An-Najah National University

Faculty of Graduate Studies

Investigating the Reasons Behind the Collapse of Building in West Bank Under Construction

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This Thesis is Submitted in Partial Fulfilment of the Requirements for the Degree of the Master of Engineering Management, Faculty of Graduated Studies, An-Najah National University, Nablus, Palestine.

2021

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Dedication

Thanks to Almighty Allah my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding for granting me the knowledge and wisdom to achieve this project. I am completely grateful for Allah for providing me with strength throughout this program and whom I dedicate all my actions and achievements.

I also dedicate this work to my wife; Duha Hijab who has encouraged me all the way, and her encouragement has made it possible to achieve this accomplishment. This work is also dictated to my son Khalil whose birthday brought joy and cheerful to our house and motivates me to accomplish this work.

To my family members who supported me in every way possible during my studies. I could not achieve this without you. So,

Thank you all. My love for you all can never be quantified. God bless you.

Acknowledgment

First and for most I am extremely grateful to Almighty Allah for what I am and for everything I have, for all the support granted to me.

The recognition of this work was only possible due to several people's collaboration, to which I desire to express my gratitude.

I wish to express my most sincere gratitude and appreciation to my supervisor: Dr. Riyad Awad for his professional guidance, invaluable advices, unlimited support, and continuous encouragement to make this research possible.

My appreciation is also extended to An Najah National University for giving me the opportunity to carry out this study. Furthermore, great thanks are also to my colleagues and lecturers in the Engineering Management Department for their continual encouragement and support.

To all my friends, thank you for your understanding and encouragement, special thanks to my friends, many thanks for your support throughout my study period. Your friendship makes my life a wonderful experience.

Finally, A special feeling of gratitude and most appreciations are to my loving parents, brothers, and my sister. Thanks for your unconditional love, guidance, encouragement, support, and patience that give me the power all life.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان :

Investigating the Reasons Behind the Collapse of Building in West Bank Under Construction

أقر بأنّ ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص ، باستثناء ما تمّت الإشارة إليه حيثما ورد ، و أنّ هذه الرسالة ككل ، أو أي جزء لم يُقدّم لنيل أي درجة أو لقب علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work and has not been submitted elsewhere for any other degree or qualification.

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Date: **التاريخ: 28 / 1 / 2021**

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Abstract

Construction industry is crucial for all countries and humans. Buildings provide one of the basic needs for humans. Recently, several building collapses occurred in West Bank, and some of these were during construction. A thorough study for the collapse reasons is carried out. A convergent mixed method is implemented to determine the main factors influencing building collapses during construction. A well-prepared questionnaire is distributed to engineers and professionals of the construction industry. A statistical analysis is implemented for the collected responses. Study cases of failures are analyzed through interviews and consultations with professionals in the field. Two specific cases are analyzed using engineering codes and programs. The results showed that the construction failures are of a considerable concern in the West Bank, the most influential reasons for the collapse of buildings in West Bank that are under construction are Soil type where building is constructed, Improper support during construction, and Execution errors and non-conformance with schedules. The study recommends applying periodical investigation for plans and construction works through the municipalities and Palestinian Engineering Association – Jerusalem Center before and during the implementation of works. The study suggests using DMAIC model as a proper quality management approach to mitigate the risks of collapsed buildings.

Chapter 1

Introduction

Motivation

Building construction is one of the most important projects that accomplished by humans. Having a comfortable place to live is one of the crucial requirements for people worldwide. As a result, buildings are required to be built with great care and high quality.

Construction industry is hazardous by nature. It comprises a wide range of activities. These tasks involve Building, alteration, and repair [1-4]. Before starting the construction, an adequate design should be prepared to achieve the intended purpose of the construction. A qualified team implements the design and builds the construction. Alteration and repair follow the use of the construction to handle any unexpected circumstances that appear during or after usage.

Many failures of construction occurred over the past. These collapses occurred worldwide and locally here in Palestine. Many accidents occurred in West Bank recently. These failures occurred during construction. For instance, a year ago a building collapsed in Nablus city and caused many injuries to the workers. Construction failures by nature are harmful and needs to be avoided.

It is important to understand the current construction industry in Palestine to address the upcoming challenges in the region. Construction in

Palestine is mostly reinforced concrete structures. The construction process starts by hiring an engineering office to attain the building drawings. The drawings are then certified by the Palestinian Engineering Association – Jerusalem Center and the municipality or local governorate representative in the region of construction. The owner of the building hires then a contractor (or simply builders) to build his/her building. While this is the official way for construction, many buildings were constructed without engineering plans or certification by related agencies. Also, builders in many cases do not adhere to the certified engineering drawings.

Construction industry in Palestine needs to adapt with the challenges in the region. State of Palestine, as part of the Middle East, have been and will be subjected to many serious climate changes. These challenges include; increasing in temperature and sea level rise; changing in snow fall amounts; reduction in the annual rainfall; and adverse hydro-meteorological conditions such as heat waves, droughts, floods, storms. These changes may impact many social and economic aspects of the construction industry [5].

Construction failures have various negative impacts. The reputation of the responsible construction company is lost when a collapse occurs. The loss in the assets magnifies the negative impacts of such failures. The impact of the failures increases if it includes the loss of human lives.

Construction failures are not specific to a certain region in West Bank. Collapses occurred in many governorates including Nablus, Hebron, Jenin, Bethlehem and Tulkarm governorates. The incidents occur while construction is still in progress.

This study focuses on the reasons that lead to the collapse of buildings in Palestine. The study provides solutions and advice to the construction industry in Palestine. The knowledge attained from this research shall improve the quality of construction process and reduce the frequency of occurrence of such primitive failures.

Problem Statement

Some buildings in the West Bank do not follow professional procedures or consultation with construction companies. These buildings are built with no management and quality control from site engineers. Investors of these building do not believe in engineers nor follow their advice. These factors affected the quality of such buildings under construction and the future of construction industry in Palestine. Buildings of this character are more prone to failures than those where professional and engineering consultation is provided.

Reason of failures in Palestine could be initially related to several factors. The complexity of constructions increased. Buildings confront higher loads that were not considered in the past. Citizens save by skipping the design stage and hence lose the possibility of anticipating any issue that affects their buildings beforehand. They do not conduct soil investigation nor look to topographic or geologic formation of the land.

Failures due to unexpected extreme conditions occurred recently in West Bank. Several steel structures were affected by the recent extreme snowfall in 2003. Examples of this case were the failures happened are in Jamaeen stone cutting plants: Geneva Company plant, and the Italian company plant.

Increase in building failures is evident in the last few years in Palestine. These failures caused human and economic losses. Adverse effects were manifested in many sectors related to the construction industry.

The increase in failures frequency in the West Bank in the last decade is concerning. The reasons behind these failures should be noted and understood. The remedies of such failures start by knowing the reason/s behind their occurrence. Currently, there are no records of the reasons behind the collapse of buildings in the West Bank.

This research studies the reasons behind the collapse of some construction buildings in West Bank. This research helps in mitigating the negative effects of failures in buildings by introducing causes for risks during construction. In addition, the study focuses on practical implementation of these solutions in Palestine.

Research statement

Due to the increase of the building failures in West Bank, an objective study is essential to address the reasons for failures and the possible mitigation procedures. The analysis of the previous failures in West Bank casts light on the common reasons for failures. Avoiding the failures could be achieved simply by handling the common reasons of failures. The frequency of failures should decrease immensely by simply dealing with the common failure reasons.

The study assists in improving the decision of the best quality control management strategies and practices in minimizing and mitigating the negative consequences resulting from possible failures in buildings. Therefore, this research answers the following two important questions:

1- What are the main reasons for the collapse of the buildings under construction in the West Bank?

2- Are the results site specific or do the reasons of failures differ based on location?

Research Objectives

The main objectives of this research are:

1. To propose a quality management approach to mitigate hazards for the risks of collapse of buildings.
2. To investigate the causes of failures in buildings.

Chapter 2

Literature Review

General background of Construction Industry

A universal definition of the construction industry might not exit. To properly define the construction industry, it is necessary to look at what exactly constitutes it. In this thesis, construction industry is a heterogeneous process composed of complexity and non-transparency in addition to flexibility and dynamic nature. This is because it has multiple activities, agent's communications natures, documentation size, measuring parameters, and legislation. This industry is characterized by being temporally and unique at product level [6].

The construction Industry includes several construction operations. Some of these operations are the on-site assembly and erection of prefabricated buildings, roads, railroads, aerodromes, irrigation projects, harbor or river works, gas, dams, bridges, tunnels, sewerage, or storm water drains or mains, electricity or other transmission lines or towers, pipelines, oil refineries or other specified civil engineering projects. In general, units mainly engaged in the repair of buildings or other structures are also included as are those engaged in the alteration or renovation of buildings, preparation of mine sites, demolition, or excavation.

Construction has been an aspect of life since the beginning of human existence. The first buildings were huts and shelters constructed by hands or with simple tools. As cities grew during the Bronze Age, a class of professional craftsmen like bricklayers and carpenters appeared. Occasionally, slaves were used for construction work. In the 19th century, steam-powered machinery appeared, and later diesel and electric powered vehicles such as cranes, excavators and bulldozers were used in the construction industry. Traditional construction might be considered as having properly, commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia when humans started to abandon a nomadic existence. This transition leads to the construction of shelters. The construction of Pyramids in Egypt (2700-2500 BC) might be considered the first building practice of a large structure construction. Other ancient historic constructions include the Parthenon by Iktinos in Ancient Greece (447-438 BC), the Apian Way by Roman engineers (312 BC), and the Great Wall of China by General Ming T'ien under orders from Ch'in Emperor Shih Huang Ti (c. 220 BC). Similarly, the Romans developed civil structures throughout their empire including aqueducts, harbors, bridges, dams, and roads.

Necessity is the mother of invention, and this is what fostering a need to develop a business that seeks and thinks about finding appropriate solutions through which delivery of a comfortable and appropriate housing for a person can be attained. With this growth of the construction industry and subsequent growth of construction companies, contractual relationships related to construction are increasing. This increase shaped the current construction industry that affect human’s daily life.

Considering Palestine, the growth and increasing demand for the construction industry has followed a similar pattern as observed in the trend of the world with minor variation. The construction industry was not considered as an independent sector of the national economy in the historic prospective of Palestinian people. It was considered unworthy of generating national wealth. As a result, no comprehensive strategy for its development was considered.

Constructions in the West Bank are unique in nature. The general theme of the construction industry is erecting and casting buildings and installing roadways. This theme is due to the lack of capabilities and hence the construction operations are rarely developed. As a result, there has been no work and development of huge projects in our country, such as building dams, bridges and tunnels.

Buildings are structures that serve as shelters for humans. They must be well conceptualized, designed and constructed to gain the desired comfort. The building owners must work with high quality personnel and constant supervision of the building to obtain the best results [7]. The better the design and construction practices of the building, the more satisfying structures are generated to meet the needs of owners.

Buildings, like all other structures, are designed to support loads and to resist external forces without excessive deformation. These loads are the live loads as the weights of people and objects and the weight of rain and wind pressure, and dead loads such as the weight of the buildings themselves. All these loads must be incorporated into the structural design so that the building can hold up these loads during its lifetime. The design life for structures is typically fifty (50) years. In addition, the supervision stage is very significant since the life of the building depends on it. The placing of concrete, the vibration of concrete, the fixing of reinforcement, the concrete cover provision, and workability of concrete are all checked to ensure that they conform to the specifications in the drawings.

Palestinian owners design their buildings through experience to satisfy their common needs. They normally consult relatives for the proper design of their buildings. They rarely consult with engineers or professionals in the construction industry field. As a result, the outcome of the construction industry is dependent on the experience and the level of incorporation of ideas from different relatives [3]. This outcome is further influenced by the experience of the contractor who constructs the building, which in most cases is another relative to the owner. This process is highly vulnerable, and the outcome is a fifty-fifty chance to satisfy the owner needs.

There have been many collapses in our country recently. These collapses are due to the nature of the construction industry applied. The failures led to damage to human lives and the economy. The failures occurred in many regions of the West Bank. A clear understanding of the reasons for failures is needed to mitigate their effects, and most importantly to reduce the frequency of their occurrence.

Reasons and Examples of Building Collapse

Reasons for building failures vary historically. However, most engineers either in Palestine or internationally agree that most buildings collapse for the same reasons. The reasons a building collapses can be due to poor structural design, poor compliance with specifications, poor quality control, faulty construction methodology, foundation failure, and corruption. Natural disaster is also identified as a cause of building collapse. The most common reasons for collapses in buildings are as follows according to Adefusi [8]; 1) Defects in design and drawings; 2) Use of inferior materials; 3) Faulty execution and inadequate supervision; 4) Faulty repairing or restoration/renovation; 5) Early ageing; 6) Lack of maintenance; 7) Foundation failures; 8) Excessive forces due to natural disaster; 9) Overloading; 10) Change in structural configuration.

One of the main reasons for the building failures is the soil structure. In2004, Za-Chieh investigated the reasons for failures internationally [9]. The research concluded a set of reasons behind the building’s collapses. However, the main reason behind the collapses of buildings was soil structure. This factor is crucial "due to the lack of inadequacy of construction requirements regarding the extent and quality of site investigation work. Failures led to the collapse of buildings during construction" [9]. According to the authors, the lack of knowledge in site investigation of the current conditions and absence of geotechnical supervision are the main reasons behind the buildings collapses. The importance of site investigation was evident in the case of Brazil [10]. A study conducted by Hussain showed water quality deterioration and soil erosion are the two major environmental responses to the unplanned urban growths on the problematic soil in surrounding areas of District Federal in Brazil. These two factors adversely affected the structures, and failures occurred due to negligence of site investigation. An experiment was prepared to check the response of Brazilian soil under different loading conditions. This investigation is achieved by vertical load applied on one flank of the slope. This loading receives a reaction from the ground. The experiment was able to explain the reason of failures for the Brazilian case.

Site investigation is considered as one of the most important phases during the construction of any building or projects. Site investigation is handled through various steps. The steps include the reconnaissance, preliminary and detailed Phases. Tests for site investigation includes but not limited to boreholes, test piles, trenches, adits, field and laboratory tests, geophysical survey, aerial photographs, geological maps, seismology, groundwater, magnitude (Richter scale) and intensity (modified Mercalli scale), intensity (magnitude, Epicenter distance, Focal depth, groundwater, local geology, foundation, type and quality of structure and facilities). The Richter scale of earthquake magnitude is determined from an event that has occurred. The specifications and professional engineers apply the knowledge of the site to deliver safe and suitable structures.

Another reason for failures could be attributed the material deficiency. According to Chehade’s research [11], Concrete compressive strength on uncontrolled construction sites can reveal the adequacy of constructed building. The methodology depends on taking concrete samples from various locations during construction processes such as columns, ceilings, foundations, and walls in order to make sure that the concrete achieved the required strength. This method verifies that the building is safe or unsafe. "The information obtained on the concrete compressive strength allows design engineers to take into consideration in their conception a high probably weak concrete when the construction is performed. So, the safety of construction is improved and we can avoid building collapses as happened recently in our countries." [11]

Applying this approach on buildings in Lebanon revealed that concrete quality is the main reason for building failures. The investigations prove that the causes of the collapses are the quality of concrete compressive strength, the mixing ratio of the concrete components (Water, cement and aggregate), and the quality of each component compromising the concrete. Inadequacy of concrete quality increases the probability of the building’s collapses.

The same approach was applied to building failures in Nigeria. The analysis was on the properties of the reinforcing steel bars [12]. Investigations about building collapse revealed that the flexibility of reinforcing steel was very small with high rigidity. This condition caused breaking in the steel and building collapsed. It is important to ensure the quality management and ensure the material properties used in construction works. Another research[13]studied the quality of steel rods used in structural buildings in Nigeria. The experimental data on the chemical and mechanical properties of steel rods from collapsed building sites and local steel plants have been reported. They collected the steel rod samples of 12 mm diameter from six different collapsed building sites in Lagos, Nigeria. Laboratory testing was carried out to obtain the yield strength, ultimate tensile strength, and percentage elongation. Results showed inadequacy of reinforcement bars for most of the tested specimens.

Another reason for failures is the inadequacy of the construction formwork. In 2011, an investigation by Li et al. [14]stated that the formwork causes the buildings collapses during construction. There are cases of some collapses occurred due to incorrect formwork in West Bank too. Poor formwork accompanied with casting of concrete at low or high temperatures with a fast speed without waiting periods increases the likelihood of the collapse of the building.

Another reason for building failures is the unexpected natural loading. Huang et al. explained that earthquakes are a common stimulus to cause building collapses [15]. The collapse of a building by the earthquakes is one of the main causes of causalities globally. Earthquakes cause a lot of economic and material losses and loss of lives. They used a scanning system for analyzing affected buildings by the earthquakes. "There are airborne laser scanning (ALS) can obtain high resolution 3D Data point cloud. It is possible to detect damage to the building, the use of ALS point cloud data after the earthquake helps engineers to solve problems and repair. The strong earthquake caused building collapse is one of the main reasons for casualties, so it can save emergency relief time if quickly find the earthquake-induced building damage. ALS is a newer remote sensing technology which can acquire high resolution three dimensional point cloud data" [15]. Samaro Showed in a master thesis at An-Najah National University that unexpected loading is among other factors that can cause failures [16]. The thesis discusses the relation between the snow falling percentage and the steel structures that collapsed in West Bank after the 2013 snowfall. The possibility of steel structures collapse increase when the snow falling percentage increased. During the investigation, investigator studied two cases of steel structures collapse by using computer simulation software. The conclusion was that the buildings were built correctly and according to engineering standards, but the collapse happened because of unexpected quantity of the snowfall. According to Samaro, failures were mainly due to poor design and construction practices for the steel structures under considerations. Absence of regular check-ups and maintenance adversely affect the situation. Finally, the climate change in general and the snow expectancy in more specific urges a modification in the anticipated loading in the design codes applied in Palestine. These findings require a local design code for buildings in Palestine that accounts for specific loadings and conditions in the country rather than using universal codes [16].

One of the major reasons for building collapse is the absence of true engineering supervision. Asante and Sasu investigated the reasons of failure in Ghana. The research showed that the failures are due to absence of engineering supervisions in the construction sites. Their study focused on the area of Kumasi. They took a random sample from the collapsed area.

"the majority of building collapses in Nigeria are traceable to human activity or inactivity, including mainly structural failure, poor supervision and workmanship, and the use of sub- standard building materials” [17]. The investigators were not able to complete their study due to a set of limitations and challenges. These obstacles include insufficient logistics/manpower, political interference in investigations of collapses, and building policies. The investigators were stopped from completing the investigation by politics and not having enough sources for gathering data regarding collapses that occur in the area.

The absence of true engineering supervision was evident in the case of Nigeria. The method of scientific research was a well-structured questionnaire and random oral interviews. The reasons for the collapse of the buildings were attributed to inadequate staffing and lack of engagement of building professionals. The planning approval authorities were not useful in scrutinizing, vetting, and evaluating building drawings submitted for approval. The supervision and monitoring the level of compliance of buildings under construction with the operational building codes and by-laws in the study area was relatively poor. The study concluded that these lapses in local building approval authorities’ roles can contribute to the increasing cases of collapsed buildings in Enugu Metropolis[18].

Getting a competent workmanship and using the right material measurements are some of the factors to consider for a strong building. Rachel Irene [8] indicated that most buildings collapse mainly because of structural failure. This is when a building is designed to carry a specified load while actual loads are over the considered ones. The structural designs of these cases are done poorly. As a result, the building is bound to collapse. In Palestine, there are many cases where buildings and constructions are constructed poorly using inappropriate cheap or alternative materials. This situation results in making the buildings more prone to be overloaded and unable to carry the expected loads during the usage.

Some companies may also change the design from the real one. For instance, buildings that were originally designed to bear three floors and later they were loaded two additional floors without consulting a structural engineer or professional. These buildings may collapse due to overload and consequent over stress of the foundation. Some construction companies in Palestine do that to satisfy the desire of the owner, and sometimes the design are prepared without knowing the intents of the owner. This situation sometimes results in making the designed construction inappropriate for their usage.

In the Palestinian case the most common reason would be faulty execution and inadequate supervision, and lack of maintenance. Most buildings in Palestine lack inadequate supervision due to the cultural reasons and economic reasons mentioned previously [19].

Impact of Building Collapse on Economic and Society

Since the dawn of civilization, humans have designated a protected area for themselves, their families, and animals. This safe place was created by exploiting natural areas, and then applying the experiences gained in favor of using the available materials. People build structures of different types for different purposes; buildings - to live and state the place / space; bridges - to connect points and reservoirs – to store materials. Over the years, humans have learned to manipulate elements and materials, and use them more effectively. Today, buildings have a wide range of materials; concrete; stone; Wood; Steel; Aluminum; Plastic; and other materials. If these materials are used well and professionally, buildings will not fall.

Architects and city planners frequently use models to show and display the buildings in a three-dimensional fashion, and check that the height of the buildings is appropriate to the surrounding environment. Models can be computer images or natural models. Engineers also use computerized models to test their stability in extreme cases.

Reasons for failures could reveal social and political aspects. An investigation of collapsed building incidents on soft marine deposit showed that failure investigations should consider both the social and technical perspectives [20]. The collapsed incident occurred on 10th of October 2016 in Wenzhou City in China and resulted in 22 casualties and six injuries. Most of victims were migrant laborers (rural dwellers who moved to urban areas for a temporary work). These incidents revealed social problems of the existing dual structure land-use policy in China. Chinese dual structure land-use policy caused deficiencies in the supervision of the construction market in rural area. This situation resulted in the technical factors were not well supervised by the various quality control departments. This situation leaded to; (1) poor quality of residential buildings; (2) unauthorized roof top additions; and (3) Residential buildings in urban villages, where differential settlements occur, were built with poor quality control. This poor control often resulted in structurally unsound structures. Migrant people from rural areas often have no place to live and seek low rental accommodations in urban villages regardless of the quality of the building.

Building collapse has negative impacts on humans. Ikuta et al. showed a relation between collapses and damages affecting human[21]. Accurate construction saves economic costs, avoids future damages, and improves building security. The study used a Canadian case study. The study revealed that human body is severely affected including death in some cases from the collapse either by construction materials or furniture. The study concluded that saving the building is necessary to save lives. According to Ritche Patel, every time a building collapses in any part of world, it sends waves of tremors in minds of many common people around the world[19]. Collapses do not occur due to merely one reason unless there is a fatal error in ignoring that reason. Failure is a result of multiple reasons activating together.

Construction sector is important to all countries in the world. Recently, there have been many collapses in this sector that led to economic damage and the loss of many victims. In the collapse of a hotel in the city of Quanzhou in China, as happened in Turkey in the city of Izmir recently, many buildings collapsed due to an earthquake that struck the region. These collapses cause the loss of many lives in general. A reduction in the negative effects that are generated with failures is essential. The benefits are the preservation of life being and the strengthening of steadfastness. The life of humans is the most valuable thing to save. Preserving the building means preserving people inside it. It also means preserving money from an economic side on the other hand.

To sum up, construction industry is essential for any specific country. Failure in this sector needs to be avoided. Recently, many failures occurred in this sector in Palestine. Reducing the frequency of these failures should mitigate the negative effects on humans and their belongings. As Palestine has a complicated situation considering the political, economic, and health factors, saving and improving this sector becomes crucial. There is no research considering the collapses of buildings in Palestine. This research fills the gap through analyzing the reasons of failures for buildings under construction in the West Bank considering the views of experts in this field.

Chapter 3

Methodology

Overview

This chapter discusses the research methodology throughout the thesis. Research methodology represents the process implemented to complete the research. Different types of research methodologies exist. These methodologies could be quantitative, qualitative, or mixed methods [22]. Each method has its own merits and disadvantages.

The quantitative methodology is best suited for scientific research. Data are collected and analyzed to draw conclusions and theories. A common type of the quantitative research is to create questionnaires and apply statistical analysis techniques to highlight main conclusions [22]. The most critical stage in the statistical process is the data collection phase. Any error in the data collection process results in a statistical error. Another form of quantitative research is applying theories to analyze cases [22]. The better the theory in describing the case, the more realistic results is attained.

The qualitative research properly addresses humanitarian research. Several types of qualitative research exist [22]. Case studies and interviews are two common types of qualitative research. In the qualitative research, the researcher investigates unseen or unmeasured factors that affect the outcome of the issue under consideration.

The mixed methods research applies principles from both quantitative and qualitative research. It combines the merits of each research method to better address the issue under consideration [22]. The common types of this research are convergent, explanatory, and exploratory techniques. The difference between these types of research is how the mix is applied of the qualitative and quantitative research. In convergent, both types are conducted separately and with the same importance. In contrast with the explanatory which starts with quantitative research followed by qualitative research, and exploratory where qualitative research starts first followed by a quantitative research.

In this study, the mixed method research is implemented following the convergent approach to analyze the current situation, and answer the question of what is happening and why buildings collapse.

Quantitative Method Procedure

Data Collection and Analysis

The quantitative scientific approach was implemented throughout this thesis. A well-prepared questionnaire was introduced to address the reasons for failure for buildings under construction (See Appendix A). This questionnaire was then distributed to relevant agencies and personnel in the construction industry. Replies from the participants were gathered for further evaluation.

The data gathered from questionnaires is manipulated and analyzed using Microsoft Excel, Statistical Package for the Social Sciences (SPSS), and Minitab programs as needed. The analyzed data then categorizes the reasons for failures from the most common and influential to the least.

Structural Approach

Structural Analysis Program (SAP 2000) and Extended 3D (Three-Dimensional) Analysis of Building Systems (ETABS) are used to analyze special cases of building failures occurred in West Bank. The collected cases are simulated in computerized models for testing the stability of buildings. The purpose of the analysis is to produce the required comparative study. The first step of this task was creating a baseline of the construction management process of buildings under construction in West Bank. The process should be derived from the Palestinian Engineers Association-Jerusalem Center. The second step was studying and analyzing a set of case studies locally and considering international research in the field.

Two case studies of buildings where failure occurred were obtained. Details for these cases were collected through contacting official engineering offices. The reasons for failures per the thoughts of the offices were explored in detail. A 3D model is generated for the cases under consideration. The analysis applied finite element method, and the results were compared considering the actual condition.

Qualitative Method Procedure

Data Collection and Analysis

Data for this research was collected by reviewing the literature and related publications, visiting local buildings where failures occurred, investigating the reasons behind the failures, and collecting data from the Palestinian Engineers Association – Jerusalem Center and local engineers in municipalities where failure occurred. Social media was used as well to collect further information on the failure cases. Discussions among professionals in this field were held on the social media such as Facebook were considered for the failure cases under consideration.

The researcher does not provide the personnel beliefs regarding the case studies under consideration. The analysis for the data was simply stating the beliefs of the interviewee or professionals in the field. A summary of the reasons of failure was provided at the end of the section to state the beliefs the researcher found regarding the failure cases.

Quality Management Approach

Research Design/Methodology

Customers generally tend to compare the product they 'experience' with the product they 'expect'. If the experience does not match the expectation, a gap arises. The provider for a service or a product applies all the efforts to meet the expectations of the customer. Construction industry is not an exception. The failures in buildings certainly provide a deficiency in meeting the customer expectations. In the collapse of the buildings the quality dimensions to consider are; Soil type where construction occur; Building support during construction; Meeting Timelines; Engineering design; Concrete type and quality; Engineering supervision; and building durability and strength.

Customer satisfaction is measured after looking at process performance and clarifying to which extent the degree of customer critical to qualities (CTQs) are met or exceeded. Higher satisfaction is attained by exceeding the CTQs. In construction industry, people want comfortable, safe, and suitable buildings. Failures in such buildings should be avoided.

Management principles and standards exist to ensure customer satisfaction. The International Standard for Quality management [23] adopts several management principles that can be used by top management to guide their organizations of buildings towards improved performance, customer focus, leadership, and involvement of people.

Data/Model Analysis

There are many methods for quality improvement. These cover buildings improvement, process of building design improvement, and people-based improvement. The following list is methods of quality management and techniques that incorporate and drive quality improvement:

1. Six Sigma (6σ), a business strategy which combines established methods such as statistical process control (SPC), design of experiments in an overall framework.

2. PDCA (Plan, Do, Check, and Act cycle) for quality control purposes, Six Sigma's DMAIC method (Define, Measure, Analyze, Improve, and Control) may be viewed as a particular implementation of this.

This study intends to improve the quality of the construction of buildings to drive towards the customer satisfaction. This goal can be achieved after understanding the need for change by using the six-sigma tools to improve and monitor the process's performance. The quality improvement process is better depicted in Figure 3. 1.

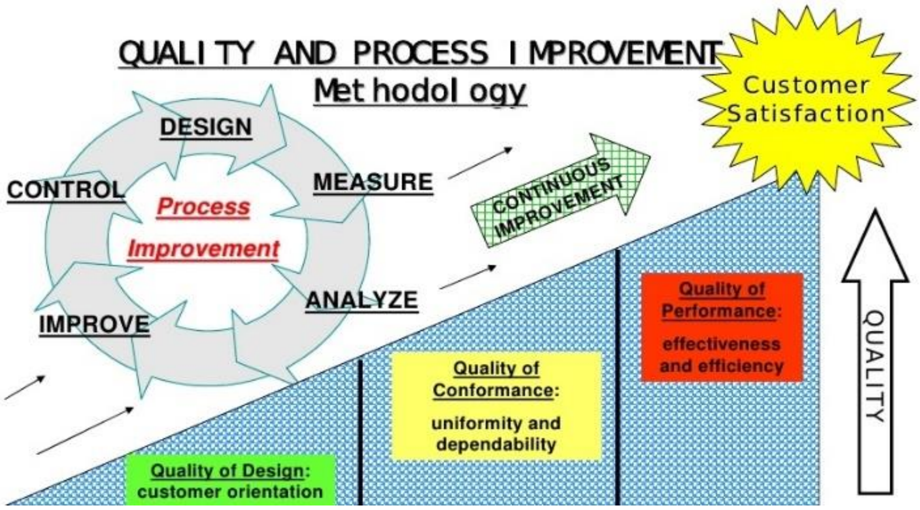

Figure 3. 1: Quality Improvement Process

Chapter 4

Data Collection, Analysis, Results, and Discussion

Data Collection

The process of collecting sample data follows the quality improvements techniques. In addition to the Six Sigma (6σ) and PDCA techniques, the following procedures are carried out:

1. Descriptive techniques to describe some cases of buildings collapse.
2. Computerized models using computers images or natural models and applying simulations for testing buildings properties and stability in extreme cases.

To achieve the objectives of the study, the researcher used a14-item questionnaire for construction companies in West Bank to address. The questionnaire is formed based on the previous literature and the researcher's own experience in the field of Engineering. The questionnaire consisted of three sections: the first focused on demographic data of the respondents such as age, gender, career, experience. The second addressed demographic data of the buildings were failures occur such as period of building, building age, and the capital of the company. The idea of collecting the demographic data is to compare the responses based on the aforementioned factors. The third part consisted of 14 questions about the reasons behind the collapse of building in West Bank under construction. The scores of responses to each item were calculated according to a four-point Likert scale; for the first three domains responses in which very effective = 4 points, effective = 3 points, moderate = 2 points, little effect = 1 point. The idea behind the 14 questions is to rank the reasons for failures from the common case to least expected reason.

Analysis and Results

The data collected were analyzed using (SPSS -17) considering the questions of the study. Means, frequencies, and standard deviations are common statistical measures obtained in the analysis. Two independent sample T-test and One-Way analysis of variance (ANOVA) was applied to the data as well. ANOVA test is an analysis tool used in statistics that splits an observed aggregate variability into two parts for a specific data set; systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study. To analyze the findings, the researcher used the following scales to represent the estimation level of sample responses:

More than 3: 75.0 % High

2.00-3.00: 50.0 – 74.9 % Moderate

Less than 2.0: 49.9 % Low

Statistical Analysis and Results

Characteristics of the data collected are presented in Table 4.1 – 4.7.

Table 4.1: Respondent Age

Age (years)	Frequency	Percent	Valid Percent	Cumulative Percent
20-29	13	43.3	43.3	43.3
30-39	11	36.7	36.7	80.0
40-49	2	6.7	6.7	86.7
50-59	2	6.7	6.7	93.3
60 and more	2	6.7	6.7	100.0
Total	30	100.0	100.0	

Table 4.2: Respondent Gender

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	19	63.3	63.3	63.3
Female	11	36.7	36.7	100.0
Total	30	100.0	100.0	

Table 4.3: Respondent Career

Career	Frequency	Percent	Valid Percent	Cumulative Percent
Academic	3	10.0	10.0	10.0
Supervisor	17	56.7	56.7	66.7
Project Engineer	7	23.3	23.3	90.0
Owner	3	10.0	10.0	100.0
Total	30	100.0	100.0	

Table 4.4: Respondent Experiences

# of years	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	10	33.3	33.3	33.3
6-10	9	30.0	30.0	63.3
11-15	4	13.3	13.3	76.7
16-20	3	10.0	10.0	86.7
more than 20	4	13.3	13.3	100.0
Total	30	100.0	100.0	

Table 4.5: Period of building

# of years	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	15	50.0	50.0	50.0
6-10	2	6.7	6.7	56.7
11-15	2	6.7	6.7	63.3
16-20	2	6.7	6.7	70.0
more than 20	9	30.0	30.0	100.0
Total	30	100.0	100.0	

Table 4.6: Building age

Building Age (years)	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	16	53.3	53.3	53.3
6-10	4	13.3	13.3	66.7
11-15	2	6.7	6.7	73.3
16-20	8	26.7	26.7	100.0
Total	30	100.0	100.0	

Table 4.7: Capital of company

Capital of company ($)	Frequency	Percent	Valid Percent	umulative Percent
Less than 100,000	6	20.0	20.0	20.0
100,000 - 150,000	7	23.3	23.3	43.3
160,000 - 200,000	5	16.7	16.7	80.0
300,000 - 400,000	9	30.0	30.0	90.0
500,000 and more	3	10.0	10.0	100.0
Total	30	100.0	100.0	

Complete statistical analysis is presented in Appendix B.

