, E.19 According to the seismic input data shown in Table 3.

After the design process was completed, the existing design was compared with the proposed one to complete the building's strengthen system.

All structural design steps are detailed in Appendix E.

Table 3

Seismic parameters for modified building

Parameter	Value	Resource
Z	0.15	From seismic map, 10% accel.
Risk	3	IBC code 2015/ Table 1604.5
Site class	C	IBC code 2015/ Table 20.3-1
I (importance factor)	1.25	IBC code 2015/ Table 1.5-2
Ss	0.375	Ss= 2.5 Z
S1	0.1875	S1=1.25Z
Fa (Short Period Site coefficient)	1.3	IBC code 2015/Table 11.4-1
Fv(Long-Period site coefficient)	1.5	IBC code 2015/Table 11.4-2
SMS	0.4875	SMS=Fa*Ss
SM1	0.28125	SM1=Fv*S1
SDS	0.4875	SDS=SMS
SD1	0.28125	SD1=SM1
Seismic design category	D	Least value from (Table 11.6-1 & Table 11.6-2)
R(Response Modification coefficient)	6	IBC code 2015/Table 12.2-1
Omega(Over strength Factor)	2.5	IBC code 2015/Table 12.2-1
Cd (Deflection amplification factor)	5	IBC code 2015/Table 12.2-1

Columns Re-design:

It is noted that not all the columns need to strengthen; however, they were all jacketed to maintain the distribution of stiffness in the building, so that the load distribution on beams remains the same. Thus, ensuring that there is no need to strengthen the beams. The final distribution of the shear walls and column after jacketing is shown in figure E.29.Also, Table E.27 shows the dimensions of the columns before and after jacketing.

Shear wall design:

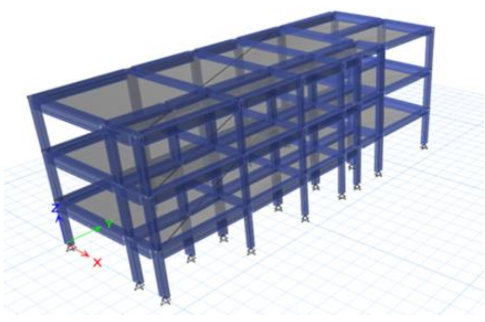
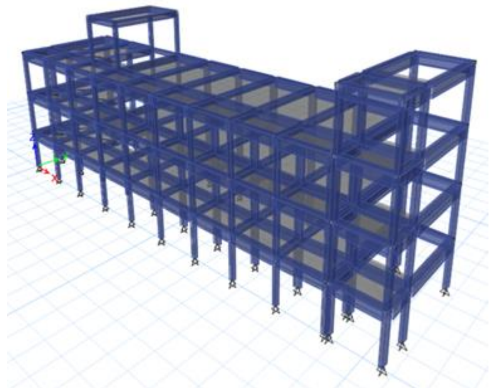
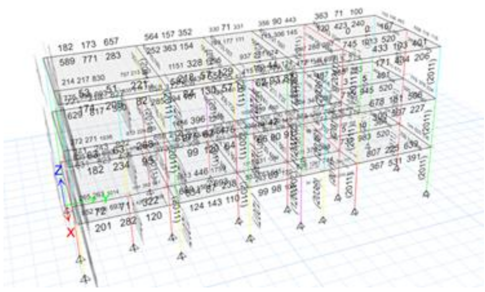
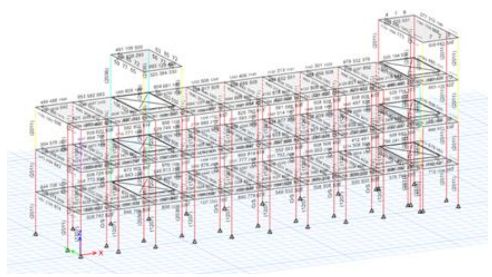
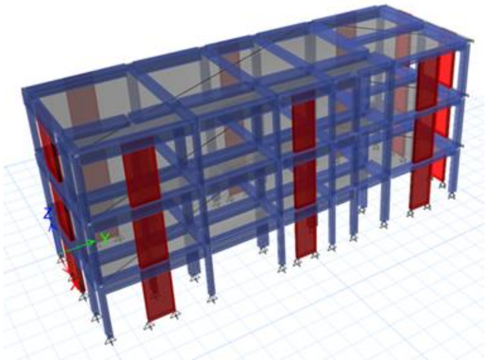
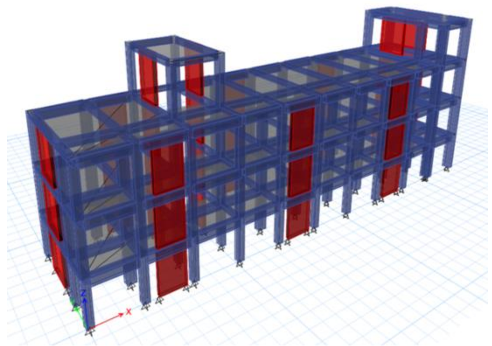
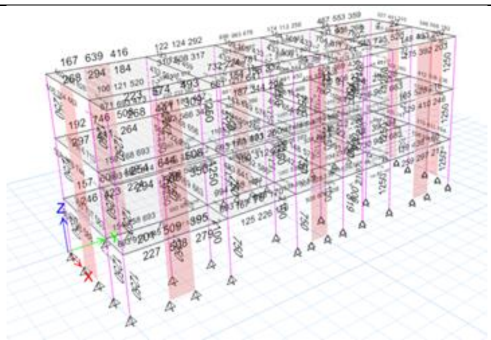
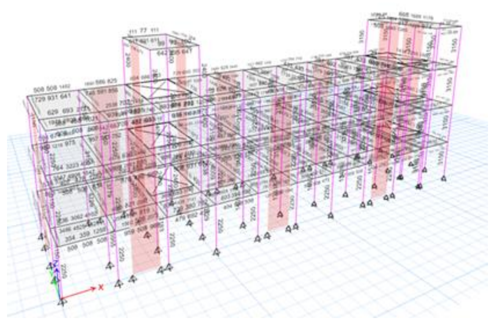
The dimensions of the shear walls are shown in Table E.23 and the reinforcement details as illustrated in figure E.26

Finally, the school building will be safe under the influence of seismic loads after its strengthening by the addition of shear walls, and RC columns Jacketing techniques.

Table 4

Structural models before and after seismic retrofitting

	Block A	Block B

Original models		
Structural elements design		
Modified models		
Structural elements design		

Chapter Three

Results and Discussions

The main objective of this study was to evaluate the seismic performance of existing essential buildings in the city of Tulkarm in Palestine. It also aimed to prioritize measures to improve seismic performance, as mentioned in chapter one.

To achieve the above main objectives, FEMA P-154 was used as an RVS procedure to obtain a score representing the seismic performance of the buildings and then to rank them according to the need for rehabilitation. The assessment was carried out on the ground for each building individually; all details were explained in Chapter Two.

The following are the results of this study that led to the achievement of the desired objectives, and since this research is based on desprective analytical method; results and discussions were combined as follow:

3.1 RVS Evaluation Results

General Results

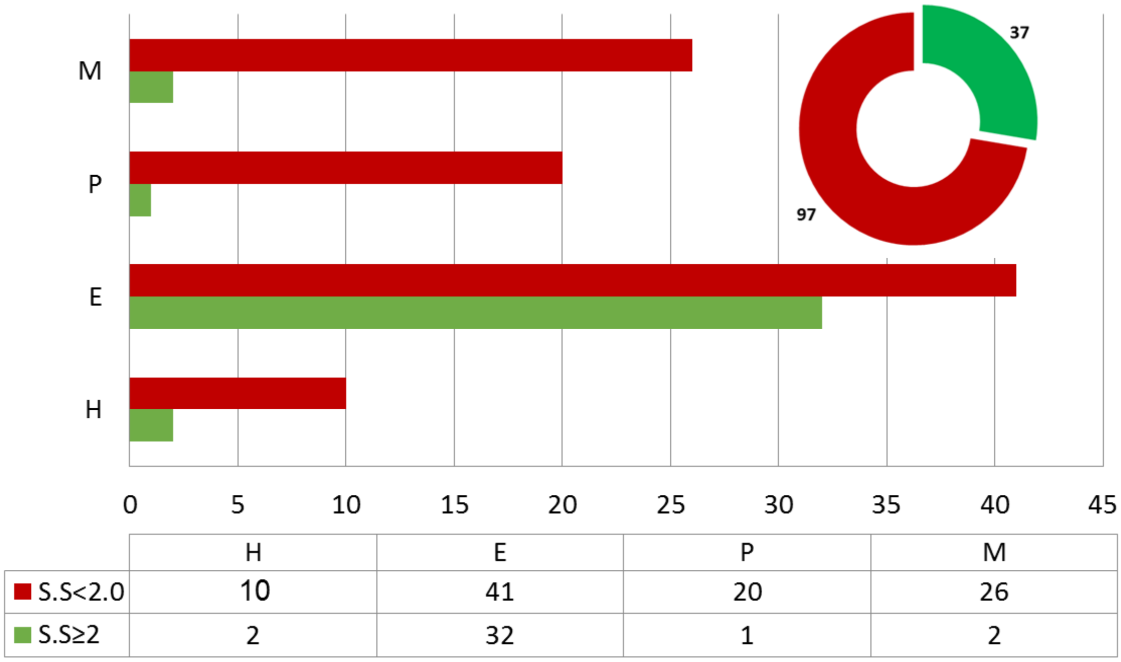
The main objective of this dissertation was achieved by the result of the rapid measurement. Figure 5 shows the distribution of the result values for the buildings compared to the cut-off value which is 2.

37 out of 134 buildings get a score higher than 2, which means that they are considered to have adequate seismic performance to prevent collapse if the area is hit by an earthquake. On the other hand, 97 of the buildings have a total score of less than 2; therefore, they need to be evaluated in more detail.

For a better understanding of the results according to building use, the calculated scores in Table 3 have been grouped according to the grades of damage stipulated EMS-98 as shown in Table F.1 EMS -98 and their description in Table F.2.

Figure 5

Resulted RVS Scores



* S.S = Structural Score, Cut-off score=2

Table 5

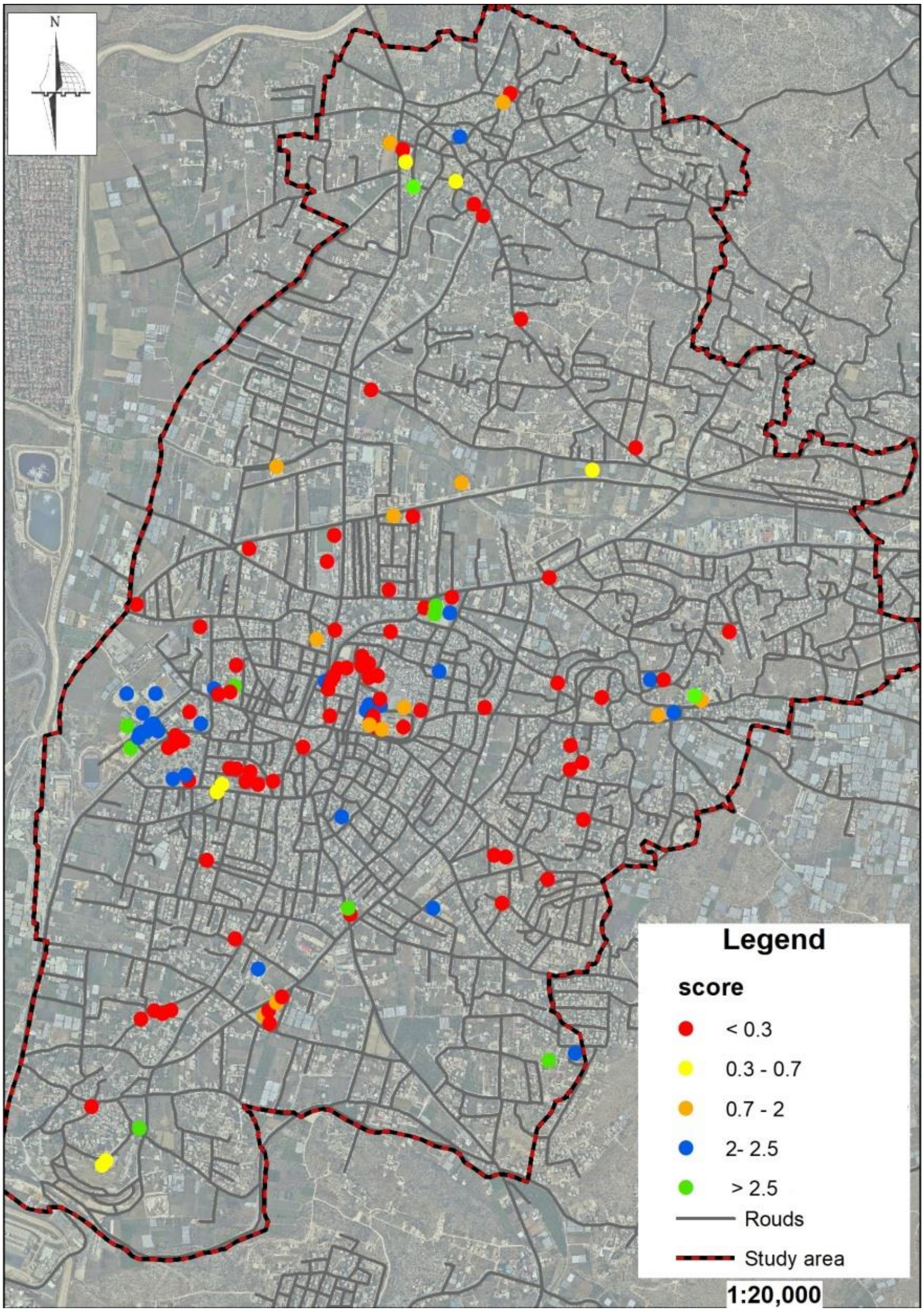
Expected Damage Grades according to Building use

Damage Grade	DG5	DG4	DG3	DG2	DG1
Building Use	S.S≤0.3	0.3<S.S≤0.7	0.7<S.S≤2.0	2<S.S≤2.5	S.S>2.5
Health-Care	9	1	0	1	1
Educational	32	3	6	26	6
Public	11	2	7	0	1
Mosques	24	1	1	1	1
Total	76	7	14	28	9

Risk maps for the essential buildings in Tulkarm downtown and Thenabah, Irtah and Shwaike neighborhoods were produced using GIS, as shown in Figures F.1, F.2, F.3 and F.4. The maps illustrate the seismic vulnerability of the buildings in each area and represent the degree of damage to each building in the event of an earthquake. Figure F.5 shows the damageability of the buildings in the four study areas.

Figure 6

Final RVS Scores Distribution (Vulnerability of Essential Buildings in Tulkarm city)



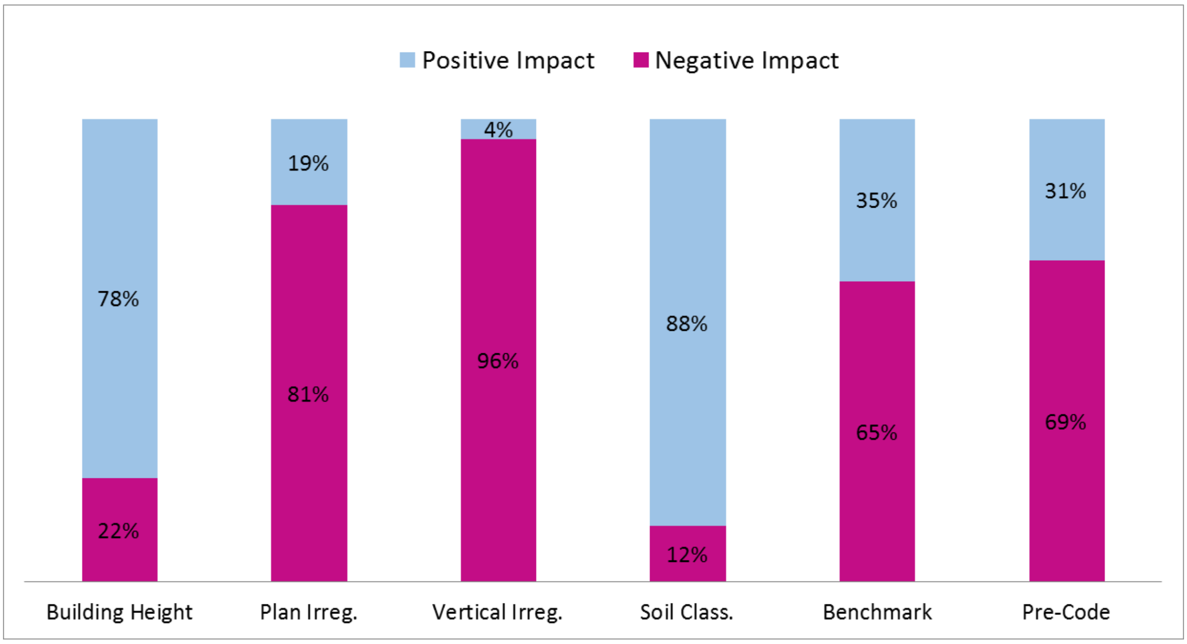
Sub- Results

This survey was applied for 134 RC buildings with special requirements for their permanent performance, such as hospitals and health centers, which represent 9% of all buildings, educational institutions such as universities and schools, which represented more than 50% of the sample. The rest were the other public buildings, which play a crucial role in disaster preparedness, accounting for 37% of all buildings. Figure D.4 illustrates the distribution of buildings by occupancy.

The following are the results of this study that led to the achievement of the desired objectives. Since this is based on desprective analytical method; results and discussions are combined together.

Figure 7

The Impacts of Evaluation Factors on Results



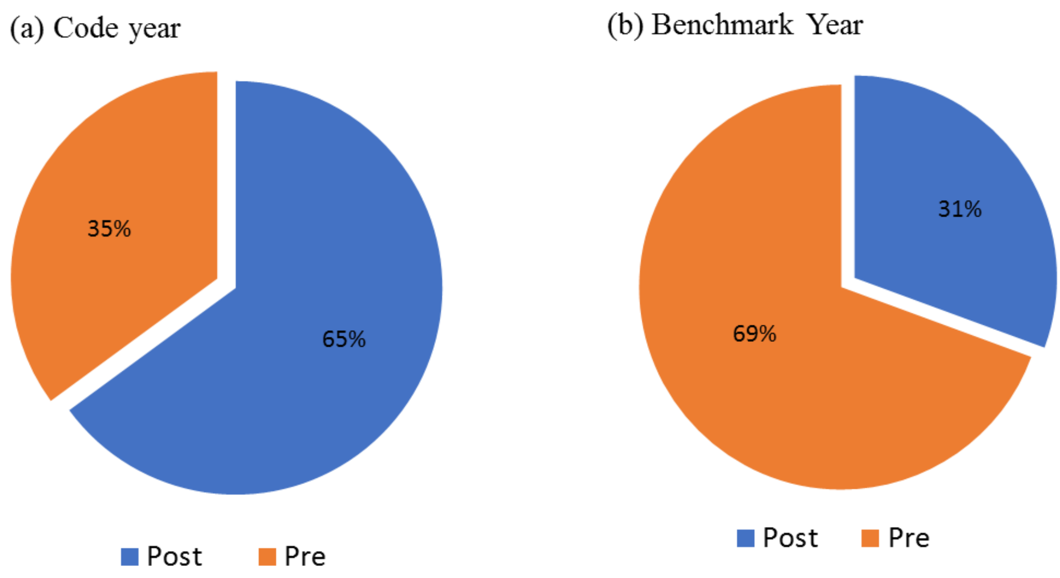
In general, regardless of the FEMA building type, the most prominent factors that affect the final evaluation result of the structures, are the age of the building followed by irregularities in the construction, i.e., they make the building more susceptible to seismic damage.

Since most of the screened buildings are exist before seismic codes were included in the design, they were either constructed in a traditional, non-engineering manner (very old buildings) or only under the effect of gravity loads.

Unfortunately, even buildings that can be considered non-old or built on an engineering basis they usually have a vertical or horizontal violation or more, due to the existing common patterns of construction in the city.

Figure 8

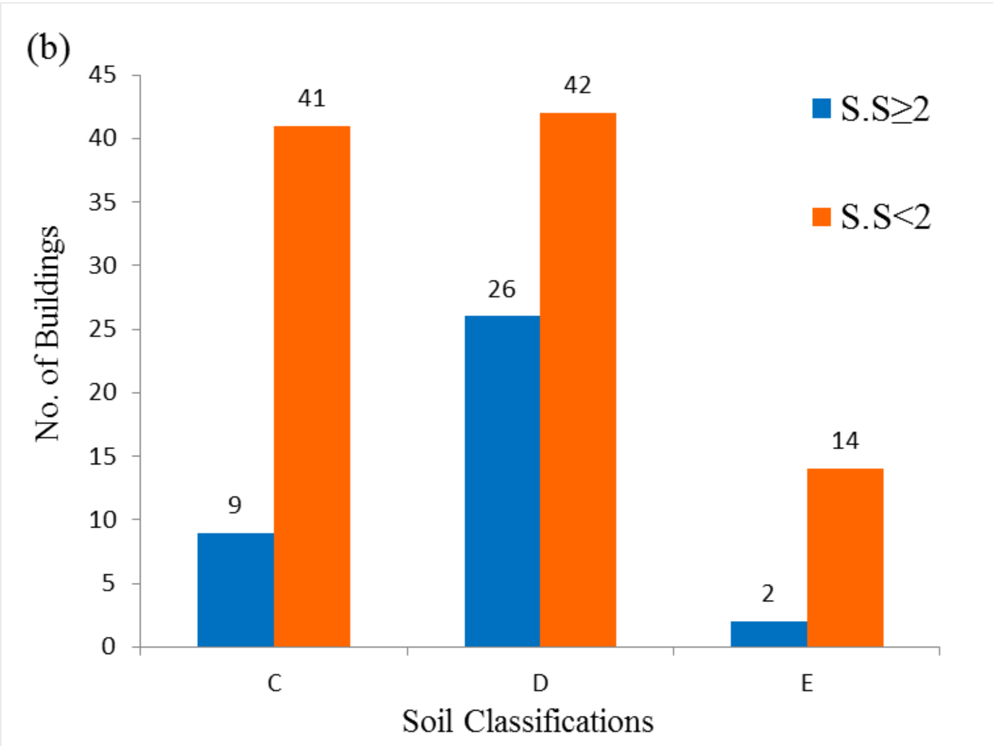
Distribution of Buildings according to (a) Code year, (b) Benchmark year considerations



Tulkarm is an old city, in which the urban development is moderate to few, compared to other Palestinian cities such as Nablus, Ramallah and Hebron, which are witnessing a great and rapid urban development. That seemed obvious in Figure D.3, which shows the distribution of the buildings within time periods according to the date of their built. Besides, figures 8(a) and 8(b) show that more than 60% of all the essential buildings were constructed prior to the initial adoption of seismic codes, these codes were mandated by authorities. This indicator had great negative influence on the final evaluation results, due to its negative score modifiers in the calculation of SS. The pre-code constructed buildings are expected to exhibit poor performance with high susceptibility in event of earthquakes.

Figure 9

The Effect of (a) Soil Classification, (b) Type of Buildings on S.S Values



* N: Number of stories, S.S: Structural Score.

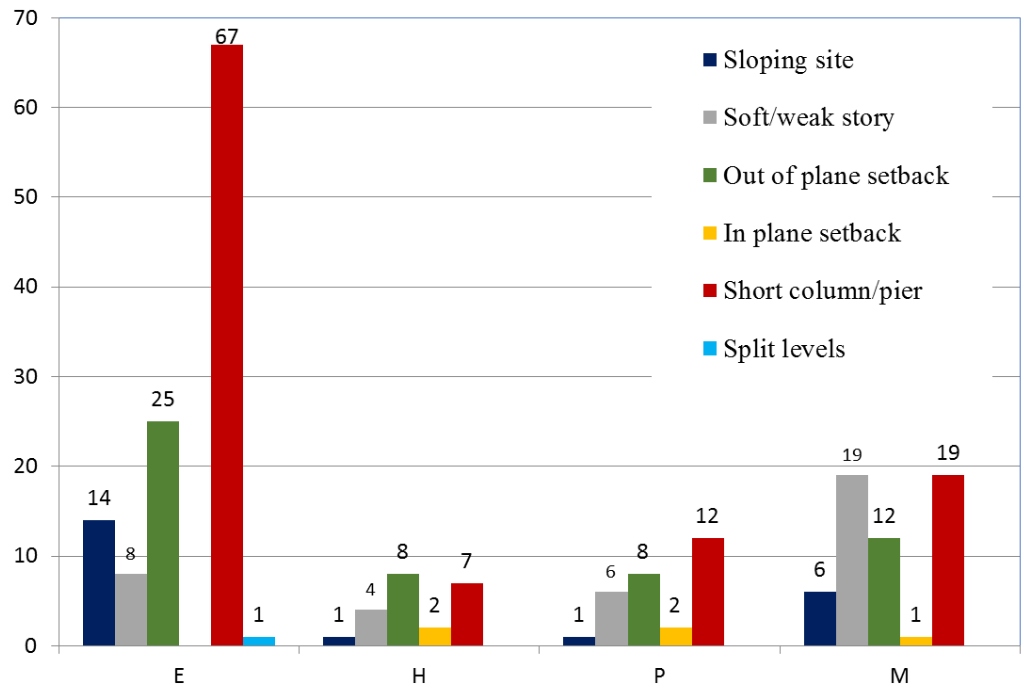
The average height of the buildings is 3 stories, with buildings ranging from one to seven stories in height, as shown in Figure D.1. This parameter only affected the vulnerability assessment results for buildings located on Type E soil. In Figure 9(a), the RVS values were linked with the soil type for the buildings.

Figure 9(b) shows that 69% of the buildings are C1 (Moment Resisting Frame) type, as this system is used in most public buildings such as hospitals, mosques, and educational institutions, which counted more than half of the buildings studied. While the C2 shear walls system was used only to a limited extent in public security buildings in the city, in addition to some of the Palestine Technical University buildings. Although the final score of the building is equal to the sum of the score modifiers for seven indicators; but this indicator determines the base score with which the evaluation process begins.

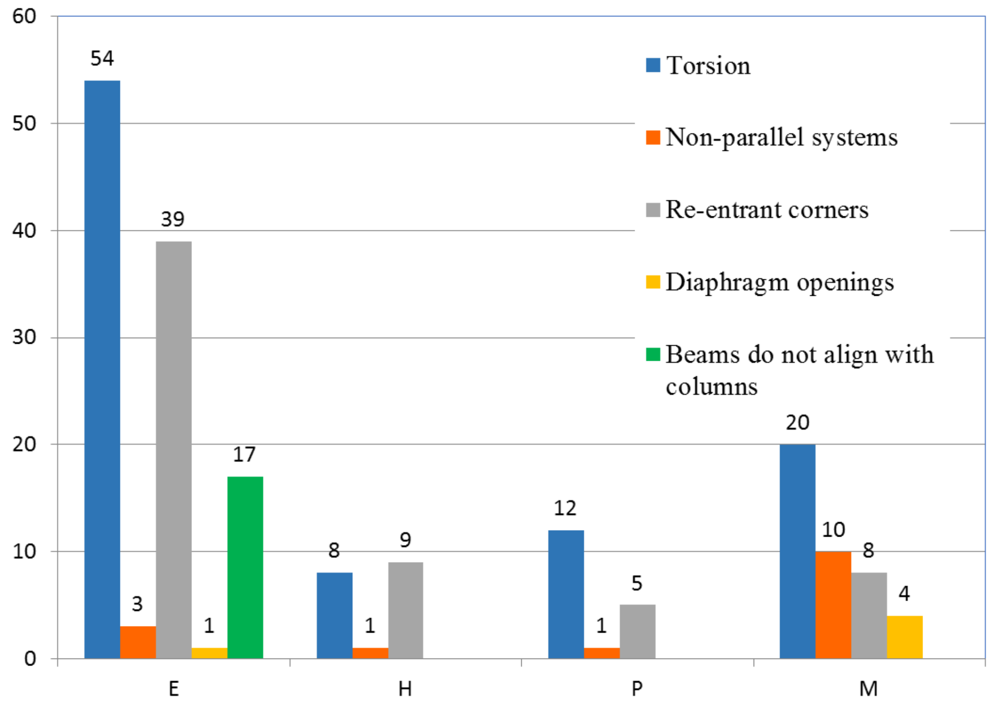
Figure 10

(a) Vertical Irregularity (b) Plan Irregularity Distribution according to Building use

(a)



(b)



Sever structural irregularities were identified during the investigation. However, as already shown in Figure D.5, vertical asymmetry, which is one of the most complicated cases, is more common among the buildings than plan irregularity, as about 96% of the buildings had different types of vertical irregularities. The same is true for plan irregularities: 81% of the buildings had one or more of these defects.

In general, deficiencies in both types of irregularities are the highest in health and education buildings, followed by mosques and other public buildings .see Figure F.7

There are many vulnerabilities that have increased the weakness of buildings, predicting their inability to withstand a seismic disaster when exposed to it. The results of the survey in Figure F.8 show that almost 80% of the buildings have short columns, which is more common in educational buildings than others, where these columns were observed in 67 out of 73 schools. This is due to the presence of open corridors in schools that serve classrooms. Short columns also formed in some public buildings and hospitals due to frequent and adjacent window openings in building facades.

Many buildings have setbacks on upper floors that are out of plane. In schools, for example, this is due to the fact that the upper floors were built with a smaller area than that of the existing floor due to funding constraints usually. The presence of cantilevers is also indicative of this type of setback. They were noted in many healthcare and public buildings, unlike in plane setbacks, which were noted in only five buildings. Another vertical indicator of asymmetry is the presence of a soft story in some buildings, especially mosques, where the prayer hall is an open space without partitions, with a height greater than that of the other floors .

The soft story also observed in other buildings where the first floor has no external walls, while the upper floor has closed walls. In a few buildings, sloping site and split levels were found to be the causes of asymmetry. Figure 10(a)

Figure F.9 shows that the most common types of plan irregularities observed are torsion, and re-entrant corners, while the non-parallel system was hardly observed in the buildings. In general, the main cause of these defects is the asymmetry and irregular floor plans of the buildings.

Some of the mosques have included parameter diaphragm openings due to the presence of Islamic domes. On the other hand, some of the schools were found to have the external beams didn't align with the columns. Figure 10 (b)

The presence of at least one of these factors had a negative impact on the result of the RVS assessment.

It is important to realize that the final score of the rapid assessment is the sum of the score modifiers for seven different indicators. Each of them has a particular weight in influencing the final score for a structure positively or negatively.

3.2 Detailed Evaluation Results

A detailed structural assessment was performed for an existing school building in the city of Tulkarm. The result confirmed the validity of the RVS assessment; the building is not capable of resisting the seismic forces and needs to be strengthened .

Two common retrofit techniques are proposed to improve the building's performance and thus increase its seismic efficiency. These are the installation of shear walls and the sheathing of columns (RC), which are effective and applicable techniques.

These measures for the structure will ensure that it can better withstand the lateral forces to which it will be subjected in the future. On the other hand, this will help to reduce the time needed to restore the school building after an earthquake disaster.

Chapter Four

Discussions and Conclusions

Loss and damage from natural disasters are increasing at an alarming rate. Thus, the urgency of financing disaster relief and reconstruction is exacerbated by weak economies, high levels of poverty, damage to infrastructure and many other causes. According to reports by the World Bank, losses from natural disasters in 2020 increased by 26% compared to 2019. (World Bank).

Earthquakes are one of the most destructive natural disasters, causing loss of life and property. Studies have shown that losses from earthquakes in developing countries have escalated in recent years; this is due to several factors, most notably rapid urbanization without following standard building practices or seismic design considerations, making them easy targets for any major earthquake. Therefore, buildings should be prepared to respond to and recover from such events.

Critical buildings, which are the active and effective factor of the post-earthquake response, are an undeniable priority to enable them to cope with earthquakes to ensure the continuity of their services. It is therefore essential to develop an effective seismic risk management program for these buildings, which play a vital role in society. In hospitals, for example, this program saves lives and reduces damage to the hospital's property to ensure continuity of service. In schools, it also protects the lives of many students (children and youth) and provides protection to a large number of affected people as shelters. Such programs and other related measures that reduce environmental and economic damage and losses due to earthquakes are capable of creating a safer future while ensuring the management of seismic risks before they occur.

In order to protect existing sensitive structures from seismic excitation, it is necessary to assess their performance in the event of an earthquake and whether they are adequately prepared, otherwise corrective actions are taken to improve the response of these facilities to withstand earthquakes.

This research is a necessary fundamental step in developing effective seismic mitigation programs and improving the readiness of the key buildings in the city of Tulkarm, in the West Bank, where it addressed the assessment of 134 buildings, representing a large inventory for detailed assessments. For this purpose, FEMA P-154 was used as the RVS procedure. This approach generates a final performance score for each structure based on governing criteria such as the structural resistance system, the height , the age of the building, structural irregularities and soil type.

The seismic evaluation analysis of this study is based on the results of the rapid assessment (Structural Scores) and the classification of damage status according to the scale EMS -98. The results of the assessment were represented by spatial maps using GIS, which were also used in the data collection and development of different databases during the research.

As explained in the previous chapter, the results of the RVS evaluation showed extremely dangerous indicators that reflect the current state of the existing essential structures in the city, so a detailed assessment should be considered. Finally, propose optimal intervention measures to improve and rehabilitate vulnerable buildings according to priorities. This was presented in detail in the study case of the Jerusalem school building.

4.1 Conclusions

General Conclusions

In general, the conclusions for this research are as follows:

1. The RVS assessment disclosed that a more than two-thirds of the essential buildings in Tulkarm require more detailed assessment, i.e., they are at high risk of collapse in the event of an earthquake in the region. Approximately 60% of these buildings lie in DG4 and DG5, which will be most affected by heavy to very heavy structural damage in the event of an earthquake, while nearly 21% of all buildings are predicted to have moderate to substantial damages .
2. Age of the building is the most significant factor that contributes to an increase of risk. Approximately 65% of the buildings were built prior the implementation of building codes, Consequently many of these buildings are either non-engineered or semi- engineered, lacking proper seismic considerations.

Furthermore, a significant number of buildings exhibit various types of irregularities. In the vertical direction, most irregularities were found in the form of short columns in the buildings, also, as vertical setbacks (out of plane). The plan irregularities were mostly due to the formation of torsions resulting from major stiffness eccentricities, as well as to the re-entrant corners in some of the buildings with shapes +, L, T, U, and E. This demonstrates that the seismic vulnerability of such buildings with the expected extent of damage is mainly influenced by the quality of the structures in addition to their construction behaviors.

The findings of this study reveal the urgent requirement for development and implementation effective seismic mitigation strategies. The study demonstrates that if a relatively strong earthquake were to occur in the future, an alarmingly high level of expected damage, reaching 72% of the essential buildings in the city, would be deemed unacceptable.

Therefore, immediate action is necessary to address this pressing issue and safeguard the city's crucial infrastructure.

Specific Conclusions

The followings are the specific Conclusions of the research:

1. The majority of health care facilities-10 of 12 buildings-did not meet the minimum requirements of the seismic design codes. In other words, the two remaining buildings will not be adequate to handle seismic emergencies, which may result in a lack of health and medical services for civilians. This highlights the need to strengthen these critical buildings or design new, safer buildings.
2. Nearly 55% of educational facilities could suffer significant losses as a result of damage and collapse (DG3, DG4, and DG5), making these buildings unable to house affected citizens in the event of a major earthquake in the future. Only four of the 21 educational facilities proposed as shelters in the city's emergency response plan (Tulkarm, 2019-2020) have passed the rapid assessment and met the minimum seismic risk standards.
3. Most of the public facilities in Tulkarm are very old structures, such as mosques and some government buildings. They were built to resist only gravity loads only, besides vertical and plan irregularities were found due to the construction patterns

used. Therefore, more than 90% of them were classified as severely damaged (DG 3, 4 and 5). As part of the emergency plan for Tulkarm, four of these buildings were recommended as emergency shelters and five others as field hospitals. Unfortunately, according to the RVS assessment, only one of the nine buildings met seismic requirements.

4. The conclusion is that essential buildings were not designed or built with great care for seismic events. This confirms that no serious disaster preparedness measures have been taken; there is a lack of disaster preparedness or mitigation activities.
   There is an urgent need to evaluate more essential buildings in the city with RVS methods and to analyze the existing buildings with inadequate seismic performance using more detailed methods to determine the optimal intervention strategies for strengthening and rehabilitation Also in order to modify and develop the existing plans and programs.
5. Various structural retrofit solutions exist to improve the seismic performance of existing structures. In this study, the effectiveness of both shear walls additions, and RC column jacketing techniques to improve the seismic behavior of the RC structure was demonstrated with detailed calculations.

4.2 Recommendations

Within the limits of the study area, it is recommended that:

1. Complementary to this study, it is recommended that the seismic performance of all the essential buildings should be assessed and a risk map that corresponds to the seismic situation of Tulkarm Governorate as a whole should be prepered.

2. Based on the results of this study, it is recommended to develop a plan to strengthen and repair the important buildings at risk.

3. Based on the results of this study, it is recommended that the emergency response plan prepared by official bodies, for the city of Tulkarm, should be modified.

General Recommendations:

At a general level, there is an urgent need to intensify the efforts of stakeholders (organizations and individuals) to adhere of seismic risk mitigation measures, the most important of which are:

1. Recommending to relevant authorities to raise awareness of the severity of the impact of earthquakes on society and to support public awareness, safety programs and campaigns for safe construction practices.
2. Improving the construction process of new structures by enacting strict seismic design compliance laws according to seismic codes, with mandatory monitoring and controlling of the construction implementation process
3. Develop public level plans to strengthen and rehabilitate existing structures to be earthquake resistant, under specific national laws and policies.
4. Developing structural portfolios which contains basic information for essential facilities, and make them available to the relevant authorities
5. Invest in activating the role of GIS in disaster risk reduction and collect geospatial data for different locations in Palestinian cities.

4.3 Limitations of the study

1. In general, RVS methods are not as accurate as other detailed methods because they depend only on external inspection .
2. Lack of geospatial data for buildings in the city of Tulkarm.
3. Confusion in determining seismic resistance system for some buildings.
4. Limited access to certain parts of buildings, some of them are for security reasons, the others because of restrictions imposed due to the Covid-19 virus.

4.4 Future Work

1. The study could be broadened to assess infrastructures and roads that serve essential buildings.
2. Customized studies on safe schools and safe health facilities.

List of Abbreviations

Abbreviation	Meaning
IBC	International Building Code
ASCE	The American Society of Civil Engineer
RC	Reinforced Concrete
S.S	Structural Score
MRF	Moment Resisting Frame
BFS	Building Frame System
EMS	European Macro-Seismic
DG	Damage Grade
GIS	Geographic Information System
RVS	Rapid Visual Screening
NCERD	National Center for Educational Research and Development
FEMA	Federal Emergency Management Agency

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1. https://www.un.org (united nations website)
2. https://www.undp.org/sustainable-development-goals(United Nations Development Programme)
3. https://www.worldbank.org/en/topic/disasterriskmanagement

Appendices

Appendix A

Supporting Documents

A.1 Emergency Response Plan - Tulkarm 2019-2020.

https://docs.google.com/spreadsheets/d/1mn08Djq9eOI_ohNOgVhUvxmdNwQ0j4jP/edit?usp=sharing&ouid=107913117106765596172&rtpof=true&sd=true

A.2 Schools Framework in the West Bank 2021-2022, Source: The Palestinian Ministry of Education

https://docs.google.com/spreadsheets/d/1mn08Djq9eOI_ohNOgVhUvxmdNwQ0j4jP/edit?usp=sharing&ouid=107913117106765596172&rtpof=true&sd=true

A.3 Pre- screening data. (Excell workbook)

https://docs.google.com/spreadsheets/d/1VCUGS2XB7n4RMyowrcaCYx9MmGfQitH9/edit?usp=sharing&ouid=107913117106765596172&rtpof=true&sd=true

A.4 Post-assessment results. (Excell workbook)

https://docs.google.com/spreadsheets/d/1mn08Djq9eOI_ohNOgVhUvxmdNwQ0j4jP/edit?usp=sharing&rtpof=true&sd=true

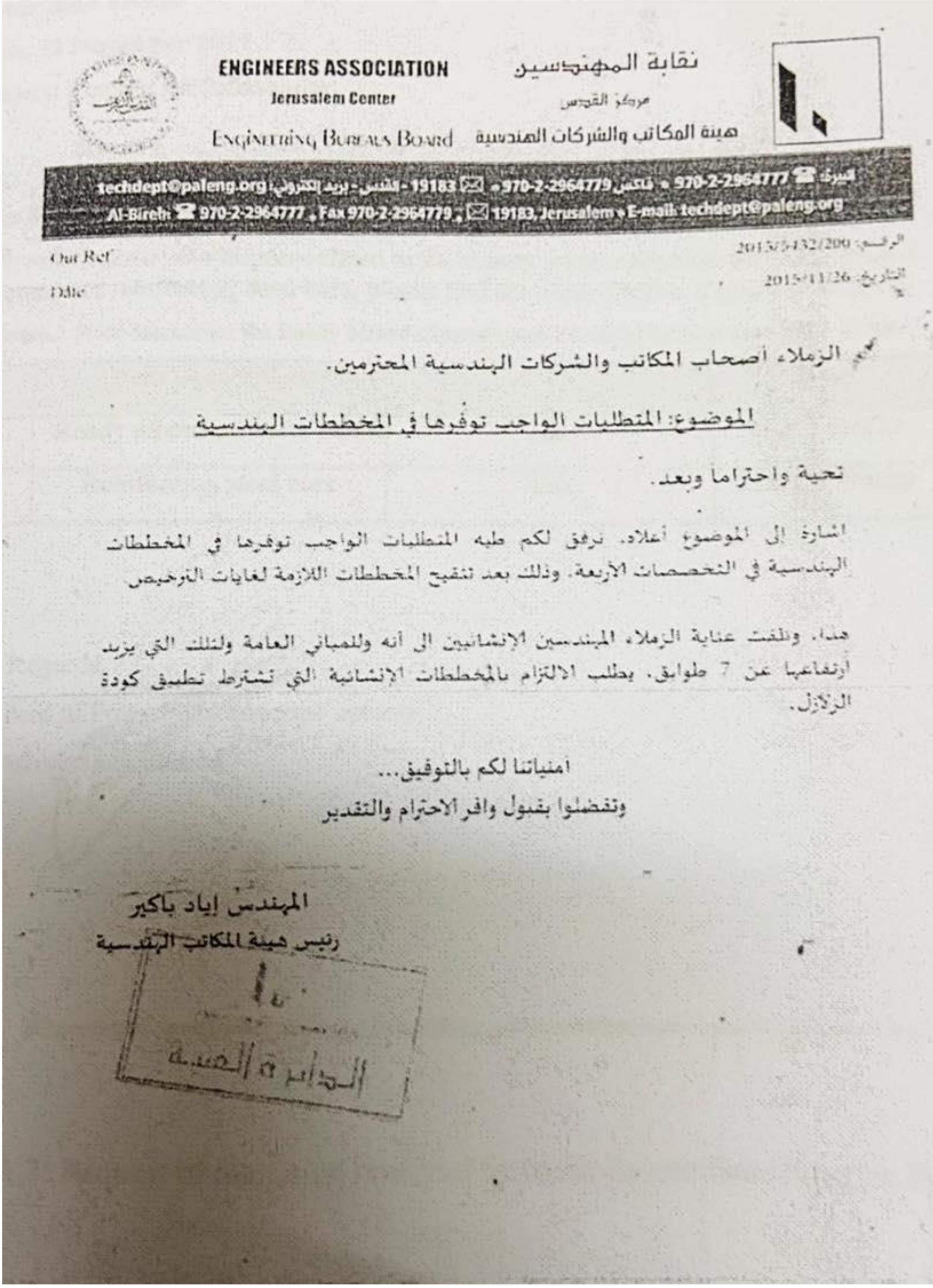
A.5 Minimum Requirements for Structural Drawings.

Engineers Association - Jerusalem Center 2015.

https://www.paleng.org/wp-content/uploads/2015/11/Req_2015-1.pdf

Figure A.1

The circulation of the imperatively seismic design of buildings



ENGINEERS ASSOCIATION
Jerusalem Center
Engineering Bureaus Board

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Our Ref — الرقم: 2015/5432/200
Date — التاريخ: 2015/11/26

الزملاء أصحاب المكاتب والشركات الهندسية المحترمين.

<u>الموضوع: المتطلبات الواجب توفرها في المخططات الهندسية</u>

تحية واحتراما وبعد.

اشارة إلى الموضوع أعلاه، نرفق لكم طيه المتطلبات الواجب توفرها في المخططات الهندسية في التخصصات الأربعة، وذلك بعد تنقيح المخططات اللازمة لغايات الترخيص

هذا، ونلفت عناية الزملاء المهندسين الإنشائيين الى أنه وللمباني العامة ولتلك التي يزيد ارتفاعها عن 7 طوابق، يطلب الالتزام بالمخططات الإنشائية التي تشترط تطبيق كودة الزلازل.