The sample consisted of 30 individuals in the construction sector in Palestine. The background of the study sample is varied in terms of age, gender, career, experience, period of building, building age and the capital of the company. The classification is shown in Table 4.8.

This study aimed at identifying reasons behind the collapse of buildings in West Bank that are under construction. It also aimed at identifying the effect of demographic variables on the responses obtained from the questionnaire. To accomplish the aims of the study, the researcher analyzed the data in accordance with the study questions, and the results are explained later of this chapter.

Quality Management Approach

Six Sigma DMAIC Methodology is a closed-loop process that eliminates unproductive steps. It often focuses on new measurements, and applied technology for continuous improvement [24]. Implementation of

DMAIC Methodology took place in five phases as outlined below and established at Motorola; Problem identification and definition takes place in define phase; After identifying main processes, their performance is calculated in measure phase with the help of data collection; Root causes of the problem are found out in analysis phase; Solutions to solve problem and implementing them are in improve phase; and Improvement is maintained in control phase.

DMAIC Model

Define

This phase determines the objective and scope of the study. Information about the present processes is collected. At this phase, the definition of customers and deliverables to customers are also determined.

The Project Charter defines the scope, objectives, deliverables, and overall approach for the work to be completed. The importance of Project Charter is that it is a critical element for initiating, planning, executing, controlling, and monitoring the study. It is the absolute master document for the study and as such it should be the single point of reference on the study for goals and objectives, scope, organization, estimates, deliverables, and budget [25].

Table 4.8: Distribution of Sample According to Study Independent Variables

Variable	Class	Frequency	Percentage %
	20-29	13	43.3
Age	30-39	11	36.7
	40-49	2	6.7
	50-59	2	6.7
	60 and more	2	6.7
Gender	Male	19	63.3
	Female	11	36.7
	Academic	3	10.0
Career	Supervisor	17	56.7
	Project Engineer	7	23.3
	Owner	3	10.0
	1-5	10	33.3
Experience	6-10	9	30.0
	11-15	4	13.3
	16-20	3	10.0
	More than 20	4	13.3
	1-5	15	50.0
Period of Building	6-10	2	6.7
	11-15	2	6.7
	16-19	2	6.7
	20 and more	9	30.0
	1-5	16	53.3
Building Age	6-10	4	13.3
	16-19	2	6.7
	20 and more	8	26.7
	Less than 100,000	6	20.0
Company Capital	100,000-150,000	7	23.3
	160,000-200,000	5	16.7
	210,000-400,000	9	30.0
	500,000 and more	3	10.0
Total		30	100.0

Table 4.9: Details of Project Scope

Business case This project supports the business quality goals, reduce the collapse, and get more profit and increase the customer's satisfaction.	**Opportunity statement** An opportunity exists to reduce the gap between the engineering offices and house owner by enhancing the mutual trust between them in the construction process.
Goal statement Reduce the collapse as much as possible.	**Project scope** Building collapse in West Bank with focus on Hebron and Nablus cities.
Project plan Activity Start End Define 18/7 23/7 Measure 24/7 1/8 Analyze 2/8 15/8 Improve 16/8 17/8 Control 20/8	**Team** The researcher The owner Engineering offices

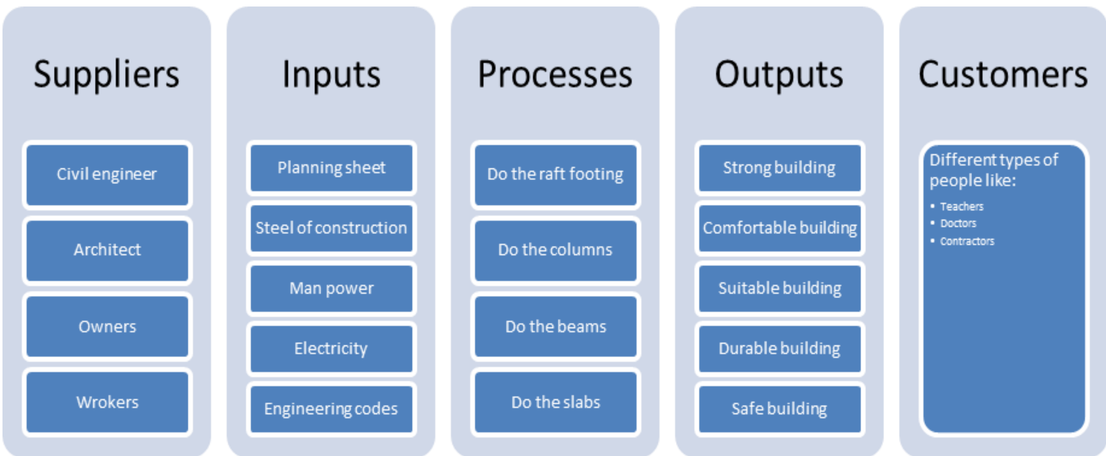

Figure 4.1: SIPOC Diagram

Table 4.9 shows the details of project scope, business case, opportunity statement, goal statement, team, and project plan.

In order to give a simple overview of the process and to understand the basic elements, the Suppliers, Inputs, Process, Outputs, and Customers diagram (SIPOC) is a Six Sigma tool used for documenting business processes. Figure 4.1 presents the SIPOC diagram for construction industry.

The critical factors for collapse can be determined via focusing on the operations in building constructions and the soil type. The occurred failure area where the building was affected could be determined. After finding this area, critical factors responsible for collapse of some buildings were identified.

Measure

Check sheet is a tool to record the potential causes for the collapse of buildings and the causes for defects during the construction which make the customer unsatisfied. It is also used to count the occurrences of various defects throughout the testing period. This counting log is very useful to investigate the main causes for performance weakness. The quality management system and its tools focused its efforts to determine the precise specifications the customer wants; by taking some case studies from Nablus and Hebron cities, the causes and the reasons of these collapses are investigated.

Analysis

Pareto chart is a useful tool to determine what are the most defects happened and where improvements could be achieved. The chart can be investigated for various reasons for building collapse. Figure 4.2 -Figure

4.12 represent the Pareto charts for all the factors under consideration in this study.

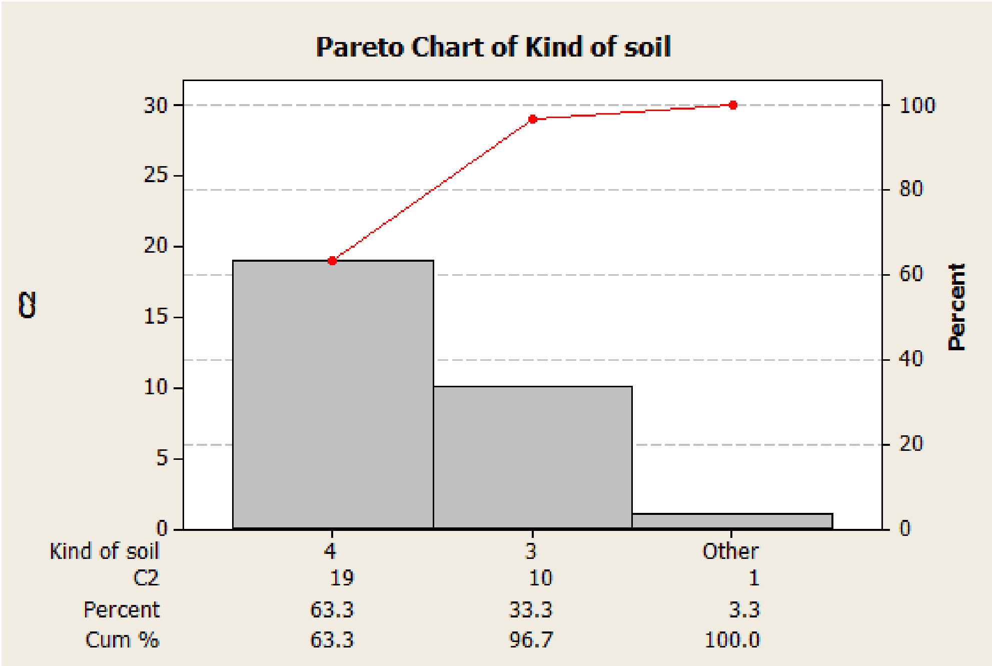

Figure 4.2: Pareto Chart for Soil Type

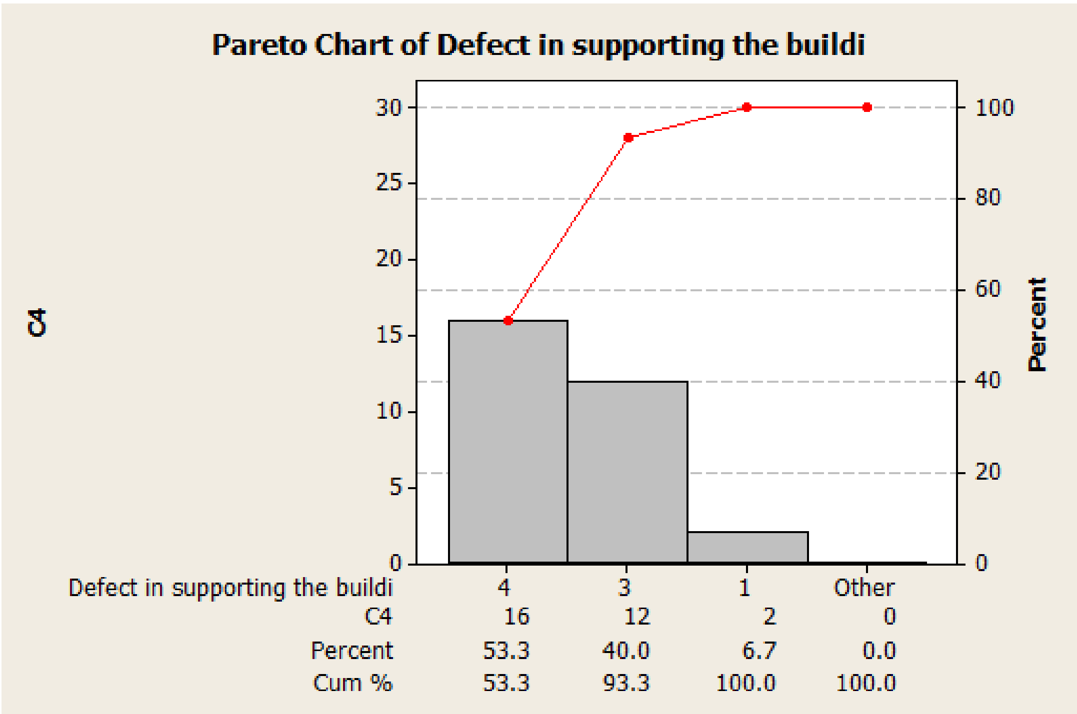

Figure 4.3: Pareto Chart for Defects in Building Support

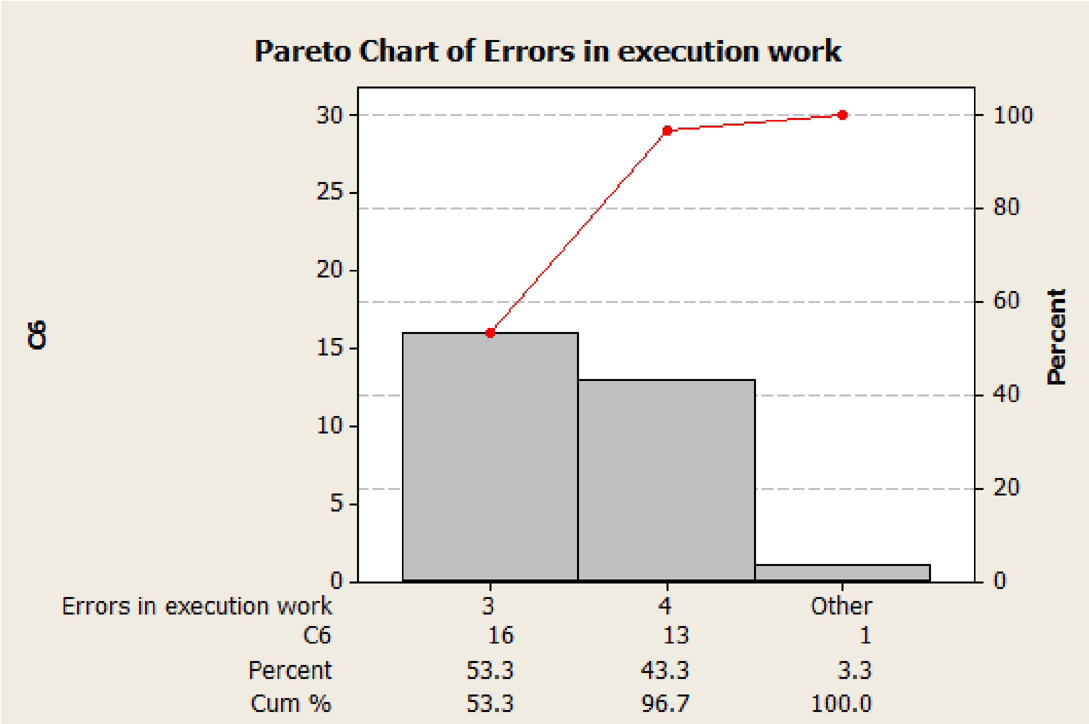

Figure 4.4: Pareto Chart for improper work execution

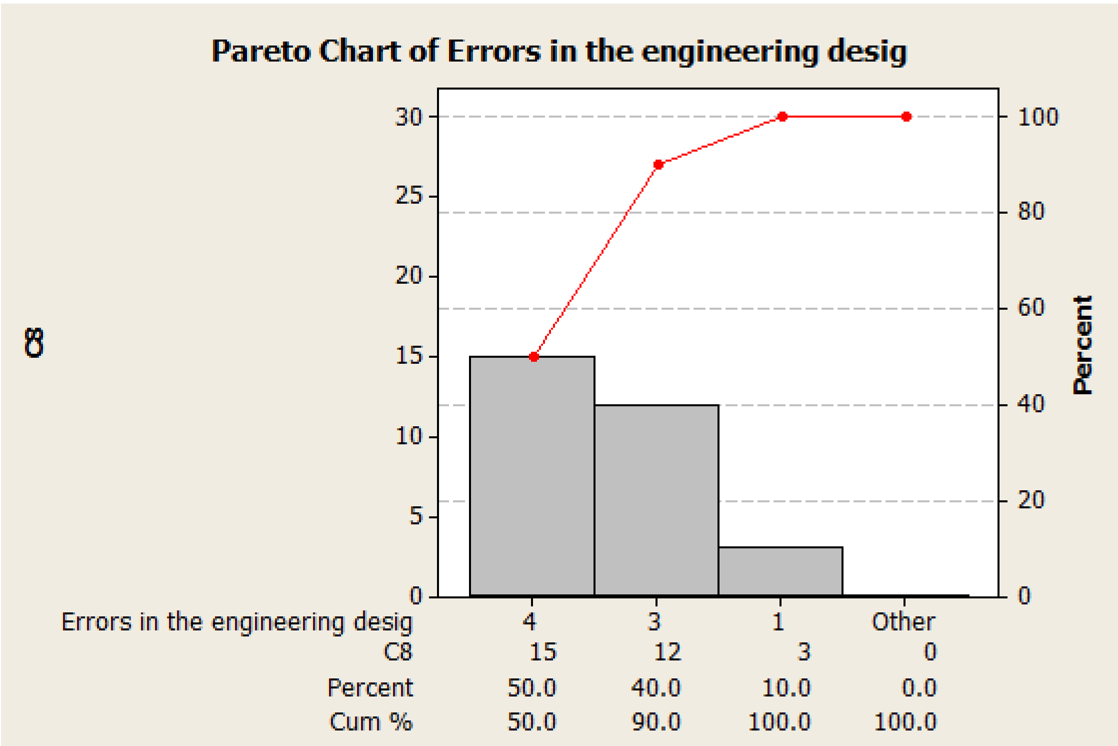

Figure 4.5: Pareto Chart for Engineering Design Mistakes

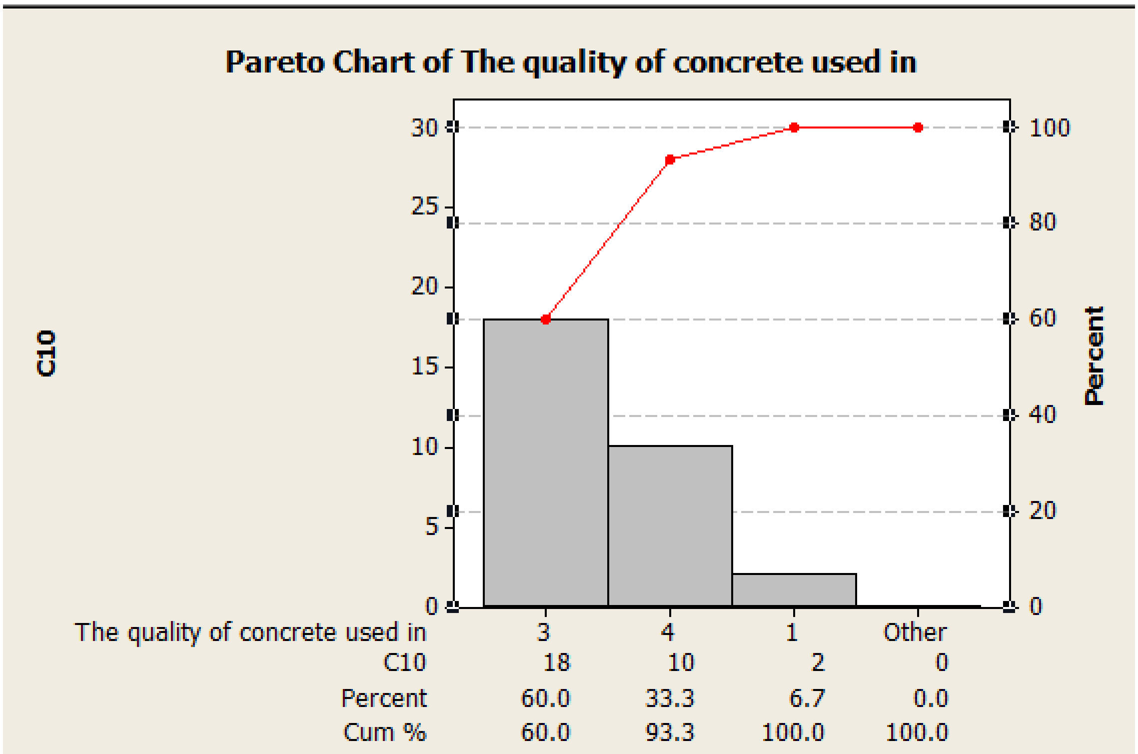

Figure 4.6: Pareto Chart for Concrete Quality

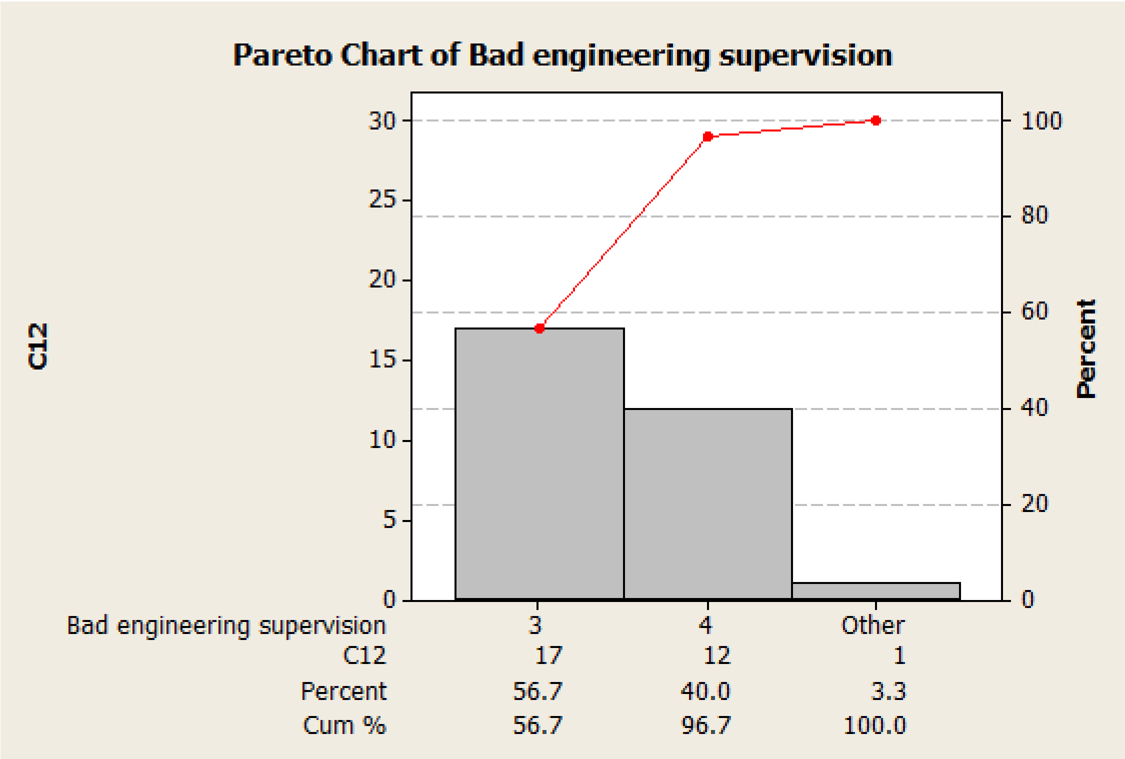

Figure 4.7: Pareto Chart for Improper Engineering Supervision

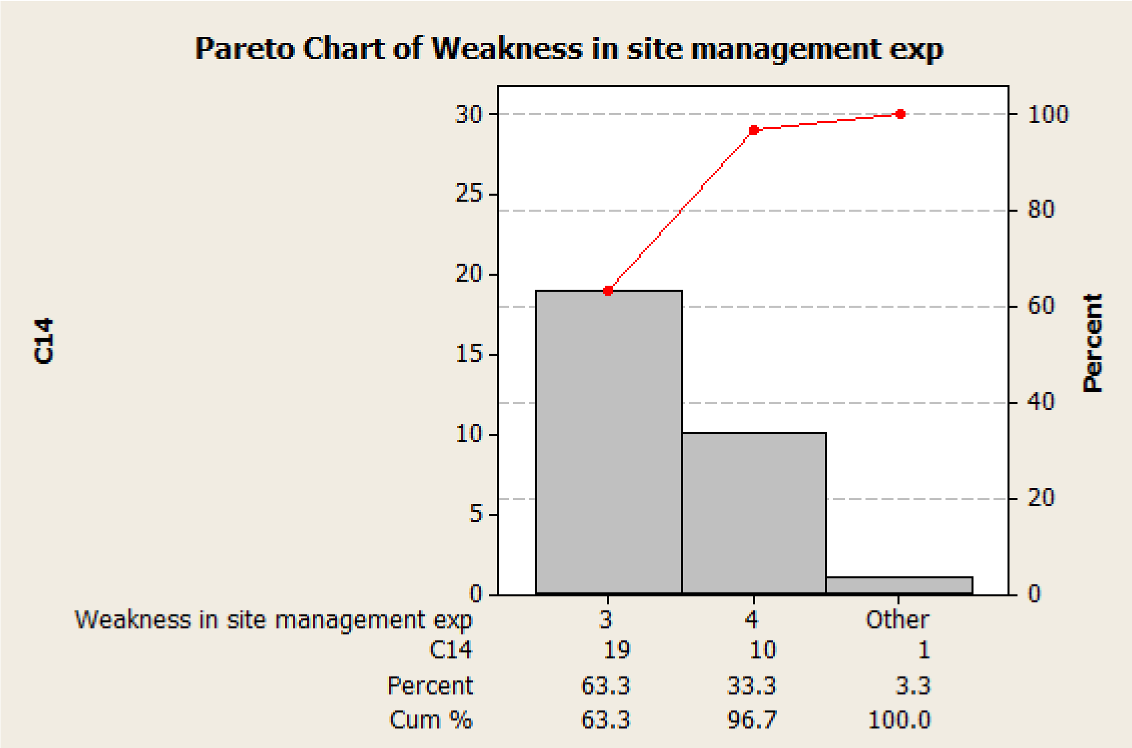

Figure 4.8: Pareto Chart for Inadequate Site Management Experience

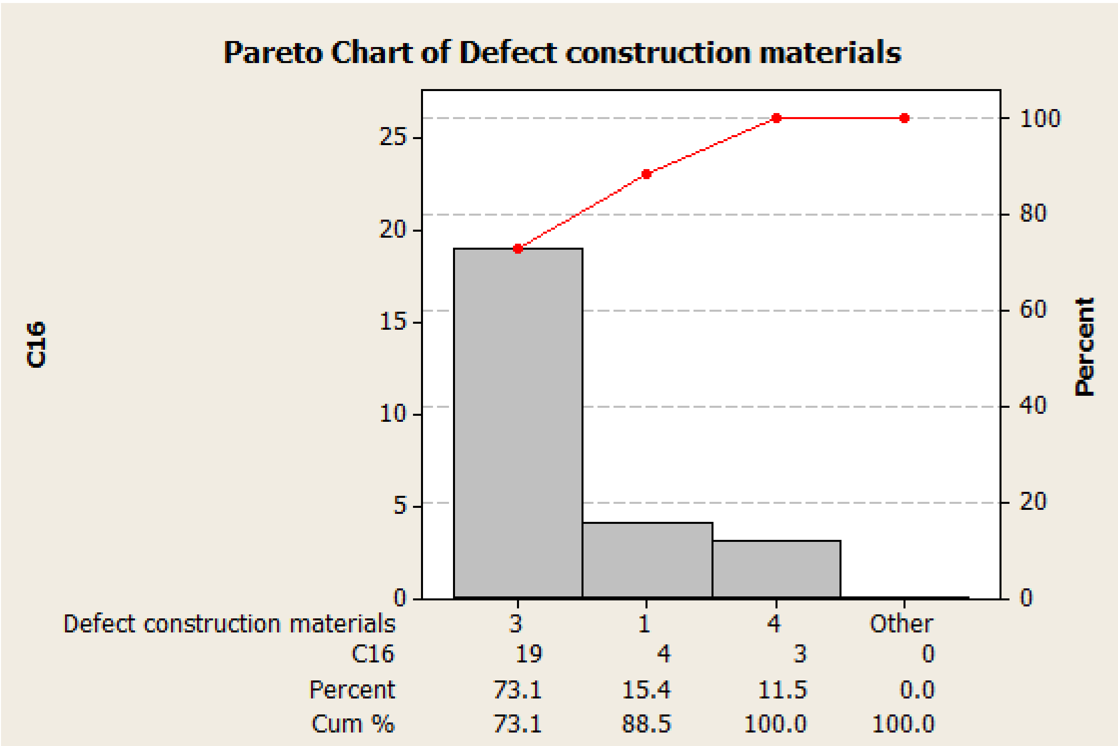

Figure 4.9: Pareto Chart for Defects in Construction Materials

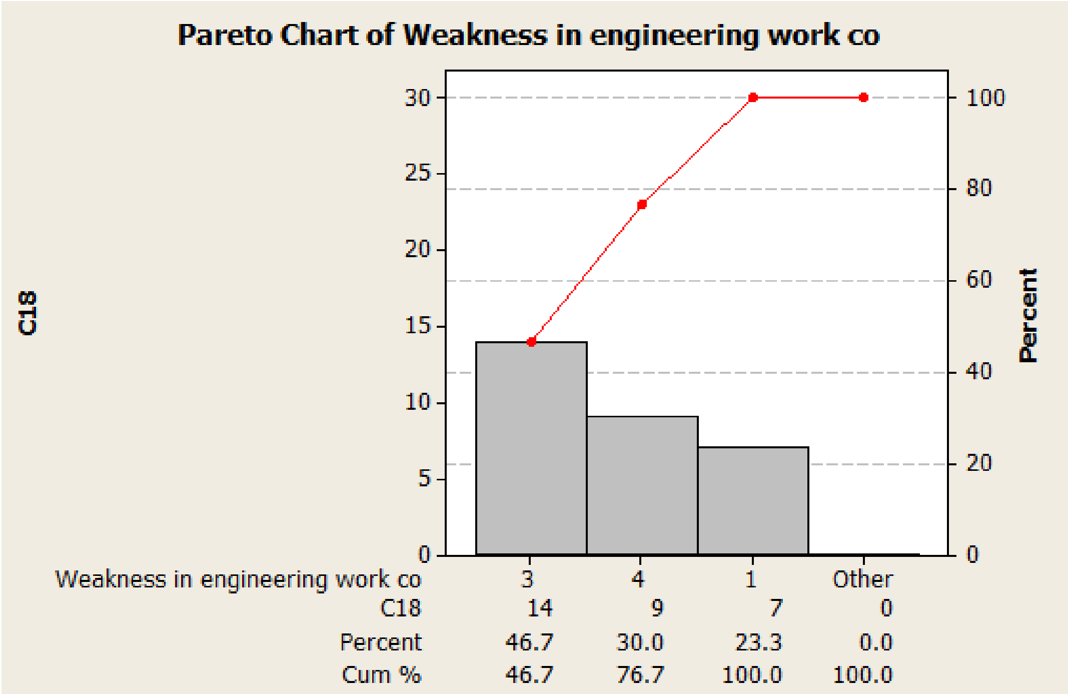

Figure 4.10: Pareto Chart for Improper Company Engineering Work

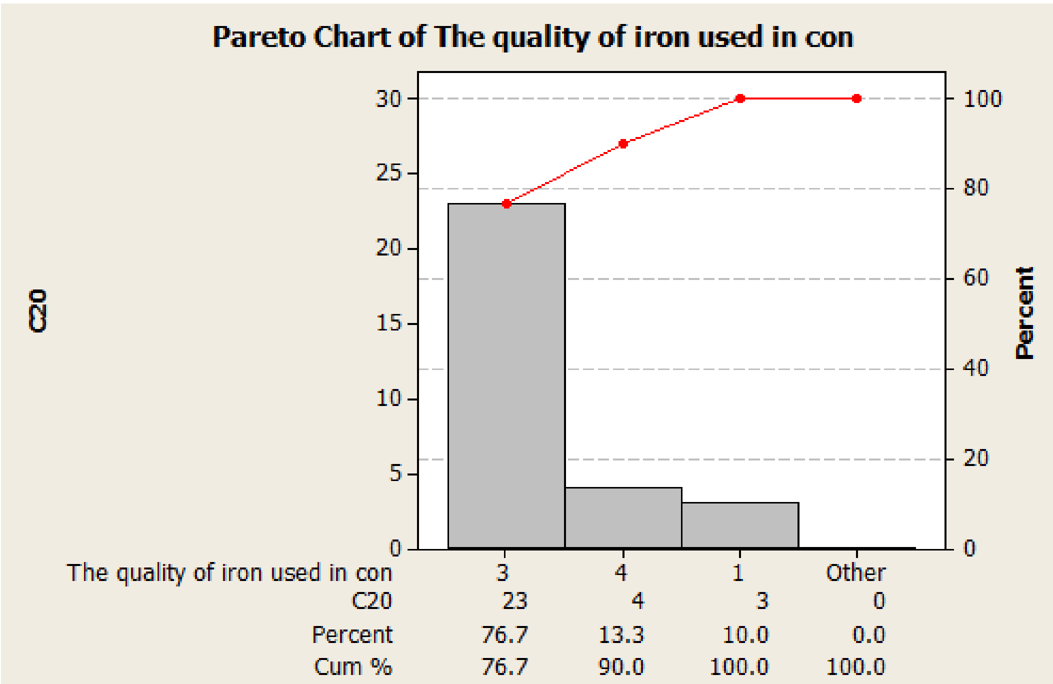

Figure 4.11: Pareto Chart for Reinforcement Quality

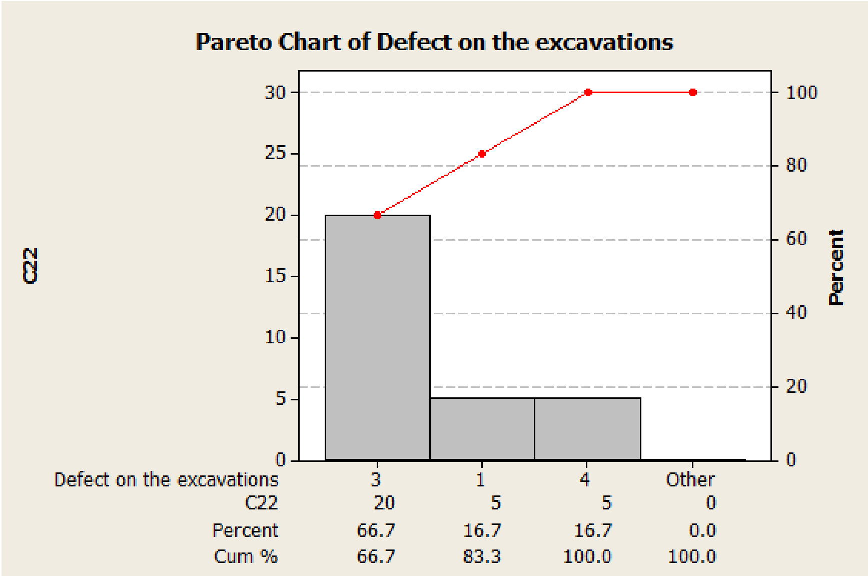

Figure 4.12: Pareto Chart for Improper Excavations

Cause and effect tool (see Figure 4.13) is a very useful tool to show the main causes that generate the collapse in building. These causes are related to the weak form of the soil, bad engineering design, and poor engineering supervision.

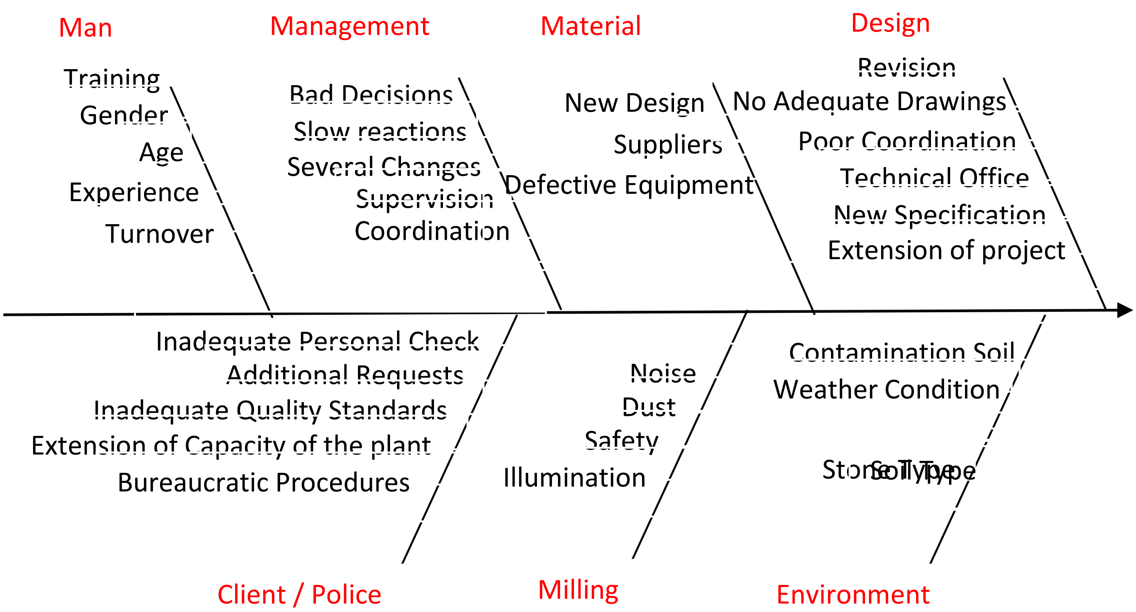

Figure 4.13: Fish Bone Diagram for Causes and Effects of Building Failures

Improve

Solution to the mentioned issues can be done through a valid protocol to lessen the impacts of the building failures. Each causing effect can be mitigated on its own. As a result, the frequency of building failures is significantly reduced.

Control

Many solutions are suggested to eliminate the causes of the collapse problems. Some of these solutions can be applied immediately and others need time and money to be applied. In this phase, the solutions are applied and then verified by monitoring the frequency of building failures after applying the controlling activities. If the frequency is reduce, then the suggested solutions are appropriate, and an enforcement of them is needed.

Structural Analysis

Loads that a structural member withstands:

1. Main Loads: It is grouped into:

   a. Dead load: as self-weight, slabs weight, wall weight, internal work weight such as plastering and paint,…etc.

   b. Live load: It is that load induced by inhabitants and furniture that occupy the building. In other words, it is any load that is not applied permanently to the structure. This load includes the forces applied during the implementation such as equipment loads.

c. Wind load: Wind loads are significant to any structure. Some countries consider wind load as secondary, while others consider it primary. This depends on the wind nature and climate in each country.

d. Earthquake load: Ready tables to compute this kind of load on structures based on the knowledge of the building type. Such as administrative, residential, or military, … etc.

2. Secondary loads: Any load that is applied indirectly to the structure such as shrinkage in concrete, settlement in foundations, and creep. All these loads are considered during the design phase.

Structural analysis may be defined as the science that considers the effect of the aforementioned loads on stresses and strains within the structural members of a building [26, 27].

Considerations during design phase:

(a) Economic cost.

(b) Factor of safety for each structural member.

(c) Serviceability of the structure by reducing deflections and annoying cracks.

(d) Shape and aesthetic.

Design stages for each concrete structural building:

Stage I: Decide a proper structural system and analyze each element separately.

Stage II: Design each member and provide details including horizontal and longitudinal plans and sections. Also, provide details for reinforcement for each element.

The common elements to consider in concrete structures:

1. Slabs
2. Beams
3. Columns
4. Footings
5. Walls
6. Stairs

Common Palestinian buildings use framing systems [4]. In this system, loads are traversed from the slabs to beams which transfer the loads to columns. Columns load is finally transferred to the ground through the footings. Figure 4.14 shows the load transfer in this system. A proper design requires adequate and high-quality assurance for the load transfer to avoid undesirable failures in buildings.

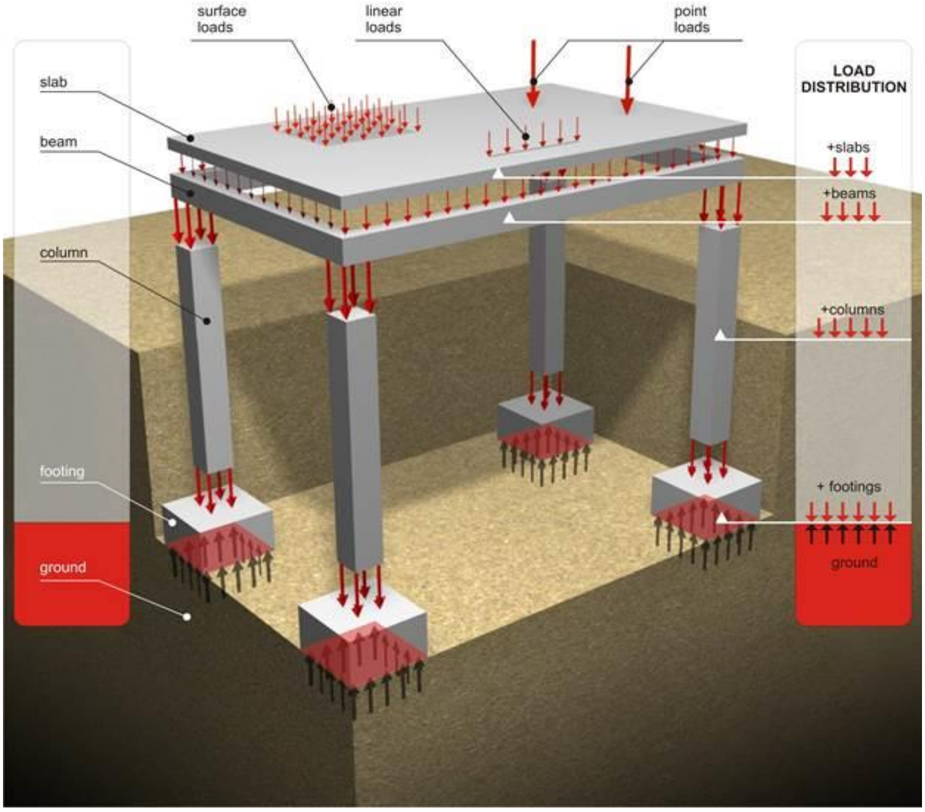

Figure 4.14: Transfer of Loads in the Structure

Two case studies from failures that occurred in West Bank are considered. The details and the reasons for failure are explained in detail below. The thesis avoided providing identifying details as the purpose is to spread knowledge, not to judge or evaluate the construction industry and personnel related to each case study.

Case Study I: 26/05/2019 Hebron City

Roofs of a commercial building collapsed during construction while casting ready mix concrete. Investigations revealed that the incident occurred due to the improper formwork, which is a common reason for failures for building in West Bank. The formwork was not properly installed and braced. The height of the commercial stores was around five meters, which is a common elevation for such premises in West Bank. The traditional formwork had proved inadequacy to these conditions. Akro system is the replacement for the traditional formwork for such conditions. Special calculations are needed to assure the quality of construction and avoid failures during casting. Figure 4.16 and Figure **4.17** show the building that collapsed. The actual structural design was adequate as the design was analyzed using SAP 2000.

Interviews for stakeholders and neighbors explained that the reason for failure was the formwork. Bracing was not introduced properly, and no lateral supporting exists.

Technical Analysis for Failure

Formwork Explanation:

The formwork consisted of supports (pipes); each consisted of two or three segments. Each segment was installed on top of each other to achieve the required elevation at floor level of five meter as appears in Figure 4.16 and Figure **4.17**.

Disadvantages of the Formwork Elements:

Supports with different sources, ages, and types were used. Some were good and kept straight up, while others are old and rusty. Too many supports were not straight with inclinations and buckling. Straightness of the supports is crucial to avoid the loss or weakness of the supports. No bracing was introduced. Also, the supports were not properly installed. This situation resulted in weakening their ability to withstand loads.

Additional factors that showed disrespect and recklessness in formwork installation were putting some supports upside down, not applying ground supports to avoid the movements of metal supports.

Explanation of Failure:

The formwork installation was improper (Support segments on top of each other). That is because it is impossible to keep the straightness for all the support segments. Any deviation from the axial center even for small centimeters results in weakening the support ability to withstand loads. The main reason is the loss of stability of this formwork system. This loss issue increases with the increase in heights.

Buckling in the supports reduces the ability of the supports to withstand axial loads. Also, lack of bracing increases the chance of loss of stability in the supports. Connecting supports horizontally with wires is improper and does not guarantee impeding movement horizontally.

Considering all the aforementioned reasons and the simple Euler Buckling Equation reveals the reason for this case failure. Schematic of buckling is presented in Figure 4.15:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Assuming that the height of each segment is three meters, the entire elevation is five meters. The comparison between the theoretical strength for one segment alone and the entire assembly reveals

One segment	Entire assembly
$P_{cr} = \frac{\pi^2 EI}{L^2}$	$P_{cr} = \frac{\pi^2 EI}{L^2}$
$P_{cr} = \frac{\pi^2 EI}{3^2}$	$P_{cr} = \frac{\pi^2 EI}{5^2}$
1/9	1/25
0.111	0.04

This analysis means that the strength of the struts considering all the factors mentioned above is less than forth of tenth (4/10) of the segment strength. The exact percentage is 0.04/0.111 = 0.360. This is the maximum that could be achieved considering that the struts or supports of 5 m length are straight and composed of one segment which is not the case.

This case revealed that the formwork was initially unstable, and any strut losing its vertical stability results in the collapse and redistribution of the loads to adjacent unstable struts.

To sum this up, the reason for failure is formwork collapse due to the improper installation and type. This formwork does not fit the required conditions to support the building during construction. Existence of buckled and rusty supports helped in the failure occurrence.

Additional indirect reasons could be attributed to the absence of true engineering supervision. This supervision could easily find out that formwork is not properly installed and hence, casting permission should be provided after this inspection.

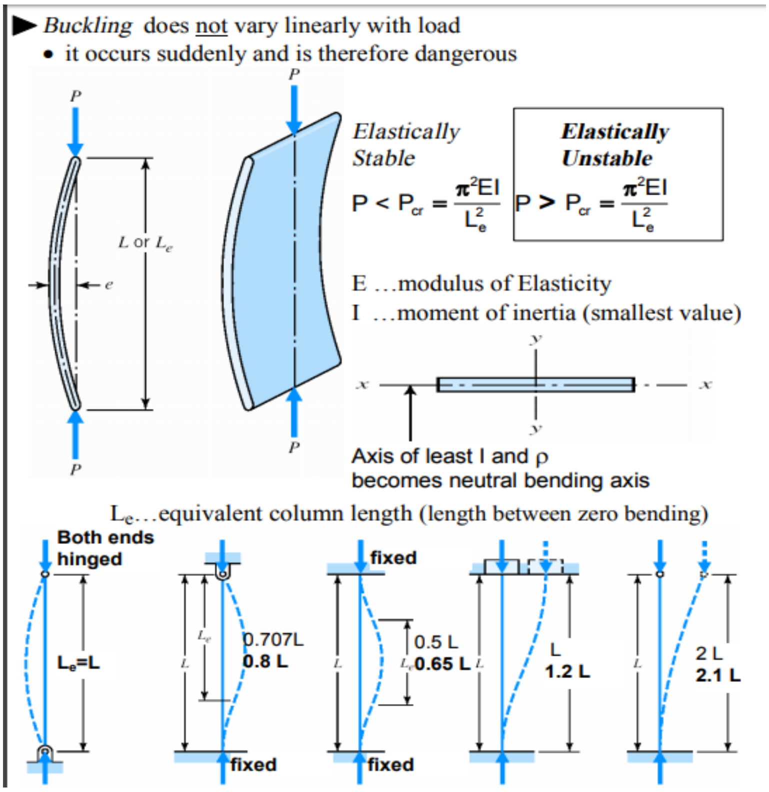

Figure 4.15: Buckling in long columns

Figure 4.16: Formwork collapse in Hebron City Case- First Prospective

Figure 4.17: Formwork collapse in Hebron City Case- Second Prospective

Case study II: 17/06/2020 in Nablus City

A failure occurred to a newly constructed building. This building showed cracks within beams and columns after removing the formwork. The structure was 20 cm ribbed slab, with beams of 20 cm deep, and columns of 20 x 40 cm, and the footings were 100 x 100 x 20 cm. Figure 4.18 - Figure 4.22 show the general layout of the structure and the supports for the buildings.

Figure 4.18: Nablus City Case – General Layout

Figure 4.19: Absence of Proper Footings

Figure 4.20: Type of Supports for the Building

Figure 4.21: Cores in Beams to Determine Concrete Strength

Figure 4.22: Cores in Columns to Determine Concrete Strength

As it is clear from the figures, this is a small traditional building. The thesis is not planning to evaluate the design. Instead, it highlights the key concepts obtained from such building. An engineering office had already evaluated this building and provides recommendations to solve the issues with the buildings. This thesis will use the general common sense for construction industry in West Bank and analyze a hypothetical case of a room of 4 x 4 with the same dimensions used for this building. Since this building showed cracks during construction, only dead load will be considered. Earthquakes did not occur on or before the date of the collapse of this building.

Technical Analysis for Failure

Deflection Consideration:

Since the system is ribbed slabs, using the traditional dimensions for rooms in West Bank and ACI table for deflection. The hypothetical case would result in:

This case is simply supported and the slab depth should be = 4/16 = 0.25 m.

But since the building shows continuity, the slab depth could be reduced to 4/18.5 = 0.22 m or 4/21 = 0.19 m.

Hence, the assumption of 20 cm ribbed slab could be reasonable for deflection.

Slab analysis:

Dead load = Own weight = (0.12 x 0.14+0.52 x 0.06) x 25 + 0.4 x 0.14 x 10 = 1.76 kN/m of rib

Ultimate load = 1.4 Dead load = 1.4 x 1.76 = 2.464 kN/m of rib

Shear force = $\frac{WL}{2}$= $\frac{2.464\,x\,4}{2}$=4.928 kN at center of beam (Center was selected as it is more critical than the at distance d.)

Bending Moment = $\frac{WL^2}{8}$=$\frac{2.464x\,4^2}{8}$= 4.928 kN.m at bottom center of rib

Beam analysis:

Support reaction for each rib is transferred to the beam = 4.928 kN / each rib width

Beam ultimate load is = 4.928 / 0.52 + 0.2 x 0.2 x 25 x 1.4 + 3 x 0.2 x 10 x 1.4 = 19.277 kN /m

Shear force = $\frac{WL}{2}$= $\frac{19.277\,x\,4}{2}$=38.554 kN at center of column

Bending Moment = $\frac{WL^2}{8}$=$\frac{19.277x\,4^2}{8}$= 38.554 kN.m at mid span of the beam

Column Analysis:

Support reaction for each beam is transferred to the column = 38.554 kN.

Since only one floor was constructed, the total load on the column to be considered is coming from one floor, column own weight, half the secondary beam weight, and the perimeter wall on the secondary beam.

Column ultimate load = 38.554 + 0.2 x 0.4 x 25 x 1.4 + 0.2 x 0.2 x 4 / 2 x 25 x 1.4 + 3 x 0.2 x10 x 4 / 2 x 1.4 = 60.954 kN.

Design axial load is 60.954 at bottom of the column

Footing Analysis:

The footing should withstand the loads at the bottom of the column = 60.954 kN in addition to the self-weight of the footing. It also should consider the soil properties (weight) and depth of foundation.

Self-weight of the footing is distributed load, while column loads are concentrated and assumed to influence the mid of the footing.

Design of Bottom Steel Reinforcement of Slab (R.S D=20cm):

Maximum positive moment M_{max} =4.93 kN.m/m

M = $\frac{Fy}{0.85*Fc'}$ = $\frac{420}{0.85*24}$ = 20.6

Rn = $\frac{Mu}{0.9*b*d^2}$ = $\frac{4.93*10^6}{0.9*120*150^2}$ = 2.03Mpa

ρ = 1* [1-√ (1-2mRn)/Fy)]/m

ρ = 1* [1-√ (1-2*20.6*2.03)/420)]/20.6 = 0.0051

As_{req}= ρ *b*d = 0.0051*120*150 = 91 mm^2/m

As_{min}= ρ*b*h = 0.0018*120*200 = 43 mm^2/m

So required As = 91 mm^2/m

Use 2ϕ10 per rib, which is common in our country. The ribs reinforcements could be of diameters 12, 14, and 16. The results obtained, showed that the slab may by okay to withstand the loads.

Design of Beams:

Moment envelope for the selected Beam Model from ETABS program gives

Maximum positive moment M_{max} =38.5 kN.m/m

$M = \frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24} = 20.6$

$Rn = \frac{Mu}{0.9*b*d^2} = \frac{38.5*10^6}{0.9*200*140^2} = 9.51Mpa$

$\rho = 1* [1-\sqrt{(1-2mRn)/Fy}]/m$

$\rho = 1* [1-\sqrt{(1-2*20.6*9.51)/420}]/20.6 = 0.0359$

$As_{req} = \rho *b*d = 0.0359*200*140 = 1077\ mm^2/m$

$As_{min}= \rho*b*h = 0.0033*200*200 = 132\ mm^2/m$

So, As = 1077 mm2/m   Use 6ϕ16

This amount of reinforcement is certainly can’t be placed in small beam dimensions of 20 x 20 cm. The minimum required width of the beam should be 50 cm to accommodate 6ϕ16.

An explanation to the building failure could be due to the improper structural capacity of the building. The dimensions of the beams are small to sustain loads. If these dimensions were used, then a failure occurred in the building due to the lack of proper steel in the beams of the building, and that the beam section was supposed to be larger than what is present to contain the needed reinforcement.

This case was modeled through ETABS. The complete structural analysis is presented in Appendix C. The results from the program showed that in addition to the improper dimension for reinforcement, shear stress failure should occur in the sections of the beam.

Samples of Failures in West Bank

Case One: Hebron city: Al-Safa Girl preliminary School

The school has 354 students. The second-grade classroom had collapsed on 25/12/2019 on the Christmas. The dimensions of the collapse were as the following: 5 meters width, 25 meters tall and 12 meters height. The site had supporting pillar. The collapse resulted from rocky fall because of neighboring excavations near the project according to the head of engineering offices, Tareq Al-Zaro. The excavation level was deep of 12 meters without taking into consideration engineering actions and suitable support. The excavation was vertical without slope to the other direction to mitigate the danger of collapse. The investigation of the collapse revealed that the accident happened due to the absence of suitable cautions and the absence of suitable supporting as stated by the Palestinian Engineering Association. According to the Municipality Board member, Abed Abu Isneeneh, the owner was authorized for excavation, but he was warned several times about that his actions were not in accordance with the engineering schedules. Yousef Al-Ja’bary, Municipality deputy chief, stated that the owner had permits to establish his building on a part of the land with several warnings by the Palestinian police to stop his project as it is not matching the license the owner attained. Tareq Al-Zaro reported that engineering plans and bill of quantities have not been approved from the Palestinian Engineering Association. According to Palestinian law, it is forbidden to start the project even with excavations without being permitted, and it is not legal to permit the excavations according to previous invalid permission without knowing what the recent one includes. The Civil Defense manager, Yazzan Yousef, reported that the department was not informed about the excavations. Moreover, Hebron Municipality said that it has sent five warnings to the owner who had admitted that he had achieved two of them: the former for excavations and the later for infringement on the road. Consultation meeting among stakeholders had been held and the recommendations were the following: The file of Al-Safa School had been transferred to the Palestinian courts; Starting the redemption of the school immediately; Searching for alternative center; The expenses of the redemption of the school and the alternative center are on the contractor; and the responsibility for the collapse should be shouldered by more than one party. This failure could be catastrophic since it affected a school, and luckily the collapse occurred on a holiday. This failure could be easily avoided if a true engineering supervision was applied. Also, this situation could be mitigated if the owner of the excavation followed the engineering procedures to mitigate the risk of collapse.

Figure 4.23: Excavation Failure Near Al-Safa Girl Preliminary School

Figure 4.24: Impact of Failure on Al-Safa Girl Preliminary School

Case Two: Hebron city: Wad Al -Tufah Street near Al-Rayan Restaurant 25-2-2020.

Wad Al – Tufah is a street in Hebron city. This street serves as a local street used frequently by citizens of the city. The supporting wall of Wad Al-Tufah Street collapsed on 25-02-2020 near Al-Rayan Restaurant. The collapse occurred because of inadequate support for the wall, the weakness of the soil, the bad weather conditions resulted in land driftage, and the absence of excavation suitable procedures.

Figure 4.25: Impact of Wall Collapse in Wad Al-Tufah

Figure 4.26: Wad Al-Tufah Failure

Case Three: Nablus city-Aseera Street. 15-02-2020

Nablus city had the largest number of collapses. The city had failures more than any other city in the West Bank recently. Aseera street collapse started with falling rocks towards a building. The noise of falling had a severe effect on the inhabitants and caused panic regardless to details. Soil moving followed the rocks behind the wall (soil moving and not the falling rocks from top to down) causing collapse of the garage ceiling behind the building. Engineering committee had been established by Nablus Governorate consisted of Dr. Jalal Al-Dabeek, Dr. Sami Hejawi, Dr. Essam Jerdaneh, Civil Defense Engineer, and the Nablus Municipality engineer. The site has been visited and the following have been revealed; The collapses did not affect the building safety; There is no more danger from the collapse on the building; and the Civil Defense Department should evacuate another building to prevent panic resulted from another night collapse. Thorough investigation revealed that the wall has been built without consideration of any future change in the soil. There is an error in executing the construction of the wall, and there is an error on the collapsed garage ceiling. The newly opened road behind the building which is only 20 meters next to building had been considered, and the investigation showed that it has not been affected by the accident. It was also found the soil in the collapse is old, and it has nothing from the road soil. The wall collapse had not happened from top to down, but instead a huge soil rushing behind the collapsed wall. The major cause of the failure is the incorrect excavation without following safe procedures and consideration of the white soil behind the wall. The wall has been built without engineering supervision. This failure could be attributed to the unexpected natural loads as well.

Unstable huge masses of soil had been noticed in a high place behind the building. With inability to use excavation tools, water pressure had been suggested to remove these huge masses by pumping water directly to these masses. 90 water cubic meters have been pumped by Nablus Fire Department which succeeded in removing the danger. The first owner of the building promised to rebuild the wall and parking place under engineering supervision and to return people to the evacuated building. There is a huge break in the soil behind several adjacent buildings.

After the collapse, the Municipality studied and collected data about all walls in more than one site. It is forbidden to cast concrete in walls without permission, studying the building systems, and studying the procedures of excavations.

Figure 4.27: Garage Wall Failure

Figure 4.28: Rocks Falling on Garage Ceiling

Figure 4.29: Scale of the Collapse

Figure 4.30: Impact of Failure on the Building

Figure 4.31: Garage Ceiling Collapse

Case Four: Nablus city – Rafeedia Street. 27-07-2019

The engineering office supervising this site was visited, and the site was visited, and data had been collected on the site. The resident engineer stated that the main reason behind the collapse is the difference in the quality of the neighboring soil, which was not taken into account, and the presence of running water in the area, which helped in the collapse of the piles.

The number of all the piles surrounding the building was 175 piles, and they were only affected by a certain pressure that led to gradual cracks. The supervising office had suggested two solutions to solve the issue of the collapse. These solutions were;

The first solution: Use huge stone quarries of length of 2 meters x width 2 meter x thickness 2 meter (boulders) to support the facade where the collapse occurred.

The second engineering solution: Use inverted recessed beams in the design of the slabs to compensate for the column loads that were in the engineering design plan. The length of the beam is 19 meter x width 0.70 meter x thickness 1.40 meter.

Figure 4.34 and Figure **4.35** show the supporting process that was put in place, and the beams that were used in the solution.

This failure had the following insights from different professional engineers who were informed with the collapse; used steel bars were of various kinds; and sheet piles were used to avoid collapses at initial stage of excavation. The soil testing laboratory had an important role, and the engineer had another role in the design. The laboratory was responsible for soil testing and the determination of the embedment sheet pile length inside the ground. The free height of the pile determines the embedment length that may reaches 40-60 % of its length and it could be increased according to several factors including: the soil properties, loads on the pile and the lateral pressure. The design engineer’s role was to determine the pile diameter and the distance between piles. The above information is usually known before starting the excavation. The collapse length was 29 meters, its width was 4 meters and its height was 6 meters or more. According to the investigations, the results were as following: The collapse happened in the wall consisted of pillars because of the excavations were not as the engineering laws and procedures without taking any safety measures into considerations, inadequate supporting with a gap resulting in the weakness of the wall, and the piles were not deep enough to support the soil. It is clear that the piles were constructed with insufficient embedded length in the soil substrata to avoid overturning.

The proposed solution to avoid the collapse was adequate supporting with preventative measures under the engineering supervision based on approved schedules from the Palestinian Engineering Association. Also, it was suggested to make what is called a (top down system) in order to avoid the collapse according to engineering laws.

Figure 4.32: Construction Site Failure

Figure 4.33: Impact of Construction Site Failure

Figure 4.34: First Solution by Supervising Office

Figure 4.35: Second Engineering Solution to Construction Site Collapse

Case Five: Nablus city – Tell Village street. 24-02-2020

A governmental kindergarten was built on Tell Street of Nablus city. On 24-02-2020, a ceiling fall during casting concrete in the governmental kindergarten occurred. The damage was material with no human injuries. The main reason was the inadequate supporting beams and formwork. The procedures were not according the engineering measurements. In another words, the loads were more than the carriers can withstand, which resulted in the ceiling collapse.

Figure 4.36: Ceiling Collapse During Concrete Casting

Case Six: Al-Basateen street near Al-Safa Bank. 21-07-2019

Al-Basateen region in Nablus city had witnessed a failure during construction. This region is well known of its clayey soil as it was for agricultural purposes historically in Nablus. The failure occurred on the opposite corner of Al-Safa bank. The reason for the accident was the collapse of the wall with piles in which these were not in an adequate depth. The collapse resulted from the extra pressure on the road from the moving traffic. This load was transferred to the soil which pressured the wall that does not have enough supporting beams. As a result, a collapse occurred.

Figure 4.37: Al-Basateen Street Failure

Case Seven: Nablus city – Nablus Al-Jadeedah. 01-03-2019.

Nablus Al-Jadeedah presented the newest addition to the Nablus city. Expansion of the city of Nablus looked to additional regions for citizens to invest in. Buildings were constructed on this new region but collapses also occurred. The accident had happened because of the neighboring excavations to 7 meters depth without suitable planning and without any supporting precautions. The collapse caused damages in the adjacent building and penetrates in an adjacent small wall. The building was evacuated, and no injuries were recorded.

Figure 4.38: Nablus Al-Jadeedah Failure

Case Eight: Qalqilya city. 02-06-2019.

Qalqilya city had witnessed collapses too. It is true that the number of failures were lesser than those in Nablus and Hebron cities because the complicated nature of the latter two, but Qalqilya witnessed a collapse of a wall on 02-06-2019. The collapse of a wall while being constructed was because of inadequate supporting wood panels and formwork. The investigations showed that the reasons could be resulted from the rapid casting with concrete which caused pressure on the wall which does not have a proper formwork.

Figure 4.39: Qalqilya Failure

Case Nine: Ramallah city - Al-Terah suburb. 16-04-2015.

Heavy rains and ice caused the collapse of a part of the street in Al-Terah suburb in Ramallah city. The street was in danger of falling six months before the incident due to the construction works in the region. The huge collapse happened and caused soil and rocks falls towards an adjacent house. Human disaster had been avoided because of a wall that the house owner had built earlier. The citizens in the early morning of the collapse day astonished of the street collapse which caused a hole of more than five meters high. Municipality closed the street. Citizens were unsatisfied that the street had not been fixed during the construction works in the site.

According to citizens, the reasons for collapse were land driftage and Municipality ignorance to maintain the street.

Figure 4.40: Al-Terah Failure

Figure 4.41: Impact of Al-Terah Failure

Figure 4.42: Impact of Failure on Supporting Walls

Figure 4.43: Scale of Al-Terah Failure

Summary of Failure Cases in West Bank

The case studies mentioned earlier are part of the failures occurred in West Bank. The reasons for failures for the mentioned cases can be summarized in three main reasons which could be mitigated by true engineering supervision. The first is neglecting the site investigation. The second is improper formwork and support during construction. The last one is improper excavation procedures. Table 4.10 represents a summary of failures that occurred in West Bank in the last decade.

Table 4.10: Reported Cases of Collapsed Buildings in West Bank for a Period of 10 Years (2010-2020)

No.	Location	Date	Building Type	Collapse Stimuli	Casualties
1	Hebron city	25/12/2019	Al-Safa Girl Basic School	Improper Excavation adjacent to the building	zero
2	Hebron city	25/02/2020	Retaining wall	Unanticipated weather conditions >> estimating loads improperly	zero
3	Nablus city	15/02/2020	Aseera Street	Mistakes in executing the construction, and no site investigation	zero
4	Nablus city	27/07/2019	Piles wall	Soil type near excavation >>improper design of sheet piles	zero
5	Nablus city	24/02/2020	Governmental kindergarten	Inadequate supporting beams and formworks	2 Injured
6	Nablus city	11/11/2015	Ceiling collapse during construction	The lack of sufficient formwork supports	8 Injured
6	Nablus city	21/07 /2019	Al-Basateen street	Collapse of the wall with piles	zero
7	Nablus city	23/12/2015	Ceiling of a Masjed collapsed during construction	The lack of sufficient formwork supports	10 injured
8	Nablus city	1/3/2019	Retaining wall	Absence of walls in the site and excavation	zero
9	Nablus city	2/7/2014	Ceiling of house collapse	Heavy loads of the second floor	6 injured
10	Qalqilya city	2/6/2019	Retaining wall	There are no adequate supporting wood panels	zero
11	Ramallah city	16/04/2015	Al-Terah suburb street	Heavy rains and ice caused the collapse >> estimating loads	zero

				improperly	
12	Hebron city	16/05/2020	Ceiling of house collapse during construction	Heavy load and the lack of supporting estimating loads improperly	zero
13	Salfit city	18/04/2020	Facade brick wall	Heavy loads caused the collapse estimating loads improperly	2 Injured
14	Salfit city	4/6/2014	Ceiling of factory collapse during construction	The ceiling is over 9 meters high and the support is weak	10 injured
15	Jerusalem	14 /02/2020	Old house	Excavations of the Israeli occupation	zero
16	Jenin city	10/12/2019	A collapsed street in the Yamoun area	Soil erosion and heavy rain	zero
17	Jenin city	18/08/2019	The fall of a high-pressure electric tower	Excavations by neighbors	zero

Discussion

Validity

Validity of the Questionnaire

To ensure the validity of the questionnaire, it was rated by a jury of experts in the field of engineering at An-Najah National University. The respondents' comments and the jury's suggestions were taken into consideration to modify and improve the questionnaire's content and phrasing by omitting, adding, or rephrasing items. This procedure resulted in bringing the number of items in the questionnaire to 14 items.

Reliability of the Questionnaire

The reliability of the questionnaire as calculated through Cornbach Alpha formula for the total degree was (0.844) which is acceptable for conducting the research.

Procedure

The final draft of the questionnaire was given to a study sample at West Bank. It took about five weeks for the questionnaire to be distributed, collected, and returned to the researchers. The total number of the returned questionnaires was 30 and four questionnaires have been excluded as their responses were neither consistent nor complete.

Limitations

Sample size is the main limitation as statistical tests normally require a larger sample size to ensure a representative distribution of the population to be considered representative. The following consideration should be stated:

1. Lack of available and reliable data because of the lack of cooperation of the people involved in the cases where failures occurred. This lack of cooperation is due to their fear of reopening the topic. Self-reported data is limited regardless whether the researchers are relying on pre-existing data or conducting a qualitative research study or gathering the data. Self-reported data is limited by the fact that it can rarely be independently verified. In other words, the researcher must take what people say for granted, whether in interviews, focus groups, or on questionnaires. Self-reported data can contain several potential sources of bias that the researcher should be alert to and note as limitations.
2. COVID 19 virus was one of the most important obstacles in the scientific research process for this thesis. It was not possible to transport between the governorates to obtain enough information for this research, and the continuous closures resulted in not obtaining the adequate amount of information to support the research.
3. Incorporation of related parties resulting in hardening the process to get information.

Discussion of Research Questions

This study aimed at identifying reasons behind the collapse of buildings in West Bank that are under construction. It also aimed at identifying the effect of demographic variables on the responses of the questionnaire. To accomplish the aims of the study, the researcher analyzed the data in accordance with the study questions and the results were as follows:

Results related to the First Question:

What are the reasons behind the collapse of buildings in West Bank that under construction?

Table 4.11: Means, Standard Deviations and Estimated Level of Means, Standard Deviations and Estimated Level of the Reasons Behind the Collapse of Building in West Bank Under Construction.