امنياتنا لكم بالتوفيق...
وتفضلوا بقبول وافر الاحترام والتقدير

المهندس إياد باكير
رئيس هيئة المكاتب الهندسية

الدائرة الفنية

Appendix B
Study Area Profile

Figure B.1

Soil classification of the study area

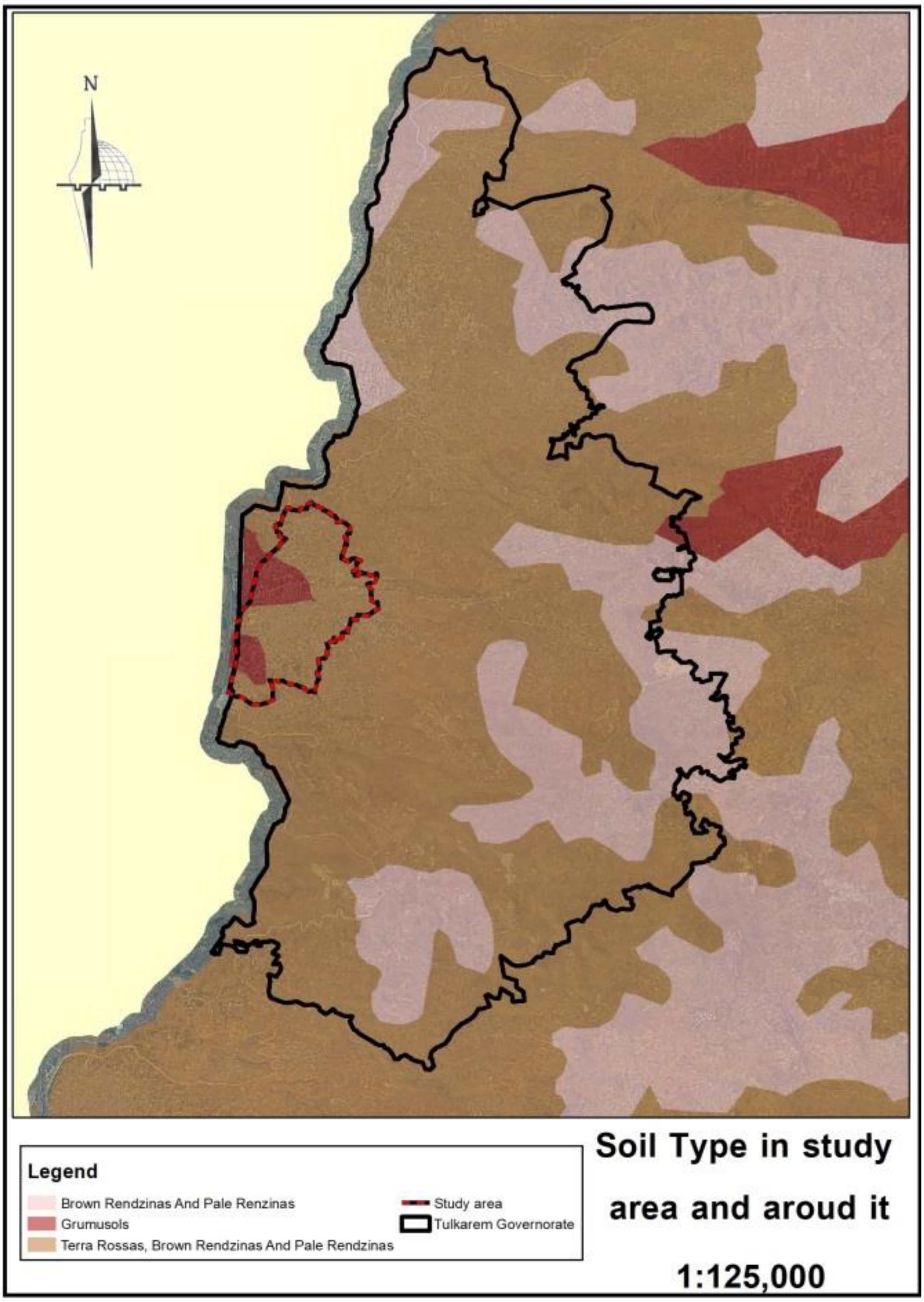


Figure B.2

The agricultural value of the study area

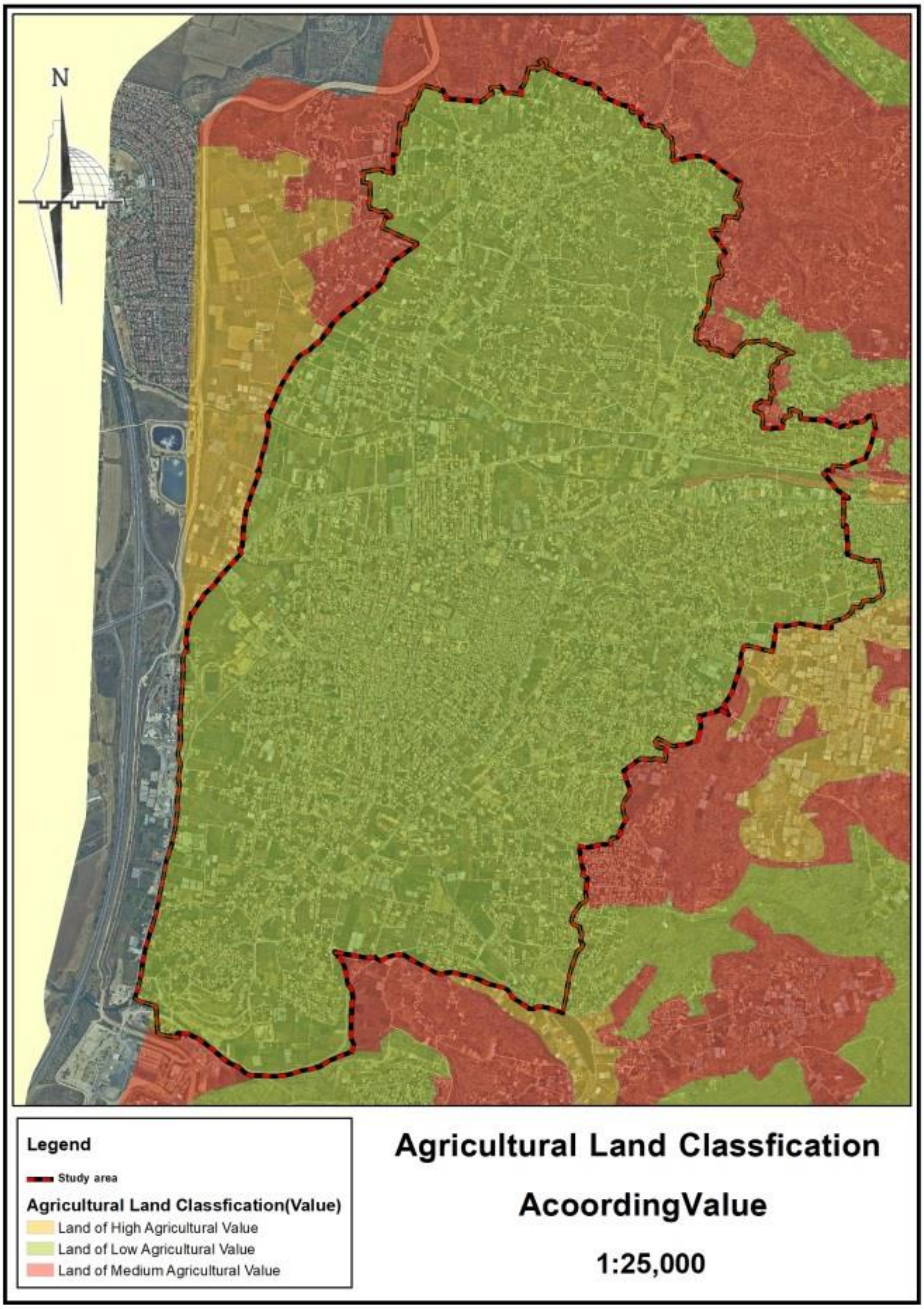


Figure B.3

Rainfall of the study area

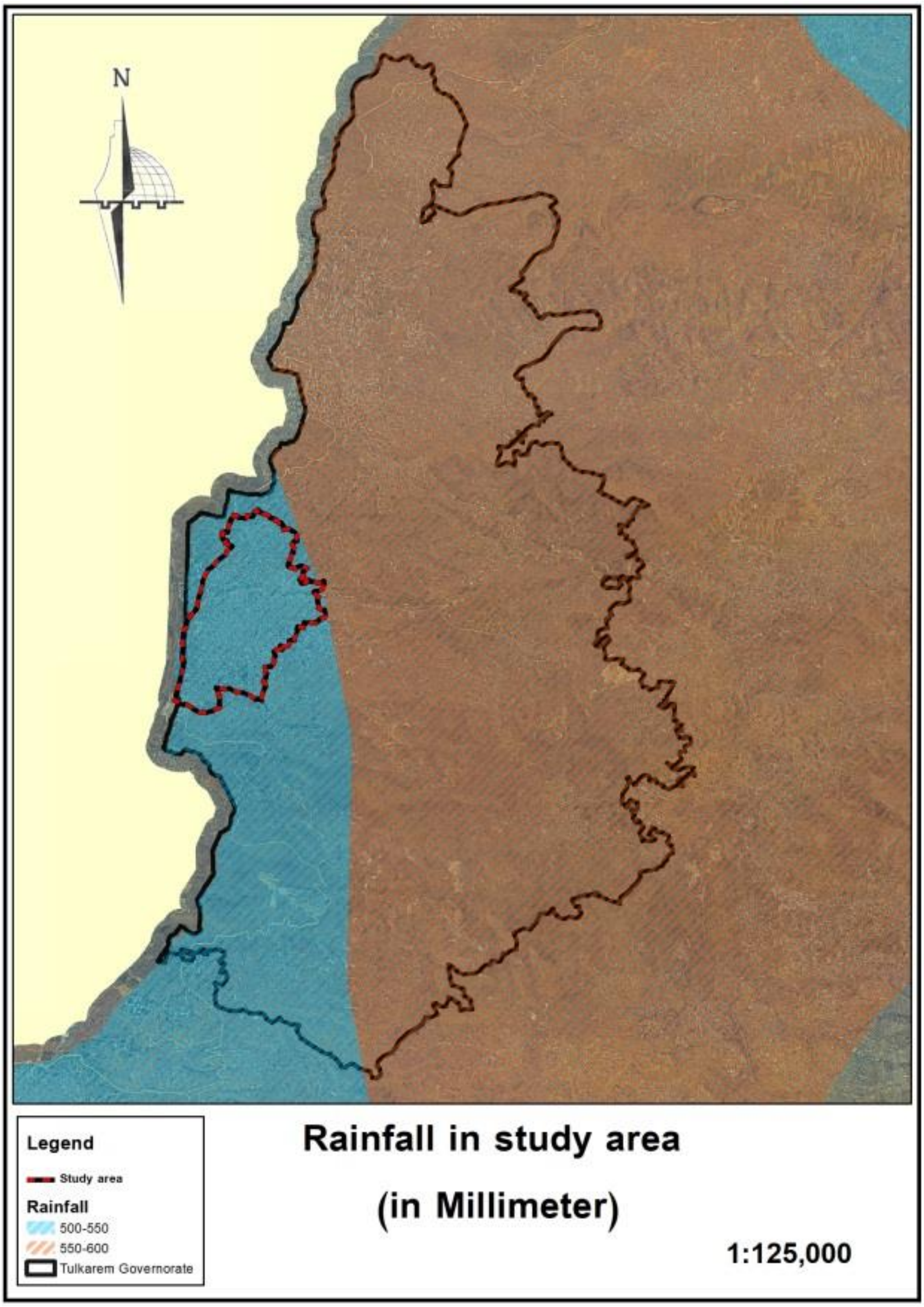


Figure B.4

Catchments in the study area

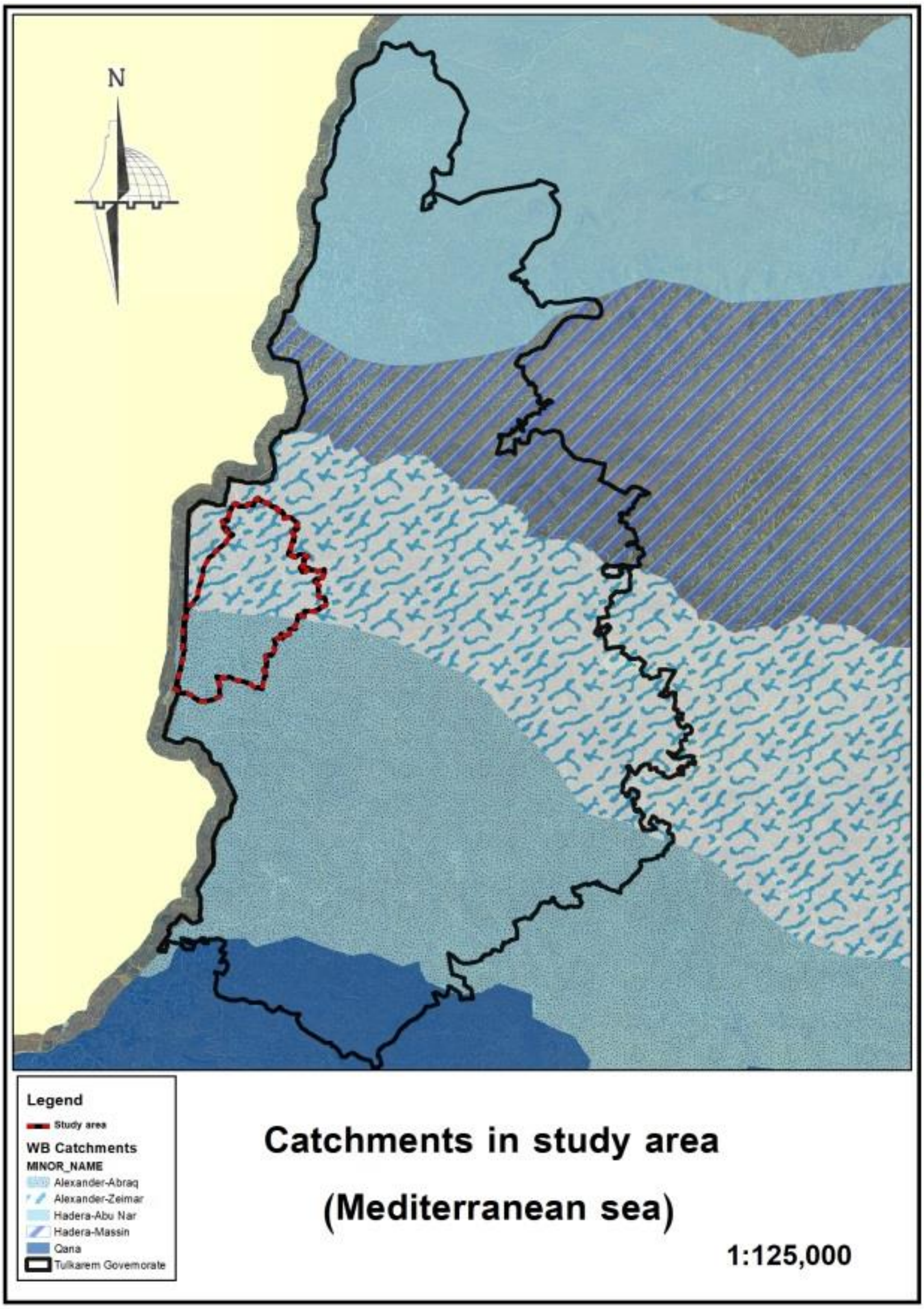
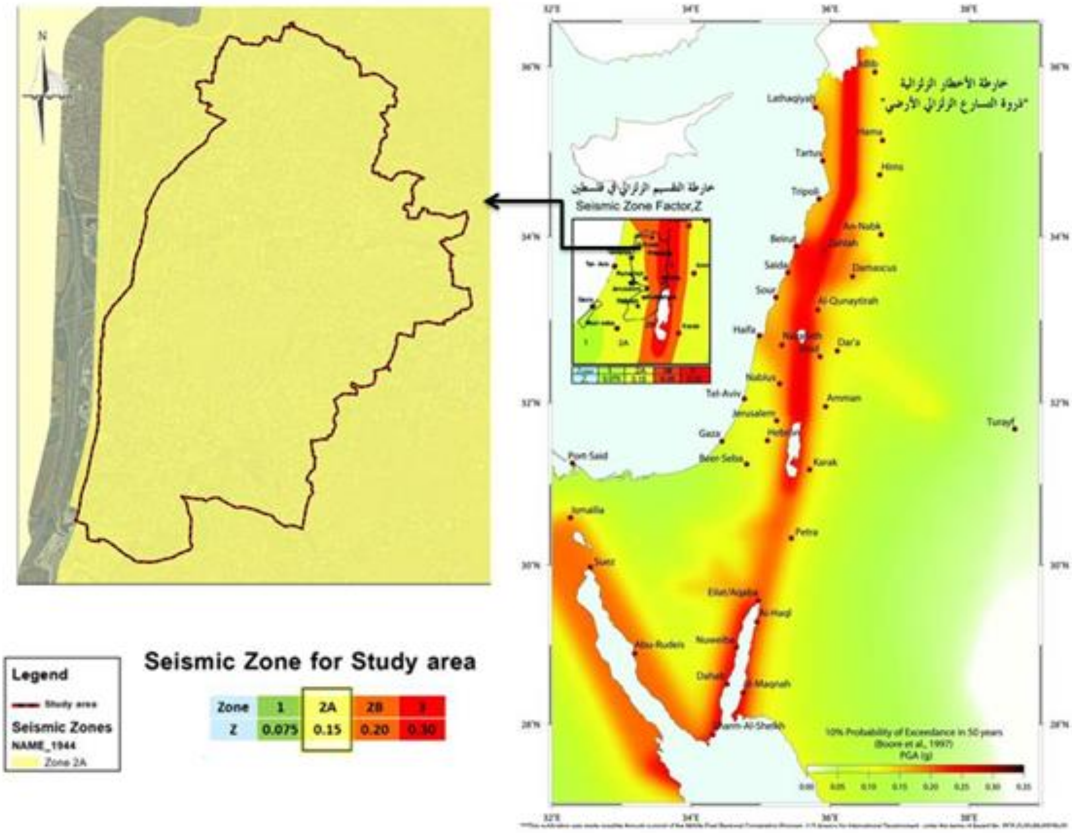


Figure B.5

Seismic zone of the study area



Appendix C

RVS Evaluation

FEMA P-154 Reference Guides

Data collection form

Table C.1

Seismicity Region Determination from MCE$_R$ Spectral Acceleration Response

Seismicity Region	Range of Response Values for Each Region		Median Response Values for Each Region	
	$S_s(g)$	$S_1(g)$	$S_{s,avg}(g)$	$S_{1,avg}(g)$
Low(L)	$S_s < 0.25g$	$S_1 < 0.1g$	0.2	0.08
Moderate (M)	$0.25g \leq S_s < 0.5g$	$0.1g \leq S_1 < 0.2g$	0.4	0.16
Moderately High (M)	$0.5g \leq S_s < 1g$	$0.2g \leq S_1 < 0.4g$	0.8	0.32
High (H)	$1g \leq S_s < 1.5g$	$0.4g \leq S_1 < 0.6g$	1.2	0.48
Very High (VH)	$S_s \geq 1.5g$	$S_1 \geq 0.6g$	2.25	0.9

Note. (g) acceleration of gravity in horizontal direction. , (MCER) Maximum Considered Earthquake.

Table C.2

Site Classification

Soil type	Name	Shear wave velocity V_{s30} (Ft/s)
Hard rock	Type A	> 5000
Soft rock	Type B	$2500 < V_{s30} \leq 5000$
Dense soil	Type C	$1200 < V_{s30} \leq 2500$
Stiff soil	Type D	$600 < V_{s30} \leq 1200$
Soft soil	Type E	≤ 600
Poor soil	Type F	Requires specific evaluation

Figure C.1

Moderate seismicity – Level 1 data collection form

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

Level 1
MODERATE Seismicity

PHOTOGRAPH

SKETCH

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:

☐ 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		**5.1**	**4.5**	**3.8**	**2.7**	**2.6**	**3.5**	**2.5**	**2.7**	**2.1**	**2.5**	**2.0**	**2.1**	**1.9**	**2.1**	**2.1**	**1.7**	**2.9**
Severe Vertical Irregularity, V_{L1}		-1.4	-1.4	-1.4	-1.2	-1.2	-1.4	-1.1	-1.2	-1.1	-1.2	-1.0	-1.1	-1.0	-1.1	-1.1	-1.0	NA
Moderate Vertical Irregularity, V_{L1}		-0.9	-0.9	-0.9	-0.8	-0.7	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.7	-0.6	-0.7	-0.7	-0.6	NA
Plan Irregularity, P_{L1}		-1.4	-1.3	-1.2	-1.0	-0.9	-1.2	-0.9	-0.9	-0.8	-1.0	-0.8	-0.9	-0.8	-0.8	-0.8	-0.7	NA
Pre-Code		-0.3	-0.5	-0.6	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.5
Post-Benchmark		1.4	2.0	2.5	1.5	1.5	0.8	2.1	NA	2.0	2.3	NA	2.1	2.5	2.3	2.3	NA	1.2
Soil Type A or B		0.7	1.2	1.8	1.1	1.4	0.6	1.5	1.6	1.1	1.5	1.3	1.6	1.3	1.4	1.4	1.3	1.6
Soil Type E (1-3 stories)		-1.2	-1.3	-1.4	-0.9	-0.9	-1.0	-0.9	-0.9	-0.7	-1.0	-0.7	-0.8	-0.7	-0.8	-0.8	-0.6	-0.9
Soil Type E (> 3 stories)		-1.8	-1.6	-1.3	-0.9	-0.9	NA	-0.9	-1.0	-0.8	-1.0	-0.8	NA	-0.7	-0.7	-0.8	-0.6	NA
Minimum Score, S_{MIN}		*1.6*	*1.2*	*0.9*	*0.6*	*0.6*	*0.8*	*0.6*	*0.6*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*	*0.2*	*1.5*

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

Level 1 Building Addition Reference Guide

Table C.3

Screening guidance for buildings with horizontal additions

Building Addition Screening Criteria	Response	Screening Guidance
Criterion 1: Does the building have visible and aligned joints over the entire height of two exterior walls and across the roof?	Yes	Determine scores for each separate building defined by the joints and consider the potential for pounding using the adjacency guidelines in Section 3.9.
	No	See Criterion 2
Criterion 2: Does the building have any of the following characteristics: a) abrupt and noticeable differences in architectural style that occur on two sides of the building over the entire height of the exterior walls? b) visible differences in structural framing between distinct portions of the building? c) differences in floor elevation between portions of the building?	Yes	Screen as separate buildings defined by the differences noted in Criterion 2. Determine score for each portion and record the lower score.
	No	Screen as a single building.