No.	No. in the Questionnaire	Item	Means	standard deviations	Percentage %	Estimated level
1.	3	Soil type where building is constructed	3.50	.77	87.5	High
2.	4	Improper support during construction	3.20	.99	80.0	High
3.	14	Execution errors and non-conformance with schedules	3.16	.87	79.0	High
4.	8	Errors in the engineering design	3.13	1.04	78.0	High
5.	2	Concrete quality	3.13	.81	78.0	High
6.	5	Inadequate engineering supervision	3.13	.86	78.0	High
7.	13	Lack of experience and knowledge ins site management	2.96	.88	7.40	Moderate
8.	6	Construction material deficiency	2.80	.96	70.0	Moderate
9.	12	Culture of local constructions	2.70	1.14	67.5	Moderate
10.	1	Steel and reinforcement quality	2.66	.84	66.5	Moderate
11.	10	Improper excavations	2.63	.96	65.8	Moderate
12.	11	Weather conditions in work sites	2.36	.85	59.0	Moderate
13.	7	Rapid concrete casting	2.30	.83	57.5	Moderate
14.	9	Insufficient lighting	1.90	.71	47.5	Low
Total			2.82	.49	71.0	Moderate

Table 4.11 shows that the total degree for the reasons behind the collapse of buildings in West Bank under construction was (2.82) which suggests moderate level of estimation. The highest mean was given to the item (Soil type where building is constructed). The lowest was for the item (Insufficient lighting).

Results related to Second question:

Are there any significant statistical differences at (α =0.05) in the response degree regarding the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age, and the capital of the company?

To answer this question, study hypotheses have been analyzed by using independent sample t tests and One-Way ANOVA test was used. Table 4.12 – Table 4.24 present the results.

Results related to the first hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age.

To test this hypothesis, One Way ANOVA test was used. Results are as follows:

Table 4.12: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Age

Age (Total Degree)		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	20-29	13	2.94	.41
	30-39	11	2.74	.48
	40-49	2	2.39	1.26
	50-59	2	3.00	.20
	60 and more	2	2.82	.55
	Total	30	2.82	.49

Table 4.13: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Age

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	.701	4	.175	.682	.611
	Within Groups	6.418	25	.257		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.13 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age. The significant value was (.611) which is more than (.05).

Results related to the second hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of gender.

To test this hypothesis, Independent sample t test was used.

Table 4.14: Independent Two Sample t Test Result of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Age

	Age	N	Mean	S. D	t	Sig.*
Total degree	Male	19	2.81	.50	-.236	**.815**
	Female	11	2.851	.49		

***. The mean difference is significant at the 0.05 level.**

Table 4.14 shows that there are no significant statistical differences at (α =0.05) in the response’s degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of gender. The significant value was (.815) which is more than (.05).

Results related to the third hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of career.

To test this hypothesis, One Way ANOVA test was used.

Table 4.16 shows that there are no significant statistical differences at (α =0.05) in the response’s degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of career. The significant value was (.694) which is more than (.05).

Results related to the fourth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of experience.

To test this hypothesis, One Way ANOVA test was used.

Table 4.18 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of experience. The significant value was (.572) which is more than (.05).

Table 4.15: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Career

Career (Total Degree)		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	Academic	3	2.85	.93
	Supervisor	17	2.91	.36
	Project Engineer	7	2.67	.65
	Owner	3	2.66	.41
	Total	30	2.82	.49

Table 4.16 Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Career

The reasons behind the collapse of buildings in West Bank that are under construction	Source of variance	Sum of Squares	df	Mean Square	F	Sig.
Total	Between Groups	.379	3	.126	.488	.694
	Within Groups	6.739	26	.259		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.17: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Experience

Experience (Total Degree)		N	Mean	S.D
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	10	2.85	.44
	6-10	9	2.83	.54
	11-15	4	2.46	.75
	16-20	3	3.07	.18
	More than 20	4	2.92	.37
	Total	30	2.82	.49

Table 4.18: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Experience

The reasons behind the collapse of buildings in West Bank that are under construction	Source of variance	Sum of Squares	df	Mean Square	F	Sig.
Total	Between Groups	.756	4	.189	.743	.572
	Within Groups	6.362	25	.254		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Results related to the fifth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of period of building.

To test this hypothesis, One Way ANOVA test was used.

Table 4.20 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of period of building.

The significant value was (.148) which is more than (.05).

Results related to the sixth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of building age.

To test this hypothesis, One Way ANOVA test was used.

Table 4.19: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Period of Building

***Period of building* (Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	15	2.88	.47
	6-10	2	3.10	.05
	11-15	2	2.07	.80
	16-20	2	3.17	.45
	More than 20	9	2.76	.42
	Total	30	2.82	.49

Table 4.20: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Period of Building

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.636	4	.409	1.865	.148
	Within Groups	5.483	25	.219		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.21: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Building Age

***Buildingage* (Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	16	2.95	0.42
	6-10	4	2.37	0.85
	16-19	2	2.75	0.15
	20 and more	8	2.83	0.39
	Total	30	2.82	.49

Table 4.22: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Building Age

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.075	3	.358	1.541	.228
	Within Groups	6.044	26	.232		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table **4.22** shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of building age.

The significant value was (.148) which is more than (0.05).

Results related to the seventh hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of company capital.

To test this hypothesis, One Way ANOVA test was used. Table 4.24 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of company capital. The significant value was (.254) which is more than (.05).

Table 4.23: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Company Capital

Buildingage **(Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	Less than 100000	6	2.63	.66
	100,000-150,000	7	2.64	.47
	160,000-200,000	5	2.94	.31
	300,000-400,000	9	2.87	.46
	500000 and more	3	3.33	.14
	Total	30	2.82	.49

Table 4.24: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Company Capital

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.323	4	.331	1.427	.254
	Within Groups	5.795	25	.232		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Major Findings

The DMAIC model can play a major role as a quality management approach to mitigate hazards for the risks of collapse of buildings. This model defines the issues related to the building collapse, measures their impact on the construction industry and humans, analyzes the results, improves the performance, and controls the outcomes. This technique mitigates the hazards for the risks of collapse of buildings.

The results of the current study reveal that the total degree of the reasons behind the collapse of buildings in West Bank that are under construction suggests a moderate level of responses. The highest mean was given to the item "Soil type where building is constructed”. On the other hand, the lowest mean was given to the items "Insufficient lighting".

The researcher due these results concludes that the collapse of buildings in West Bank is of a considerable concern. The moderate level suggests precautious actions needed to be implemented to avoid an increase probability of building failures.

The highest reasons for the collapse of buildings in West Bank that are under construction are soil type where building is constructed, Improper support during construction, and execution errors and non-conformance with schedules. These factors were among the top ones in the questionnaire, and they are the main reasons for the case studies explained earlier.

The researcher due these results suggests that site investigation procedures need to be an essential requirement before providing permits or licenses from the official parties. Also, a true supervision is a mandate to eliminate other reasons for failures in the buildings. The most frequent reasons for failure could be easily handled with true experienced engineering supervision.

The moderate reasons for The reasons behind the collapse of buildings in West Bank that are under construction are errors in the engineering design, Concrete quality, Inadequate engineering supervision, Lack of experience and knowledge in site management, Construction material deficiency, Culture of local constructions, Steel and reinforcement quality, Improper excavations, Weather conditions in work sites, and Rapid concrete casting.

The lowest item that impacts the rate of building failures was insufficient lighting. The researcher due this result thinks that the current construction industry can work efficiently regardless the time of day or night. This is achieved by the help of the newer technologies of lighting and construction industry.

Also, There are no statistically significant differences at ($\alpha = 0.05$) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age and the capital of the company.

The researcher due to these results believes that common mistakes in construction industry are well-known. The next steps are to handle these well-known issues to mitigate their occurrence in the future. The legal and engineering authorities need to foster actions that limit the influence of these issues in the field of construction industry.

Chapter 5

Summary, Conclusions, and Recommendations

Investigation of the reasons of building failures in West Bank was studied thoroughly in this thesis. In the last decade, the number of collapsed buildings or prone to collapse increased rapidly in West Bank. Several methods are conducted by the researcher to address the topic. These methods include distributing a well-prepared questionnaire for constructions were failures occurred. The questionnaire targeted both Nablus and Hebron cities, and around 30 questionnaire responses were obtained. The responses were further analyzed using appropriate statistical programs and procedures to highlight key reasons for building collapses. Several interviews were conducted with stakeholders of the collapsed buildings. The reasons for failures for these buildings were explained simply with concise. Two failure cases were further analyzed using engineering codes and programs. The failure reasons were explained scientifically, and the premature failures were possible to be avoided by adhering to simple engineering principles. Finally, the DMAIC model was discussed as a quality management approach to mitigate the hazards for the risk of the collapsed buildings.

The researcher concludes the following:

- The collapse of buildings in West Bank is of a considerable concern. The analysis revealed a moderate level of concern. This level suggests precautious actions needed to be implemented to avoid an increase probability of building failures.

- The highest reasons for the collapse of buildings in West Bank that are under construction are Soil type where building is constructed, Improper support during construction, and Execution errors and non-conformance with schedules.

- Insufficient lighting is not a real concern that causes a failure during construction. This fact is because the current construction industry can work efficiently regardless the time of day or night. This is achieved by the help of the newer technologies of lighting and construction industry.

- There are no statistically significant differences at ($\alpha = 0.05$) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age and the capital of the company. This fact shows that the reasons of failures for buildings under construction are well known by the engineering community and construction industry professionals.

- The DMIAC model can play a role in mitigating the risks of the collapsed building. It uses a thorough approach to understand the failures of buildings and suggests improvements and controls base on the analysis done for the measured characters related to the building failures.

The main recommendations are as following:

- Site investigation procedures need to be an essential requirement before providing permits or licenses from the official parties.

- True supervision is a mandate to eliminate and reduce the frequency of failures in the buildings under constructions. The most frequent reasons for failure could be easily handled with true experienced engineering supervision. This supervision mitigates the failures in buildings through applying correct procedures, reducing the use of improper materials, and handling the unexpected construction situations using the right procedures, techniques, and using the appropriate engineering codes.
- There is a need to apply periodical investigation for plans and construction works through the municipalities and Palestinian Engineering Association – Jerusalem Center before and during the implementation of works.
- There is a need to have a local construction code that considers specific loadings and conditions that could be applied in Palestine. This code can be adopted by the design engineers and the official agencies that review the technical drawings for approval.

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Appendices

Appendix A: Questionnaire

بسم الله الرحمن الرحيم

استبيانة هندسية

الأخوة الكرام.....

أنا الطالب عوني خليل مشعل ضمن سياق مشروع بحثي في كلية الدراسات العليا قسم الإدارة الهندسية جامعة النجاح الوطنية ,أقوم   بعمل دراسة تحت اشراف الدكتور رياض عبد الكريم عوض حول :

التحقيق في اسباب انهيار المباني قيد الانشاء في الضفه الغربيه."

كما و تهدف هذه الاستبيانة إلى دراسة واقع إجراءات الانهيارات ومعرفة اهم الاسباب التي تؤدي الى انهيار المباني والطرق والمنشات بشكل عام، و لإتمام متطلبات الدراسة.

لذلك نرجو تعبئة هذا الاستبيان بدقه حيث أن نتائج هذه الدراسة ستستخدم لأغراض البحث العلمي فقط, و لن يكون بالإمكان معرفة هوية المشاركين في تعبئة هذا الاستبيان.

شاكرا لكم حسن تعاونكم معنا

2019/2020

القسم الأول:

معلومات عامة :

الرجاء الإجابة على هذه الأسئلة بوضع إشارة (X) امام الخيار الذي يناسبك.

العمر:1 ◯ 20–29 2 ◯ 30 – 39 3 ◯ 40 – 449 ◯ 50–59 5 60 فما فوق ◯

الجنس : 1 ◯ ذكر 2 ◯ انثى

عملك الوظيفي : 1 ◯ مدير مشروع 2 ◯ مهندس مشرف

3 رئيس ورشة 4 ◯ دكتور أكاديمي ◯

عدد سنوات الخبرة : 1 ◯ (1- 5) 2 ◯ (6- 10) 3 ◯ (11- 15)

4 ◯ (16- 20) 5 ◯ 20سنه او اكثر

القسم الثاني : الوضع العام عن المباني حصل فيها انـهيار :

A) المده الزمنيه على انشاء المبنى ؟ 1 ◯ 1-5 2 ◯ 6-10 3 ◯ 16-19

4 11-15 5 ◯ 20سنه او اكثر ◯

B)عمر المبنى الذي حصل فيه انهيار ؟ 1 ◯ 1-5 2 ◯ 6-10

3 ◯ 16-19 4 ◯ 20سنه او اكثر

C) راس مال المنشاه ؟ 1 ◯ اقل من 100000 ◯ 100000-150000 3 -200000

160000 ◯ 4 ◯ 300000-400000 ◯ 5 500000 او اكثر

<u>القسم الثالث :</u>

أسئلة تتعلق بأهم العوامل المؤثرة على جودة العملية الانشائيه :

الرجاء وضع إشارة (X) مقابل الإجابة التي تناسبك:

الرقم	البند	قليل التأثير 1	متوسط 2	مؤثر 3	مؤثر جدا 4
1	نوعية الحديد المستخدم في عملية البناء				
2	نوعية الباطون المستخدم اثناء الصب				
3	نوعية التربه التي يتم البناء عليها				
4	الاستهتار بكيفية وضع الدعمات الخشبيه من قبل العمال				
5	سوء الاشراف الهندسي				
6	وجود خلل في المواد الانشائيه المستخدمه				
7	سرعة الصب في الموقع				
8	وجود اخطاء في التصميم الهندسي				
9	عدم وجود الإضاءة المناسبة خلال فترة العمل				
10	الحفر بطريقه غير سليمه للتربه مما يؤدي لضرر للمباني المجاوره				
11	الظروف الجويه المحيطه بموقع العمل				

12	الثقافه المحليه للناس بالنسبه لعملية البناء				
13	قلة الخبرة و المعرفه في ادارة الموقع				
14	وجود أخطاء في عملية التنفيذ				

Appendix B: Statistical Analysis

RELIABILITY /VARIABLES=q1 q2 q3 q4 q5 q6 q7 q8 q9 q10 q11 q12 q13 q14 t /SCALE ('ALL VARIABLES') ALL /MODEL=ALPHA.

Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
.844	15

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
q3	30	1.00	4.00	3.5000	.77682
q4	30	1.00	4.00	3.2000	.99655
q14	30	1.00	4.00	3.1667	.87428
q8	30	1.00	4.00	3.1333	1.04166
q2	30	1.00	4.00	3.1333	.81931
q5	30	1.00	4.00	3.1333	.86037
q13	30	1.00	4.00	2.9667	.88992
T	30	1.50	3.50	2.8286	.49544
q6	30	1.00	4.00	2.8000	.96132

q12	30	1.00	4.00	2.7000	1.14921
q1	30	1.00	4.00	2.6667	.84418
q10	30	1.00	4.00	2.6333	.96431
q11	30	1.00	4.00	2.3667	.85029
q7	30	1.00	4.00	2.3000	.83666
q9	30	1.00	3.00	1.9000	.71197
Valid N (listwise)	30				

ONEWAY t BY Age /STATISTICS DESCRIPTIVES /MISSING ANALYSIS

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
20-29	13	2.9451	.41869	.11612	2.6920	3.1981	1.79	3.36
30-39	11	2.7403	.48684	.14679	2.4132	3.0673	2.00	3.50
40-49	2	2.3929	1.26269	.89286	-8.9520-	13.7377	1.50	3.29
50-59	2	3.0000	.20203	.14286	1.1848	4.8152	2.86	3.14
60 and more	2	2.8214	.55558	.39286	-2.1703-	7.8132	2.43	3.21
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.701	4	.175	.682	.611
Within Groups	6.418	25	.257		
Total	7.118	29			

T-TEST GROUPS=Gender (1 2) /MISSING=ANALYSIS /VARIABLES=t /CRITERIA=CI (.95).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
t	Equal variances assumed	.304	.586	-.236-	28	.815	-.04511-	.19084	-.43603-	.34580
	Equal variances not assumed			-.238-	21.444	.814	-.04511-	.18957	-.43886-	.34863

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
t	Male	19	2.8120	.50799	.11654
	Female	11	2.8571	.49590	.14952

ONEWAY t BY Career /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Onaway

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Academic	3	2.8571	.93405	.53927	.5368	5.1775	1.79	3.50
Supervisor	17	2.9160	.36267	.08796	2.7295	3.1024	2.00	3.36
Project Engineer	7	2.6735	.65186	.24638	2.0706	3.2763	1.50	3.21
Owner	3	2.6667	.41239	.23810	1.6422	3.6911	2.43	3.14
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.379	3	.126	.488	.694
Within Groups	6.739				
Total	7.118	29			

ONEWAY t BY experience /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	10	2.8571	.44032	.13924	2.5422	3.1721	1.79	3.29
6-10	9	2.8333	.54632	.18211	2.4134	3.2533	2.00	3.50
11-15	4	2.4643	.75930	.37965	1.2561	3.6725	1.50	3.07
16-20	3	3.0714	.18898	.10911	2.6020	3.5409	2.86	3.21
5.00	4	2.9286	.37796	.18898	2.3271	3.5300	2.43	3.29
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.756	4	.189	.743	.572
Within Groups	6.362	25	.254		
Total	7.118	29			

ONEWAY t BY Period /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. rror	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	15	2.8857	.47748	.12329	2.6213	3.1501	1.79	
re								

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.636	4	.409	1.865	.148
Within Groups	5.483	25	.219		
Total	7.118	29			

ONEWAY t BY Building /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	16	2.9509	.42755	.10689	2.7231	3.1787	2.00	3.50
6-10	4	2.3750	.85391	.42696	1.0162	3.7338	1.50	3.14
16-19	2	2.7500	.15152	.10714	1.3886	4.1114	2.64	2.86
20 and more	8	2.8304	.39482	.13959	2.5003	3.1604	2.29	3.29
Total	30							

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.075	3	.358	1.541	.228
Within Groups	6.044	26	.232		
Total	7.118	29			

ONEWAY t BY Capital /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

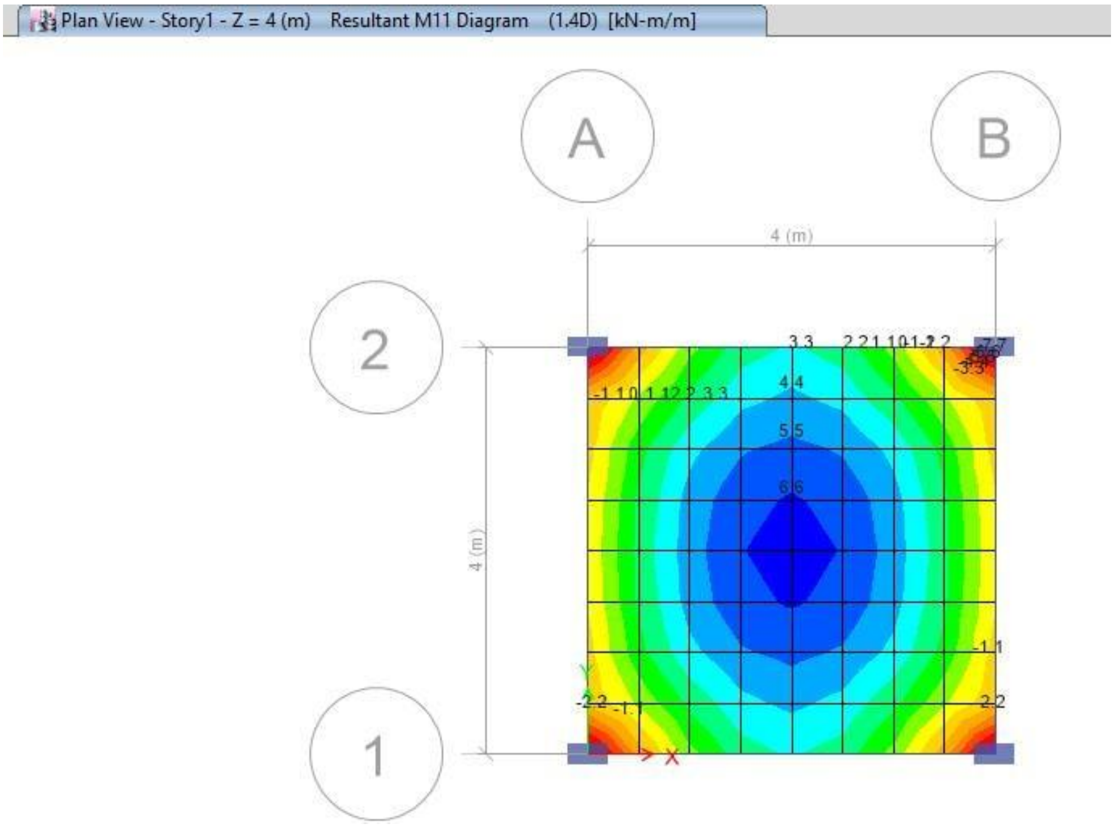
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Less than 100000	6	2.6310	.66611	.27194	1.9319	3.3300	1.50	3.29
100,000-150,000	7	2.6429	.47916	.18110	2.1997	3.0860	1.79	3.07
160,000-200,000	5	2.9429	.31703	.14178	2.5492	3.3365	2.43	3.21
300,000-400,000	9	2.8730	.46809	.15603	2.5132	3.2328	2.00	3.36
500000 and more	3	3.3333	.14869	.08585	2.9640	3.7027	3.21	3.50
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

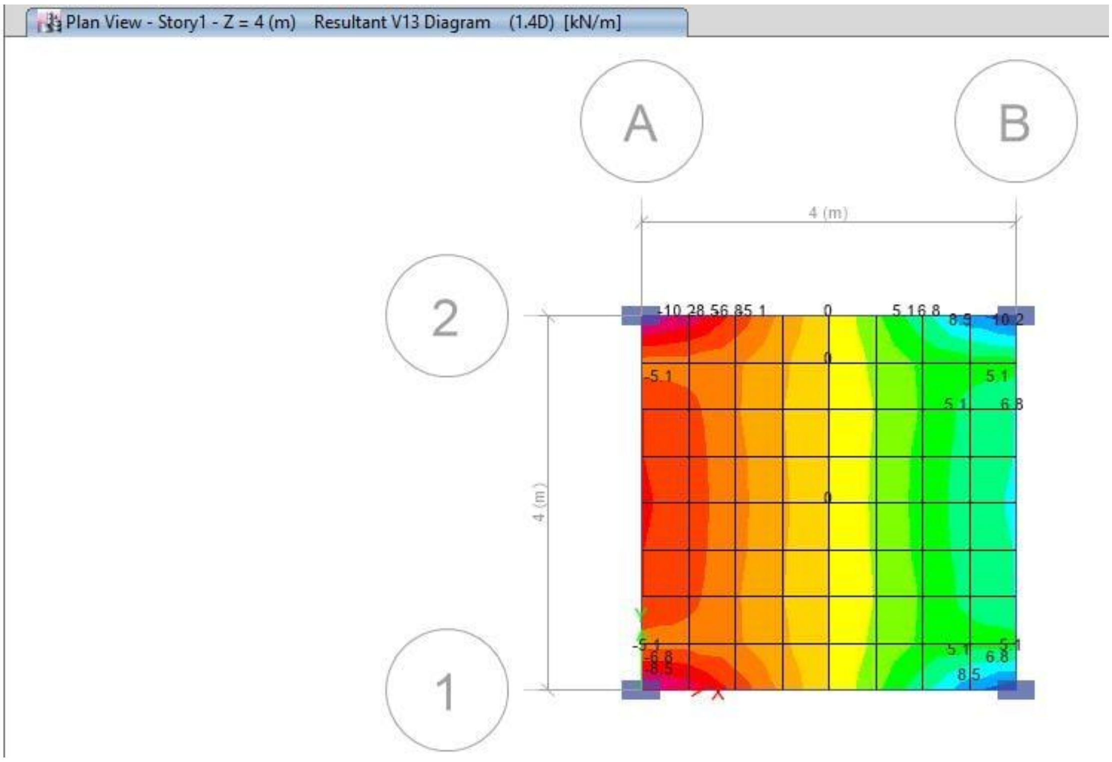
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.323	4	.331	1.427	.254
Within Groups	5.795	25	.232		
Total	7.118	29			

Appendix C: Structural Analysis and Design



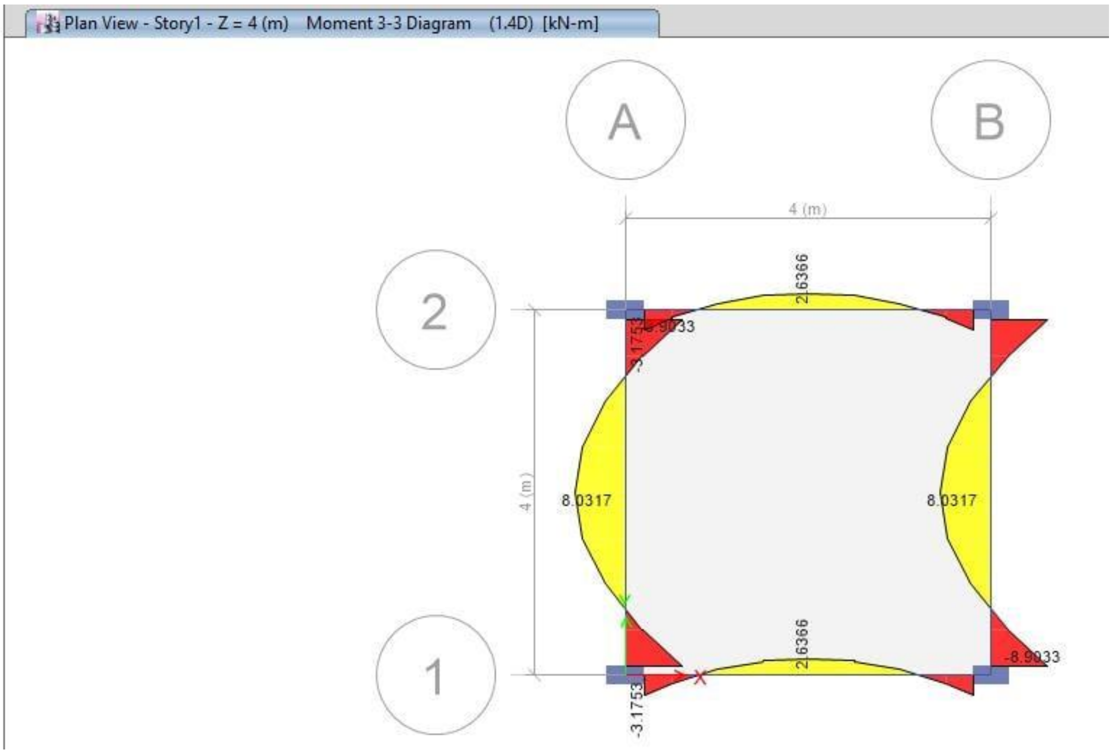
Moment =7 kN/m for slab

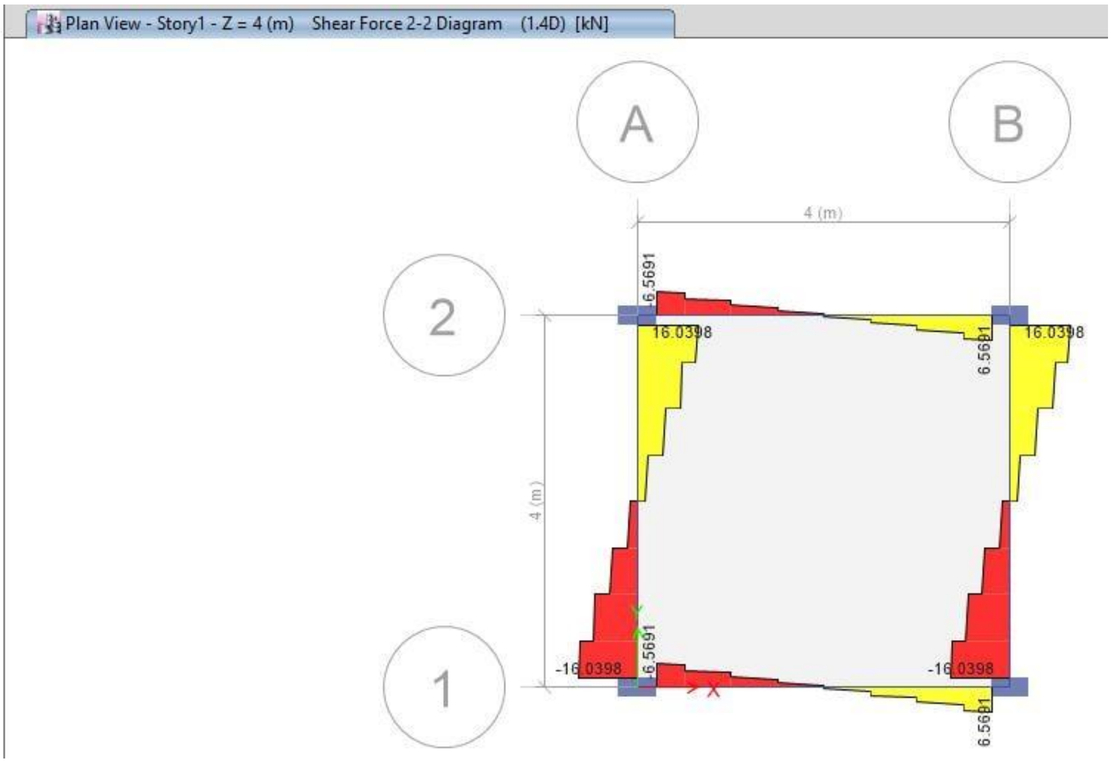
7*0.52= 3.64 kN



Shear for slab =7kN/m

7*0.52= 3.64 kN




Plan View - Story1 - Z = 4 (m) Shear Force 2-2 Diagram (1.4D) [kN]
A
B
4 (m)
2
1
4 (m)
6.5691
16.0398
-16.0398

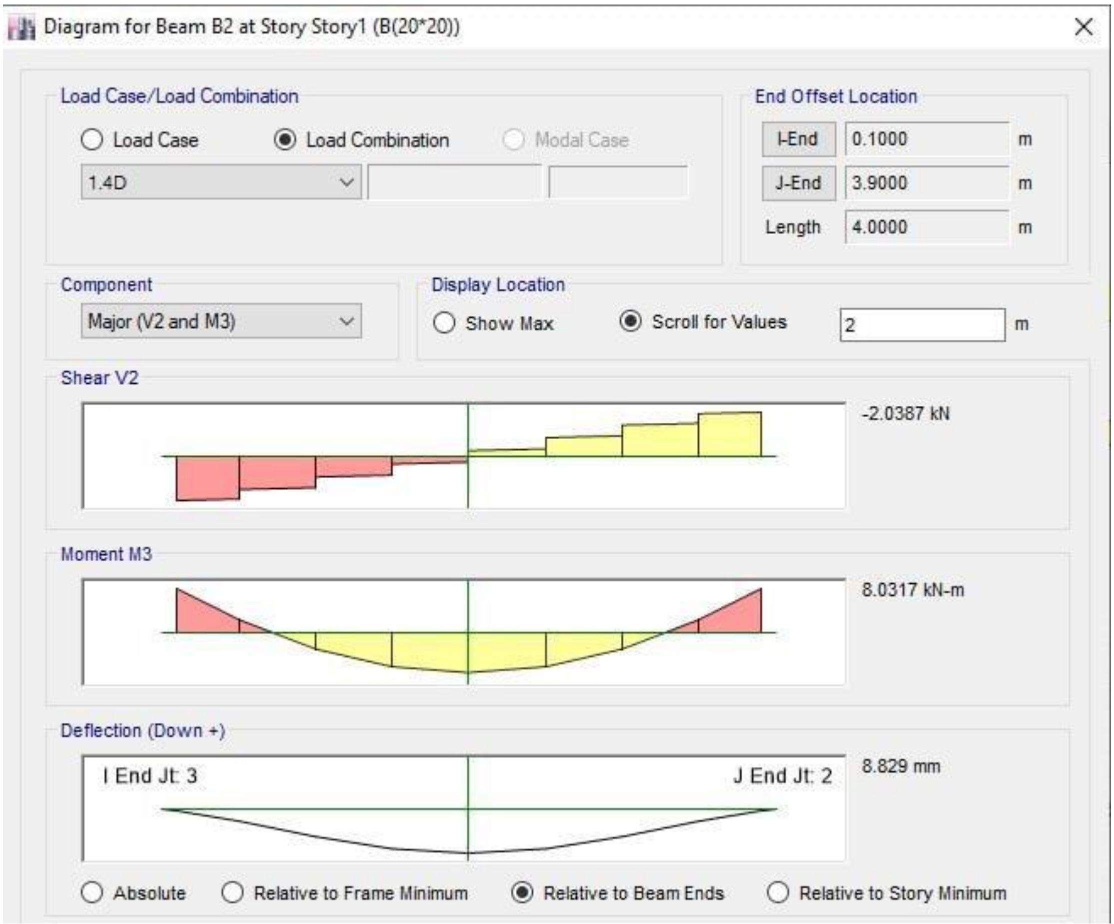
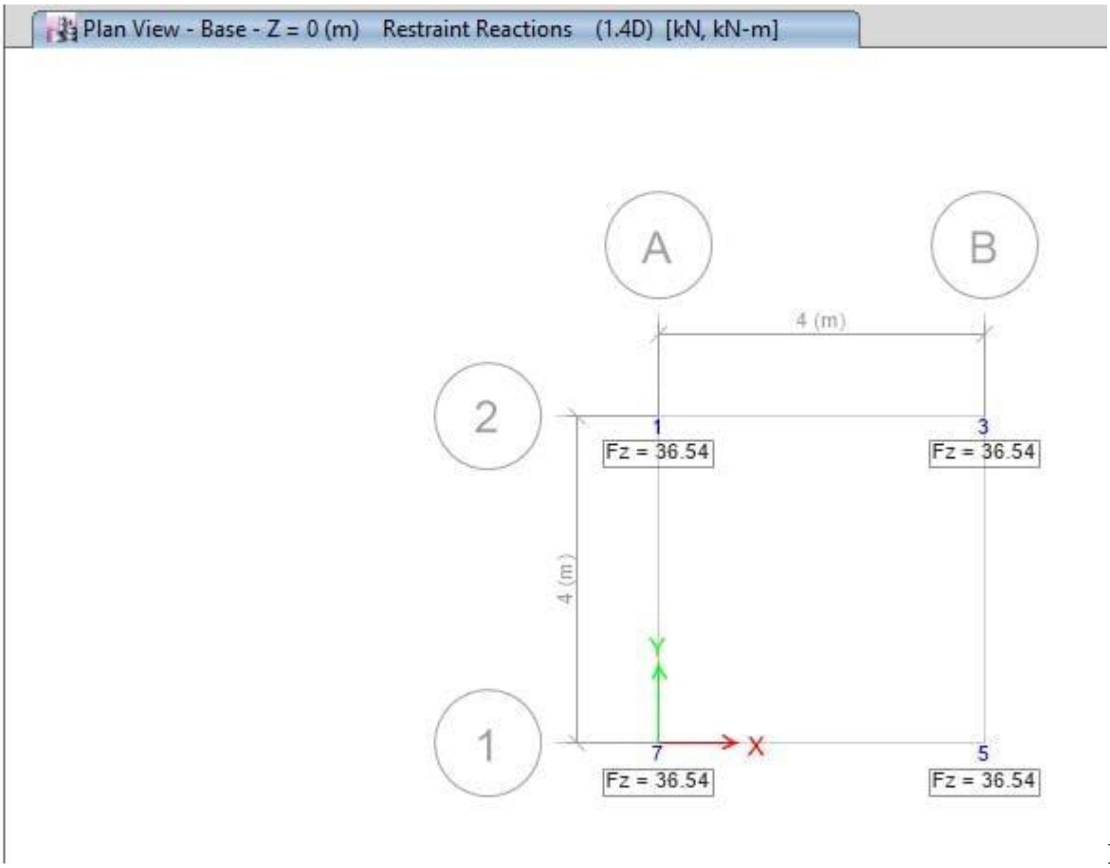


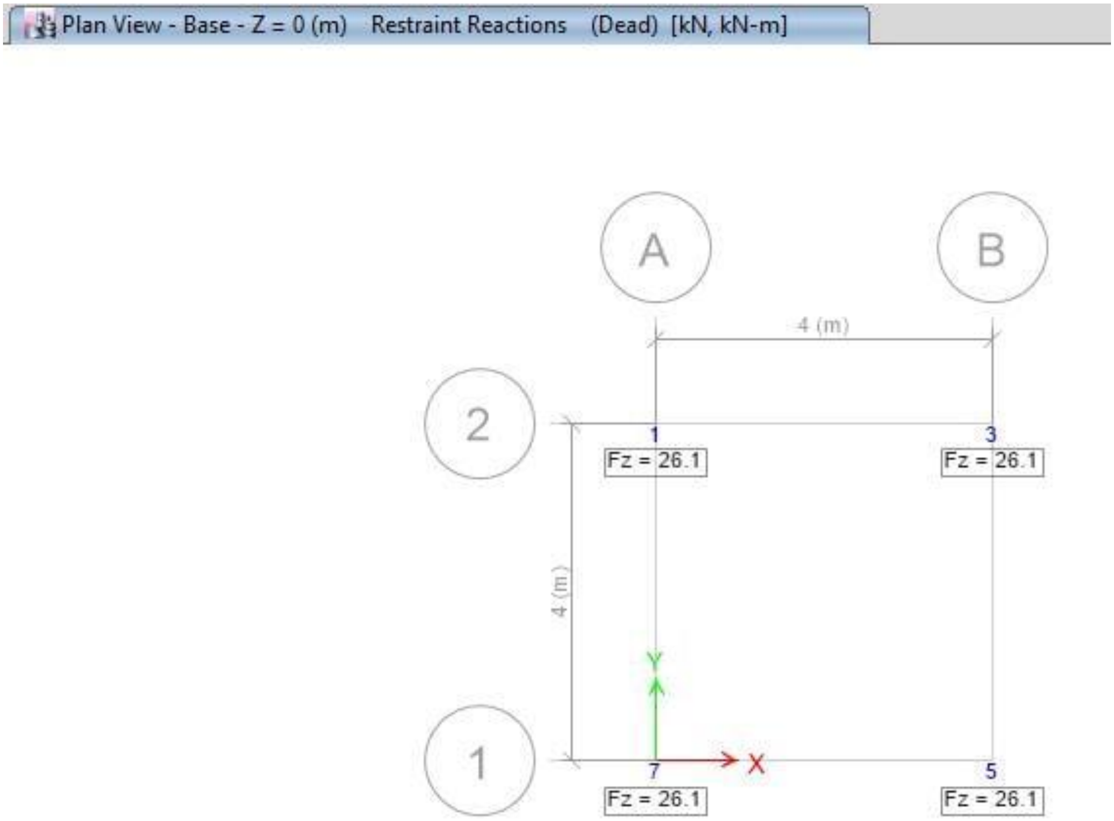
Diagram for Beam B2 at Story Story1 (B(20*20))
Load Case/Load Combination
Load Case
Load Combination
Modal Case
1.4D
End Offset Location
I-End 0.1000 m
J-End 3.9000 m
Length 4.0000 m
Component
Major (V2 and M3)
Display Location
Show Max
Scroll for Values
2 m
Shear V2
-2.0387 kN
Moment M3
8.0317 kN-m
Deflection (Down +)
I End Jt: 3
J End Jt: 2
8.829 mm
Absolute
Relative to Frame Minimum
Relative to Beam Ends
Relative to Story Minimum

Beam details

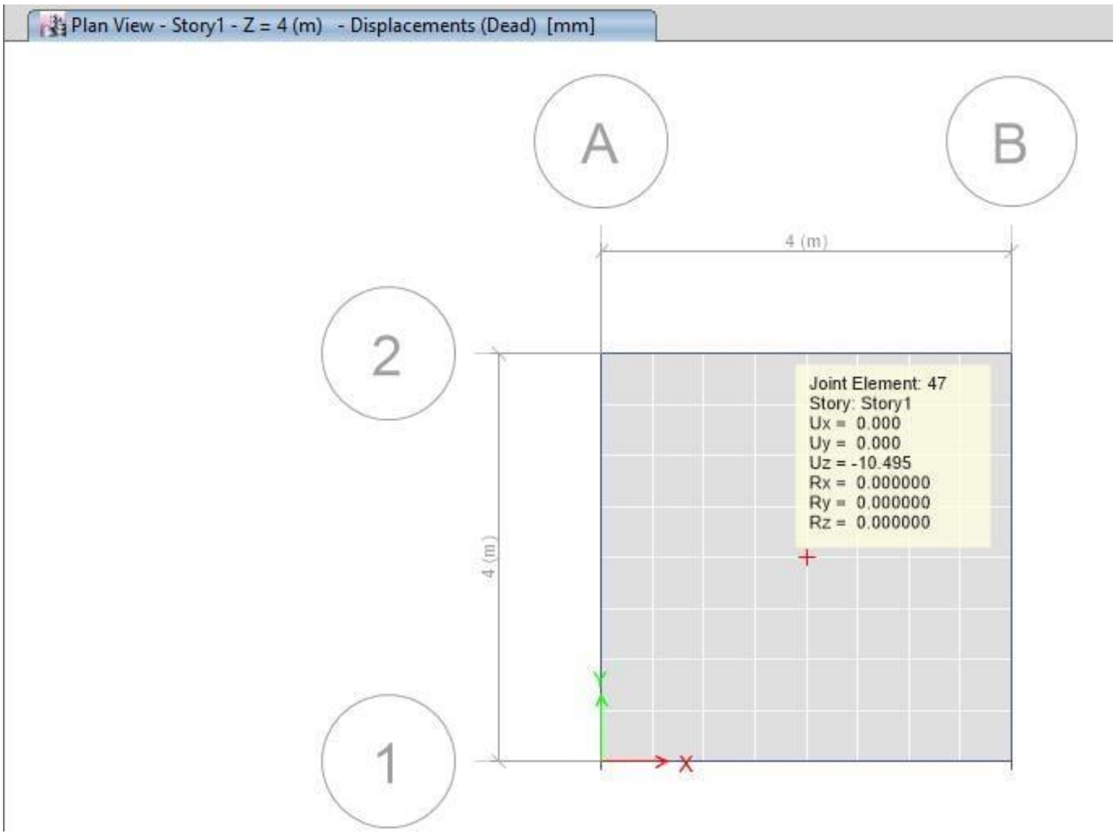


R

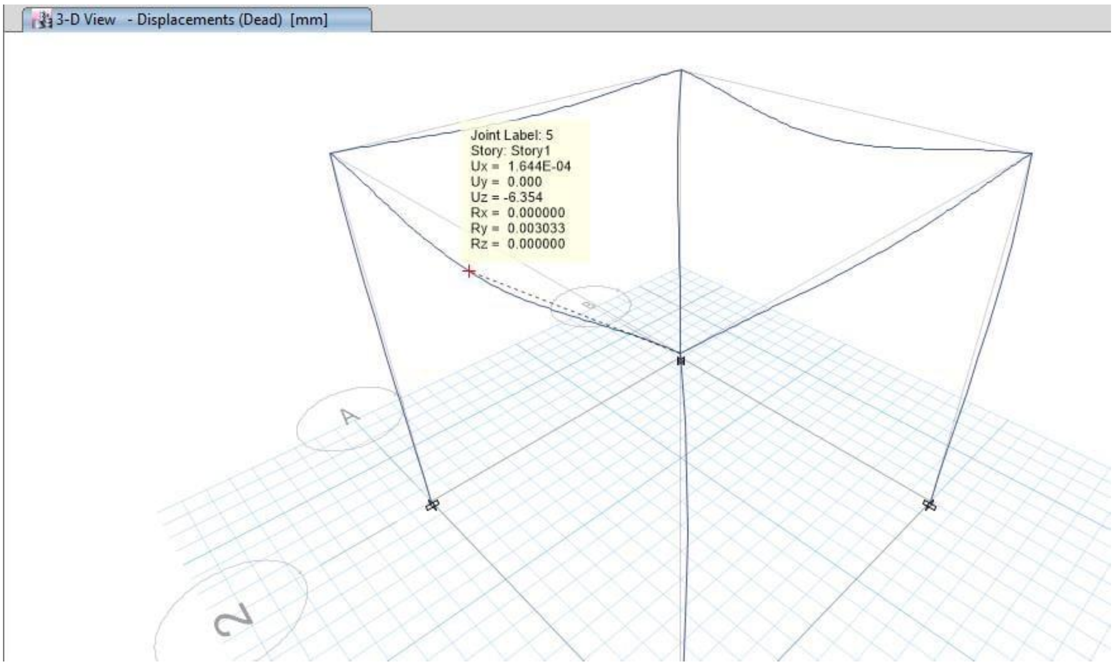
eaction 1.4 D



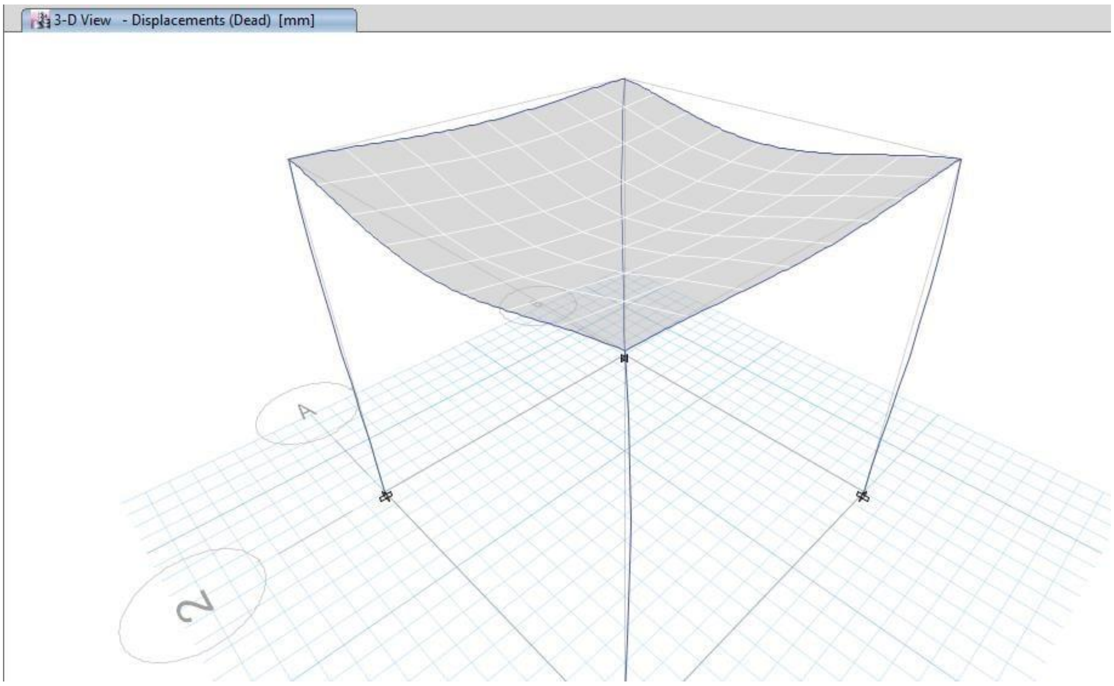
Reaction for dead load



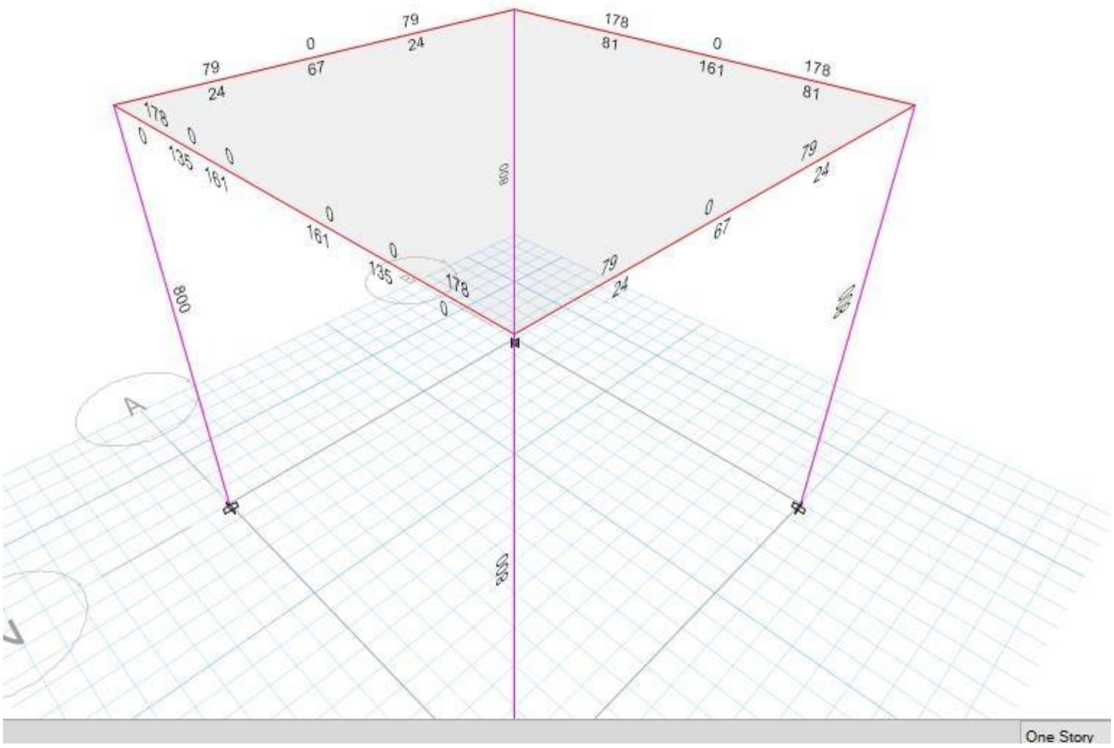
Deflection for slab =10.5 mm



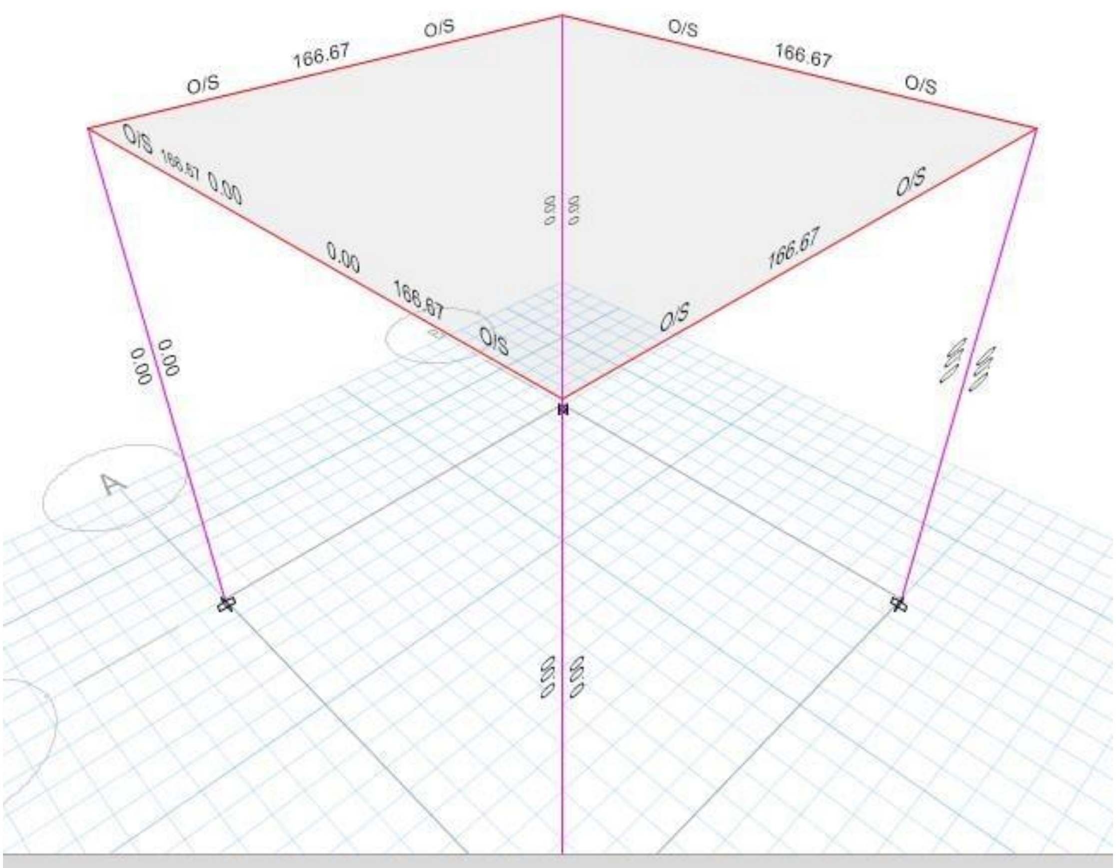
Deflection for beam = 6.35 mm



Shear stress



Area of steel for beams and columns



Shear steel for beams

o/s means over of stress

Note that the shear calculated above is from allowable loads

جامعة النجاح الوطنية

كلية الدراسات العليا

التحقيق في أسباب إنهيار بعض المباني قيد الإنشاء في الضفة الغربية

إعداد

عوني خليل عبد الكريم الدوده

إشراف

د. رياض عوض

قدمت هذه الأطروحة استكمالاً لمتطلبات الماجستير في الإدراة الهندسية بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس.

2021

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إعداد

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الملخص

عملية البناء مهمة لكل البلدان والبشر، المباني تزود الاشخاص بواحدة من اهم الاحتياجات للانسانية، هناك العديد من حالات الانهيار للمباني التي حدثت في الضفة الغربية مؤخرا وبعضها كان خلال عملية الانشاء، دراسة مستفيضة لاسباب الانهيار تم تنفيذها خلال الرسالة، طريقة بحثية مدمجة تم تطبيقها لتحديد العوامل الاساسية التي تؤثر على انهيارات المباني خلال عملية الانشاء، استبيانة منتقاة تم توزيعها على المهندسين والخبراء في مجال الانشاءات، تم تنفيذ تحليل احصائي للبيانات التي تم تجميعها من خلال اجابات الخبراء، وتمت دراسة حالات خاصة من خلال عمل مقابلات واستشارات مع خبراء في هذا المجال، ومن هذه الحالات تم تحليل حالتين بشكل مستفيض باستخدام البرامج والاكواد الهندسية ذات العلاقة، النتائج اشارت الى ان الانهيارات في الانشاءات يجب ان تكون ذات موضع اهتمام في الضفة الغربية، والاسباب الاكثر تاثيرا على انهيار المباني تحت الانشاء في الضفة الغربية هي نوعية التربة المقام عليها المبنى والتدعيم والطوبار الغير مناسبين والاخطاء التنفيذية وعدم الالتزام بالمخططات والمواصفات المطلوبة، وتوصي الرسالة بعمل مراجعات دورية على المخططات واعمال التنفيذ من خلال البلديات ونقابة المهندسين – فرع القدس قبل واثناء تنفيذ الاعمال.

Chapter 1

Introduction

Motivation

Building construction is one of the most important projects that accomplished by humans. Having a comfortable place to live is one of the crucial requirements for people worldwide. As a result, buildings are required to be built with great care and high quality.

Construction industry is hazardous by nature. It comprises a wide range of activities. These tasks involve Building, alteration, and repair [1-4]. Before starting the construction, an adequate design should be prepared to achieve the intended purpose of the construction. A qualified team implements the design and builds the construction. Alteration and repair follow the use of the construction to handle any unexpected circumstances that appear during or after usage.

Many failures of construction occurred over the past. These collapses occurred worldwide and locally here in Palestine. Many accidents occurred in West Bank recently. These failures occurred during construction. For instance, a year ago a building collapsed in Nablus city and caused many injuries to the workers. Construction failures by nature are harmful and needs to be avoided.

It is important to understand the current construction industry in Palestine to address the upcoming challenges in the region. Construction in

Palestine is mostly reinforced concrete structures. The construction process starts by hiring an engineering office to attain the building drawings. The drawings are then certified by the Palestinian Engineering Association – Jerusalem Center and the municipality or local governorate representative in the region of construction. The owner of the building hires then a contractor (or simply builders) to build his/her building. While this is the official way for construction, many buildings were constructed without engineering plans or certification by related agencies. Also, builders in many cases do not adhere to the certified engineering drawings.

Construction industry in Palestine needs to adapt with the challenges in the region. State of Palestine, as part of the Middle East, have been and will be subjected to many serious climate changes. These challenges include; increasing in temperature and sea level rise; changing in snow fall amounts; reduction in the annual rainfall; and adverse hydro-meteorological conditions such as heat waves, droughts, floods, storms. These changes may impact many social and economic aspects of the construction industry [5].

Construction failures have various negative impacts. The reputation of the responsible construction company is lost when a collapse occurs. The loss in the assets magnifies the negative impacts of such failures. The impact of the failures increases if it includes the loss of human lives.

Construction failures are not specific to a certain region in West Bank. Collapses occurred in many governorates including Nablus, Hebron, Jenin, Bethlehem and Tulkarm governorates. The incidents occur while construction is still in progress.

This study focuses on the reasons that lead to the collapse of buildings in Palestine. The study provides solutions and advice to the construction industry in Palestine. The knowledge attained from this research shall improve the quality of construction process and reduce the frequency of occurrence of such primitive failures.

Problem Statement

Some buildings in the West Bank do not follow professional procedures or consultation with construction companies. These buildings are built with no management and quality control from site engineers. Investors of these building do not believe in engineers nor follow their advice. These factors affected the quality of such buildings under construction and the future of construction industry in Palestine. Buildings of this character are more prone to failures than those where professional and engineering consultation is provided.

Reason of failures in Palestine could be initially related to several factors. The complexity of constructions increased. Buildings confront higher loads that were not considered in the past. Citizens save by skipping the design stage and hence lose the possibility of anticipating any issue that affects their buildings beforehand. They do not conduct soil investigation nor look to topographic or geologic formation of the land.

Failures due to unexpected extreme conditions occurred recently in West Bank. Several steel structures were affected by the recent extreme snowfall in 2003. Examples of this case were the failures happened are in Jamaeen stone cutting plants: Geneva Company plant, and the Italian company plant.

Increase in building failures is evident in the last few years in Palestine. These failures caused human and economic losses. Adverse effects were manifested in many sectors related to the construction industry.

The increase in failures frequency in the West Bank in the last decade is concerning. The reasons behind these failures should be noted and understood. The remedies of such failures start by knowing the reason/s behind their occurrence. Currently, there are no records of the reasons behind the collapse of buildings in the West Bank.

This research studies the reasons behind the collapse of some construction buildings in West Bank. This research helps in mitigating the negative effects of failures in buildings by introducing causes for risks during construction. In addition, the study focuses on practical implementation of these solutions in Palestine.

Research statement

Due to the increase of the building failures in West Bank, an objective study is essential to address the reasons for failures and the possible mitigation procedures. The analysis of the previous failures in West Bank casts light on the common reasons for failures. Avoiding the failures could be achieved simply by handling the common reasons of failures. The frequency of failures should decrease immensely by simply dealing with the common failure reasons.

The study assists in improving the decision of the best quality control management strategies and practices in minimizing and mitigating the negative consequences resulting from possible failures in buildings. Therefore, this research answers the following two important questions:

1- What are the main reasons for the collapse of the buildings under construction in the West Bank?

2- Are the results site specific or do the reasons of failures differ based on location?

Research Objectives

The main objectives of this research are:

1. To propose a quality management approach to mitigate hazards for the risks of collapse of buildings.
2. To investigate the causes of failures in buildings.

Chapter 2

Literature Review

General background of Construction Industry

A universal definition of the construction industry might not exit. To properly define the construction industry, it is necessary to look at what exactly constitutes it. In this thesis, construction industry is a heterogeneous process composed of complexity and non-transparency in addition to flexibility and dynamic nature. This is because it has multiple activities, agent's communications natures, documentation size, measuring parameters, and legislation. This industry is characterized by being temporally and unique at product level [6].

The construction Industry includes several construction operations. Some of these operations are the on-site assembly and erection of prefabricated buildings, roads, railroads, aerodromes, irrigation projects, harbor or river works, gas, dams, bridges, tunnels, sewerage, or storm water drains or mains, electricity or other transmission lines or towers, pipelines, oil refineries or other specified civil engineering projects. In general, units mainly engaged in the repair of buildings or other structures are also included as are those engaged in the alteration or renovation of buildings, preparation of mine sites, demolition, or excavation.

Construction has been an aspect of life since the beginning of human existence. The first buildings were huts and shelters constructed by hands or with simple tools. As cities grew during the Bronze Age, a class of professional craftsmen like bricklayers and carpenters appeared. Occasionally, slaves were used for construction work. In the 19th century, steam-powered machinery appeared, and later diesel and electric powered vehicles such as cranes, excavators and bulldozers were used in the construction industry. Traditional construction might be considered as having properly, commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia when humans started to abandon a nomadic existence. This transition leads to the construction of shelters. The construction of Pyramids in Egypt (2700-2500 BC) might be considered the first building practice of a large structure construction. Other ancient historic constructions include the Parthenon by Iktinos in Ancient Greece (447-438 BC), the Apian Way by Roman engineers (312 BC), and the Great Wall of China by General Ming T'ien under orders from Ch'in Emperor Shih Huang Ti (c. 220 BC). Similarly, the Romans developed civil structures throughout their empire including aqueducts, harbors, bridges, dams, and roads.

Necessity is the mother of invention, and this is what fostering a need to develop a business that seeks and thinks about finding appropriate solutions through which delivery of a comfortable and appropriate housing for a person can be attained. With this growth of the construction industry and subsequent growth of construction companies, contractual relationships related to construction are increasing. This increase shaped the current construction industry that affect human’s daily life.

Considering Palestine, the growth and increasing demand for the construction industry has followed a similar pattern as observed in the trend of the world with minor variation. The construction industry was not considered as an independent sector of the national economy in the historic prospective of Palestinian people. It was considered unworthy of generating national wealth. As a result, no comprehensive strategy for its development was considered.

Constructions in the West Bank are unique in nature. The general theme of the construction industry is erecting and casting buildings and installing roadways. This theme is due to the lack of capabilities and hence the construction operations are rarely developed. As a result, there has been no work and development of huge projects in our country, such as building dams, bridges and tunnels.

Buildings are structures that serve as shelters for humans. They must be well conceptualized, designed and constructed to gain the desired comfort. The building owners must work with high quality personnel and constant supervision of the building to obtain the best results [7]. The better the design and construction practices of the building, the more satisfying structures are generated to meet the needs of owners.

Buildings, like all other structures, are designed to support loads and to resist external forces without excessive deformation. These loads are the live loads as the weights of people and objects and the weight of rain and wind pressure, and dead loads such as the weight of the buildings themselves. All these loads must be incorporated into the structural design so that the building can hold up these loads during its lifetime. The design life for structures is typically fifty (50) years. In addition, the supervision stage is very significant since the life of the building depends on it. The placing of concrete, the vibration of concrete, the fixing of reinforcement, the concrete cover provision, and workability of concrete are all checked to ensure that they conform to the specifications in the drawings.

Palestinian owners design their buildings through experience to satisfy their common needs. They normally consult relatives for the proper design of their buildings. They rarely consult with engineers or professionals in the construction industry field. As a result, the outcome of the construction industry is dependent on the experience and the level of incorporation of ideas from different relatives [3]. This outcome is further influenced by the experience of the contractor who constructs the building, which in most cases is another relative to the owner. This process is highly vulnerable, and the outcome is a fifty-fifty chance to satisfy the owner needs.

There have been many collapses in our country recently. These collapses are due to the nature of the construction industry applied. The failures led to damage to human lives and the economy. The failures occurred in many regions of the West Bank. A clear understanding of the reasons for failures is needed to mitigate their effects, and most importantly to reduce the frequency of their occurrence.

Reasons and Examples of Building Collapse

Reasons for building failures vary historically. However, most engineers either in Palestine or internationally agree that most buildings collapse for the same reasons. The reasons a building collapses can be due to poor structural design, poor compliance with specifications, poor quality control, faulty construction methodology, foundation failure, and corruption. Natural disaster is also identified as a cause of building collapse. The most common reasons for collapses in buildings are as follows according to Adefusi [8]; 1) Defects in design and drawings; 2) Use of inferior materials; 3) Faulty execution and inadequate supervision; 4) Faulty repairing or restoration/renovation; 5) Early ageing; 6) Lack of maintenance; 7) Foundation failures; 8) Excessive forces due to natural disaster; 9) Overloading; 10) Change in structural configuration.

One of the main reasons for the building failures is the soil structure. In2004, Za-Chieh investigated the reasons for failures internationally [9]. The research concluded a set of reasons behind the building’s collapses. However, the main reason behind the collapses of buildings was soil structure. This factor is crucial "due to the lack of inadequacy of construction requirements regarding the extent and quality of site investigation work. Failures led to the collapse of buildings during construction" [9]. According to the authors, the lack of knowledge in site investigation of the current conditions and absence of geotechnical supervision are the main reasons behind the buildings collapses. The importance of site investigation was evident in the case of Brazil [10]. A study conducted by Hussain showed water quality deterioration and soil erosion are the two major environmental responses to the unplanned urban growths on the problematic soil in surrounding areas of District Federal in Brazil. These two factors adversely affected the structures, and failures occurred due to negligence of site investigation. An experiment was prepared to check the response of Brazilian soil under different loading conditions. This investigation is achieved by vertical load applied on one flank of the slope. This loading receives a reaction from the ground. The experiment was able to explain the reason of failures for the Brazilian case.

Site investigation is considered as one of the most important phases during the construction of any building or projects. Site investigation is handled through various steps. The steps include the reconnaissance, preliminary and detailed Phases. Tests for site investigation includes but not limited to boreholes, test piles, trenches, adits, field and laboratory tests, geophysical survey, aerial photographs, geological maps, seismology, groundwater, magnitude (Richter scale) and intensity (modified Mercalli scale), intensity (magnitude, Epicenter distance, Focal depth, groundwater, local geology, foundation, type and quality of structure and facilities). The Richter scale of earthquake magnitude is determined from an event that has occurred. The specifications and professional engineers apply the knowledge of the site to deliver safe and suitable structures.

Another reason for failures could be attributed the material deficiency. According to Chehade’s research [11], Concrete compressive strength on uncontrolled construction sites can reveal the adequacy of constructed building. The methodology depends on taking concrete samples from various locations during construction processes such as columns, ceilings, foundations, and walls in order to make sure that the concrete achieved the required strength. This method verifies that the building is safe or unsafe. "The information obtained on the concrete compressive strength allows design engineers to take into consideration in their conception a high probably weak concrete when the construction is performed. So, the safety of construction is improved and we can avoid building collapses as happened recently in our countries." [11]

Applying this approach on buildings in Lebanon revealed that concrete quality is the main reason for building failures. The investigations prove that the causes of the collapses are the quality of concrete compressive strength, the mixing ratio of the concrete components (Water, cement and aggregate), and the quality of each component compromising the concrete. Inadequacy of concrete quality increases the probability of the building's collapses.