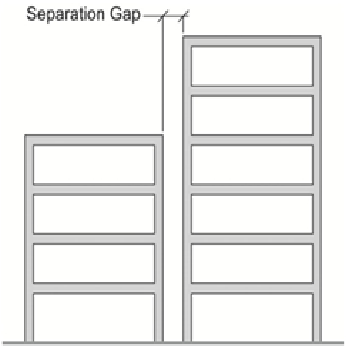
Level 1 Pounding Reference Guide

Table C.4

Pounding Reference Guide

Consider pounding when the separation between adjacent buildings is less than:

- 2″ times number of stories in shorter building (in Very High seismicity region)
- 1 1/2″ times number of stories in shorter building (in High seismicity region)
- 1″ times number of stories in shorter building (in Moderately High seismicity region)
- 1/2″ times number of stories in shorter building (in Moderate and Low seismicity regions)



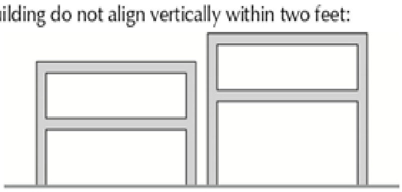
Examples:

a) Two 2-story buildings next to each other in High seismicity region:
Minimum Separation = 1 1/2″ x 2 = 3″

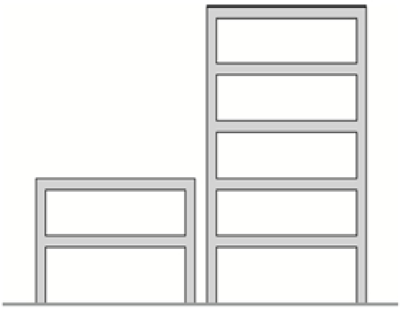
b) 6-story building next to a 4-story building in Moderate seismicity region: Minimum Separation = 1/2″ x 4 = 2″

AND one or more of the following conditions apply:

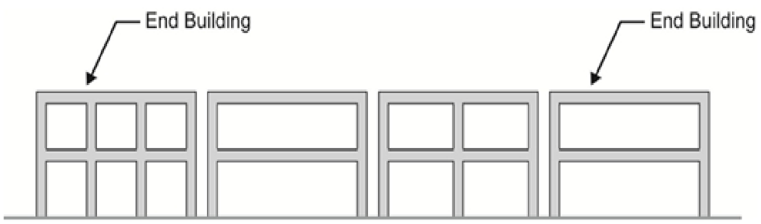
1. Floors of adjacent building do not align vertically within two feet:



2. One building is 2 or more stories taller than the other:



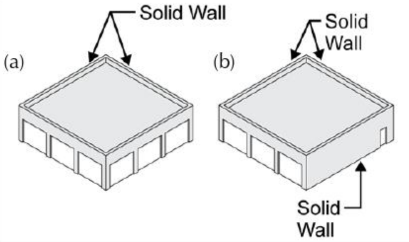
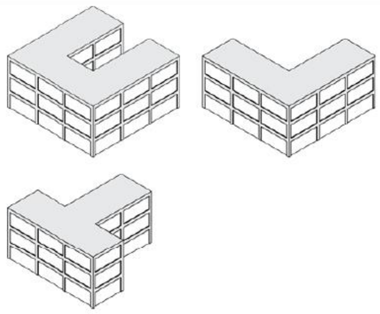
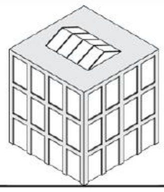
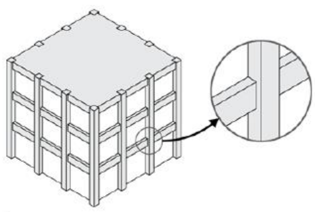
3. Building is at the end of the block:



Plan Irregularity Reference Guide

Table C.5
Plan Irregularity Reference Guide

Table B-5 Plan Irregularity Reference Guide

Plan Irregularity		Level 1 Instructions
Torsion	 	Apply if there is good lateral resistance in one direction, but not the other, or if there is eccentric stiffness in plan (as shown in Figures (a) and (b); solid walls on two or three sides with walls with lots of openings on the remaining sides).
Non-Parallel Systems		Apply if the sides of the building do not form 90-degree angles.
Reentrant Corner		Apply if there is a reentrant corner, i.e., the building is L, U, T, or + shaped, with projections of more than 20 feet. Where possible, check to see if there are seismic separations where the wings meet. If so, evaluate for pounding.
Diaphragm Openings		Apply if there is a opening that has a width of over 50% of the width of the diaphragm at any level.
Beams do not align with columns		Apply if the exterior beams do not align with the columns in plan. Typically, this applies to concrete buildings, where the perimeter columns are outboard of the perimeter beams.

Vertical Irregularity Reference Guide

Table C.6
Vertical Irregularity Reference Guide

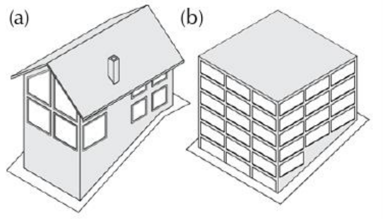
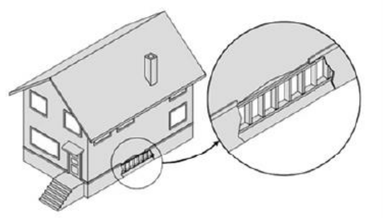
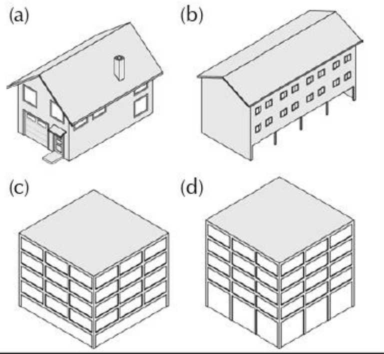
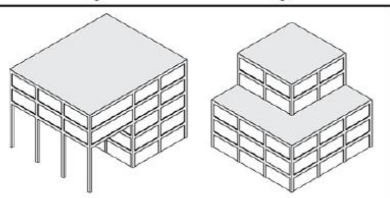
Vertical Irregularity		Severity	Level 1 Instructions
Sloping Site		Varies	Apply if there is more than a one-story slope from one side of the building to the other. Evaluate as Severe for W1 buildings as shown in Figure (a); evaluate as Moderate for all other building types as shown in Figure (b).
Unbraced Cripple Wall		Moderate	Apply if unbraced cripple walls are observed in the crawlspace of the building. This applies to W1 buildings. If the basement is occupied, consider this condition as a soft story.
Weak and/or Soft Story		Severe	Apply: Figure (a): For a W1 house with occupied space over a garage with limited or short wall lengths on both sides of the garage opening. Figure (b): For a W1A building with an open front at the ground story (such as for parking). Figure (c): When one of the stories has less wall or fewer columns than the others (usually the bottom story). Figure (d): When one of the stories is taller than the others (usually the bottom story).
Out-of-Plane Setback		Severe	Apply if the walls of the building do not 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 (a). The condition in Figure (b) also triggers this irregularity. If nonstacking walls are known to be nonstructural, this irregularity does not apply. Apply the setback if greater than or equal to 2 feet.

Table C.6

Vertical Irregularity Reference Guide (Continued)

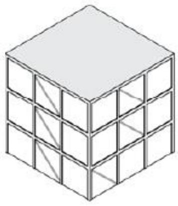
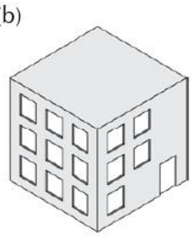
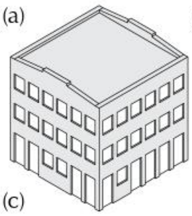
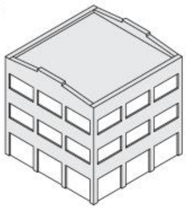
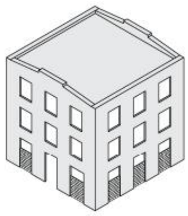
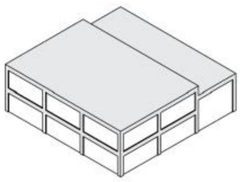
Vertical Irregularity		Severity	Level 1 Instructions
In-plane Setback	(a)  (b) 	Moderate	Apply if there is an in-plane offset of the lateral system. Usually, this is observable in braced frame (Figure (a)) and shear wall buildings (Figure (b)).
Short Column/Pier	(a)  (b)  (c) 	Severe	Apply if: Figure (a): Some columns/piers are much shorter than the typical columns/piers in the same line. Figure (b): The columns/piers are narrow compared to the depth of the beams. Figure (c): There are infill walls that shorten the clear height of the column. Note this deficiency is typically seen in older concrete and steel building types.
Split Levels		Moderate	Apply if the floors of the building do not align or if there is a step in the roof level.

Table C.7

Building types according to FEMA

FEMA Building Type		Year Seismic Codes Initially Adopted and Enforced	Benchmark Year when Codes Improved
W1	Light wood frame single- or multiple-family dwellings		
W1A	Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet		
W2	Wood frame commercial and industrial buildings > 5,000 sqft		
S1	Steel moment-resisting frame		
S2	Braced steel frame		
S3	Light metal frame		
S4	Steel frame with cast-in-place concrete shear walls		
S5	Steel frame with unreinforced masonry infill walls		
C1	Concrete moment-resisting frame		
C2	Concrete shear wall		
C3	Concrete frame with unreinforced masonry infill walls		
PC1	Tilt-up construction		
PC2	Precast concrete frame		
RM1	Reinforced masonry with flexible floor and roof diaphragms		
RM2	Reinforced masonry with rigid floor and roof diaphragms		
URM	Unreinforced masonry bearing-wall buildings		
MH	Manufactured housing		
Anchorage of Heavy Cladding Year in which seismic anchorage requirements were adopted:			

Appendix D
Surveyed Buildings Data

Characteristics for surveyed buildings

Figure D.1

Height of buildings in stories

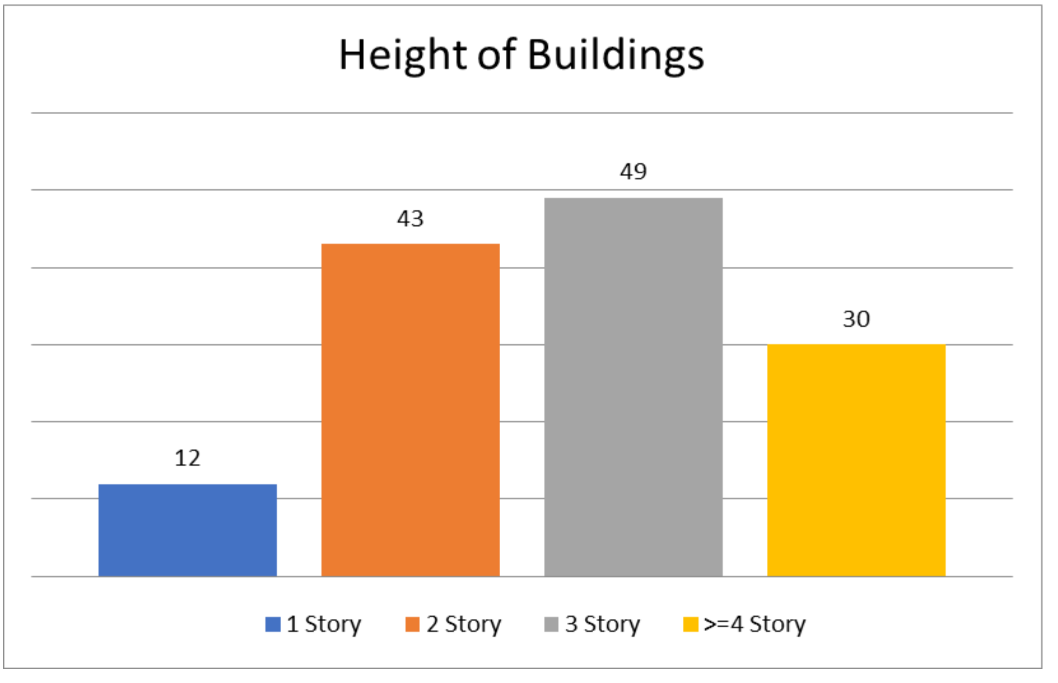


Figure D.2

Soil type distribution for buildings

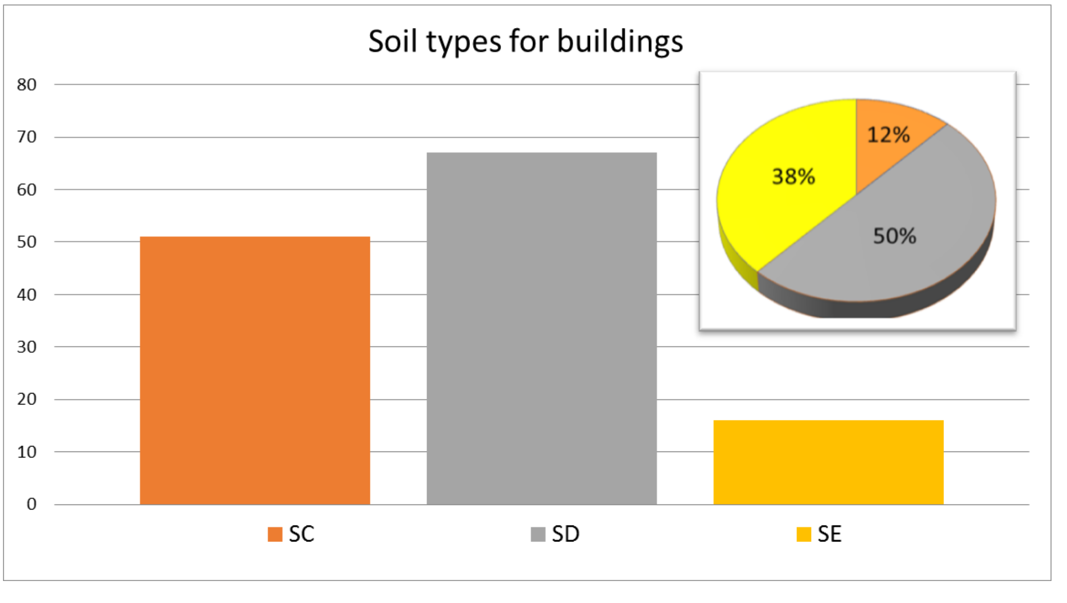


Figure D.3

Percentage distribution of buildings according to year of built

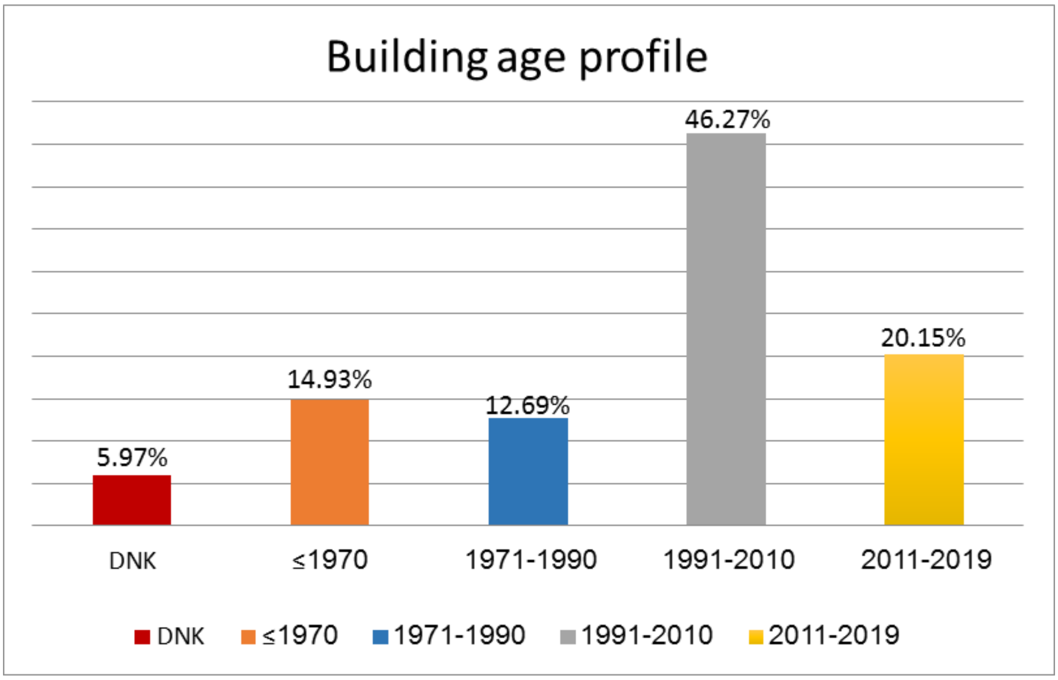


Figure D.4

Distribution of buildings according occupancy

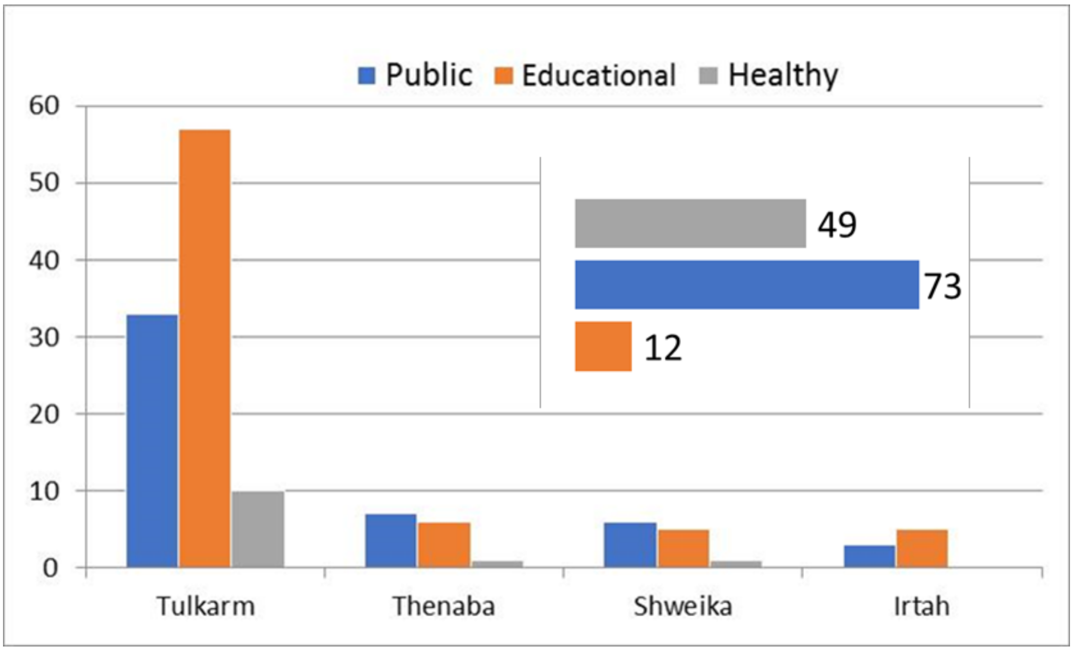


Figure D.5

Irregularities percentage for building

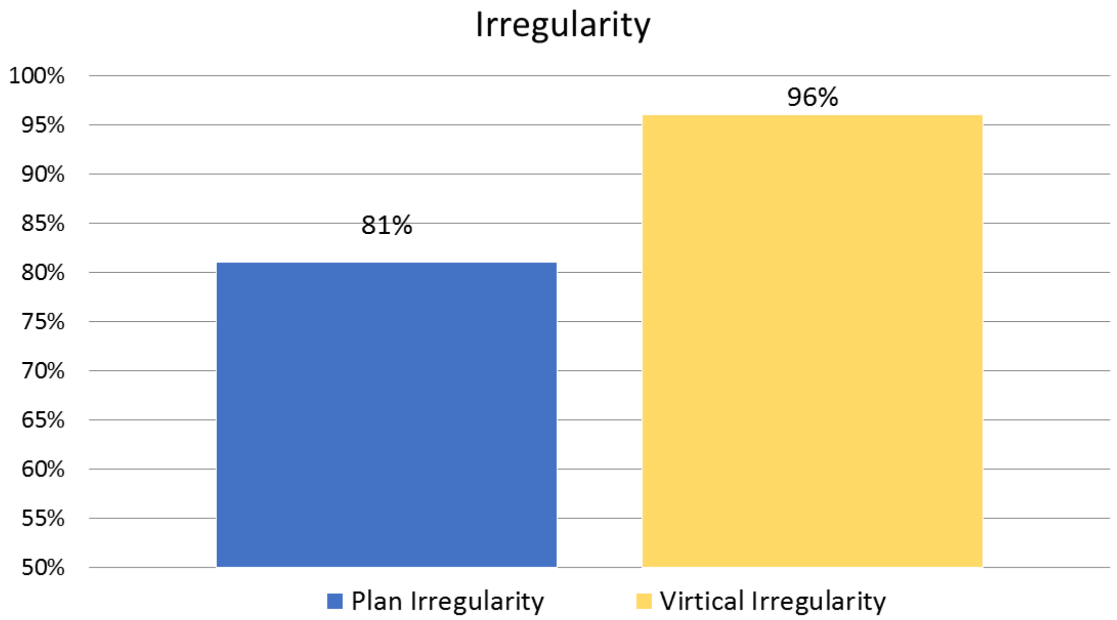
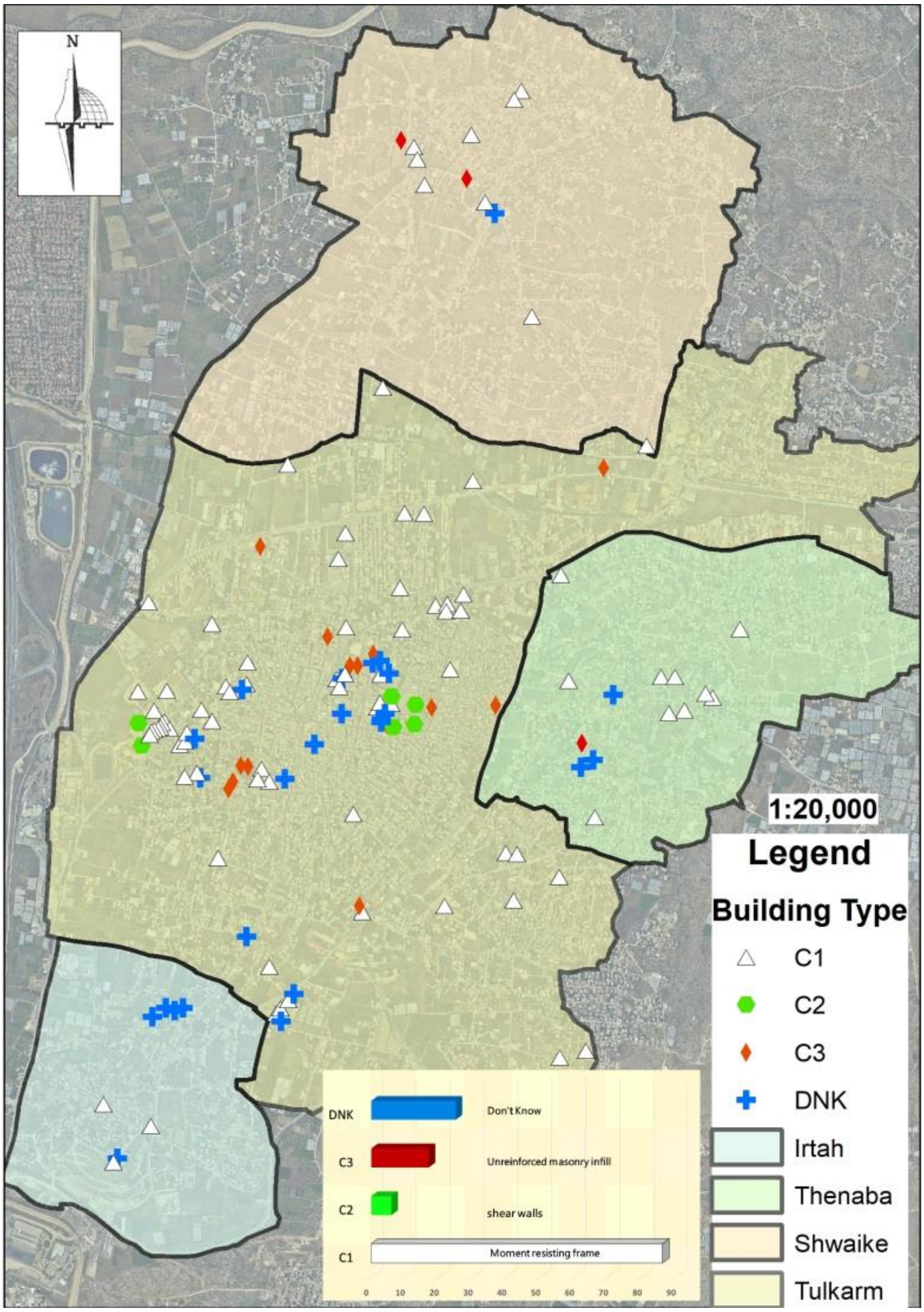