The same approach was applied to building failures in Nigeria. The analysis was on the properties of the reinforcing steel bars [12]. Investigations about building collapse revealed that the flexibility of reinforcing steel was very small with high rigidity. This condition caused breaking in the steel and building collapsed. It is important to ensure the quality management and ensure the material properties used in construction works. Another research[13]studied the quality of steel rods used in structural buildings in Nigeria. The experimental data on the chemical and mechanical properties of steel rods from collapsed building sites and local steel plants have been reported. They collected the steel rod samples of 12 mm diameter from six different collapsed building sites in Lagos, Nigeria. Laboratory testing was carried out to obtain the yield strength, ultimate tensile strength, and percentage elongation. Results showed inadequacy of reinforcement bars for most of the tested specimens.

Another reason for failures is the inadequacy of the construction formwork. In 2011, an investigation by Li et al. [14]stated that the formwork causes the buildings collapses during construction. There are cases of some collapses occurred due to incorrect formwork in West Bank too. Poor formwork accompanied with casting of concrete at low or high temperatures with a fast speed without waiting periods increases the likelihood of the collapse of the building.

Another reason for building failures is the unexpected natural loading. Huang et al. explained that earthquakes are a common stimulus to cause building collapses [15]. The collapse of a building by the earthquakes is one of the main causes of causalities globally. Earthquakes cause a lot of economic and material losses and loss of lives. They used a scanning system for analyzing affected buildings by the earthquakes. "There are airborne laser scanning (ALS) can obtain high resolution 3D Data point cloud. It is possible to detect damage to the building, the use of ALS point cloud data after the earthquake helps engineers to solve problems and repair. The strong earthquake caused building collapse is one of the main reasons for casualties, so it can save emergency relief time if quickly find the earthquake-induced building damage. ALS is a newer remote sensing technology which can acquire high resolution three dimensional point cloud data" [15]. Samaro Showed in a master thesis at An-Najah National University that unexpected loading is among other factors that can cause failures [16]. The thesis discusses the relation between the snow falling percentage and the steel structures that collapsed in West Bank after the 2013 snowfall. The possibility of steel structures collapse increase when the snow falling percentage increased. During the investigation, investigator studied two cases of steel structures collapse by using computer simulation software. The conclusion was that the buildings were built correctly and according to engineering standards, but the collapse happened because of unexpected quantity of the snowfall. According to Samaro, failures were mainly due to poor design and construction practices for the steel structures under considerations. Absence of regular check-ups and maintenance adversely affect the situation. Finally, the climate change in general and the snow expectancy in more specific urges a modification in the anticipated loading in the design codes applied in Palestine. These findings require a local design code for buildings in Palestine that accounts for specific loadings and conditions in the country rather than using universal codes [16].

One of the major reasons for building collapse is the absence of true engineering supervision. Asante and Sasu investigated the reasons of failure in Ghana. The research showed that the failures are due to absence of engineering supervisions in the construction sites. Their study focused on the area of Kumasi. They took a random sample from the collapsed area.

"the majority of building collapses in Nigeria are traceable to human activity or inactivity, including mainly structural failure, poor supervision and workmanship, and the use of sub- standard building materials” [17]. The investigators were not able to complete their study due to a set of limitations and challenges. These obstacles include insufficient logistics/manpower, political interference in investigations of collapses, and building policies. The investigators were stopped from completing the investigation by politics and not having enough sources for gathering data regarding collapses that occur in the area.

The absence of true engineering supervision was evident in the case of Nigeria. The method of scientific research was a well-structured questionnaire and random oral interviews. The reasons for the collapse of the buildings were attributed to inadequate staffing and lack of engagement of building professionals. The planning approval authorities were not useful in scrutinizing, vetting, and evaluating building drawings submitted for approval. The supervision and monitoring the level of compliance of buildings under construction with the operational building codes and by-laws in the study area was relatively poor. The study concluded that these lapses in local building approval authorities’ roles can contribute to the increasing cases of collapsed buildings in Enugu Metropolis[18].

Getting a competent workmanship and using the right material measurements are some of the factors to consider for a strong building. Rachel Irene [8] indicated that most buildings collapse mainly because of structural failure. This is when a building is designed to carry a specified load while actual loads are over the considered ones. The structural designs of these cases are done poorly. As a result, the building is bound to collapse. In Palestine, there are many cases where buildings and constructions are constructed poorly using inappropriate cheap or alternative materials. This situation results in making the buildings more prone to be overloaded and unable to carry the expected loads during the usage.

Some companies may also change the design from the real one. For instance, buildings that were originally designed to bear three floors and later they were loaded two additional floors without consulting a structural engineer or professional. These buildings may collapse due to overload and consequent over stress of the foundation. Some construction companies in Palestine do that to satisfy the desire of the owner, and sometimes the design are prepared without knowing the intents of the owner. This situation sometimes results in making the designed construction inappropriate for their usage.

In the Palestinian case the most common reason would be faulty execution and inadequate supervision, and lack of maintenance. Most buildings in Palestine lack inadequate supervision due to the cultural reasons and economic reasons mentioned previously [19].

Impact of Building Collapse on Economic and Society

Since the dawn of civilization, humans have designated a protected area for themselves, their families, and animals. This safe place was created by exploiting natural areas, and then applying the experiences gained in favor of using the available materials. People build structures of different types for different purposes; buildings - to live and state the place / space; bridges - to connect points and reservoirs – to store materials. Over the years, humans have learned to manipulate elements and materials, and use them more effectively. Today, buildings have a wide range of materials; concrete; stone; Wood; Steel; Aluminum; Plastic; and other materials. If these materials are used well and professionally, buildings will not fall.

Architects and city planners frequently use models to show and display the buildings in a three-dimensional fashion, and check that the height of the buildings is appropriate to the surrounding environment. Models can be computer images or natural models. Engineers also use computerized models to test their stability in extreme cases.

Reasons for failures could reveal social and political aspects. An investigation of collapsed building incidents on soft marine deposit showed that failure investigations should consider both the social and technical perspectives [20]. The collapsed incident occurred on 10^{th} of October 2016 in Wenzhou City in China and resulted in 22 casualties and six injuries. Most of victims were migrant laborers (rural dwellers who moved to urban areas for a temporary work). These incidents revealed social problems of the existing dual structure land-use policy in China. Chinese dual structure land-use policy caused deficiencies in the supervision of the construction market in rural area. This situation resulted in the technical factors were not well supervised by the various quality control departments. This situation leaded to; (1) poor quality of residential buildings; (2) unauthorized roof top additions; and (3) Residential buildings in urban villages, where differential settlements occur, were built with poor quality control. This poor control often resulted in structurally unsound structures. Migrant people from rural areas often have no place to live and seek low rental accommodations in urban villages regardless of the quality of the building.

Building collapse has negative impacts on humans. Ikuta et al. showed a relation between collapses and damages affecting human[21]. Accurate construction saves economic costs, avoids future damages, and improves building security. The study used a Canadian case study. The study revealed that human body is severely affected including death in some cases from the collapse either by construction materials or furniture. The study concluded that saving the building is necessary to save lives. According to Ritche Patel, every time a building collapses in any part of world, it sends waves of tremors in minds of many common people around the world[19]. Collapses do not occur due to merely one reason unless there is a fatal error in ignoring that reason. Failure is a result of multiple reasons activating together.

Construction sector is important to all countries in the world. Recently, there have been many collapses in this sector that led to economic damage and the loss of many victims. In the collapse of a hotel in the city of Quanzhou in China, as happened in Turkey in the city of Izmir recently, many buildings collapsed due to an earthquake that struck the region. These collapses cause the loss of many lives in general. A reduction in the negative effects that are generated with failures is essential. The benefits are the preservation of life being and the strengthening of steadfastness. The life of humans is the most valuable thing to save. Preserving the building means preserving people inside it. It also means preserving money from an economic side on the other hand.

To sum up, construction industry is essential for any specific country. Failure in this sector needs to be avoided. Recently, many failures occurred in this sector in Palestine. Reducing the frequency of these failures should mitigate the negative effects on humans and their belongings. As Palestine has a complicated situation considering the political, economic, and health factors, saving and improving this sector becomes crucial. There is no research considering the collapses of buildings in Palestine. This research fills the gap through analyzing the reasons of failures for buildings under construction in the West Bank considering the views of experts in this field.

Chapter 3

Methodology

Overview

This chapter discusses the research methodology throughout the thesis. Research methodology represents the process implemented to complete the research. Different types of research methodologies exist. These methodologies could be quantitative, qualitative, or mixed methods [22]. Each method has its own merits and disadvantages.

The quantitative methodology is best suited for scientific research. Data are collected and analyzed to draw conclusions and theories. A common type of the quantitative research is to create questionnaires and apply statistical analysis techniques to highlight main conclusions [22]. The most critical stage in the statistical process is the data collection phase. Any error in the data collection process results in a statistical error. Another form of quantitative research is applying theories to analyze cases [22]. The better the theory in describing the case, the more realistic results is attained.

The qualitative research properly addresses humanitarian research. Several types of qualitative research exist [22]. Case studies and interviews are two common types of qualitative research. In the qualitative research, the researcher investigates unseen or unmeasured factors that affect the outcome of the issue under consideration.

The mixed methods research applies principles from both quantitative and qualitative research. It combines the merits of each research method to better address the issue under consideration [22]. The common types of this research are convergent, explanatory, and exploratory techniques. The difference between these types of research is how the mix is applied of the qualitative and quantitative research. In convergent, both types are conducted separately and with the same importance. In contrast with the explanatory which starts with quantitative research followed by qualitative research, and exploratory where qualitative research starts first followed by a quantitative research.

In this study, the mixed method research is implemented following the convergent approach to analyze the current situation, and answer the question of what is happening and why buildings collapse.

Quantitative Method Procedure

Data Collection and Analysis

The quantitative scientific approach was implemented throughout this thesis. A well-prepared questionnaire was introduced to address the reasons for failure for buildings under construction (See Appendix A). This questionnaire was then distributed to relevant agencies and personnel in the construction industry. Replies from the participants were gathered for further evaluation.

The data gathered from questionnaires is manipulated and analyzed using Microsoft Excel, Statistical Package for the Social Sciences (SPSS), and Minitab programs as needed. The analyzed data then categorizes the reasons for failures from the most common and influential to the least.

Structural Approach

Structural Analysis Program (SAP 2000) and Extended 3D (Three-Dimensional) Analysis of Building Systems (ETABS) are used to analyze special cases of building failures occurred in West Bank. The collected cases are simulated in computerized models for testing the stability of buildings. The purpose of the analysis is to produce the required comparative study. The first step of this task was creating a baseline of the construction management process of buildings under construction in West Bank. The process should be derived from the Palestinian Engineers Association-Jerusalem Center. The second step was studying and analyzing a set of case studies locally and considering international research in the field.

Two case studies of buildings where failure occurred were obtained. Details for these cases were collected through contacting official engineering offices. The reasons for failures per the thoughts of the offices were explored in detail. A 3D model is generated for the cases under consideration. The analysis applied finite element method, and the results were compared considering the actual condition.

Qualitative Method Procedure

Data Collection and Analysis

Data for this research was collected by reviewing the literature and related publications, visiting local buildings where failures occurred, investigating the reasons behind the failures, and collecting data from the Palestinian Engineers Association – Jerusalem Center and local engineers in municipalities where failure occurred. Social media was used as well to collect further information on the failure cases. Discussions among professionals in this field were held on the social media such as Facebook were considered for the failure cases under consideration.

The researcher does not provide the personnel beliefs regarding the case studies under consideration. The analysis for the data was simply stating the beliefs of the interviewee or professionals in the field. A summary of the reasons of failure was provided at the end of the section to state the beliefs the researcher found regarding the failure cases.

Quality Management Approach

Research Design/Methodology

Customers generally tend to compare the product they 'experience' with the product they 'expect'. If the experience does not match the expectation, a gap arises. The provider for a service or a product applies all the efforts to meet the expectations of the customer. Construction industry is not an exception. The failures in buildings certainly provide a deficiency in meeting the customer expectations. In the collapse of the buildings the quality dimensions to consider are; Soil type where construction occur; Building support during construction; Meeting Timelines; Engineering design; Concrete type and quality; Engineering supervision; and building durability and strength.

Customer satisfaction is measured after looking at process performance and clarifying to which extent the degree of customer critical to qualities (CTQs) are met or exceeded. Higher satisfaction is attained by exceeding the CTQs. In construction industry, people want comfortable, safe, and suitable buildings. Failures in such buildings should be avoided.

Management principles and standards exist to ensure customer satisfaction. The International Standard for Quality management [23] adopts several management principles that can be used by top management to guide their organizations of buildings towards improved performance, customer focus, leadership, and involvement of people.

Data/Model Analysis

There are many methods for quality improvement. These cover buildings improvement, process of building design improvement, and people-based improvement. The following list is methods of quality management and techniques that incorporate and drive quality improvement:

1. Six Sigma (6σ), a business strategy which combines established methods such as statistical process control (SPC), design of experiments in an overall framework.

2. PDCA (Plan, Do, Check, and Act cycle) for quality control purposes, Six Sigma's DMAIC method (Define, Measure, Analyze, Improve, and Control) may be viewed as a particular implementation of this.

This study intends to improve the quality of the construction of buildings to drive towards the customer satisfaction. This goal can be achieved after understanding the need for change by using the six-sigma tools to improve and monitor the process's performance. The quality improvement process is better depicted in Figure 3. 1.

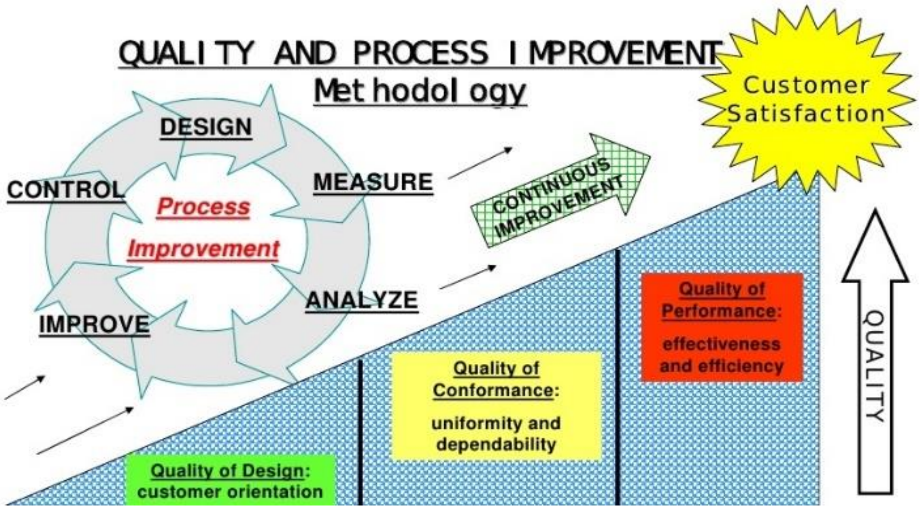

Figure 3. 1: Quality Improvement Process

Chapter 4

Data Collection, Analysis, Results, and Discussion

Data Collection

The process of collecting sample data follows the quality improvements techniques. In addition to the Six Sigma (6σ) and PDCA techniques, the following procedures are carried out:

1. Descriptive techniques to describe some cases of buildings collapse.
2. Computerized models using computers images or natural models and applying simulations for testing buildings properties and stability in extreme cases.

To achieve the objectives of the study, the researcher used a14-item questionnaire for construction companies in West Bank to address. The questionnaire is formed based on the previous literature and the researcher's own experience in the field of Engineering. The questionnaire consisted of three sections: the first focused on demographic data of the respondents such as age, gender, career, experience. The second addressed demographic data of the buildings were failures occur such as period of building, building age, and the capital of the company. The idea of collecting the demographic data is to compare the responses based on the aforementioned factors. The third part consisted of 14 questions about the reasons behind the collapse of building in West Bank under construction. The scores of responses to each item were calculated according to a four-point Likert scale; for the first three domains responses in which very effective = 4 points, effective = 3 points, moderate = 2 points, little effect = 1 point. The idea behind the 14 questions is to rank the reasons for failures from the common case to least expected reason.

Analysis and Results

The data collected were analyzed using (SPSS -17) considering the questions of the study. Means, frequencies, and standard deviations are common statistical measures obtained in the analysis. Two independent sample T-test and One-Way analysis of variance (ANOVA) was applied to the data as well. ANOVA test is an analysis tool used in statistics that splits an observed aggregate variability into two parts for a specific data set; systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study. To analyze the findings, the researcher used the following scales to represent the estimation level of sample responses:

More than 3: 75.0 % High

2.00-3.00: 50.0 – 74.9 % Moderate

Less than 2.0: 49.9 % Low

Statistical Analysis and Results

Characteristics of the data collected are presented in Table 4.1 – 4.7.

Table 4.1: Respondent Age

Age (years)	Frequency	Percent	Valid Percent	Cumulative Percent
20-29	13	43.3	43.3	43.3
30-39	11	36.7	36.7	80.0
40-49	2	6.7	6.7	86.7
50-59	2	6.7	6.7	93.3
60 and more	2	6.7	6.7	100.0
Total	30	100.0	100.0	

Table 4.2: Respondent Gender

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	19	63.3	63.3	63.3
Female	11	36.7	36.7	100.0
Total	30	100.0	100.0	

Table 4.3: Respondent Career

Career	Frequency	Percent	Valid Percent	Cumulative Percent
Academic	3	10.0	10.0	10.0
Supervisor	17	56.7	56.7	66.7
Project Engineer	7	23.3	23.3	90.0
Owner	3	10.0	10.0	100.0
Total	30	100.0	100.0	

Table 4.4: Respondent Experiences

# of years	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	10	33.3	33.3	33.3
6-10	9	30.0	30.0	63.3
11-15	4	13.3	13.3	76.7
16-20	3	10.0	10.0	86.7
more than 20	4	13.3	13.3	100.0
Total	30	100.0	100.0	

Table 4.5: Period of building

# of years	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	15	50.0	50.0	50.0
6-10	2	6.7	6.7	56.7
11-15	2	6.7	6.7	63.3
16-20	2	6.7	6.7	70.0
more than 20	9	30.0	30.0	100.0
Total	30	100.0	100.0	

Table 4.6: Building age

Building Age (years)	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	16	53.3	53.3	53.3
6-10	4	13.3	13.3	66.7
11-15	2	6.7	6.7	73.3
16-20	8	26.7	26.7	100.0
Total	30	100.0	100.0	

Table 4.7: Capital of company

Capital of company ($)	Frequency	Percent	Valid Percent	umulative Percent
Less than 100,000	6	20.0	20.0	20.0
100,000 - 150,000	7	23.3	23.3	43.3
160,000 - 200,000	5	16.7	16.7	80.0
300,000 - 400,000	9	30.0	30.0	90.0
500,000 and more	3	10.0	10.0	100.0
Total	30	100.0	100.0	

Complete statistical analysis is presented in Appendix B.

The sample consisted of 30 individuals in the construction sector in Palestine. The background of the study sample is varied in terms of age, gender, career, experience, period of building, building age and the capital of the company. The classification is shown in Table 4.8.

This study aimed at identifying reasons behind the collapse of buildings in West Bank that are under construction. It also aimed at identifying the effect of demographic variables on the responses obtained from the questionnaire. To accomplish the aims of the study, the researcher analyzed the data in accordance with the study questions, and the results are explained later of this chapter.

Quality Management Approach

Six Sigma DMAIC Methodology is a closed-loop process that eliminates unproductive steps. It often focuses on new measurements, and applied technology for continuous improvement [24]. Implementation of

DMAIC Methodology took place in five phases as outlined below and established at Motorola; Problem identification and definition takes place in define phase; After identifying main processes, their performance is calculated in measure phase with the help of data collection; Root causes of the problem are found out in analysis phase; Solutions to solve problem and implementing them are in improve phase; and Improvement is maintained in control phase.

DMAIC Model

Define

This phase determines the objective and scope of the study. Information about the present processes is collected. At this phase, the definition of customers and deliverables to customers are also determined.

The Project Charter defines the scope, objectives, deliverables, and overall approach for the work to be completed. The importance of Project Charter is that it is a critical element for initiating, planning, executing, controlling, and monitoring the study. It is the absolute master document for the study and as such it should be the single point of reference on the study for goals and objectives, scope, organization, estimates, deliverables, and budget [25].

Table 4.8: Distribution of Sample According to Study Independent Variables

Variable	Class	Frequency	Percentage %
	20-29	13	43.3
Age	30-39	11	36.7
	40-49	2	6.7
	50-59	2	6.7
	60 and more	2	6.7
Gender	Male	19	63.3
	Female	11	36.7
	Academic	3	10.0
Career	Supervisor	17	56.7
	Project Engineer	7	23.3
	Owner	3	10.0
	1-5	10	33.3
Experience	6-10	9	30.0
	11-15	4	13.3
	16-20	3	10.0
	More than 20	4	13.3
	1-5	15	50.0
Period of Building	6-10	2	6.7
	11-15	2	6.7
	16-19	2	6.7
	20 and more	9	30.0
	1-5	16	53.3
Building Age	6-10	4	13.3
	16-19	2	6.7
	20 and more	8	26.7
	Less than 100,000	6	20.0
Company Capital	100,000-150,000	7	23.3
	160,000-200,000	5	16.7
	210,000-400,000	9	30.0
	500,000 and more	3	10.0
Total		30	100.0

Table 4.9: Details of Project Scope

Business case This project supports the business quality goals, reduce the collapse, and get more profit and increase the customer's satisfaction.	**Opportunity statement** An opportunity exists to reduce the gap between the engineering offices and house owner by enhancing the mutual trust between them in the construction process.
Goal statement Reduce the collapse as much as possible.	**Project scope** Building collapse in West Bank with focus on Hebron and Nablus cities.
Project plan Activity Start End Define 18/7 23/7 Measure 24/7 1/8 Analyze 2/8 15/8 Improve 16/8 17/8 Control 20/8	**Team** The researcher The owner Engineering offices

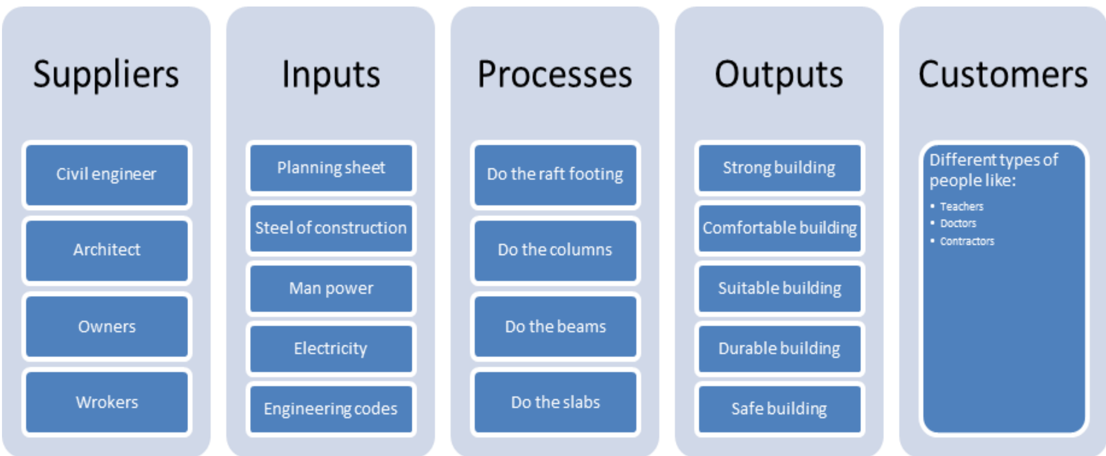

Figure 4.1: SIPOC Diagram

Table 4.9 shows the details of project scope, business case, opportunity statement, goal statement, team, and project plan.

In order to give a simple overview of the process and to understand the basic elements, the Suppliers, Inputs, Process, Outputs, and Customers diagram (SIPOC) is a Six Sigma tool used for documenting business processes. Figure 4.1 presents the SIPOC diagram for construction industry.

The critical factors for collapse can be determined via focusing on the operations in building constructions and the soil type. The occurred failure area where the building was affected could be determined. After finding this area, critical factors responsible for collapse of some buildings were identified.

Measure

Check sheet is a tool to record the potential causes for the collapse of buildings and the causes for defects during the construction which make the customer unsatisfied. It is also used to count the occurrences of various defects throughout the testing period. This counting log is very useful to investigate the main causes for performance weakness. The quality management system and its tools focused its efforts to determine the precise specifications the customer wants; by taking some case studies from Nablus and Hebron cities, the causes and the reasons of these collapses are investigated.

Analysis

Pareto chart is a useful tool to determine what are the most defects happened and where improvements could be achieved. The chart can be investigated for various reasons for building collapse. Figure 4.2 -Figure

4.12 represent the Pareto charts for all the factors under consideration in this study.