Figure D.6

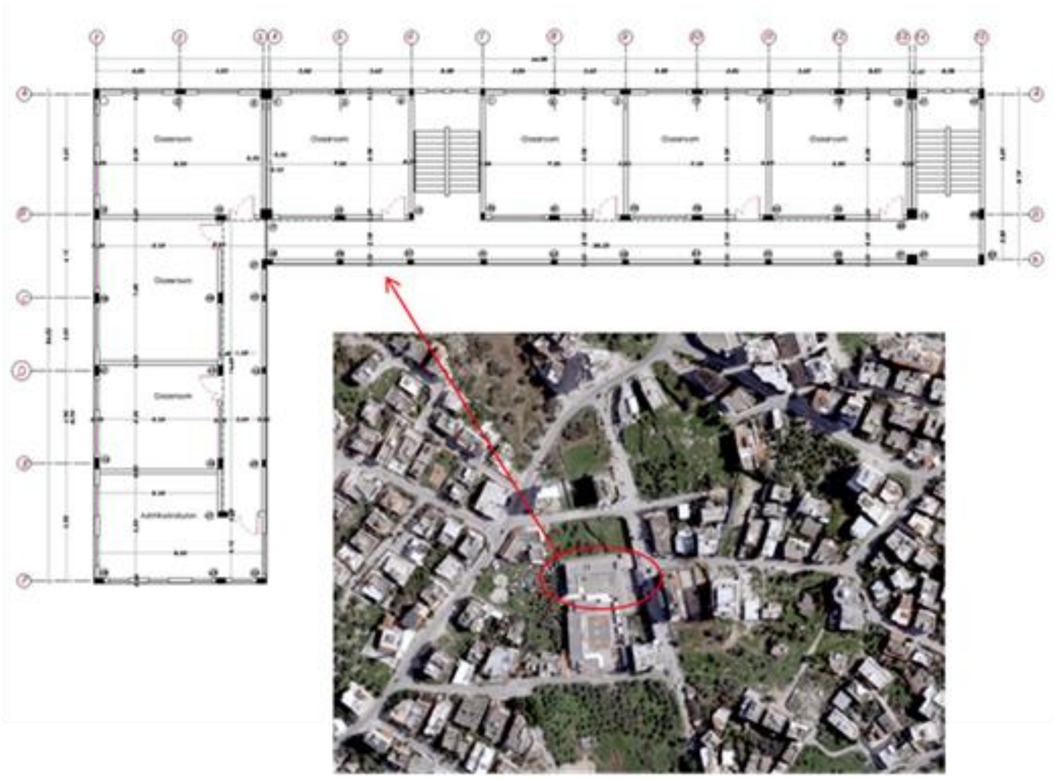
Distribution of building types in study area



Case study

Figure D.7

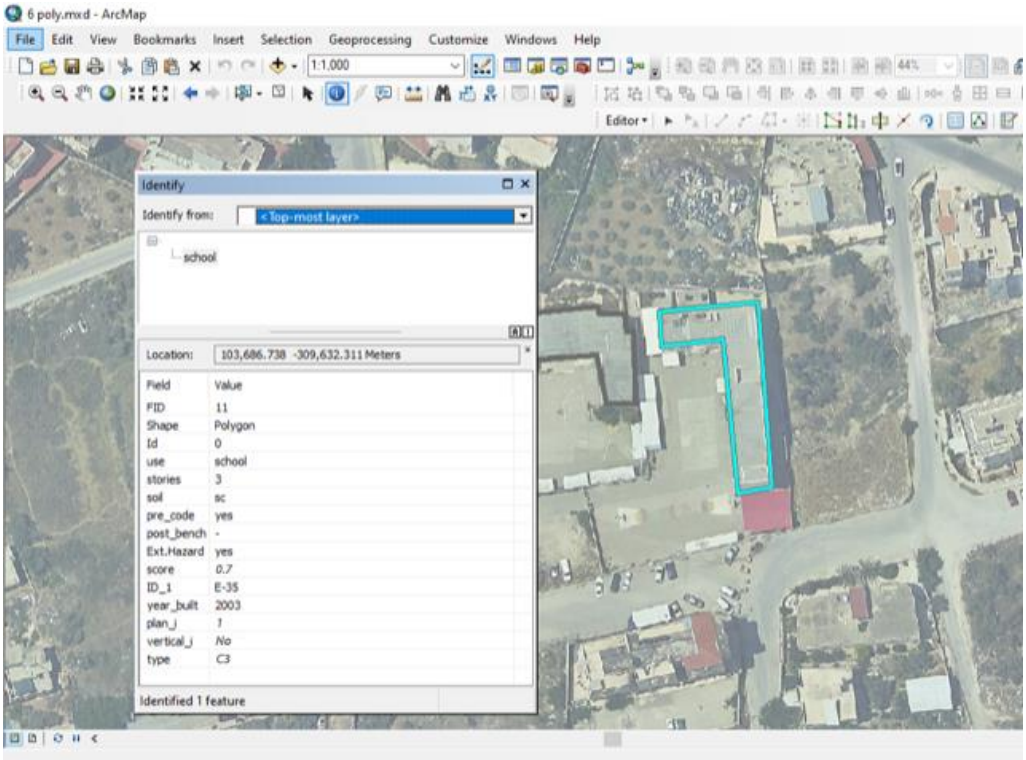
Details of case study building



* Photo from Geomolg.ps

Figure D.8

Building information for Al-Quds Girls Elementary School study area in GIS software



Appendix E

Detailed Quantitative Evaluation

Modeling

Figure E.1

Distribution of blocks in the building

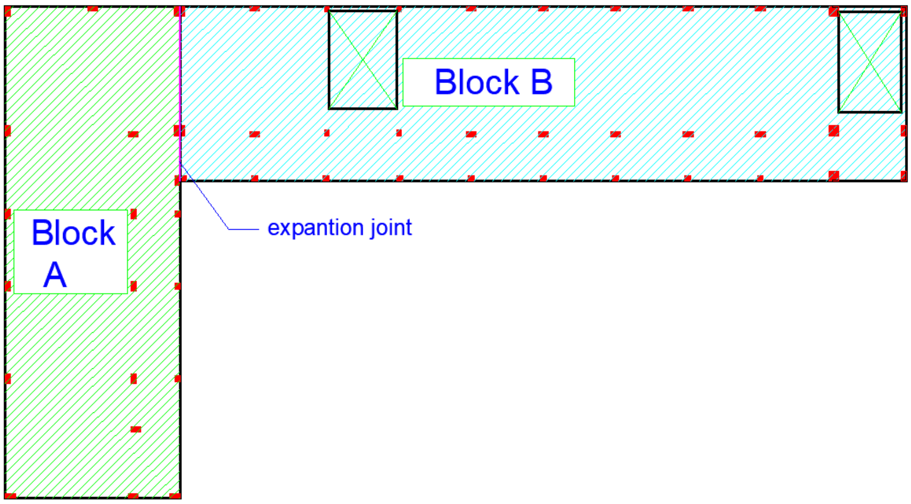


Figure E.2

Cross section in the one-way ribbed slab

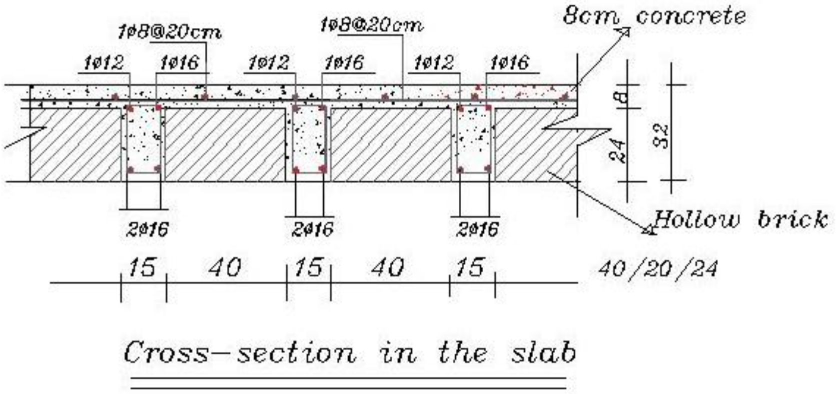


Figure E.3

Block A model

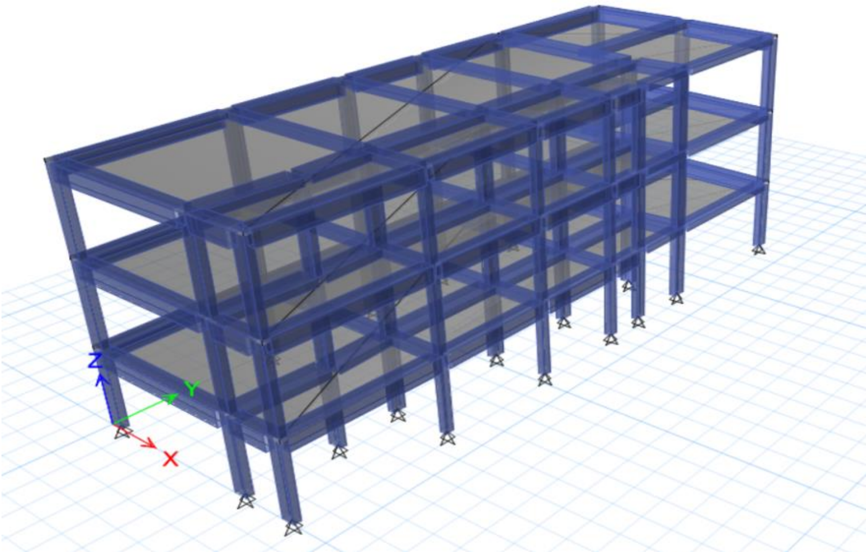


Figure E.4

Block B model

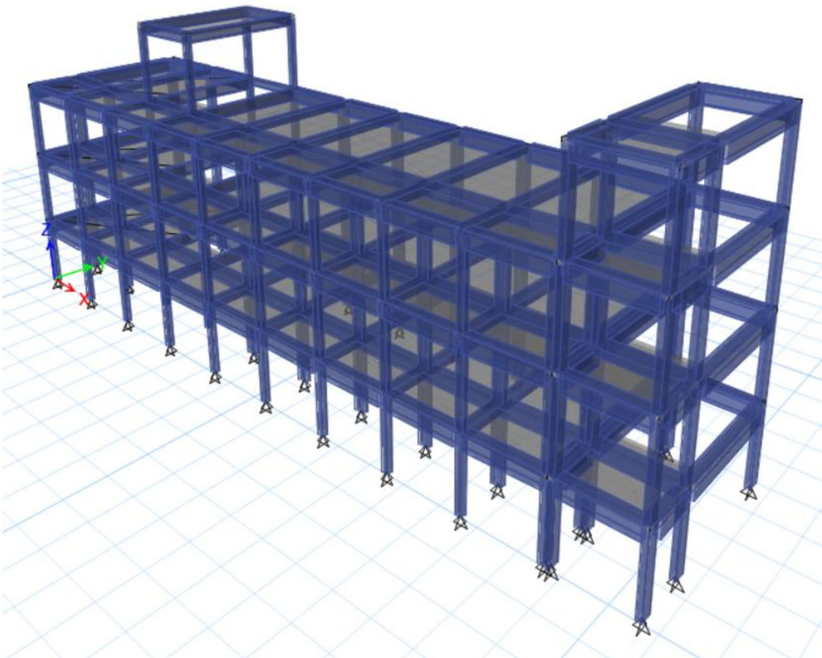


Table E.1

SID calculations

Material	Length	Height	Density	Weight Kn/m.rib	Kn/m2
Block	0.4	0.24	12	1.152	
Filling	0.55	0.1	20	1.1	
Mortar	0.55	0.02	22	0.242	
Tile	0.55	0.03	25	0.4125	
Plaster	0.55	0.02	22	0.242	
Total weight				3.1485	5.7

Checks for gravity load

Check of compatibility

Figure E.5

Compatibility of Block A

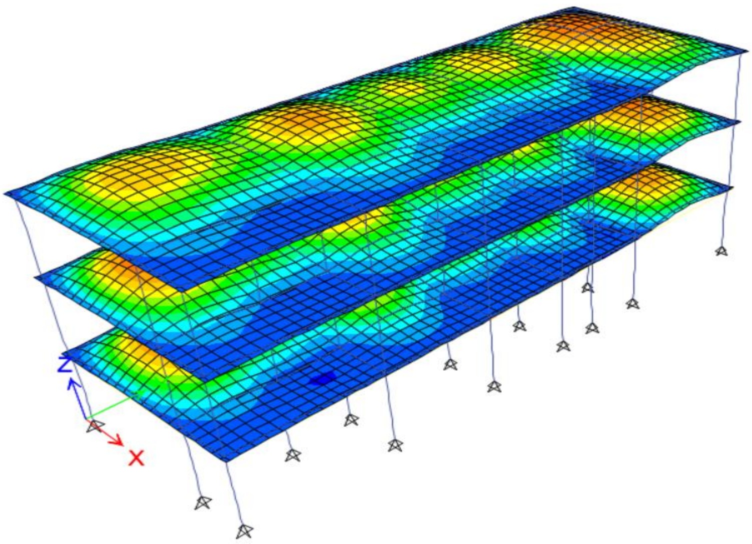
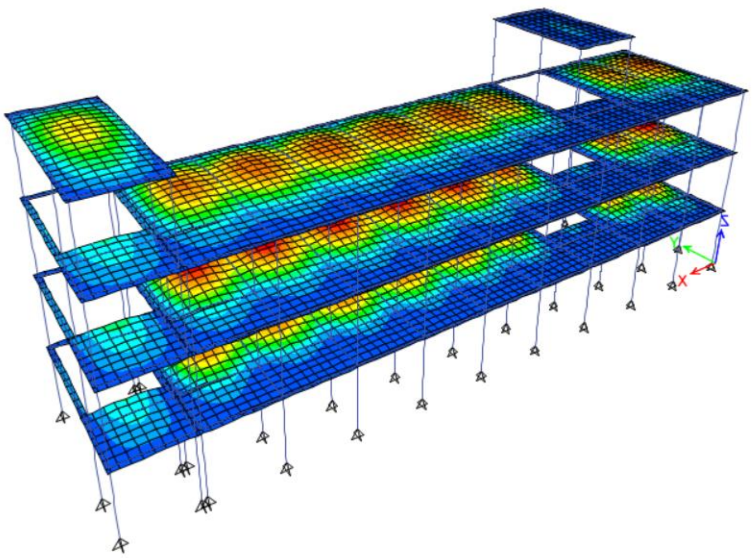


Figure E.٦

Compatibility of Block B



Check of deflection

Figure E.٧

Check of deflection for block A

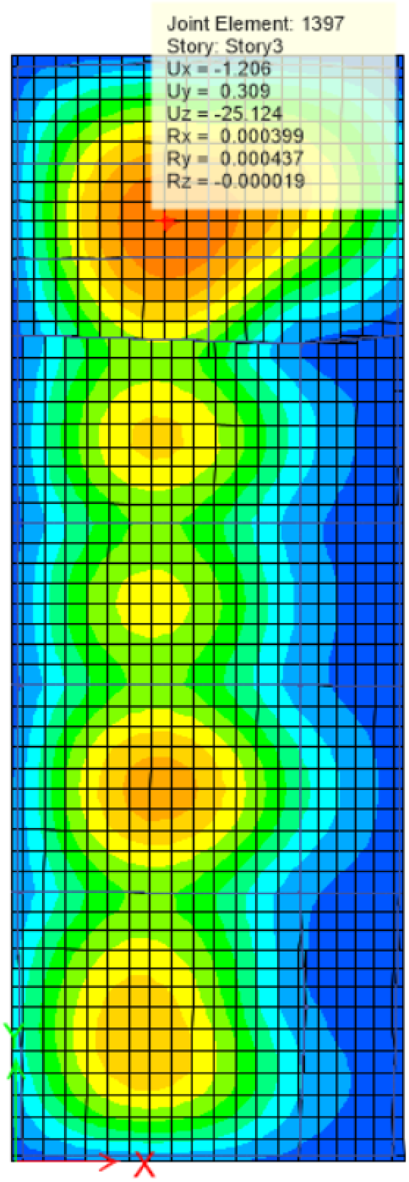
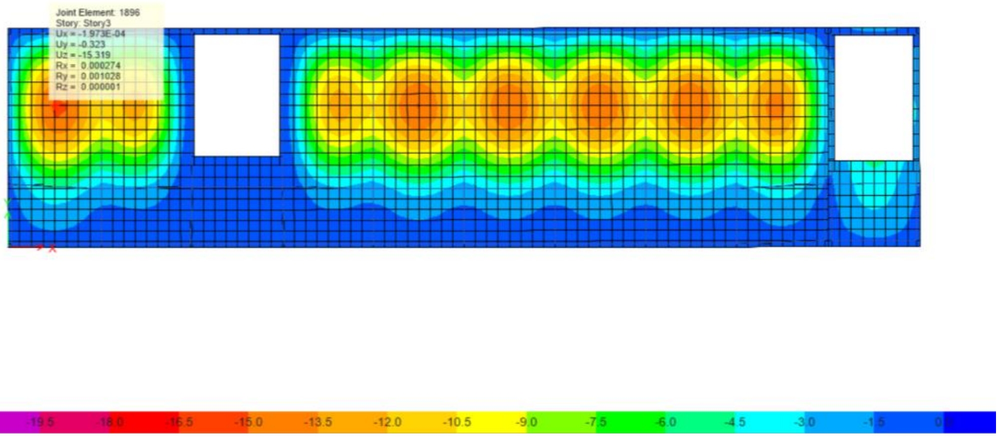


Figure E.8

Check of deflection for block B



Check of Structural elements under gravity loads effect

Figure E.9

Structural analysis of block A elements

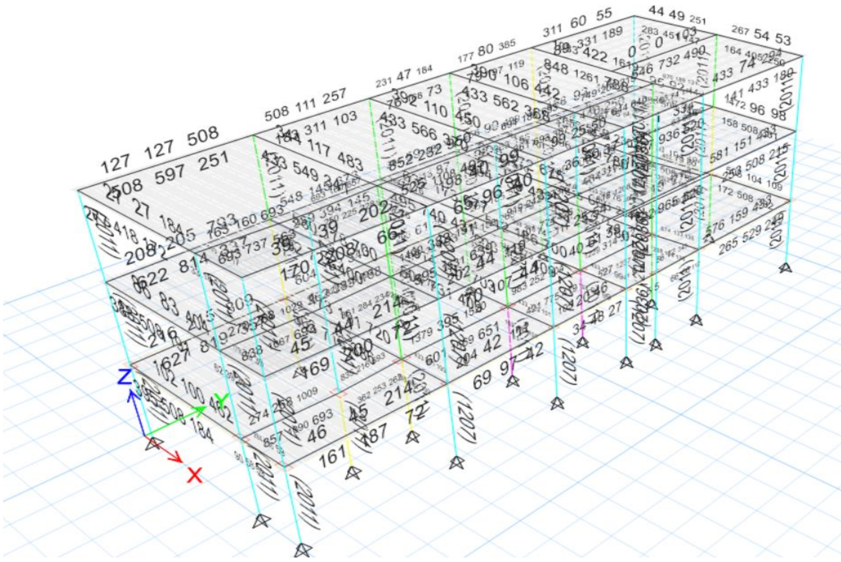
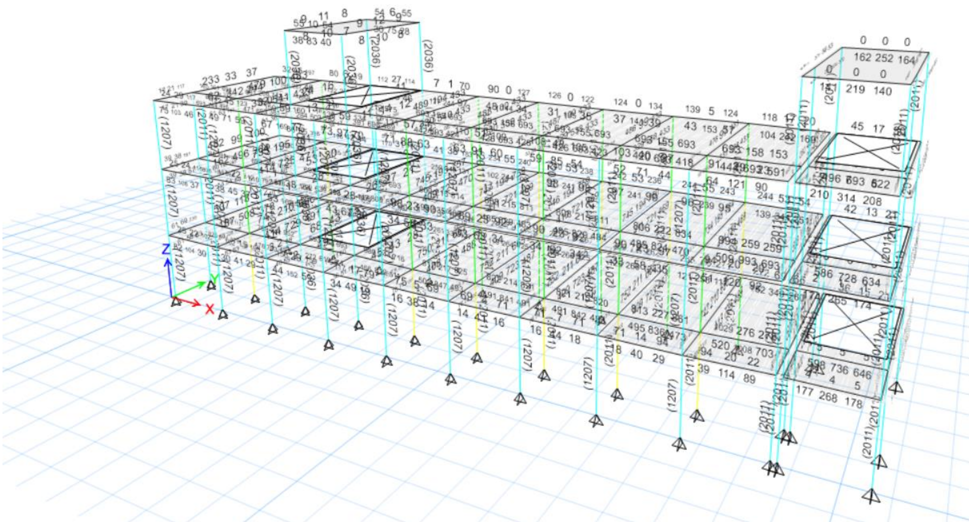


Figure E.10

Structural analysis of block B elements



Structural analysis for seismic lateral load:

Definitions for seismic structural analysis

Diaphragm:

Define all slabs as semi rigid diaphragm, to be sure it will transfer earthquake loads in plane not just out of plan.