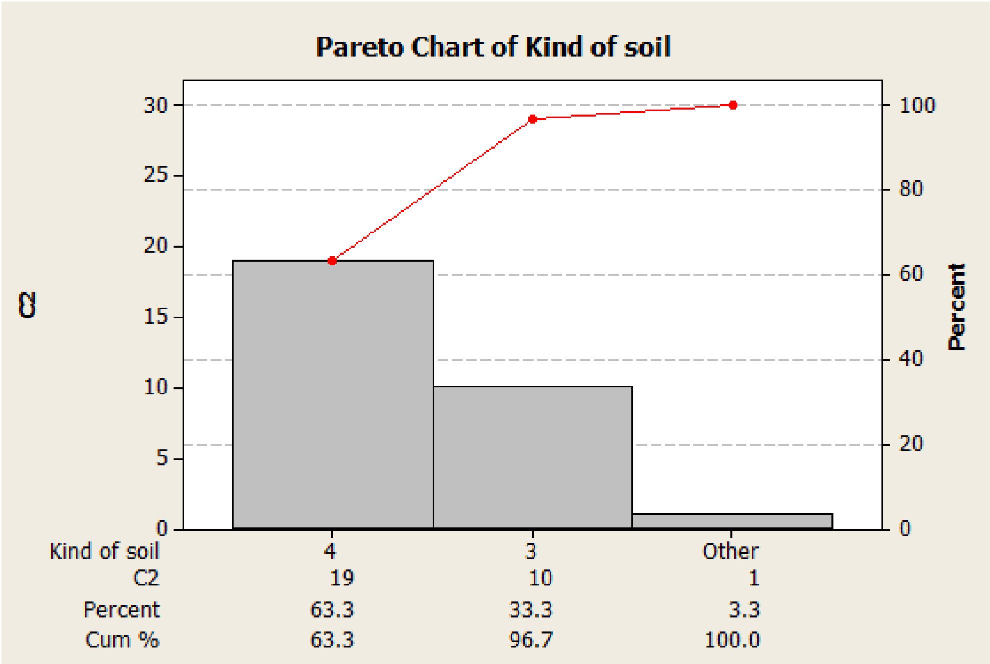

Figure 4.2: Pareto Chart for Soil Type

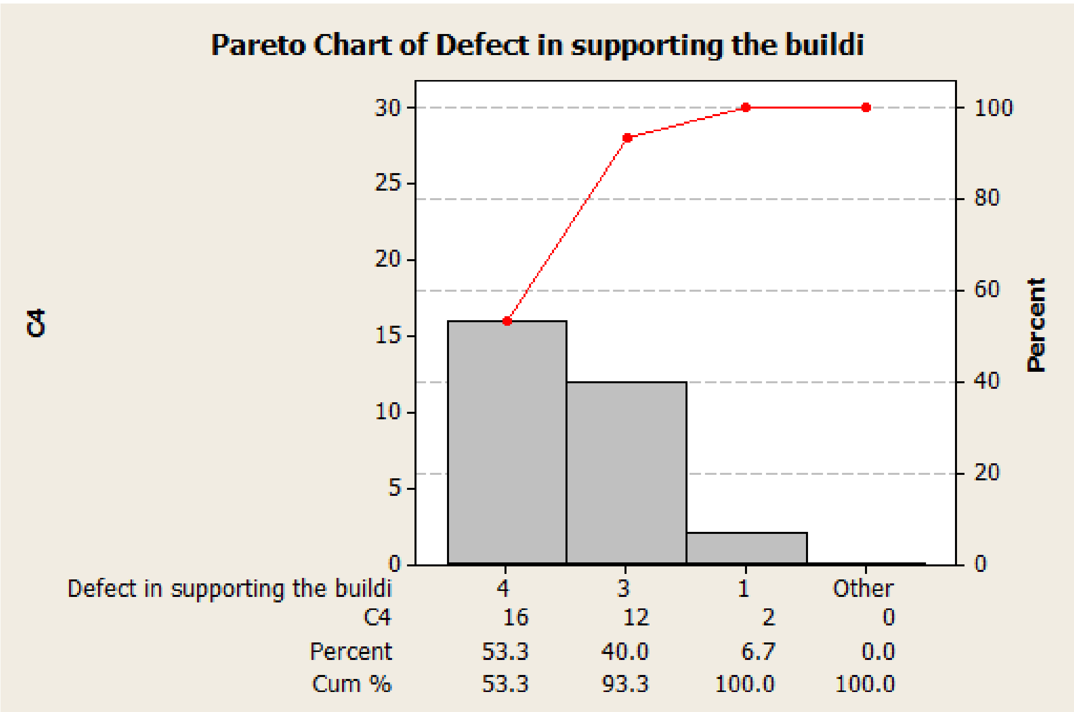

Figure 4.3: Pareto Chart for Defects in Building Support

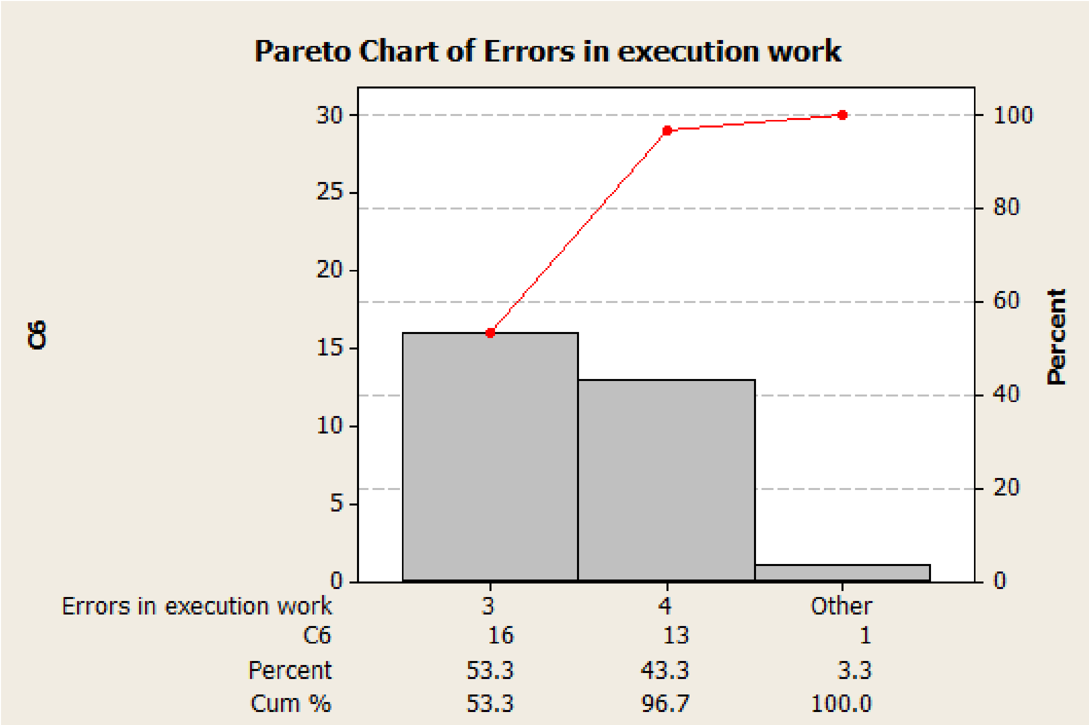

Figure 4.4: Pareto Chart for improper work execution

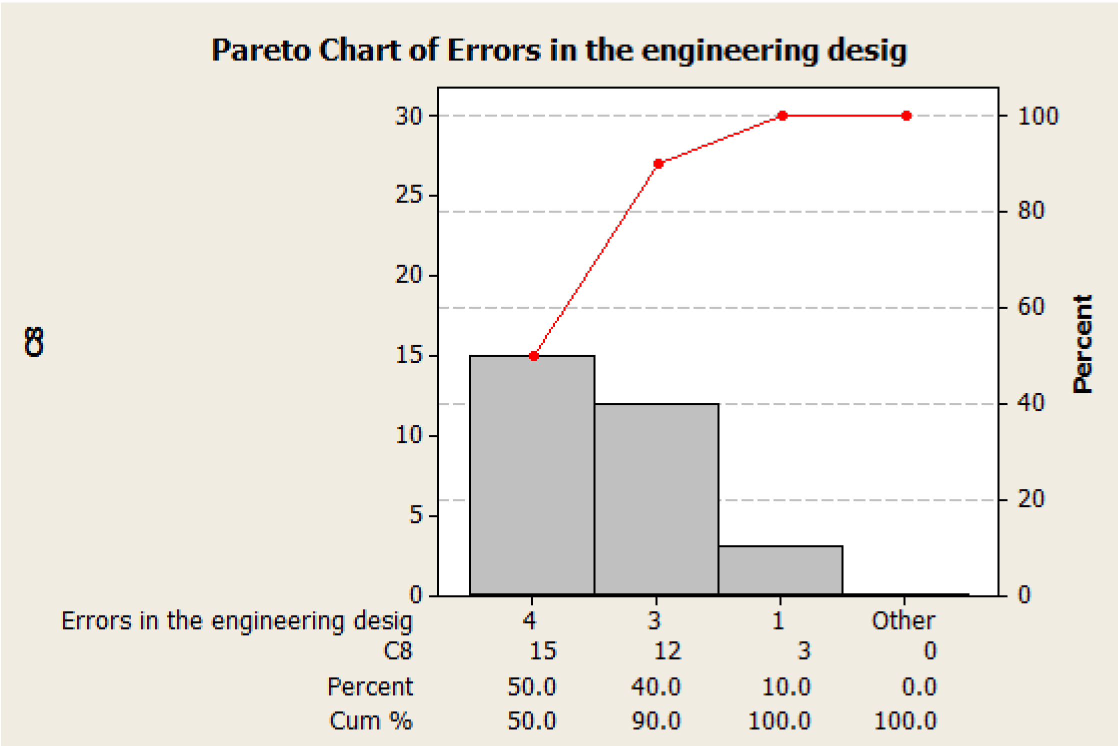

Figure 4.5: Pareto Chart for Engineering Design Mistakes

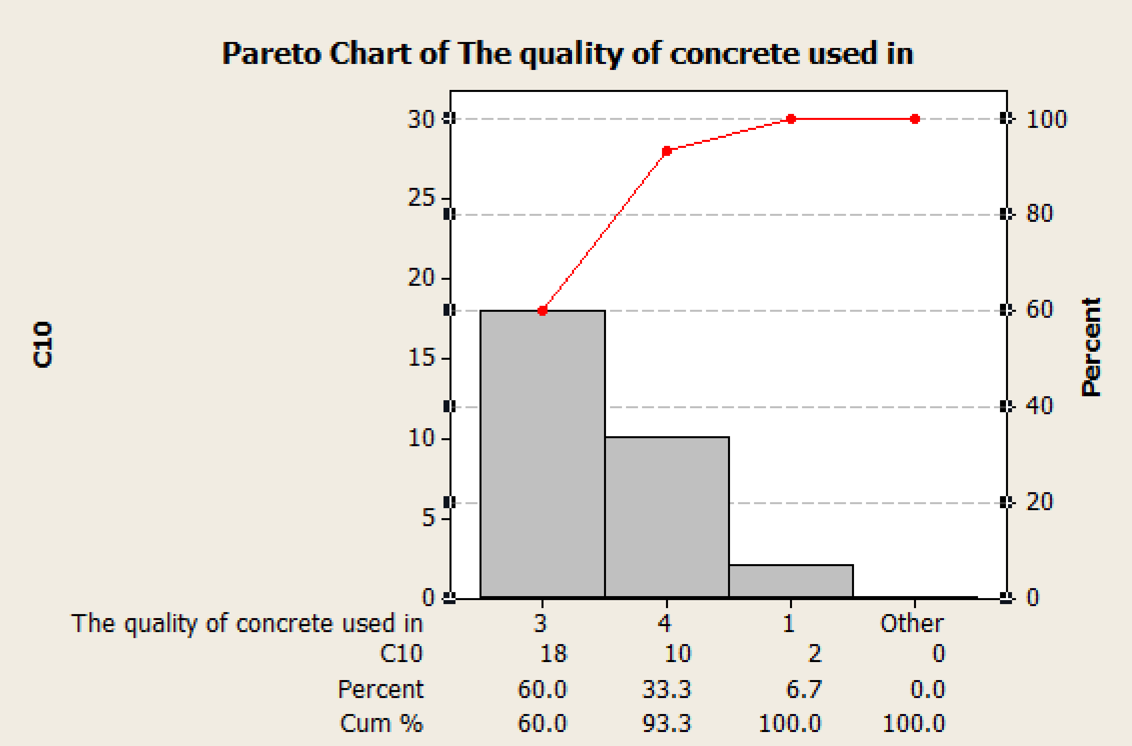

Figure 4.6: Pareto Chart for Concrete Quality

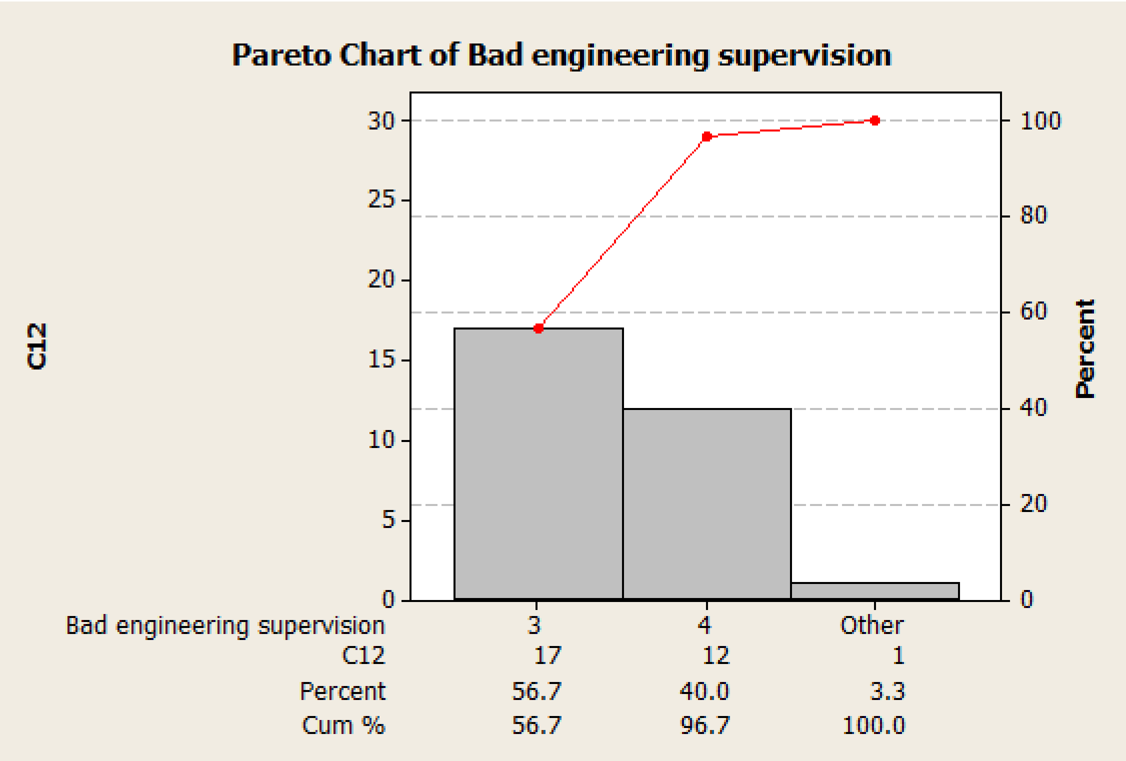

Figure 4.7: Pareto Chart for Improper Engineering Supervision

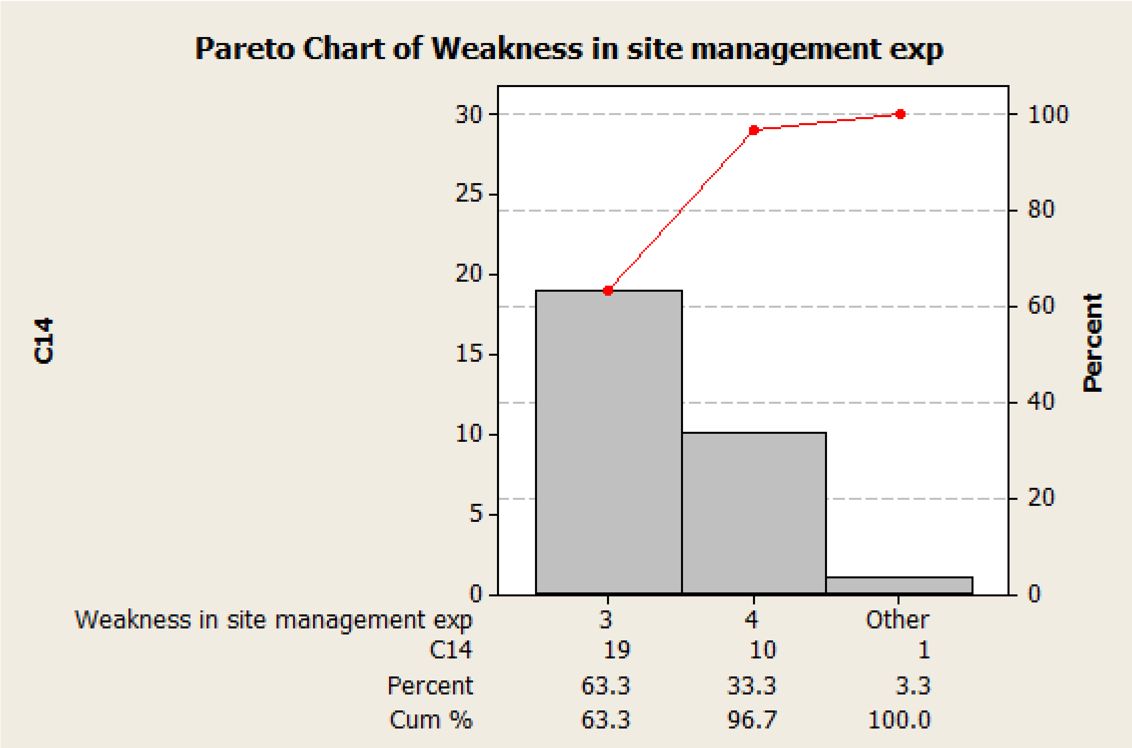

Figure 4.8: Pareto Chart for Inadequate Site Management Experience

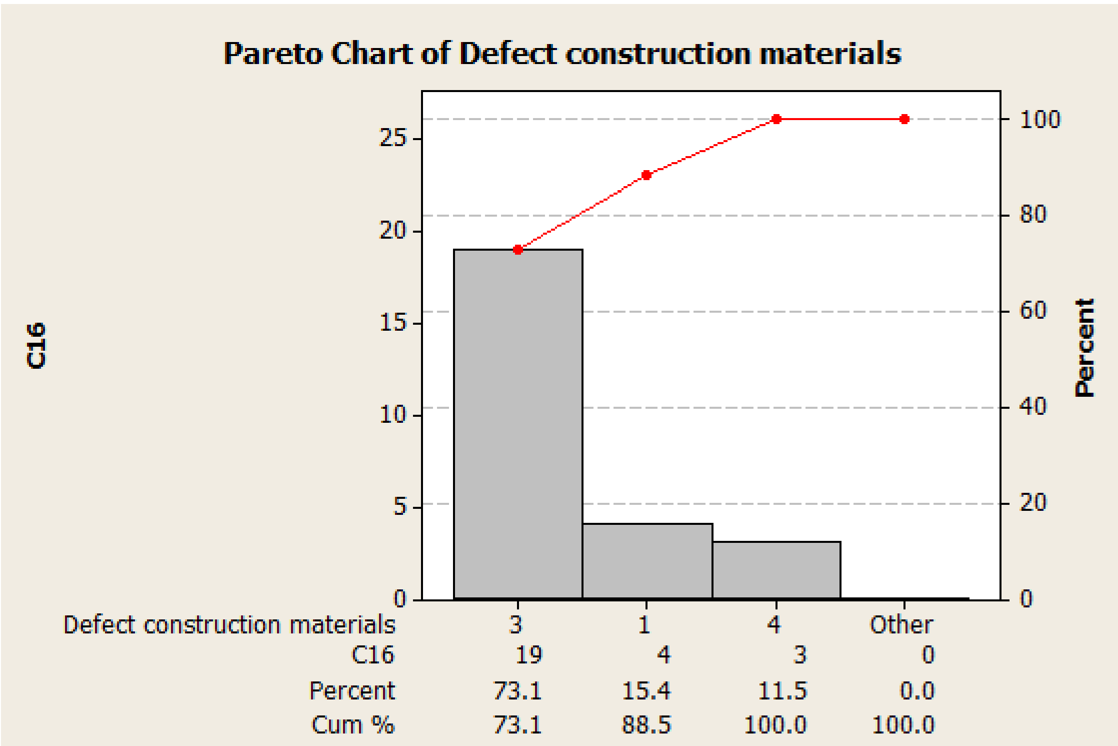

Figure 4.9: Pareto Chart for Defects in Construction Materials

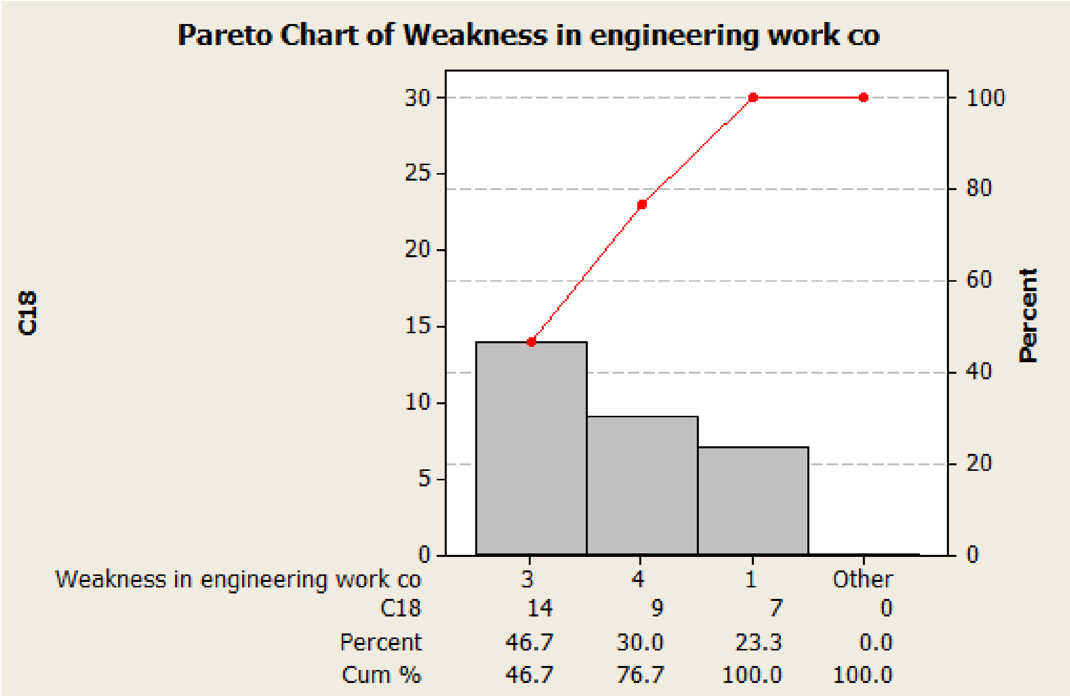

Figure 4.10: Pareto Chart for Improper Company Engineering Work

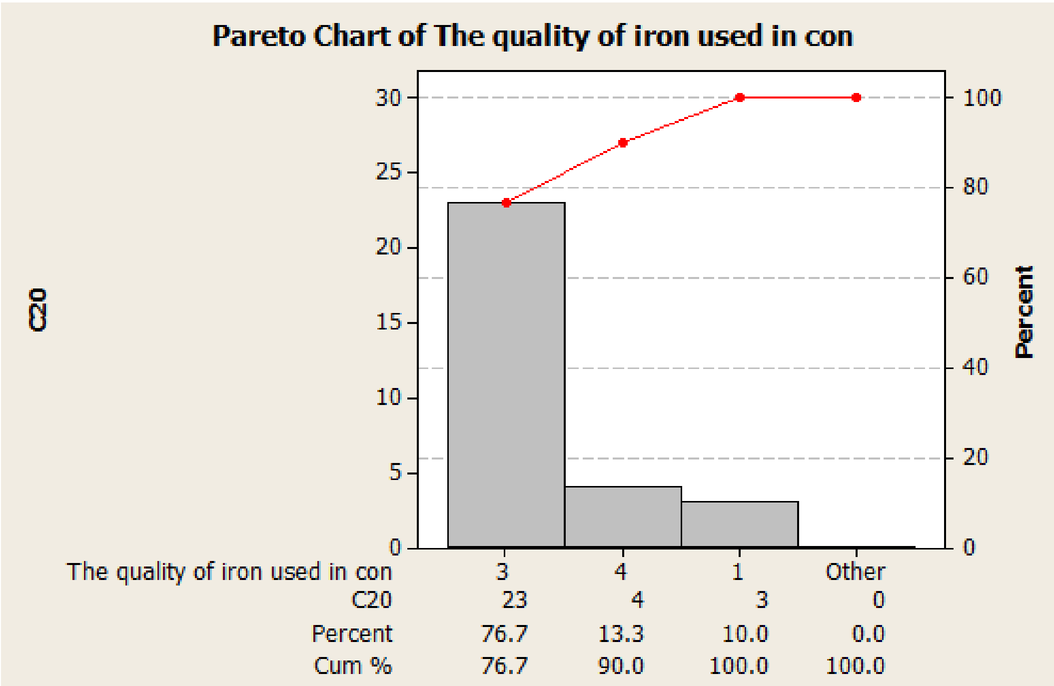

Figure 4.11: Pareto Chart for Reinforcement Quality

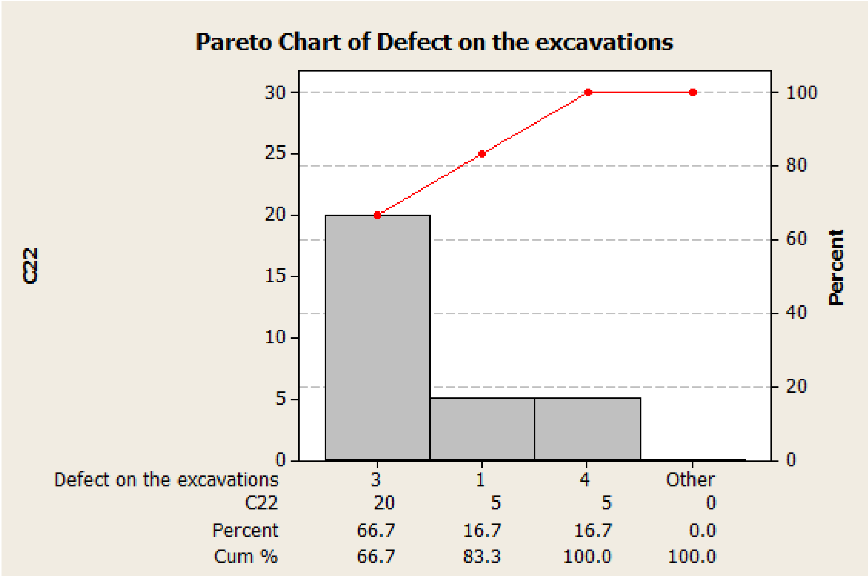

Figure 4.12: Pareto Chart for Improper Excavations

Cause and effect tool (see Figure 4.13) is a very useful tool to show the main causes that generate the collapse in building. These causes are related to the weak form of the soil, bad engineering design, and poor engineering supervision.

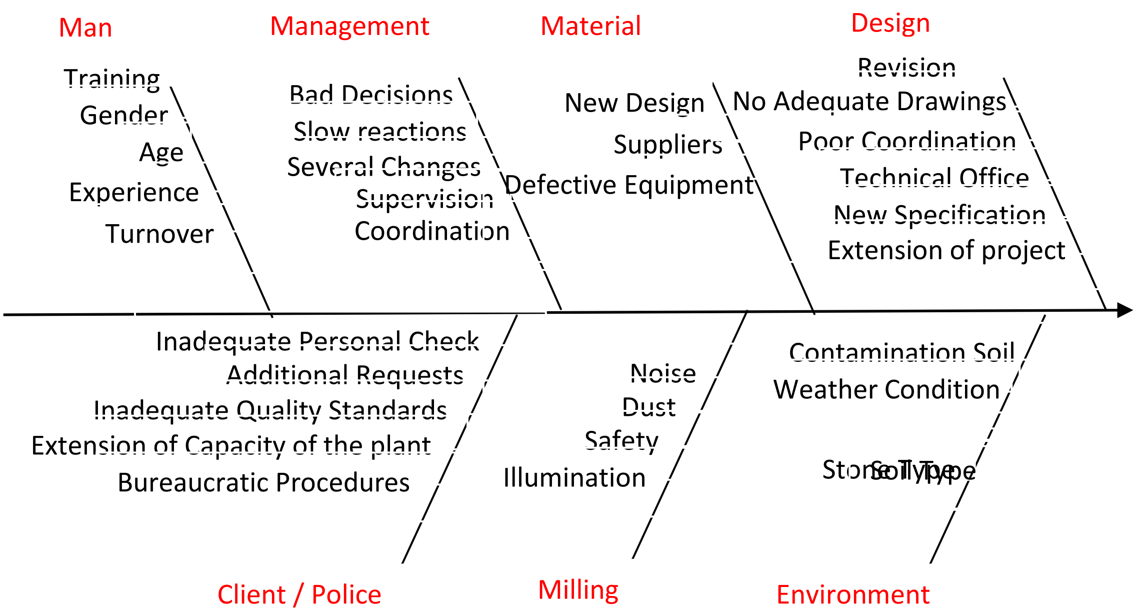

Figure 4.13: Fish Bone Diagram for Causes and Effects of Building Failures

Improve

Solution to the mentioned issues can be done through a valid protocol to lessen the impacts of the building failures. Each causing effect can be mitigated on its own. As a result, the frequency of building failures is significantly reduced.

Control

Many solutions are suggested to eliminate the causes of the collapse problems. Some of these solutions can be applied immediately and others need time and money to be applied. In this phase, the solutions are applied and then verified by monitoring the frequency of building failures after applying the controlling activities. If the frequency is reduce, then the suggested solutions are appropriate, and an enforcement of them is needed.

Structural Analysis

Loads that a structural member withstands:

1. Main Loads: It is grouped into:

   a. Dead load: as self-weight, slabs weight, wall weight, internal work weight such as plastering and paint,…etc.

   b. Live load: It is that load induced by inhabitants and furniture that occupy the building. In other words, it is any load that is not applied permanently to the structure. This load includes the forces applied during the implementation such as equipment loads.

c. Wind load: Wind loads are significant to any structure. Some countries consider wind load as secondary, while others consider it primary. This depends on the wind nature and climate in each country.

d. Earthquake load: Ready tables to compute this kind of load on structures based on the knowledge of the building type. Such as administrative, residential, or military, … etc.

2. Secondary loads: Any load that is applied indirectly to the structure such as shrinkage in concrete, settlement in foundations, and creep. All these loads are considered during the design phase.

Structural analysis may be defined as the science that considers the effect of the aforementioned loads on stresses and strains within the structural members of a building [26, 27].

Considerations during design phase:

(a) Economic cost.

(b) Factor of safety for each structural member.

(c) Serviceability of the structure by reducing deflections and annoying cracks.

(d) Shape and aesthetic.

Design stages for each concrete structural building:

Stage I: Decide a proper structural system and analyze each element separately.

Stage II: Design each member and provide details including horizontal and longitudinal plans and sections. Also, provide details for reinforcement for each element.

The common elements to consider in concrete structures:

1. Slabs
2. Beams
3. Columns
4. Footings
5. Walls
6. Stairs

Common Palestinian buildings use framing systems [4]. In this system, loads are traversed from the slabs to beams which transfer the loads to columns. Columns load is finally transferred to the ground through the footings. Figure 4.14 shows the load transfer in this system. A proper design requires adequate and high-quality assurance for the load transfer to avoid undesirable failures in buildings.

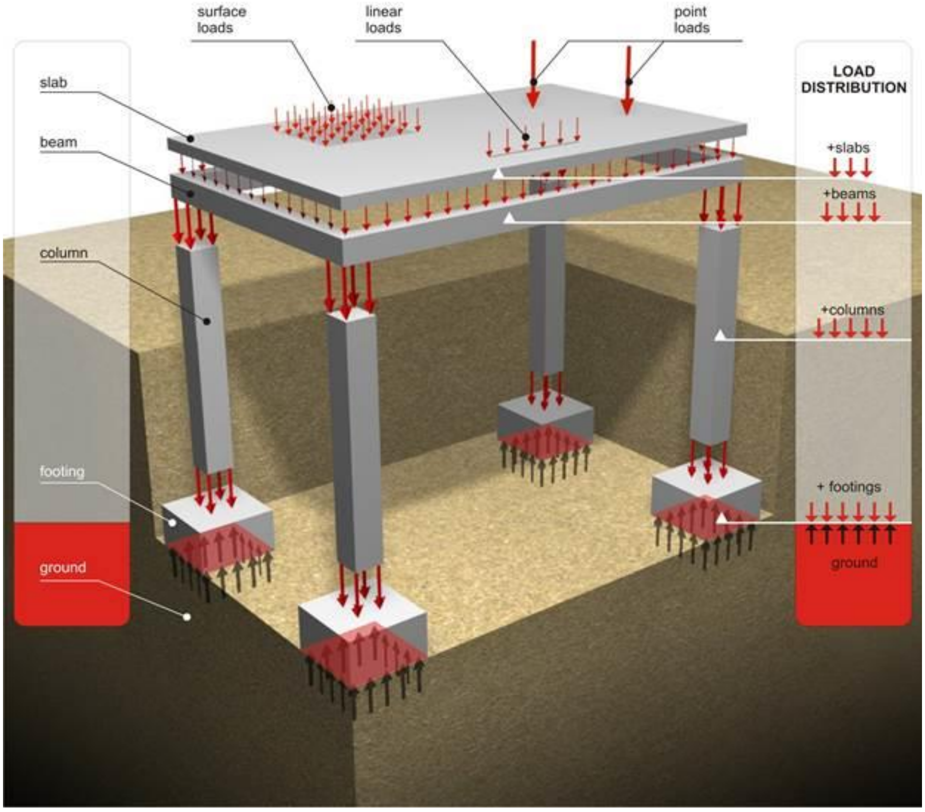

Figure 4.14: Transfer of Loads in the Structure

Two case studies from failures that occurred in West Bank are considered. The details and the reasons for failure are explained in detail below. The thesis avoided providing identifying details as the purpose is to spread knowledge, not to judge or evaluate the construction industry and personnel related to each case study.

Case Study I: 26/05/2019 Hebron City

Roofs of a commercial building collapsed during construction while casting ready mix concrete. Investigations revealed that the incident occurred due to the improper formwork, which is a common reason for failures for building in West Bank. The formwork was not properly installed and braced. The height of the commercial stores was around five meters, which is a common elevation for such premises in West Bank. The traditional formwork had proved inadequacy to these conditions. Akro system is the replacement for the traditional formwork for such conditions. Special calculations are needed to assure the quality of construction and avoid failures during casting. Figure 4.16 and Figure **4.17** show the building that collapsed. The actual structural design was adequate as the design was analyzed using SAP 2000.

Interviews for stakeholders and neighbors explained that the reason for failure was the formwork. Bracing was not introduced properly, and no lateral supporting exists.

Technical Analysis for Failure

Formwork Explanation:

The formwork consisted of supports (pipes); each consisted of two or three segments. Each segment was installed on top of each other to achieve the required elevation at floor level of five meter as appears in Figure 4.16 and Figure **4.17**.

Disadvantages of the Formwork Elements:

Supports with different sources, ages, and types were used. Some were good and kept straight up, while others are old and rusty. Too many supports were not straight with inclinations and buckling. Straightness of the supports is crucial to avoid the loss or weakness of the supports. No bracing was introduced. Also, the supports were not properly installed. This situation resulted in weakening their ability to withstand loads.

Additional factors that showed disrespect and recklessness in formwork installation were putting some supports upside down, not applying ground supports to avoid the movements of metal supports.

Explanation of Failure:

The formwork installation was improper (Support segments on top of each other). That is because it is impossible to keep the straightness for all the support segments. Any deviation from the axial center even for small centimeters results in weakening the support ability to withstand loads. The main reason is the loss of stability of this formwork system. This loss issue increases with the increase in heights.

Buckling in the supports reduces the ability of the supports to withstand axial loads. Also, lack of bracing increases the chance of loss of stability in the supports. Connecting supports horizontally with wires is improper and does not guarantee impeding movement horizontally.

Considering all the aforementioned reasons and the simple Euler Buckling Equation reveals the reason for this case failure. Schematic of buckling is presented in Figure 4.15:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Assuming that the height of each segment is three meters, the entire elevation is five meters. The comparison between the theoretical strength for one segment alone and the entire assembly reveals

One segment	Entire assembly
$P_{cr} = \frac{\pi^2 EI}{L^2}$	$P_{cr} = \frac{\pi^2 EI}{L^2}$
$P_{cr} = \frac{\pi^2 EI}{3^2}$	$P_{cr} = \frac{\pi^2 EI}{5^2}$
1/9	1/25
0.111	0.04

This analysis means that the strength of the struts considering all the factors mentioned above is less than forth of tenth (4/10) of the segment strength. The exact percentage is 0.04/0.111 = 0.360. This is the maximum that could be achieved considering that the struts or supports of 5 m length are straight and composed of one segment which is not the case.

This case revealed that the formwork was initially unstable, and any strut losing its vertical stability results in the collapse and redistribution of the loads to adjacent unstable struts.

To sum this up, the reason for failure is formwork collapse due to the improper installation and type. This formwork does not fit the required conditions to support the building during construction. Existence of buckled and rusty supports helped in the failure occurrence.

Additional indirect reasons could be attributed to the absence of true engineering supervision. This supervision could easily find out that formwork is not properly installed and hence, casting permission should be provided after this inspection.

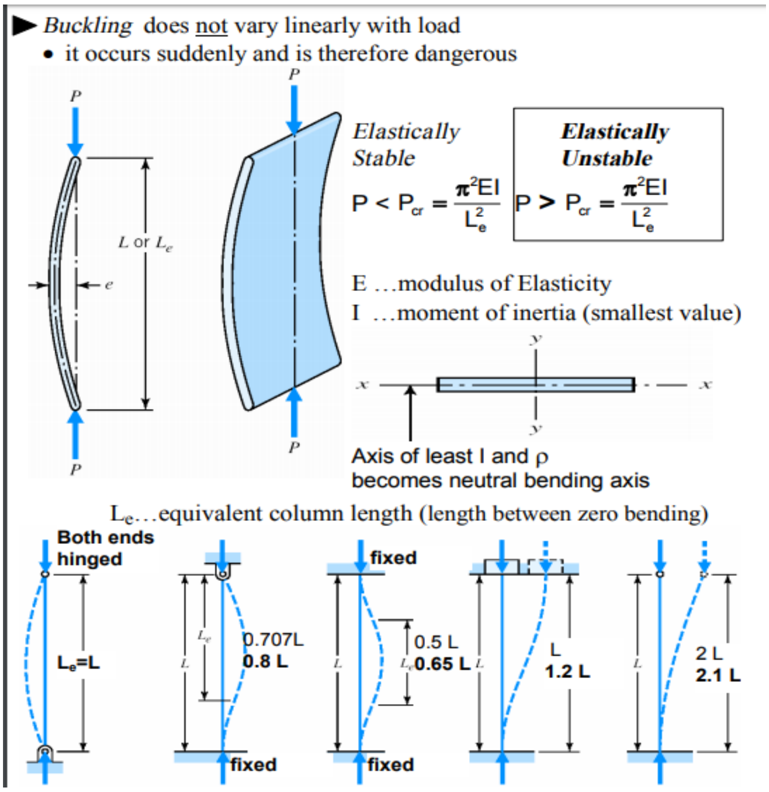

Figure 4.15: Buckling in long columns

Figure 4.16: Formwork collapse in Hebron City Case- First Prospective

Figure 4.17: Formwork collapse in Hebron City Case- Second Prospective

Case study II: 17/06/2020 in Nablus City

A failure occurred to a newly constructed building. This building showed cracks within beams and columns after removing the formwork. The structure was 20 cm ribbed slab, with beams of 20 cm deep, and columns of 20 x 40 cm, and the footings were 100 x 100 x 20 cm. Figure 4.18 - Figure 4.22 show the general layout of the structure and the supports for the buildings.

Figure 4.18: Nablus City Case – General Layout

Figure 4.19: Absence of Proper Footings

Figure 4.20: Type of Supports for the Building

Figure 4.21: Cores in Beams to Determine Concrete Strength

Figure 4.22: Cores in Columns to Determine Concrete Strength

As it is clear from the figures, this is a small traditional building. The thesis is not planning to evaluate the design. Instead, it highlights the key concepts obtained from such building. An engineering office had already evaluated this building and provides recommendations to solve the issues with the buildings. This thesis will use the general common sense for construction industry in West Bank and analyze a hypothetical case of a room of 4 x 4 with the same dimensions used for this building. Since this building showed cracks during construction, only dead load will be considered. Earthquakes did not occur on or before the date of the collapse of this building.

Technical Analysis for Failure

Deflection Consideration:

Since the system is ribbed slabs, using the traditional dimensions for rooms in West Bank and ACI table for deflection. The hypothetical case would result in:

This case is simply supported and the slab depth should be = 4/16 = 0.25 m.

But since the building shows continuity, the slab depth could be reduced to 4/18.5 = 0.22 m or 4/21 = 0.19 m.

Hence, the assumption of 20 cm ribbed slab could be reasonable for deflection.

Slab analysis:

Dead load = Own weight = (0.12 x 0.14+0.52 x 0.06) x 25 + 0.4 x 0.14 x 10 = 1.76 kN/m of rib

Ultimate load = 1.4 Dead load = 1.4 x 1.76 = 2.464 kN/m of rib

Shear force = $\frac{WL}{2}$= $\frac{2.464\,x\,4}{2}$=4.928 kN at center of beam (Center was selected as it is more critical than the at distance d.)

Bending Moment = $\frac{WL^2}{8}$=$\frac{2.464x\,4^2}{8}$= 4.928 kN.m at bottom center of rib

Beam analysis:

Support reaction for each rib is transferred to the beam = 4.928 kN / each rib width

Beam ultimate load is = 4.928 / 0.52 + 0.2 x 0.2 x 25 x 1.4 + 3 x 0.2 x 10 x 1.4 = 19.277 kN /m

Shear force = $\frac{WL}{2}$= $\frac{19.277\,x\,4}{2}$=38.554 kN at center of column

Bending Moment = $\frac{WL^2}{8}$=$\frac{19.277x\,4^2}{8}$= 38.554 kN.m at mid span of the beam

Column Analysis:

Support reaction for each beam is transferred to the column = 38.554 kN.