Figure E.11

Diaphragm definition for block A

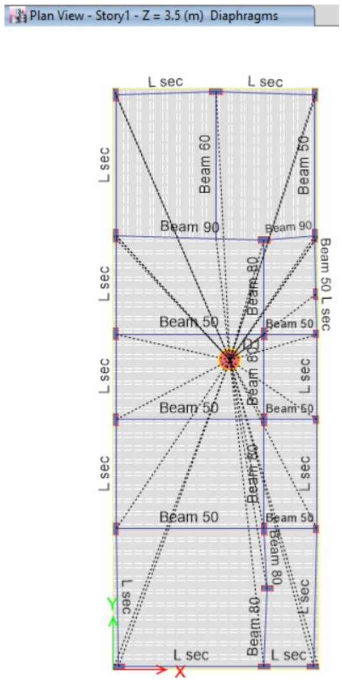
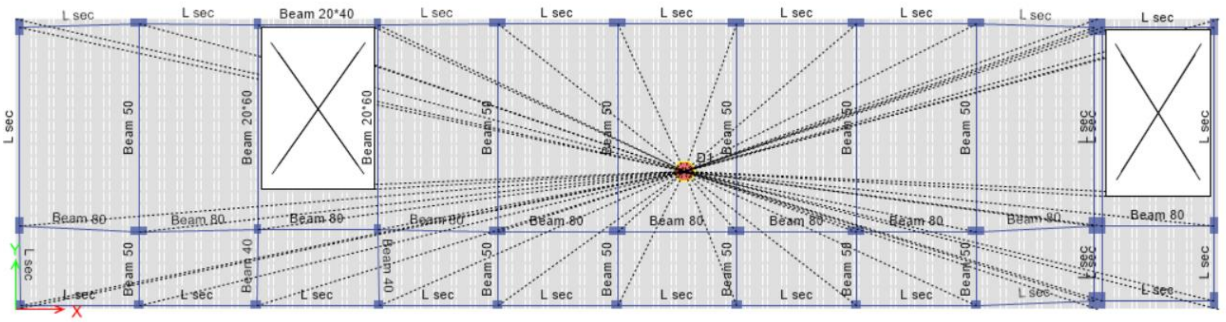


Figure E.12

Diaphragm definition for block B

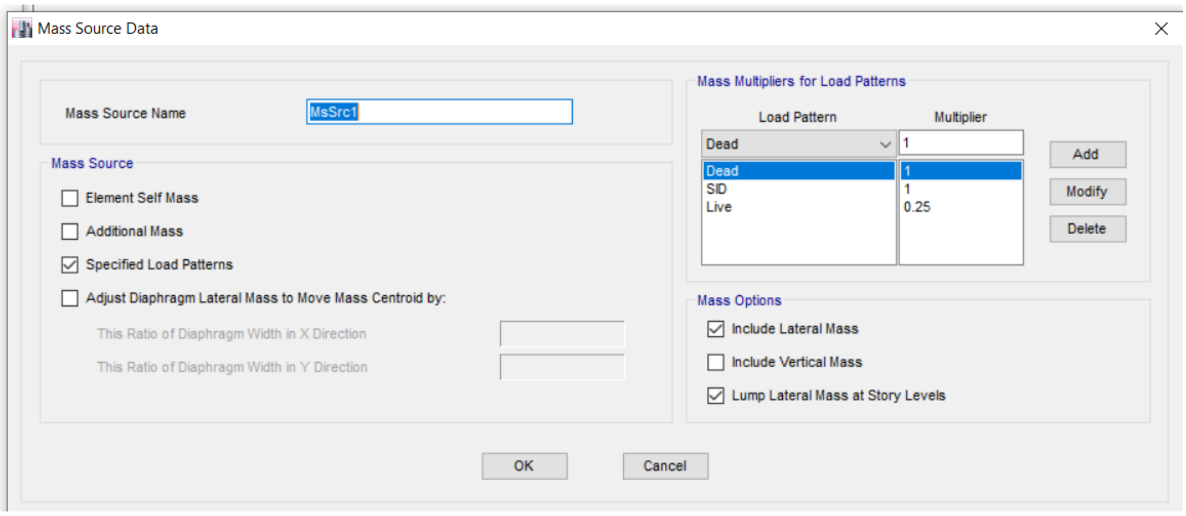


Mass source:

It defines the masses that will determine the seismic load on the building, it consist of the whole dead load and super imposed dead load, and Quarter of the value of live load.

Figure E.13

Mass source data



Determination of the Seismic Base Shear:

The base shear formula represents the shear force that will be generated at the base of a building. The basal shear coefficient is determined based on the seismic response spectrum chart.

This step aims to make the base shear value in Etabs equal to the manual value, it started with a scale factor equal to (I*g/R.**)**

Load Combinations:

1. **Ultimate Load combinations:**

U1=1.4D +1.4 SID

U2=1.2D +1.2 SID+ 1.6L

U3= 1.2 D+ 1.2 SID + 1 L

U4 = 1.3D + 1.3 SID +1.3 EQX

U5=1.3D + 1.3 SID +1.3 EQy

U6= 0.8 D+ 0.8 SID + 1.3 EQX

U7= 0.8 D+ 0.8 SID + 1.3 EQy

2. **Service load combinations:**

S1= D+SID+ L

S2= 1.1 D+ 1.1 SID + 0.91 EQx

S3= 1.1 D+ 1.1 SID + 0.91 EQy

S4= 1.26 D +1.26 SID + 0.75 L + 0.68 EQX

S5= 1.26 D +1.26 SID + 0.75 L + 0.68 EQy

S6=0.53 D+ 0.53 SID + 0.91 EQx

S7=0.53 D+ 0.53 SID + 0.91 EQy

3. **Long term deflection combination:**

LTD= 1.33 D + 1.33 SID + 1.17 L +1.7 RL

Seismic evaluation for the original model

Figure E.14

Structural elements design for block A

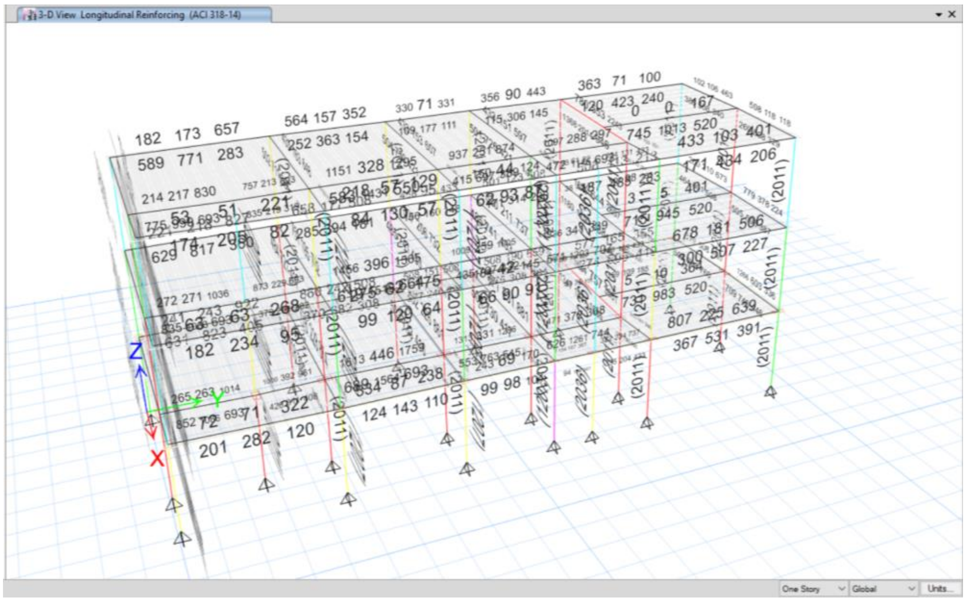


Figure E.15

Structural elements design for block B

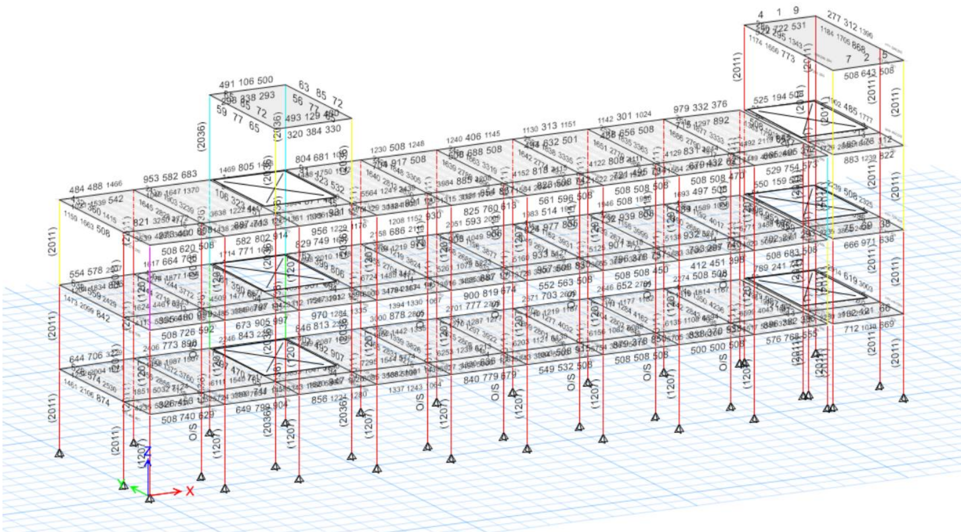


Table E.2

Period calculations of block A

Period from Etabs	2.421	
Ta	0.152746	=0.0466*(3.74^0.9)
Cu	1.41875	
Ta*Cu	0.216709	
Ta*Cu << period		Not OK

* Period check in not mandatory، but give indication to other checks.

Table E.3

Period calculations of block B

Period from Etabs	1.57	
Ta	0.185086	=0.0466*(6.29^0.75)
Cu	1.41875	
Ta*Cu	0.262591	
Ta*Cu<< period		Not OK

*Period check in not mandatory، but give indication to other checks.

Figure E16

Period by Etabs for block A

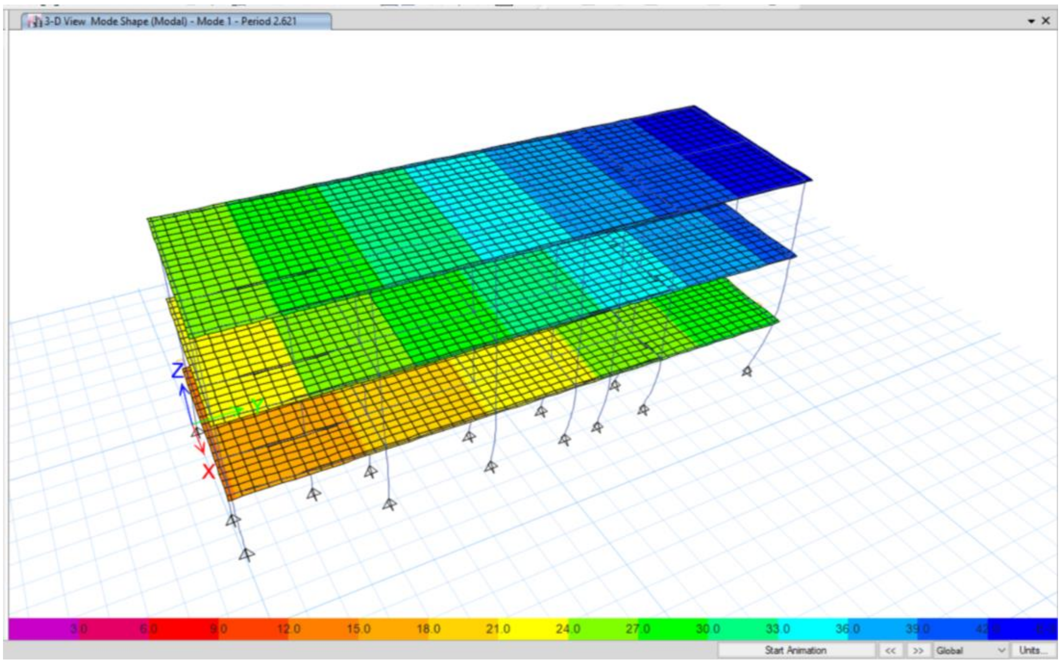


Figure E.17

Period by Etabs for block B

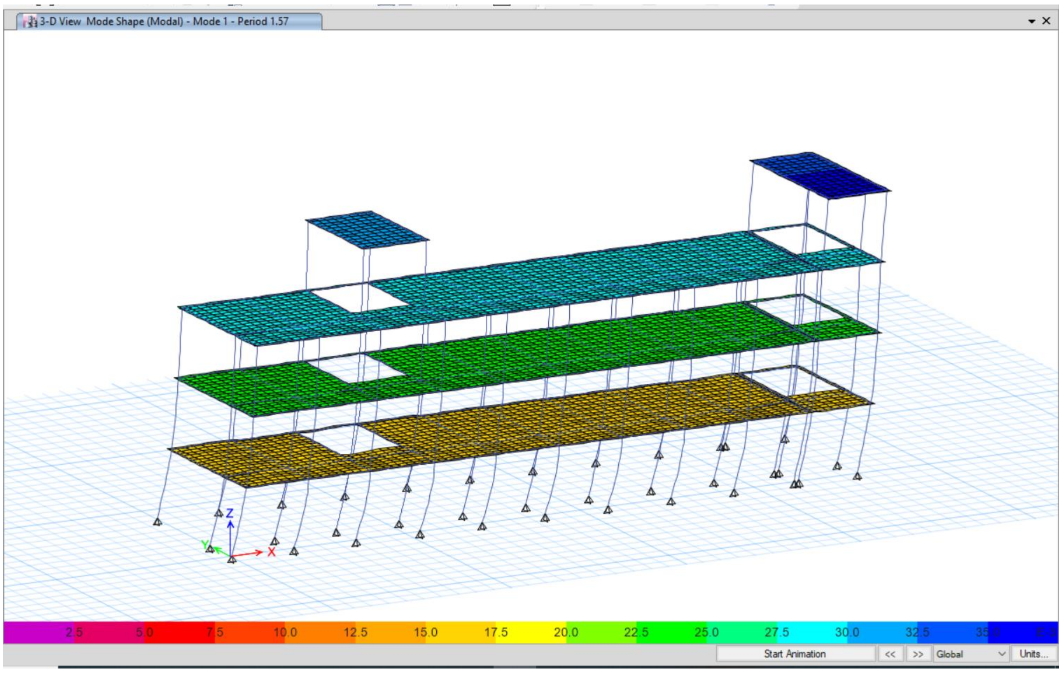


Table E.4

Drift in X-direction of block A

Drift in X-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	3740	5.5	1.25	38.75	170.5	27.236	93.5	SAFE
3	3740	5.5	1.25	32.56	143.264	44.7964	93.5	SAFE
2	3500	5.5	1.25	22.379	98.4676	98.4676	87.5	NOT SAFE
1	0	5.5	1.25	0	0	0	0	SAFE

Table E.5

Drift in Y-direction of block A

Drift in Y-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	3740	5.5	1.25	37.339	164.2916	17.864	93.5	SAFE
3	3740	5.5	1.25	33.279	146.4276	39.2524	93.5	SAFE
2	3500	5.5	1.25	24.358	107.1752	107.1752	87.5	NOT SAFE
1	0	5.5	1.25	0	0	-	0	-

Table E.6

Drift in X- direction of block B

Drift in X-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	2550	5.5	1.25	31.941	140.5404	20.7988	63.75	SAFE
3	3700	5.5	1.25	27.214	119.7416	39.7672	92.5	SAFE
2	3700	5.5	1.25	18.176	79.9744	79.9744	92.5	SAFE
1	3500	5.5	1.25	0	0	0	87.5	SAFE
8	0	5.5	1.25		0	-	0	-

Table E.7

Drift in Y-direction of block B

Drift in Y-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	2550	5.5	1.25	13.039	57.3716	12.1264	63.75	SAFE
3	3700	5.5	1.25	10.283	45.2452	18.062	92.5	SAFE
2	3700	5.5	1.25	6.178	27.1832	27.1832	92.5	SAFE
1	3500	5.5	1.25	0	0	0	87.5	SAFE
8	0	5.5	1.25		0	-	0	-

Table E.8

P-delta check in X direction for block A

In X-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vx (KN)	Ux (mm)	$\Delta_{x\ (mm)}$	ϴx	Check
12	3740	4190.6879	197.4316	38.75	6.19	0.035130773	NO
11	3740	8794.8306	342.0684	32.56	10.181	0.069989575	NO
10	3500	13387.3983	455.629	22.379	22.379	0.18787001	considered
9	0	0	0	0	0	-	-

Table E.9

P-delta check in Y direction for block A

In Y-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vy (KN)	Uy (mm)	$\Delta_{y\ (mm)}$	ϴy	Check
12	3740	4190.6879	134.9384	37.339	4.06	0.033713527	NO
11	3740	8794.8306	240.4304	33.279	8.921	0.087252933	NO
10	3500	13387.3983	322.8259	24.358	24.358	0.288603369	considered

Table E.10

P-delta check in direction for block B

In X-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vx (KN)	Ux (mm)	$\Delta_{x\ (mm)}$	ϴx	Check
12	2550	1128.3354	54.9183	31.941	4.727	0.038086104	NO
11	3740	7442.5009	278.9483	27.214	9.038	0.064475677	NO
10	3740	14299.8319	469.4023	18.176	18.176	0.14805137	considered
9	3500	21119.7629	603.3166	0	0	0	NO
8	0				0	-	-

Table E.11

P-delta check in Y direction for block B

In Y-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vy (KN)	Uy (mm)	$\Delta_{y\ (mm)}$	ϴy	Check
12	2550	1128.3354	112.4531	0	13.039	0.05130632	NO
11	3740	7442.5009	654.5963	13.039	2.756	0.00837824	NO
10	3740	14299.8319	1022.6665	10.283	4.105	0.01534752	NO
9	3500	21119.7629	1234.5447	6.178	6.178	0.03019688	NO
8	0	0	0	0	0	-	-

Seismic rehabilitation for the case study building

Modeling

Figure E.18

Modified model of block A

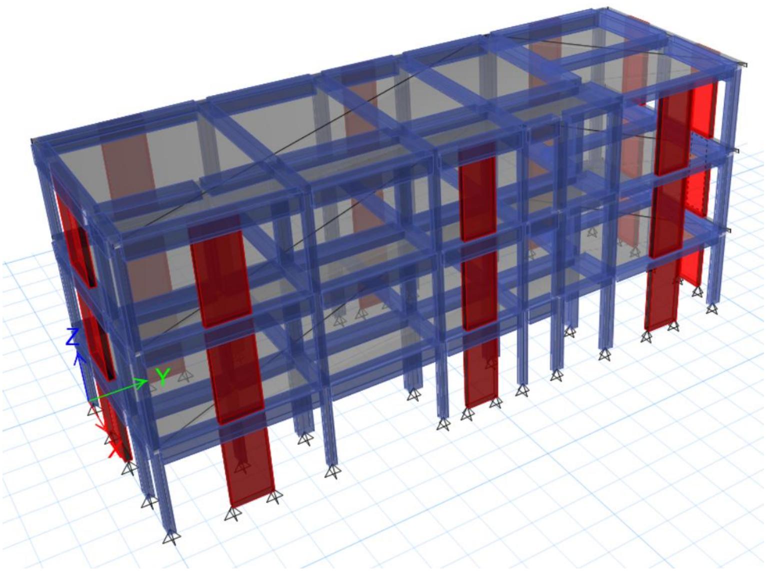
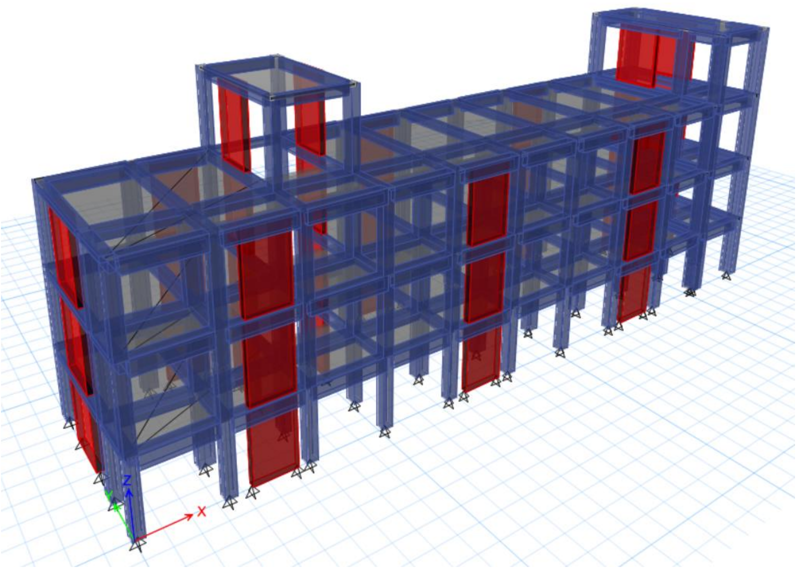


Figure E.19

Modified model of block B



Structural Elements Design For Modified Structure

Figure E.20

Block A design

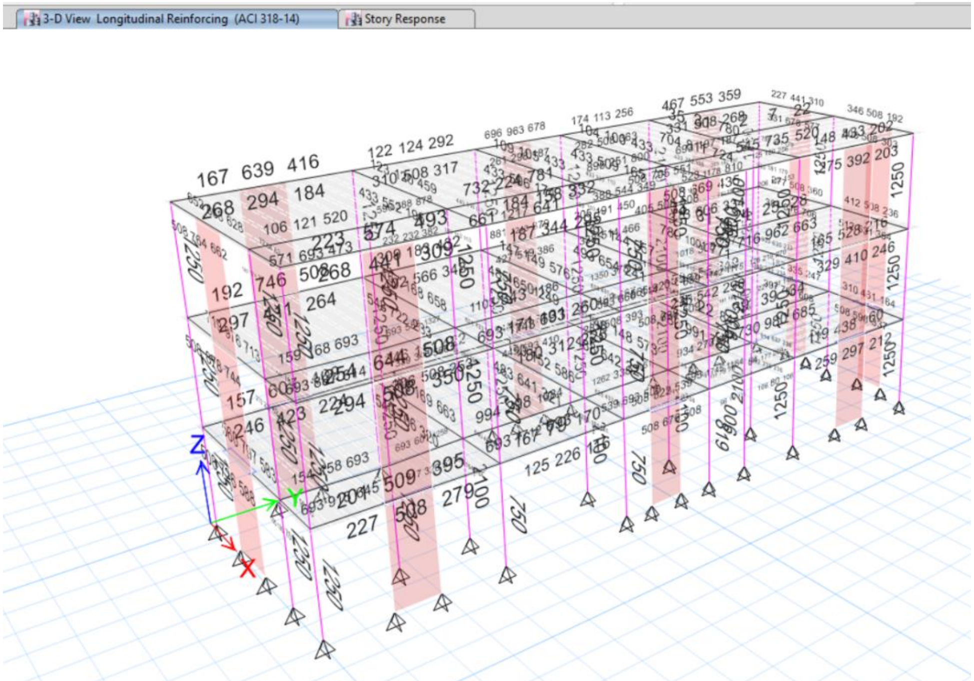
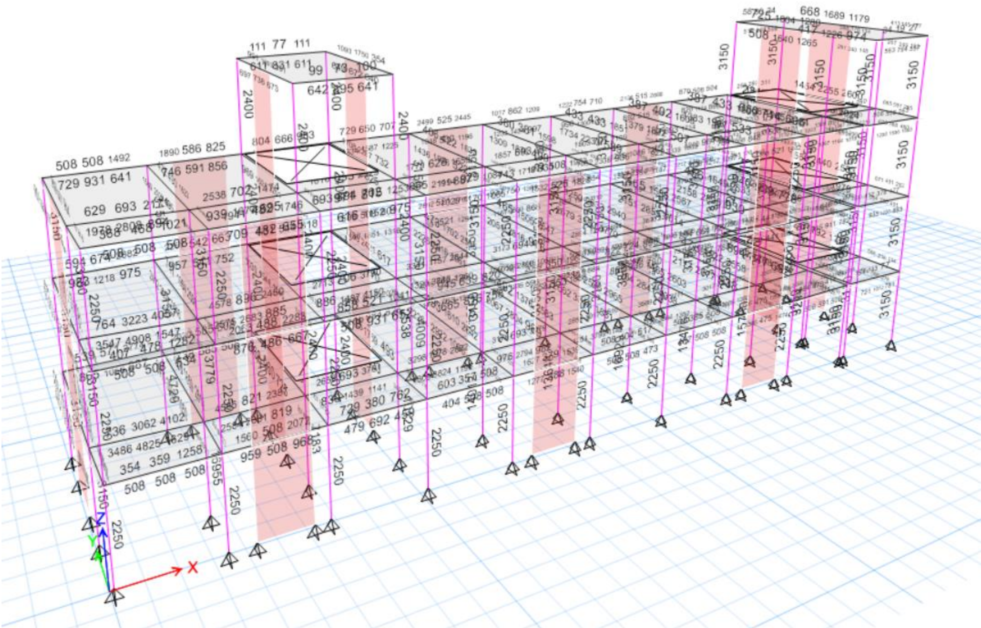


Figure E.21

Block B design



Check of fundamental period of modified structure

Figure E.22

Block A period

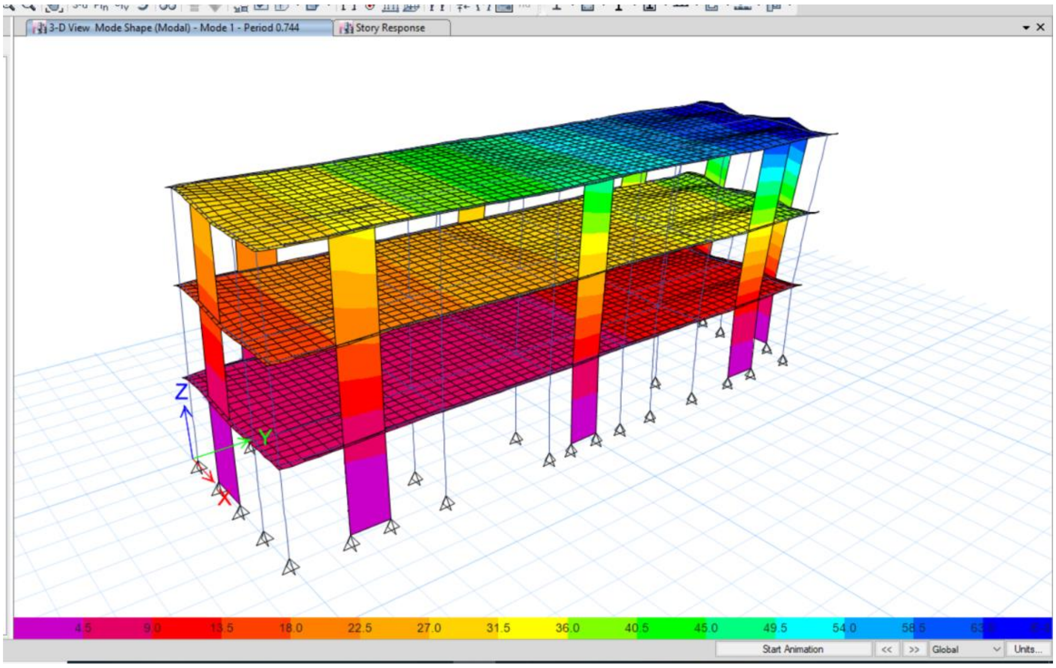


Table E.12

Period check for block A

Period from Etabs	0.744	
Ta	0.131242	=0.0488*(3.74^0.75)
Cu	1.41875	
Ta Cu	0.1862	
TaCu << period		Not OK but close

* Period check in not mandatory، but gives indication to other checks.

Figure E.23

Block B period

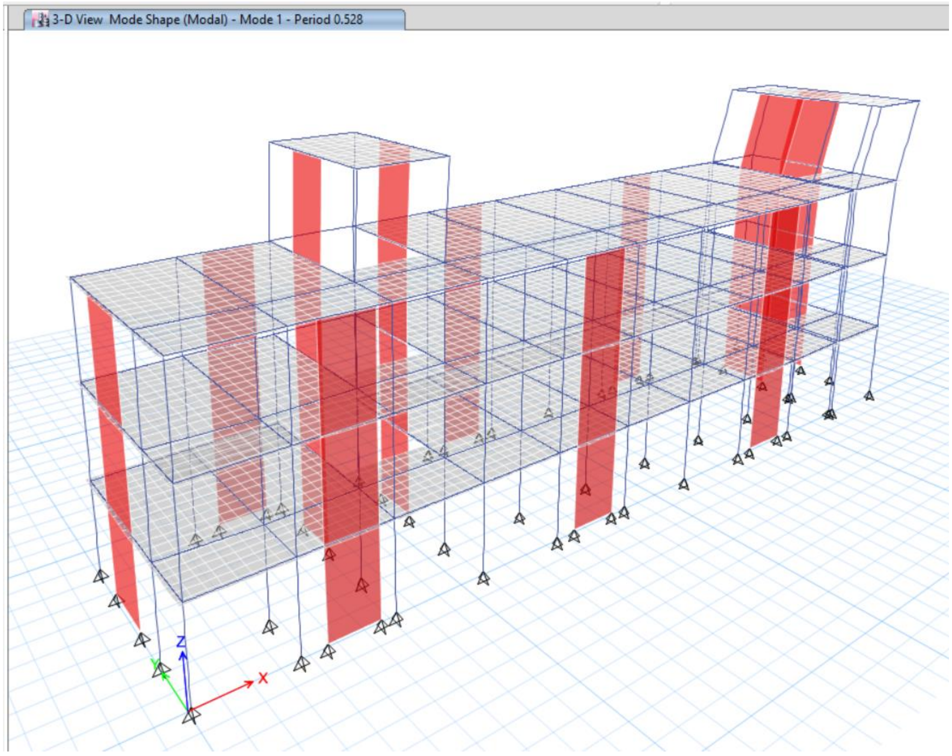


Table E.13

Period check for block B

Period from Etabs	0.٥٢٨	
Ta	0.193824	=0.0488*(٦.29^0.75)
Cu	1.41875	
Ta Cu	0.275	
TaCu << period		Not OK but close

* Period check in not mandatory، but give indication to other checks.

Story drift determination

Table E.14

Drift in X-direction of block A

Drift in X-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	3740	5	1.25	14.32	57.28	24.236	93.5	SAFE
3	3740	5	1.25	8.261	33.044	22.72	93.5	SAFE
2	3500	5	1.25	2.581	10.324	10.324	87.5	SAFE
1	0	5	1.25	0	0	0	0	SAFE

Table E.15

Drift in Y-direction of block A

Drift in Y-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	3740	5	1.25	7.221	28.884	11.704	93.5	SAFE
3	3740	5	1.25	4.295	17.18	11.724	93.5	SAFE
2	3500	5	1.25	1.364	5.456	5.456	87.5	SAFE
1	0	5	1.25	0	0	-	0	-

Table E.16

Drift check of block B in X-direction:

Drift in X-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	2550	5	1.25	3.765	15.06	6.144	63.75	SAFE
3	3700	5	1.25	2.229	8.916	5.94	92.5	SAFE
2	3700	5	1.25	0.744	2.976	2.976	92.5	SAFE
1	3500	5	1.25	0	0	-	87.5	-

Table E.17

Drift check of block B in Y-direction:

Drift in Y-direction								
Floor Number	H floor (mm)	Cd	Ie	δx elastic (mm)	δx inelastic (mm)	Inelastic drift (mm)	Allowable inelastic drift (mm)	Result
4	2550	5	1.25	7.158	28.632	11.544	63.75	SAFE
3	3700	5	1.25	4.272	17.088	11.308	92.5	SAFE
2	3700	5	1.25	1.445	5.78	5.78	92.5	SAFE
1	3500	5	1.25	0	0	-	87.5	-

P-Delta effects:

Table E.18

P-delta check in X-direction of block A

In X-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vx (KN)	Ux (mm)	Δ_x (mm)	ϴx	Check
12	3740	3644.9788	-260.5952	14.32	6.059	-0.022659898	NO
11	3740	8606.377	-525.0786	8.261	5.68	-0.024892744	NO
10	3500	13558.0427	-642.6508	2.581	2.581	-0.015557575	NO

Table E.19

P-delta check in Y-direction of block A

In Y-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vy (KN)	Uy (mm)	Δ_y (mm)	ϴy	Check
12	3740	3644.9788	-320.3597	7.221	2.926	-0.008901431	NO
11	3740	8606.377	-662.3442	4.295	2.931	-0.01018312	NO
10	3500	13558.0427	-828.3295	1.364	1.364	-0.006378818	NO

Table E.20

P-delta check of block B in X-direction

In X-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vx (KN)	Ux (mm)	Δ_x (mm)	ϴx	Check
12	2550	1321.8654	-109.4583	3.765	1.536	-0.007274273	NO
11	3700	7379.0351	-593.6717	2.229	1.485	-0.004988592	NO
10	3700	15099.4849	-1073.2066	0.744	0.744	-0.002829111	NO
9	3500	22690.7307	-1305.2087	0	0	0	NO

Table E.21

P-delta check of block B in Y-direction

In Y-direction							
Floor Number	H floor (mm)	P gravity load combination (KN)	Vy (KN)	Uy (mm)	Δ_y (mm)	ϴy	Check
12	2550	1321.8654	-109.4583	7.158	2.886	-0.013667676	NO
11	3700	7379.0351	-593.6717	4.272	2.827	-0.0094968	NO
10	3700	15099.4849	-1073.2066	1.445	1.445	-0.005494712	NO
9	3500	22690.7307	-1305.2087	0	0	0	NO

Seismic rehabilitation for the case study building

Figure E.24

Columns and shear walls distribution:

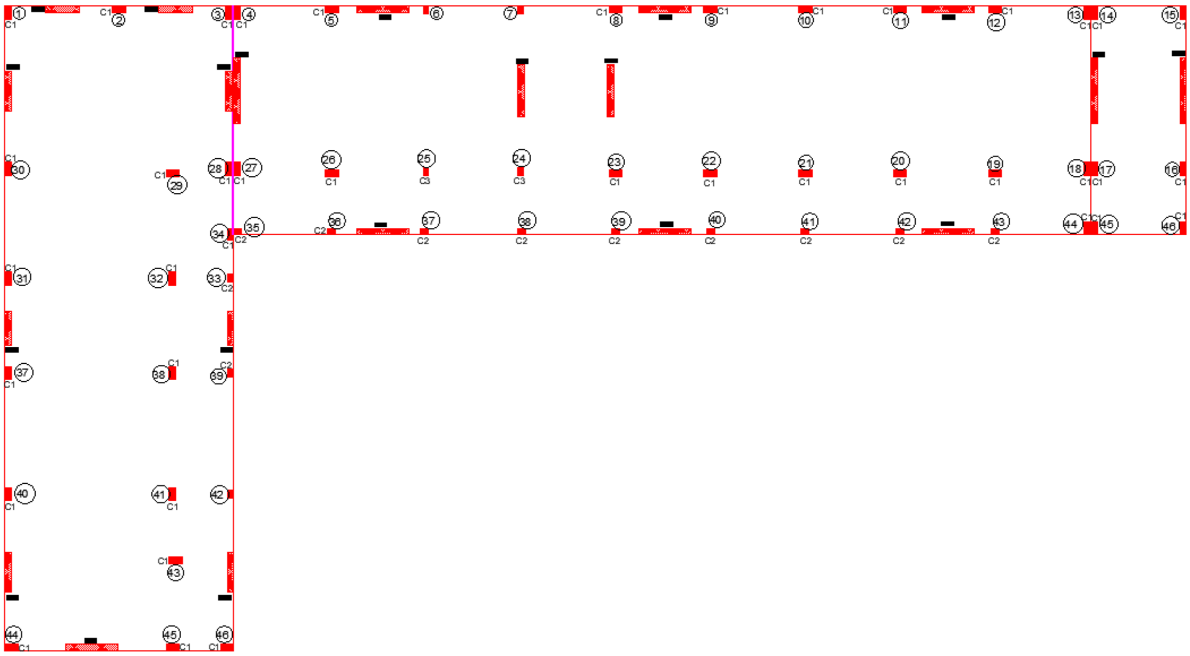


Table E.22

Modified column dimensions

Column ID	Real dimension	Modified dimension
C1	25*50	45*70
C2	25*30	45*50
C3	20*30	40*50

Table E.23

Shear wall dimension

SW No.	Dimension (cm)
SW1	25*130
SW2	25*150
SW3	25*200
SW4	25*250

Figure E.25

Details of RC jacketing column

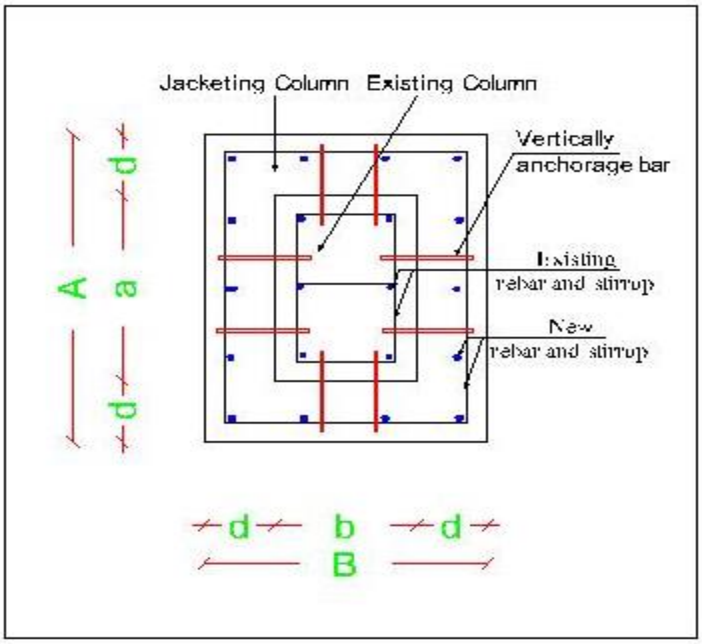
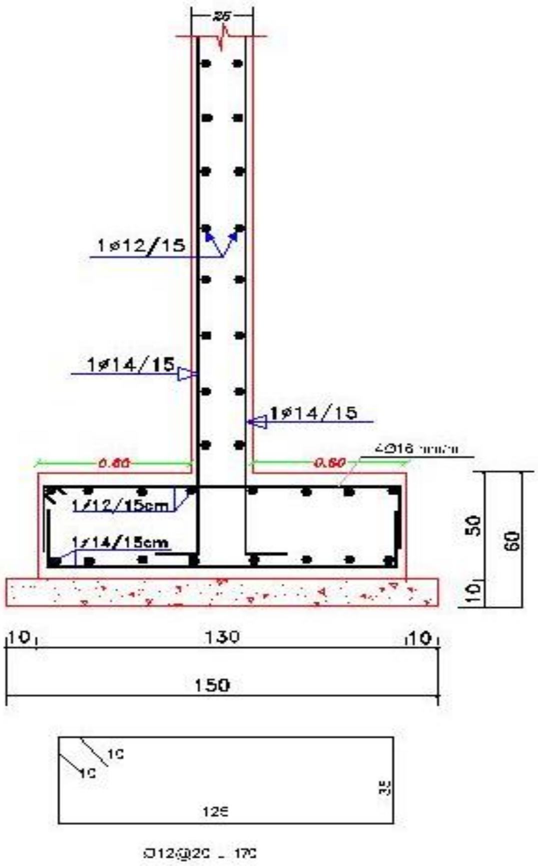


Figure E.26

Typical section in the shear wall



Appendix F

Results and Conclusions

Table F.1

Expected damage level based on RVS score

RVS score	Damage Potential
S≤0.3	High probability of Grade 5 damage; very high probability of Grade 4 damage.
0.3<S≤0.7	High probability of Grade 4 damage; very high probability of Grade 3 damage.
0.7<S≤2.0	High probability of Grade 3 damage; very high probability of Grade 2 damage.
2.0<S≤2.5	High probability of Grade 2 damage; very high probability of Grade 1 damage.
S>2.5	Probability of Grade 1 damage.

* Source: FEMA-154, 2002, (Clemente et al., 2020)

Table F.2

Description of the damage grade for RC-buildings according to EMS-98

Damage Grade	Description of damages
D1	**Negligible to slight damage: no structural damage, slight non-structural damage.** Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and in-fills.
D2	**Moderate damage: slight structural damage, moderate non-structural damage.** Cracks in columns and beams of frames and in structural walls. Falling mortar from the joints of wall panels.
D3	**Substantial to heavy damage: moderate structural damage, heavy non-structural damage.** Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Large cracks in partition and infill walls, failure of individual infill panels.
D4	**Very heavy damage: heavy structural damage, very heavy non-structural damage.** Large cracks in structural elements with compression failure of concrete and fracture of rebars; tilting of columns. Collapse of a few columns or of a single upper floor.
D5	**Destruction: very heavy structural damage.** Collapse of ground floor or parts (e. g. wings) of buildings.

* Source: EMS-98,(Karbassi & Lestuzzi, 2014)

Resulted Maps Generated By GIS:

Figure F.1

Resulted DG's of Buildings in the Study Area

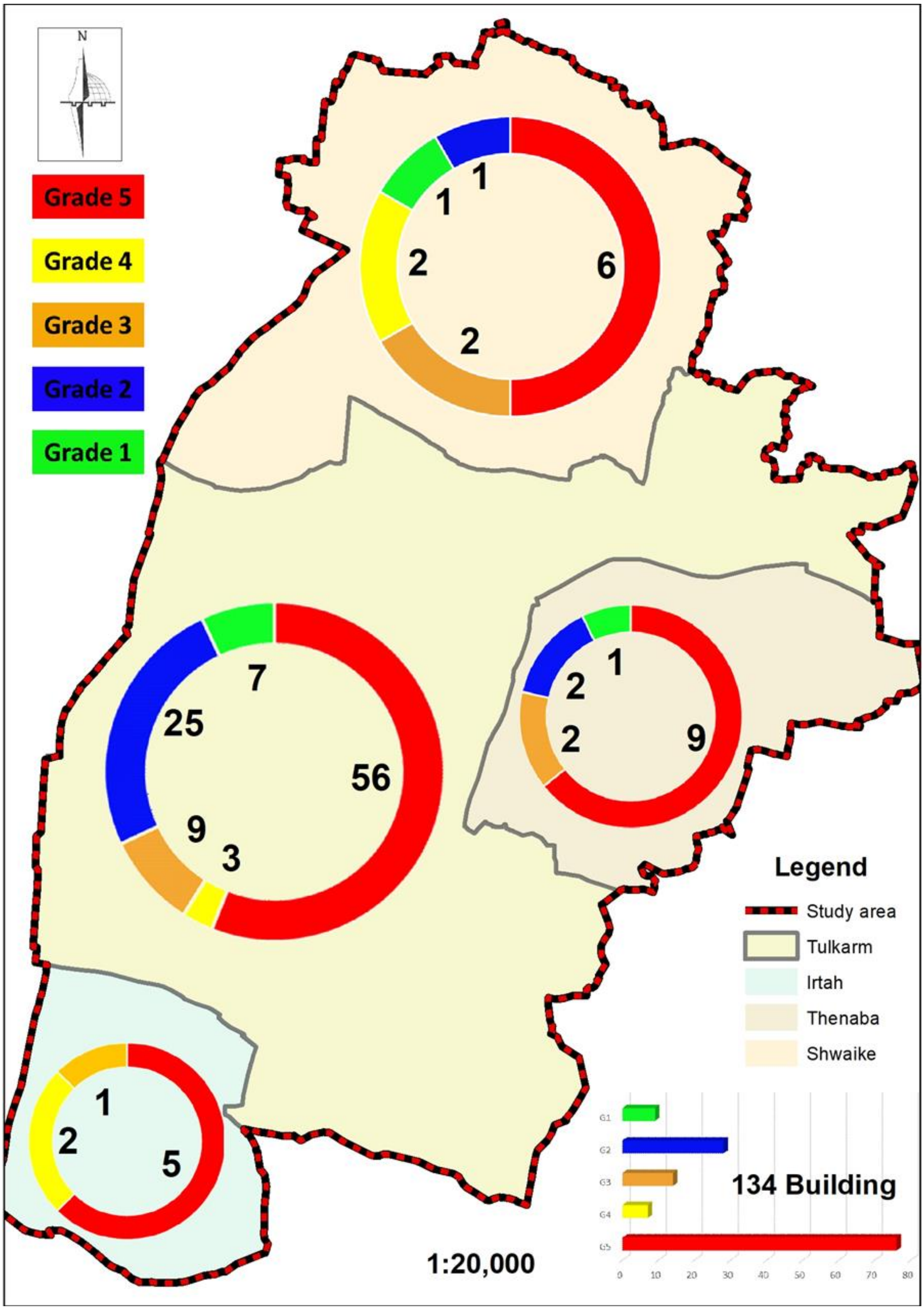


Figure F.2

Risk map of Essential Buildings in Tulkarm Downtown

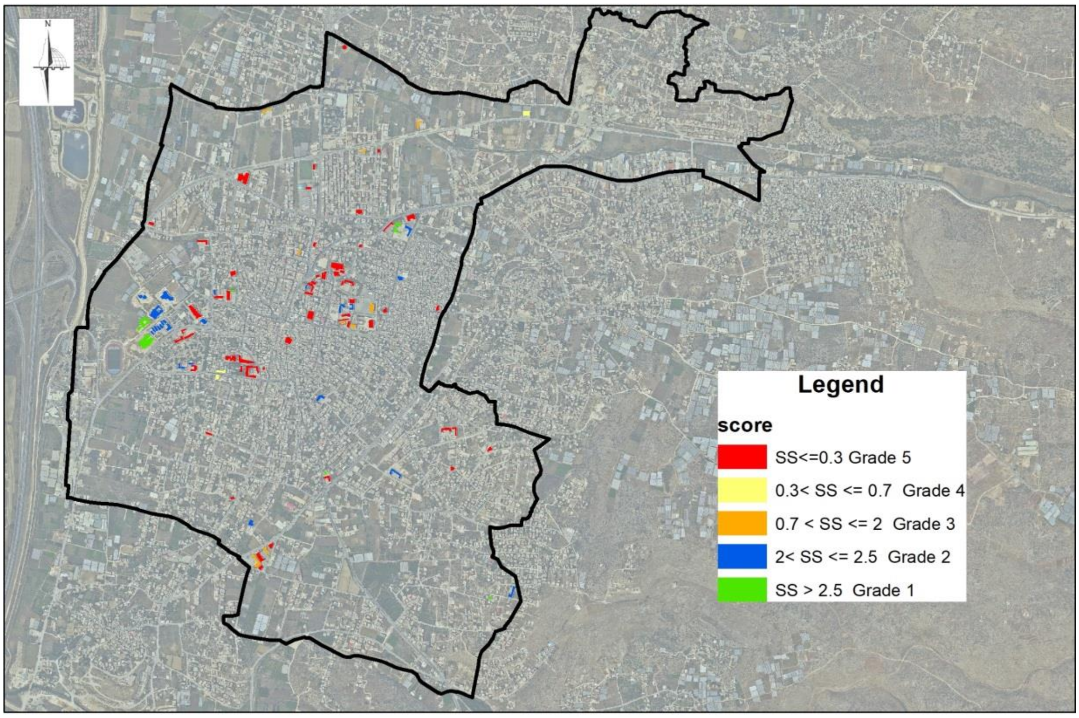


Figure F.3

Risk map of Essential Buildings in Thenabah

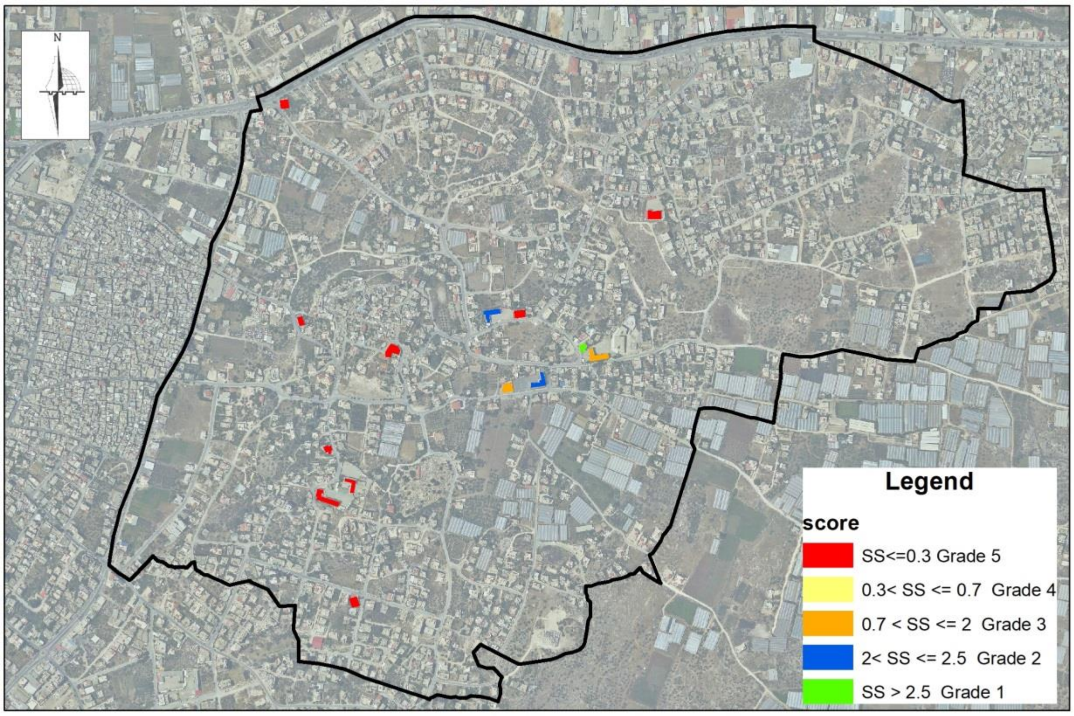


Figure F.4

Risk map of Essential Buildings in Irtah

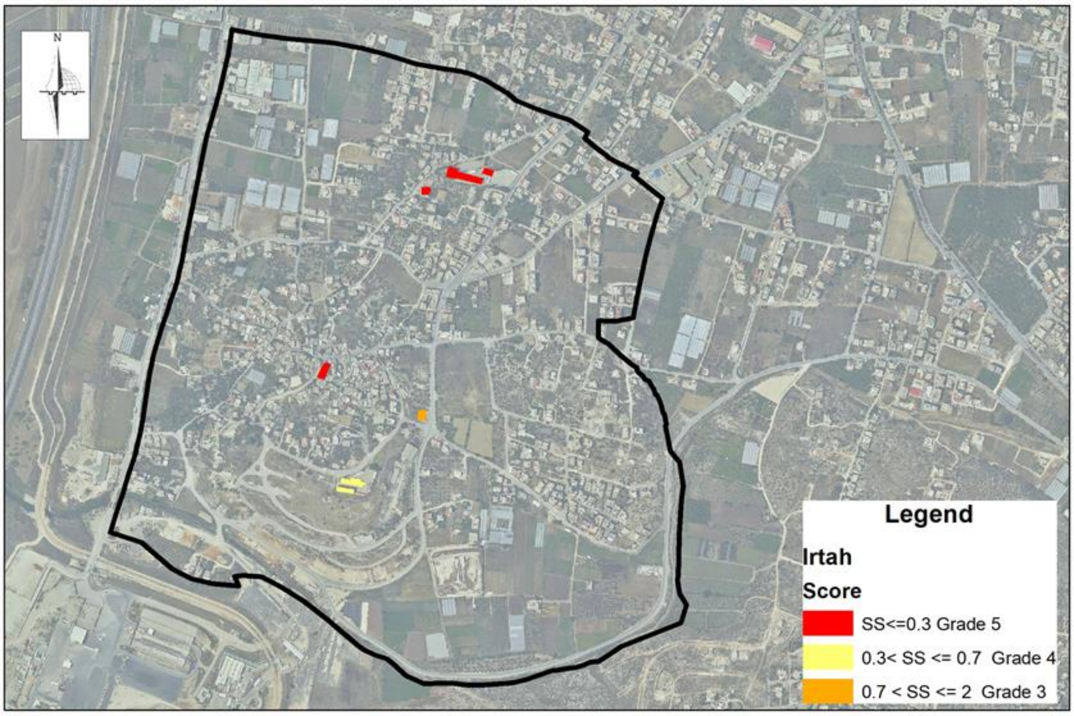
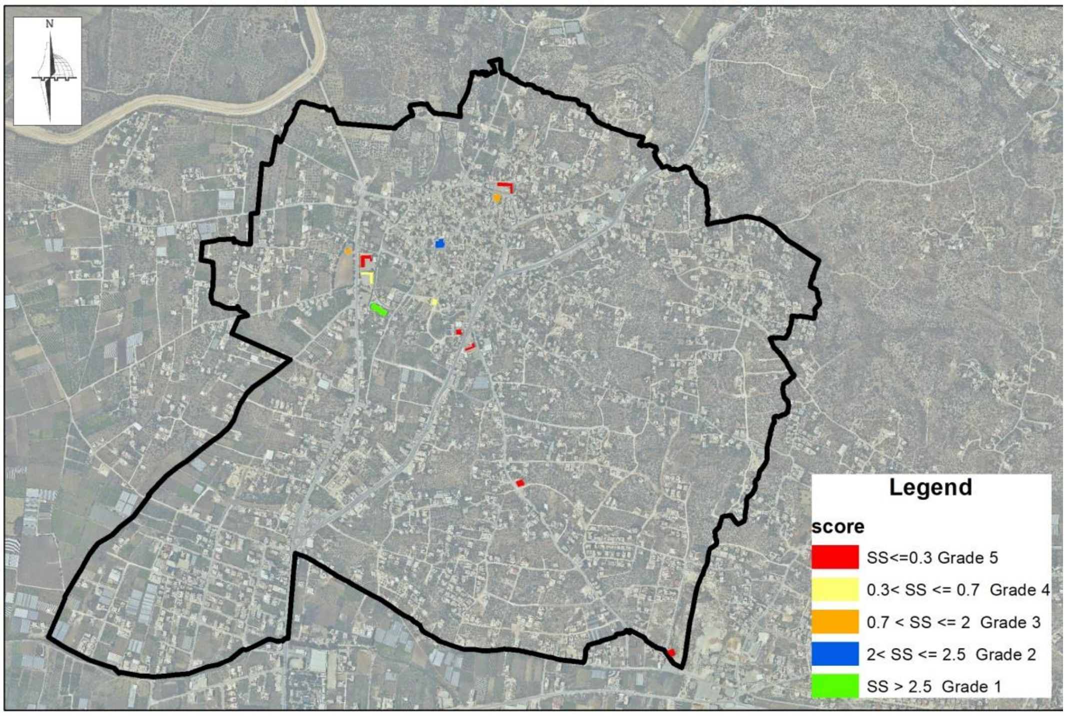


Figure F.5

Risk map of Essential Buildings in Shwaike



Results Analysis:

Figure F.6

Irregularities Distribution in Different Types of Buildings

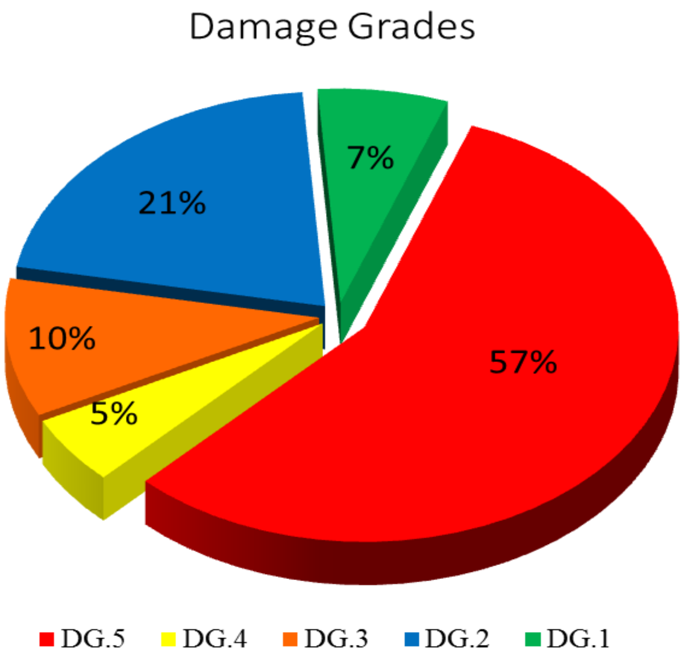


Figure F.7

Irregularities Distribution in Different Types of Buildings

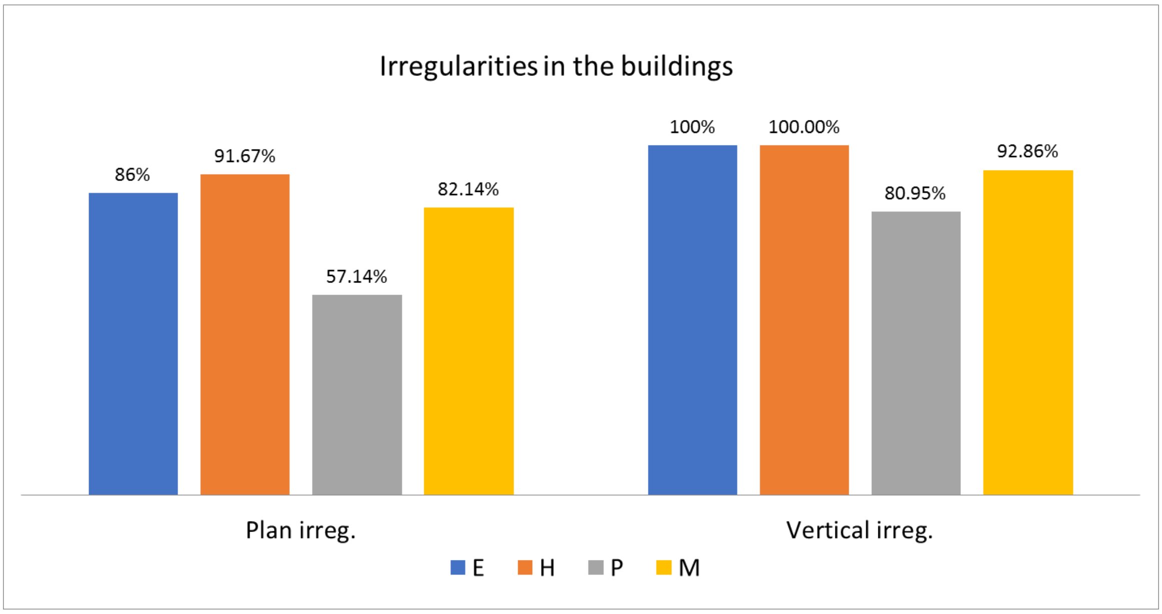


Figure F.8

Vertical Irregularity Distribution

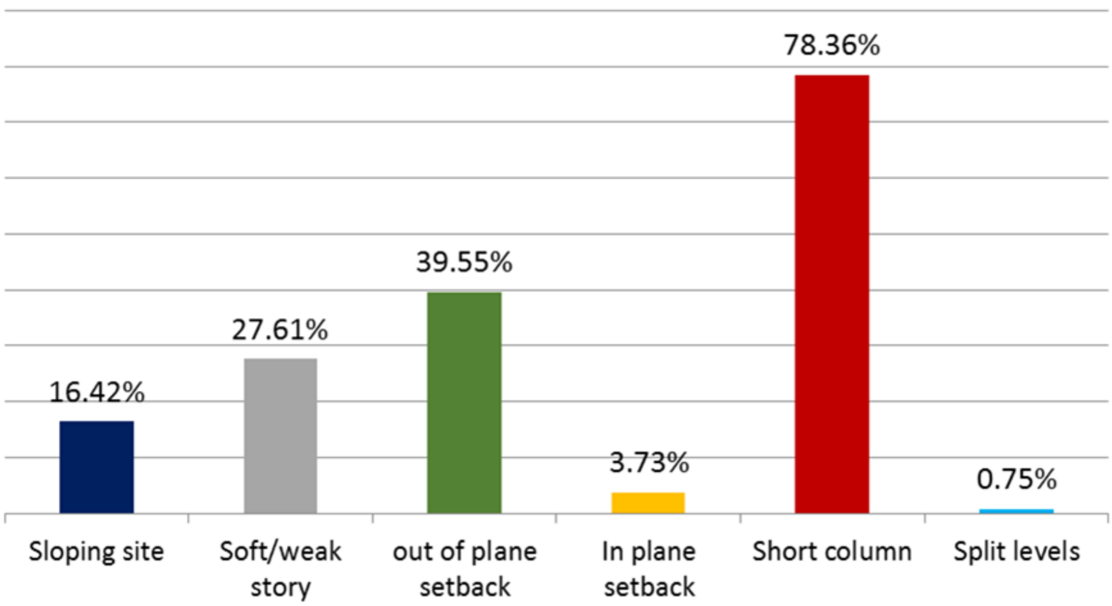


Figure F.9

Plan Irregularity Distribution

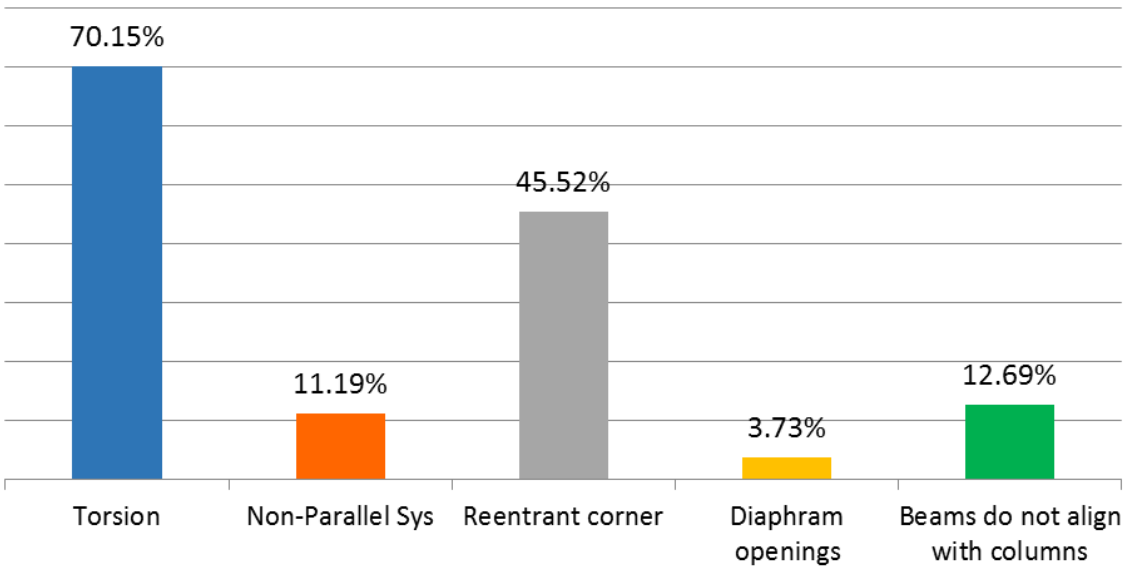
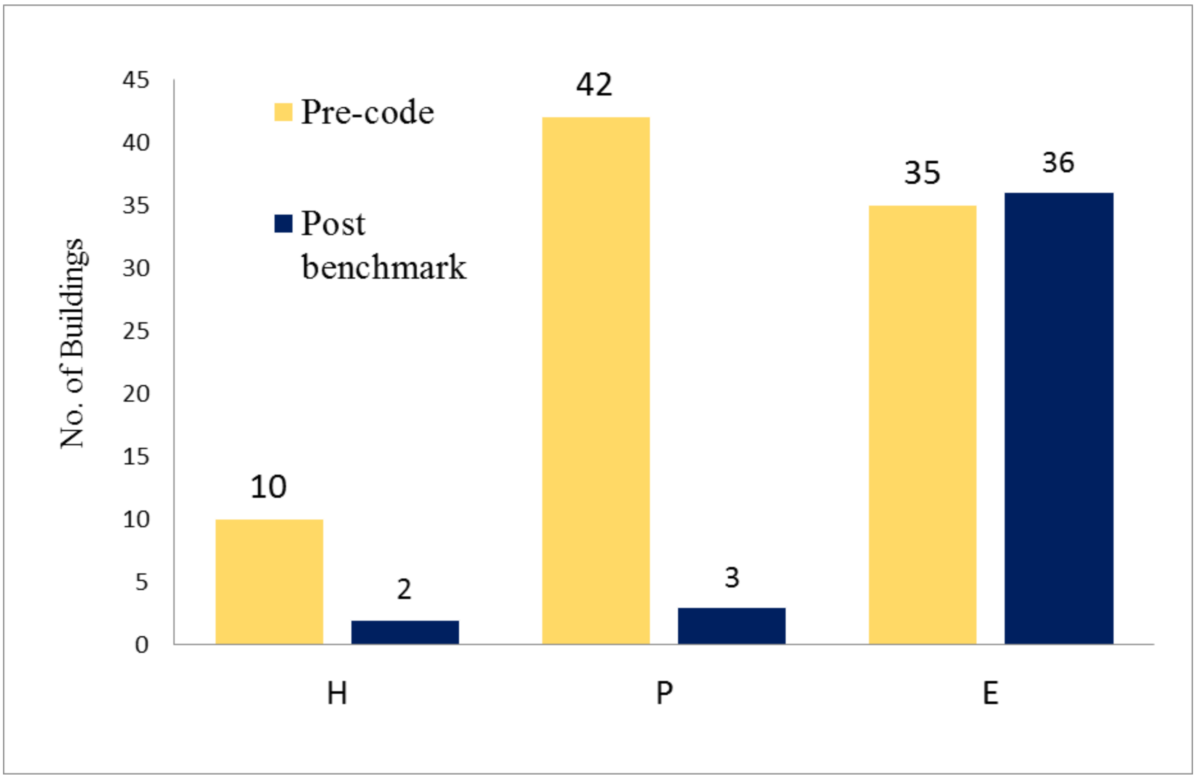


Figure F.10

Distribution of Buildings according Code and Benchmark year



جـامعــة النجاح الوطنية

كليــة الدراســات العليــا

التقييم الزلزالي السريع واستراتيجيات التدعيم الانشائي:

حالة دراسية للمباني الهامة في مدينة طولكرم

إعداد

إسراء خالد أحمد أبو هولة

إشراف

أ. د. جلال نمر صالح الدبيك

د. منذر دويكات

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في إدارة مخاطر الكوارث، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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التقييم الزلزالي السريع واستراتيجيات التدعيم الانشائي: حالة دراسية للمباني الهامة في مدينة طولكرم

إعداد

إسراء خالد أحمد أبو هولة

إشراف

أ. د. جلال نمر صالح الدبيك

د. منذر دويكات

الملخص

تأثرت الأراضي الفلسطينية في الآونة الاخيرة بسلسلة هزات أرضية ضربت المناطق المجاورة. ولحسن الحظ أنها لم تسفر عن أية أضرار أو خسائر بشرية أو اقتصادية، إلّا انها قد أثارت مخاوف جدية حول عدم الجهوزية الكافية لمواجهة زلازل أكثر خطورة. تتناول هذه الدراسة مدى الحاجة الملحة لتفعيل برامج شاملة لإدارة مخاطر الزلازل، وتسلط الضوء على ضعف المباني الأساسية كالمستشفيات والمدارس أمام هذا الخطر وأهمية الحفاظ على استمرارية خدماتها بعد الزلازل. لحماية مثل هذه المرافق الحساسة من الأحداث الزلزالية يتعين تقييم استعدادها لمواجهة الزلازل واتخاذ التدابير اللازمة لتحسين استجابتها عند الضرورة. أجري البحث في مدينة طولكرم في الضفة الغربية وشمل تقييم ١٣٤ مبنى خرسانياً باستخدام اجراءات التقييم البصري السريع استنادا لمعايير FEMA P-154 وقد اعتمد على عوامل متعددة بما في ذلك نظام المقاومة الإنشائي وعمر المبنى وارتفاعه وعدم التناسق الهيكلي أفقيا وعموديا ونوع التربة. وقد أظهرت نتائج التقييم مؤشرات مقلقة، حيث أكثر من ثلثي المباني أخفقت في إثبات قدرتها الزلزالية وانها بحاجة الى تقييم مفصل واكثر دقة من اجل تحسين كفاءتها في المستقبل. وقد لوحظ أن حوالي ٦٠% من المباني تم تصنيفها تحت درجات الضرر ٤ و٥ وفقًا لمقياس EMS-98. ١٠ من

أصل ١٢ مرفقاً صحياً وأكثر من نصف المرافق التعليمية وغالبية المباني العامة والمساجد ستتعرض إلى أضرار هيكلية وغير هيكلية كبيرة في حال وقوع زلازل مستقبلية كبيرة. وأكدت النتائج أن عمر المبنى كان له الأثر الأكبر في رفع قابلية إصابة المباني لافتقارها للتصميم الإنشائي السليم، وعدم توفر الرقابة الكافية خلال التنفيذ. إضافةً أن غالبية المباني أظهرت عدم الانتظام في التصميم أفقيا أو عموديا، مما جعلها أكثر عرضة للتأثر بالقوى الزلزالية. توصي الدراسة بضرورة إجراء تقييم شامل لأداء المباني الأساسية وإعداد خرائط المخاطر لمدينة طولكرم وتعديل خطط الاستجابة الطارئة الحالية. وتتضمن التوصيات العامة زيادة الوعي وفرض قوانين صارمة للامتثال بالتصميم الزلزالي بالإضافة إلى الاستثمار في جهود التخفيف من مخاطر الزلازل.

الكلمات المفتاحية: الأداء الزلزالي، التقييم البصري السريع، قابلية الإصابة، درجات الضرر، الحد من المخاطر.