Since only one floor was constructed, the total load on the column to be considered is coming from one floor, column own weight, half the secondary beam weight, and the perimeter wall on the secondary beam.

Column ultimate load = 38.554 + 0.2 x 0.4 x 25 x 1.4 + 0.2 x 0.2 x 4 / 2 x 25 x 1.4 + 3 x 0.2 x10 x 4 / 2 x 1.4 = 60.954 kN.

Design axial load is 60.954 at bottom of the column

Footing Analysis:

The footing should withstand the loads at the bottom of the column = 60.954 kN in addition to the self-weight of the footing. It also should consider the soil properties (weight) and depth of foundation.

Self-weight of the footing is distributed load, while column loads are concentrated and assumed to influence the mid of the footing.

Design of Bottom Steel Reinforcement of Slab (R.S D=20cm):

Maximum positive moment M_{max} =4.93 kN.m/m

M = $\frac{Fy}{0.85*Fc\prime}$ = $\frac{420}{0.85*24}$ = 20.6

Rn = $\frac{Mu}{0.9*b*d^2}$ = $\frac{4.93*10^6}{0.9*120*150^2}$ = 2.03Mpa

ρ = 1* [1-√ (1-2mRn)/Fy)]/m

ρ = 1* [1-√ (1-2*20.6*2.03)/420)]/20.6 = 0.0051

As_{req}= ρ *b*d = 0.0051*120*150 = 91 mm^2/m

As_{min}= ρ*b*h = 0.0018*120*200 = 43 mm^2/m

So required As = 91 mm^2/m

Use 2ϕ10 per rib, which is common in our country. The ribs reinforcements could be of diameters 12, 14, and 16. The results obtained, showed that the slab may by okay to withstand the loads.

Design of Beams:

Moment envelope for the selected Beam Model from ETABS program gives

Maximum positive moment M_{max} =38.5 kN.m/m

$M = \frac{Fy}{0.85*Fc'} = \frac{420}{0.85*24} = 20.6$

$Rn = \frac{Mu}{0.9*b*d^2} = \frac{38.5*10^6}{0.9*200*140^2} = 9.51$Mpa

ρ = 1* [1-√ (1-2mRn)/Fy)]/m

ρ = 1* [1-√ (1-2*20.6*9.51)/420)]/20.6 = 0.0359

As_{req} = ρ *b*d = 0.0359*200*140 = 1077 mm^2/m

As_{min}= ρ*b*h = 0.0033*200*200 = 132 mm^2/m

So, As = 1077 mm2/m   Use 6ϕ16

This amount of reinforcement is certainly can't be placed in small beam dimensions of 20 x 20 cm. The minimum required width of the beam should be 50 cm to accommodate 6ϕ16.

An explanation to the building failure could be due to the improper structural capacity of the building. The dimensions of the beams are small to sustain loads. If these dimensions were used, then a failure occurred in the building due to the lack of proper steel in the beams of the building, and that the beam section was supposed to be larger than what is present to contain the needed reinforcement.

This case was modeled through ETABS. The complete structural analysis is presented in Appendix C. The results from the program showed that in addition to the improper dimension for reinforcement, shear stress failure should occur in the sections of the beam.

Samples of Failures in West Bank

Case One: Hebron city: Al-Safa Girl preliminary School

The school has 354 students. The second-grade classroom had collapsed on 25/12/2019 on the Christmas. The dimensions of the collapse were as the following: 5 meters width, 25 meters tall and 12 meters height. The site had supporting pillar. The collapse resulted from rocky fall because of neighboring excavations near the project according to the head of engineering offices, Tareq Al-Zaro. The excavation level was deep of 12 meters without taking into consideration engineering actions and suitable support. The excavation was vertical without slope to the other direction to mitigate the danger of collapse. The investigation of the collapse revealed that the accident happened due to the absence of suitable cautions and the absence of suitable supporting as stated by the Palestinian Engineering Association. According to the Municipality Board member, Abed Abu Isneeneh, the owner was authorized for excavation, but he was warned several times about that his actions were not in accordance with the engineering schedules. Yousef Al-Ja'bary, Municipality deputy chief, stated that the owner had permits to establish his building on a part of the land with several warnings by the Palestinian police to stop his project as it is not matching the license the owner attained. Tareq Al-Zaro reported that engineering plans and bill of quantities have not been approved from the Palestinian Engineering Association. According to Palestinian law, it is forbidden to start the project even with excavations without being permitted, and it is not legal to permit the excavations according to previous invalid permission without knowing what the recent one includes. The Civil Defense manager, Yazzan Yousef, reported that the department was not informed about the excavations. Moreover, Hebron Municipality said that it has sent five warnings to the owner who had admitted that he had achieved two of them: the former for excavations and the later for infringement on the road. Consultation meeting among stakeholders had been held and the recommendations were the following: The file of Al-Safa School had been transferred to the Palestinian courts; Starting the redemption of the school immediately; Searching for alternative center; The expenses of the redemption of the school and the alternative center are on the contractor; and the responsibility for the collapse should be shouldered by more than one party. This failure could be catastrophic since it affected a school, and luckily the collapse occurred on a holiday. This failure could be easily avoided if a true engineering supervision was applied. Also, this situation could be mitigated if the owner of the excavation followed the engineering procedures to mitigate the risk of collapse.

Figure 4.23: Excavation Failure Near Al-Safa Girl Preliminary School

Figure 4.24: Impact of Failure on Al-Safa Girl Preliminary School

Case Two: Hebron city: Wad Al -Tufah Street near Al-Rayan Restaurant 25-2-2020.

Wad Al – Tufah is a street in Hebron city. This street serves as a local street used frequently by citizens of the city. The supporting wall of Wad Al-Tufah Street collapsed on 25-02-2020 near Al-Rayan Restaurant. The collapse occurred because of inadequate support for the wall, the weakness of the soil, the bad weather conditions resulted in land driftage, and the absence of excavation suitable procedures.

Figure 4.25: Impact of Wall Collapse in Wad Al-Tufah

Figure 4.26: Wad Al-Tufah Failure

Case Three: Nablus city-Aseera Street. 15-02-2020

Nablus city had the largest number of collapses. The city had failures more than any other city in the West Bank recently. Aseera street collapse started with falling rocks towards a building. The noise of falling had a severe effect on the inhabitants and caused panic regardless to details. Soil moving followed the rocks behind the wall (soil moving and not the falling rocks from top to down) causing collapse of the garage ceiling behind the building. Engineering committee had been established by Nablus Governorate consisted of Dr. Jalal Al-Dabeek, Dr. Sami Hejawi, Dr. Essam Jerdaneh, Civil Defense Engineer, and the Nablus Municipality engineer. The site has been visited and the following have been revealed; The collapses did not affect the building safety; There is no more danger from the collapse on the building; and the Civil Defense Department should evacuate another building to prevent panic resulted from another night collapse. Thorough investigation revealed that the wall has been built without consideration of any future change in the soil. There is an error in executing the construction of the wall, and there is an error on the collapsed garage ceiling. The newly opened road behind the building which is only 20 meters next to building had been considered, and the investigation showed that it has not been affected by the accident. It was also found the soil in the collapse is old, and it has nothing from the road soil. The wall collapse had not happened from top to down, but instead a huge soil rushing behind the collapsed wall. The major cause of the failure is the incorrect excavation without following safe procedures and consideration of the white soil behind the wall. The wall has been built without engineering supervision. This failure could be attributed to the unexpected natural loads as well.

Unstable huge masses of soil had been noticed in a high place behind the building. With inability to use excavation tools, water pressure had been suggested to remove these huge masses by pumping water directly to these masses. 90 water cubic meters have been pumped by Nablus Fire Department which succeeded in removing the danger. The first owner of the building promised to rebuild the wall and parking place under engineering supervision and to return people to the evacuated building. There is a huge break in the soil behind several adjacent buildings.

After the collapse, the Municipality studied and collected data about all walls in more than one site. It is forbidden to cast concrete in walls without permission, studying the building systems, and studying the procedures of excavations.

Figure 4.27: Garage Wall Failure

Figure 4.28: Rocks Falling on Garage Ceiling

Figure 4.29: Scale of the Collapse

Figure 4.30: Impact of Failure on the Building

Figure 4.31: Garage Ceiling Collapse

Case Four: Nablus city – Rafeedia Street. 27-07-2019

The engineering office supervising this site was visited, and the site was visited, and data had been collected on the site. The resident engineer stated that the main reason behind the collapse is the difference in the quality of the neighboring soil, which was not taken into account, and the presence of running water in the area, which helped in the collapse of the piles.

The number of all the piles surrounding the building was 175 piles, and they were only affected by a certain pressure that led to gradual cracks. The supervising office had suggested two solutions to solve the issue of the collapse. These solutions were;

The first solution: Use huge stone quarries of length of 2 meters x width 2 meter x thickness 2 meter (boulders) to support the facade where the collapse occurred.

The second engineering solution: Use inverted recessed beams in the design of the slabs to compensate for the column loads that were in the engineering design plan. The length of the beam is 19 meter x width 0.70 meter x thickness 1.40 meter.

Figure 4.34 and Figure **4.35** show the supporting process that was put in place, and the beams that were used in the solution.

This failure had the following insights from different professional engineers who were informed with the collapse; used steel bars were of various kinds; and sheet piles were used to avoid collapses at initial stage of excavation. The soil testing laboratory had an important role, and the engineer had another role in the design. The laboratory was responsible for soil testing and the determination of the embedment sheet pile length inside the ground. The free height of the pile determines the embedment length that may reaches 40-60 % of its length and it could be increased according to several factors including: the soil properties, loads on the pile and the lateral pressure. The design engineer's role was to determine the pile diameter and the distance between piles. The above information is usually known before starting the excavation. The collapse length was 29 meters, its width was 4 meters and its height was 6 meters or more. According to the investigations, the results were as following: The collapse happened in the wall consisted of pillars because of the excavations were not as the engineering laws and procedures without taking any safety measures into considerations, inadequate supporting with a gap resulting in the weakness of the wall, and the piles were not deep enough to support the soil. It is clear that the piles were constructed with insufficient embedded length in the soil substrata to avoid overturning.

The proposed solution to avoid the collapse was adequate supporting with preventative measures under the engineering supervision based on approved schedules from the Palestinian Engineering Association. Also, it was suggested to make what is called a (top down system) in order to avoid the collapse according to engineering laws.

Figure 4.32: Construction Site Failure

Figure 4.33: Impact of Construction Site Failure

Figure 4.34: First Solution by Supervising Office

Figure 4.35: Second Engineering Solution to Construction Site Collapse

Case Five: Nablus city – Tell Village street. 24-02-2020

A governmental kindergarten was built on Tell Street of Nablus city. On 24-02-2020, a ceiling fall during casting concrete in the governmental kindergarten occurred. The damage was material with no human injuries. The main reason was the inadequate supporting beams and formwork. The procedures were not according the engineering measurements. In another words, the loads were more than the carriers can withstand, which resulted in the ceiling collapse.

Figure 4.36: Ceiling Collapse During Concrete Casting

Case Six: Al-Basateen street near Al-Safa Bank. 21-07-2019

Al-Basateen region in Nablus city had witnessed a failure during construction. This region is well known of its clayey soil as it was for agricultural purposes historically in Nablus. The failure occurred on the opposite corner of Al-Safa bank. The reason for the accident was the collapse of the wall with piles in which these were not in an adequate depth. The collapse resulted from the extra pressure on the road from the moving traffic. This load was transferred to the soil which pressured the wall that does not have enough supporting beams. As a result, a collapse occurred.

Figure 4.37: Al-Basateen Street Failure

Case Seven: Nablus city – Nablus Al-Jadeedah. 01-03-2019.

Nablus Al-Jadeedah presented the newest addition to the Nablus city. Expansion of the city of Nablus looked to additional regions for citizens to invest in. Buildings were constructed on this new region but collapses also occurred. The accident had happened because of the neighboring excavations to 7 meters depth without suitable planning and without any supporting precautions. The collapse caused damages in the adjacent building and penetrates in an adjacent small wall. The building was evacuated, and no injuries were recorded.

Figure 4.38: Nablus Al-Jadeedah Failure

Case Eight: Qalqilya city. 02-06-2019.

Qalqilya city had witnessed collapses too. It is true that the number of failures were lesser than those in Nablus and Hebron cities because the complicated nature of the latter two, but Qalqilya witnessed a collapse of a wall on 02-06-2019. The collapse of a wall while being constructed was because of inadequate supporting wood panels and formwork. The investigations showed that the reasons could be resulted from the rapid casting with concrete which caused pressure on the wall which does not have a proper formwork.

Figure 4.39: Qalqilya Failure

Case Nine: Ramallah city - Al-Terah suburb. 16-04-2015.

Heavy rains and ice caused the collapse of a part of the street in Al-Terah suburb in Ramallah city. The street was in danger of falling six months before the incident due to the construction works in the region. The huge collapse happened and caused soil and rocks falls towards an adjacent house. Human disaster had been avoided because of a wall that the house owner had built earlier. The citizens in the early morning of the collapse day astonished of the street collapse which caused a hole of more than five meters high. Municipality closed the street. Citizens were unsatisfied that the street had not been fixed during the construction works in the site.

According to citizens, the reasons for collapse were land driftage and Municipality ignorance to maintain the street.

Figure 4.40: Al-Terah Failure

Figure 4.41: Impact of Al-Terah Failure

Figure 4.42: Impact of Failure on Supporting Walls

Figure 4.43: Scale of Al-Terah Failure

Summary of Failure Cases in West Bank

The case studies mentioned earlier are part of the failures occurred in West Bank. The reasons for failures for the mentioned cases can be summarized in three main reasons which could be mitigated by true engineering supervision. The first is neglecting the site investigation. The second is improper formwork and support during construction. The last one is improper excavation procedures. Table 4.10 represents a summary of failures that occurred in West Bank in the last decade.

Table 4.10: Reported Cases of Collapsed Buildings in West Bank for a Period of 10 Years (2010-2020)

No.	Location	Date	Building Type	Collapse Stimuli	Casualties
1	Hebron city	25/12/2019	Al-Safa Girl Basic School	Improper Excavation adjacent to the building	zero
2	Hebron city	25/02/2020	Retaining wall	Unanticipated weather conditions >> estimating loads improperly	zero
3	Nablus city	15/02/2020	Aseera Street	Mistakes in executing the construction, and no site investigation	zero
4	Nablus city	27/07/2019	Piles wall	Soil type near excavation >>improper design of sheet piles	zero
5	Nablus city	24/02/2020	Governmental kindergarten	Inadequate supporting beams and formworks	2 Injured
6	Nablus city	11/11/2015	Ceiling collapse during construction	The lack of sufficient formwork supports	8 Injured
6	Nablus city	21/07 /2019	Al-Basateen street	Collapse of the wall with piles	zero
7	Nablus city	23/12/2015	Ceiling of a Masjed collapsed during construction	The lack of sufficient formwork supports	10 injured
8	Nablus city	1/3/2019	Retaining wall	Absence of walls in the site and excavation	zero
9	Nablus city	2/7/2014	Ceiling of house collapse	Heavy loads of the second floor	6 injured
10	Qalqilya city	2/6/2019	Retaining wall	There are no adequate supporting wood panels	zero
11	Ramallah city	16/04/2015	Al-Terah suburb street	Heavy rains and ice caused the collapse >> estimating loads	zero

				improperly	
12	Hebron city	16/05/2020	Ceiling of house collapse during construction	Heavy load and the lack of supporting estimating loads improperly	zero
13	Salfit city	18/04/2020	Facade brick wall	Heavy loads caused the collapse estimating loads improperly	2 Injured
14	Salfit city	4/6/2014	Ceiling of factory collapse during construction	The ceiling is over 9 meters high and the support is weak	10 injured
15	Jerusalem	14 /02/2020	Old house	Excavations of the Israeli occupation	zero
16	Jenin city	10/12/2019	A collapsed street in the Yamoun area	Soil erosion and heavy rain	zero
17	Jenin city	18/08/2019	The fall of a high-pressure electric tower	Excavations by neighbors	zero

Discussion

Validity

Validity of the Questionnaire

To ensure the validity of the questionnaire, it was rated by a jury of experts in the field of engineering at An-Najah National University. The respondents' comments and the jury's suggestions were taken into consideration to modify and improve the questionnaire's content and phrasing by omitting, adding, or rephrasing items. This procedure resulted in bringing the number of items in the questionnaire to 14 items.

Reliability of the Questionnaire

The reliability of the questionnaire as calculated through Cornbach Alpha formula for the total degree was (0.844) which is acceptable for conducting the research.

Procedure

The final draft of the questionnaire was given to a study sample at West Bank. It took about five weeks for the questionnaire to be distributed, collected, and returned to the researchers. The total number of the returned questionnaires was 30 and four questionnaires have been excluded as their responses were neither consistent nor complete.

Limitations

Sample size is the main limitation as statistical tests normally require a larger sample size to ensure a representative distribution of the population to be considered representative. The following consideration should be stated:

1. Lack of available and reliable data because of the lack of cooperation of the people involved in the cases where failures occurred. This lack of cooperation is due to their fear of reopening the topic. Self-reported data is limited regardless whether the researchers are relying on pre-existing data or conducting a qualitative research study or gathering the data. Self-reported data is limited by the fact that it can rarely be independently verified. In other words, the researcher must take what people say for granted, whether in interviews, focus groups, or on questionnaires. Self-reported data can contain several potential sources of bias that the researcher should be alert to and note as limitations.
2. COVID 19 virus was one of the most important obstacles in the scientific research process for this thesis. It was not possible to transport between the governorates to obtain enough information for this research, and the continuous closures resulted in not obtaining the adequate amount of information to support the research.
3. Incorporation of related parties resulting in hardening the process to get information.

Discussion of Research Questions

This study aimed at identifying reasons behind the collapse of buildings in West Bank that are under construction. It also aimed at identifying the effect of demographic variables on the responses of the questionnaire. To accomplish the aims of the study, the researcher analyzed the data in accordance with the study questions and the results were as follows:

Results related to the First Question:

What are the reasons behind the collapse of buildings in West Bank that under construction?

Table 4.11: Means, Standard Deviations and Estimated Level of Means, Standard Deviations and Estimated Level of the Reasons Behind the Collapse of Building in West Bank Under Construction.

No.	No. in the Questionnaire	Item	Means	standard deviations	Percentage %	Estimated level
1.	3	Soil type where building is constructed	3.50	.77	87.5	High
2.	4	Improper support during construction	3.20	.99	80.0	High
3.	14	Execution errors and non-conformance with schedules	3.16	.87	79.0	High
4.	8	Errors in the engineering design	3.13	1.04	78.0	High
5.	2	Concrete quality	3.13	.81	78.0	High
6.	5	Inadequate engineering supervision	3.13	.86	78.0	High
7.	13	Lack of experience and knowledge ins site management	2.96	.88	7.40	Moderate
8.	6	Construction material deficiency	2.80	.96	70.0	Moderate
9.	12	Culture of local constructions	2.70	1.14	67.5	Moderate
10.	1	Steel and reinforcement quality	2.66	.84	66.5	Moderate
11.	10	Improper excavations	2.63	.96	65.8	Moderate
12.	11	Weather conditions in work sites	2.36	.85	59.0	Moderate
13.	7	Rapid concrete casting	2.30	.83	57.5	Moderate
14.	9	Insufficient lighting	1.90	.71	47.5	Low
Total			2.82	.49	71.0	Moderate

Table 4.11 shows that the total degree for the reasons behind the collapse of buildings in West Bank under construction was (2.82) which suggests moderate level of estimation. The highest mean was given to the item (Soil type where building is constructed). The lowest was for the item (Insufficient lighting).

Results related to Second question:

Are there any significant statistical differences at (α =0.05) in the response degree regarding the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age, and the capital of the company?

To answer this question, study hypotheses have been analyzed by using independent sample t tests and One-Way ANOVA test was used. Table 4.12 – Table 4.24 present the results.

Results related to the first hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age.

To test this hypothesis, One Way ANOVA test was used. Results are as follows:

Table 4.12: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Age

Age (Total Degree)		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	20-29	13	2.94	.41
	30-39	11	2.74	.48
	40-49	2	2.39	1.26
	50-59	2	3.00	.20
	60 and more	2	2.82	.55
	Total	30	2.82	.49

Table 4.13: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Age

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	.701	4	.175	.682	.611
	Within Groups	6.418	25	.257		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.13 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age. The significant value was (.611) which is more than (.05).

Results related to the second hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of gender.

To test this hypothesis, Independent sample t test was used.

Table 4.14: Independent Two Sample t Test Result of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Age

	Age	N	Mean	S. D	t	Sig.*
Total degree	Male	19	2.81	.50	-.236	**.815**
	Female	11	2.851	.49		

***. The mean difference is significant at the 0.05 level.**

Table 4.14 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of gender. The significant value was (.815) which is more than (.05).

Results related to the third hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of career.

To test this hypothesis, One Way ANOVA test was used.

Table 4.16 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of career. The significant value was (.694) which is more than (.05).

Results related to the fourth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of experience.

To test this hypothesis, One Way ANOVA test was used.

Table 4.18 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of experience. The significant value was (.572) which is more than (.05).

Table 4.15: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Career

Career (Total Degree)		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	Academic	3	2.85	.93
	Supervisor	17	2.91	.36
	Project Engineer	7	2.67	.65
	Owner	3	2.66	.41
	Total	30	2.82	.49

Table 4.16 Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Career

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	.379	3	.126	.488	.694
	Within Groups	6.739	26	.259		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.17: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Experience

Experience (Total Degree)		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	10	2.85	.44
	6-10	9	2.83	.54
	11-15	4	2.46	.75
	16-20	3	3.07	.18
	More than 20	4	2.92	.37
	Total	30	2.82	.49

Table 4.18: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Experience

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	.756	4	.189	.743	.572
	Within Groups	6.362	25	.254		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Results related to the fifth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of period of building.

To test this hypothesis, One Way ANOVA test was used.

Table 4.20 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of period of building.

The significant value was (.148) which is more than (.05).

Results related to the sixth hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of building age.

To test this hypothesis, One Way ANOVA test was used.

Table 4.19: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Period of Building

Period of building **(Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	15	2.88	.47
	6-10	2	3.10	.05
	11-15	2	2.07	.80
	16-20	2	3.17	.45
	More than 20	9	2.76	.42
	Total	30	2.82	.49

Table 4.20: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Period of Building

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.636	4	.409	1.865	.148
	Within Groups	5.483	25	.219		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table 4.21: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Building Age

Buildingage **(Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	1-5	16	2.95	0.42
	6-10	4	2.37	0.85
	16-19	2	2.75	0.15
	20 and more	8	2.83	0.39
	Total	30	2.82	.49

Table 4.22: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Building Age

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.075	3	.358	1.541	.228
	Within Groups	6.044	26	.232		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Table **4.22** shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of building age.

The significant value was (.148) which is more than (0.05).

Results related to the seventh hypothesis which is:

There are no significant statistical differences at (α =0.05) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of company capital.

To test this hypothesis, One Way ANOVA test was used. Table 4.24 shows that there are no significant statistical differences at (α =0.05) in the response's degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variable of company capital. The significant value was (.254) which is more than (.05).

Table 4.23: Frequencies, Means and Standards Deviations of the Reasons of Contractors Failure in West Bank Attributed to the Variable of Company Capital

Buildingage **(Total Degree)**		**N**	**Mean**	**S.D**
The reasons behind the collapse of buildings in West Bank that are under construction	Less than 100000	6	2.63	.66
	100,000-150,000	7	2.64	.47
	160,000-200,000	5	2.94	.31
	300,000-400,000	9	2.87	.46
	500000 and more	3	3.33	.14
	Total	30	2.82	.49

Table 4.24: Results of One-Way ANOVA of the Reasons Behind the Collapse of Buildings in West Bank That are Under Construction Attributed to the Variables of Company Capital

The reasons behind the collapse of buildings in West Bank that are under construction	**Source of variance**	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Total	Between Groups	1.323	4	.331	1.427	.254
	Within Groups	5.795	25	.232		
	Total	7.118	29			

*** The mean difference is significant at the 0.05 level.**

Major Findings

The DMAIC model can play a major role as a quality management approach to mitigate hazards for the risks of collapse of buildings. This model defines the issues related to the building collapse, measures their impact on the construction industry and humans, analyzes the results, improves the performance, and controls the outcomes. This technique mitigates the hazards for the risks of collapse of buildings.

The results of the current study reveal that the total degree of the reasons behind the collapse of buildings in West Bank that are under construction suggests a moderate level of responses. The highest mean was given to the item "Soil type where building is constructed”. On the other hand, the lowest mean was given to the items "Insufficient lighting".

The researcher due these results concludes that the collapse of buildings in West Bank is of a considerable concern. The moderate level suggests precautious actions needed to be implemented to avoid an increase probability of building failures.

The highest reasons for the collapse of buildings in West Bank that are under construction are soil type where building is constructed, Improper support during construction, and execution errors and non-conformance with schedules. These factors were among the top ones in the questionnaire, and they are the main reasons for the case studies explained earlier.

The researcher due these results suggests that site investigation procedures need to be an essential requirement before providing permits or licenses from the official parties. Also, a true supervision is a mandate to eliminate other reasons for failures in the buildings. The most frequent reasons for failure could be easily handled with true experienced engineering supervision.

The moderate reasons for The reasons behind the collapse of buildings in West Bank that are under construction are errors in the engineering design, Concrete quality, Inadequate engineering supervision, Lack of experience and knowledge in site management, Construction material deficiency, Culture of local constructions, Steel and reinforcement quality, Improper excavations, Weather conditions in work sites, and Rapid concrete casting.

The lowest item that impacts the rate of building failures was insufficient lighting. The researcher due this result thinks that the current construction industry can work efficiently regardless the time of day or night. This is achieved by the help of the newer technologies of lighting and construction industry.

Also, There are no statistically significant differences at ($\alpha = 0.05$) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age and the capital of the company.

The researcher due to these results believes that common mistakes in construction industry are well-known. The next steps are to handle these well-known issues to mitigate their occurrence in the future. The legal and engineering authorities need to foster actions that limit the influence of these issues in the field of construction industry.

Chapter 5

Summary, Conclusions, and Recommendations

Investigation of the reasons of building failures in West Bank was studied thoroughly in this thesis. In the last decade, the number of collapsed buildings or prone to collapse increased rapidly in West Bank. Several methods are conducted by the researcher to address the topic. These methods include distributing a well-prepared questionnaire for constructions were failures occurred. The questionnaire targeted both Nablus and Hebron cities, and around 30 questionnaire responses were obtained. The responses were further analyzed using appropriate statistical programs and procedures to highlight key reasons for building collapses. Several interviews were conducted with stakeholders of the collapsed buildings. The reasons for failures for these buildings were explained simply with concise. Two failure cases were further analyzed using engineering codes and programs. The failure reasons were explained scientifically, and the premature failures were possible to be avoided by adhering to simple engineering principles. Finally, the DMAIC model was discussed as a quality management approach to mitigate the hazards for the risk of the collapsed buildings.

The researcher concludes the following:

- The collapse of buildings in West Bank is of a considerable concern. The analysis revealed a moderate level of concern. This level suggests precautious actions needed to be implemented to avoid an increase probability of building failures.

- The highest reasons for the collapse of buildings in West Bank that are under construction are Soil type where building is constructed, Improper support during construction, and Execution errors and non-conformance with schedules.
- Insufficient lighting is not a real concern that causes a failure during construction. This fact is because the current construction industry can work efficiently regardless the time of day or night. This is achieved by the help of the newer technologies of lighting and construction industry.
- There are no statistically significant differences at ($\alpha = 0.05$) in the response degree of the reasons behind the collapse of buildings in West Bank that are under construction attributed to the variables of age, gender, career, experience, period of building, building age and the capital of the company. This fact shows that the reasons of failures for buildings under construction are well known by the engineering community and construction industry professionals.
- The DMIAC model can play a role in mitigating the risks of the collapsed building. It uses a thorough approach to understand the failures of buildings and suggests improvements and controls base on the analysis done for the measured characters related to the building failures.

The main recommendations are as following:

- Site investigation procedures need to be an essential requirement before providing permits or licenses from the official parties.

- True supervision is a mandate to eliminate and reduce the frequency of failures in the buildings under constructions. The most frequent reasons for failure could be easily handled with true experienced engineering supervision. This supervision mitigates the failures in buildings through applying correct procedures, reducing the use of improper materials, and handling the unexpected construction situations using the right procedures, techniques, and using the appropriate engineering codes.
- There is a need to apply periodical investigation for plans and construction works through the municipalities and Palestinian Engineering Association – Jerusalem Center before and during the implementation of works.
- There is a need to have a local construction code that considers specific loadings and conditions that could be applied in Palestine. This code can be adopted by the design engineers and the official agencies that review the technical drawings for approval.

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Appendices

Appendix A: Questionnaire

استبيانة هندسية

الأخوة الكرام.....

أنا الطالب عوني خليل مشعل ضمن سياق مشروع بحثي في كلية الدراسات العليا قسم الإدارة الهندسية جامعة النجاح الوطنية ,أقوم   بعمل دراسة تحت اشراف الدكتور رياض عبد الكريم عوض حول :

التحقيق في اسباب انهيار المباني قيد الانشاء في الضفه الغربيه."

كما و تهدف هذه الاستبيانة إلى دراسة واقع إجراءات الانهيارات ومعرفة اهم الاسباب التي تؤدي الى انهيار المباني والطرق والمنشات بشكل عام، و لإتمام متطلبات الدراسة.

لذلك نرجو تعبئة هذا الاستبيان بدقه حيث أن نتائج هذه الدراسة ستستخدم لأغراض البحث العلمي فقط, و لن يكون بالإمكان معرفة هوية المشاركين في تعبئة هذا الاستبيان.

شاكرا لكم حسن تعاونكم معنا

2019/2020

<u>القسم الأول:</u>

معلومات عامة :

الرجاء الإجابة على هذه الأسئلة بوضع إشارة (X) امام الخيار الذي يناسبك.

العمر:1 ○ 20–29 2 ○ 30 – 39 3 ○ 40 – 449 ○ 50–59 5 60 فما فوق ○

الجنس : 1 ○ ذكر 2 ○ انثى

عملك الوظيفي : 1○مدير مشروع 2 ○مهندس مشرف

3 رئيس ورشة 4○ دكتور أكاديمي ○

عدد سنوات الخبرة : 1 ○ (1- 5) 2 ○ (6- 10) 3 ○(11- 15)

4 ○(16- 20) 5 ○ 20سنه او اكثر

<u>القسم الثاني :</u> الوضع العام عن المباني حصل فيها انـهيار :

A) المده الزمنيه على انشاء المبنى ؟ 1○1-5 2 ○6-10 3 ○ 16-19

11-15 54 ○ 20سنه او اكثر○

B)عمر المبنى الذي حصل فيه انهيار ؟ 1 ○ 5-1 2 ○ 6-10

3 ○ 16-19 4 ○20سنه او اكثر

C) راس مال المنشاه ؟ 1○ اقل من ○100000-150000 100000 3 -200000

160000○ 4 ○ 300000-400000 ○ 5 500000 او اكثر

<u>القسم الثالث :</u>

أسئلة تتعلق بأهم العوامل المؤثرة على جودة العملية الانشائيه :

الرجاء وضع إشارة (X) مقابل الإجابة التي تناسبك:

الرقم	البند	قليل التأثير 1	متوسط 2	مؤثر 3	مؤثر جدا 4
1	نوعية الحديد المستخدم في عملية البناء				
2	نوعية الباطون المستخدم اثناء الصب				
3	نوعية التربه التي يتم البناء عليها				
4	الاستهتار بكيفية وضع الدعمات الخشبيه من قبل العمال				
5	سوء الاشراف الهندسي				
6	وجود خلل في المواد الانشائيه المستخدمه				
7	سرعة الصب في الموقع				
8	وجود اخطاء في التصميم الهندسي				
9	عدم وجود الإضاءة المناسبة خلال فترة العمل				
10	الحفر بطريقه غير سليمه للتربه مما يؤدي لضرر للمباني المجاوره				
11	الظروف الجويه المحيطه بموقع العمل				

12	الثقافه المحليه للناس بالنسبه لعملية البناء				
13	قلة الخبرة و المعرفه في ادارة الموقع				
14	وجود أخطاء في عملية التنفيذ				

Appendix B: Statistical Analysis

RELIABILITY /VARIABLES=q1 q2 q3 q4 q5 q6 q7 q8 q9 q10 q11 q12 q13 q14 t /SCALE ('ALL VARIABLES') ALL /MODEL=ALPHA.

Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
.844	15

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
q3	30	1.00	4.00	3.5000	.77682
q4	30	1.00	4.00	3.2000	.99655
q14	30	1.00	4.00	3.1667	.87428
q8	30	1.00	4.00	3.1333	1.04166
q2	30	1.00	4.00	3.1333	.81931
q5	30	1.00	4.00	3.1333	.86037
q13	30	1.00	4.00	2.9667	.88992
T	30	1.50	3.50	2.8286	.49544
q6	30	1.00	4.00	2.8000	.96132

q12	30	1.00	4.00	2.7000	1.14921
q1	30	1.00	4.00	2.6667	.84418
q10	30	1.00	4.00	2.6333	.96431
q11	30	1.00	4.00	2.3667	.85029
q7	30	1.00	4.00	2.3000	.83666
q9	30	1.00	3.00	1.9000	.71197
Valid N (listwise)	30				

ONEWAY t BY Age /STATISTICS DESCRIPTIVES /MISSING ANALYSIS

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
20-29	13	2.9451	.41869	.11612	2.6920	3.1981	1.79	3.36
30-39	11	2.7403	.48684	.14679	2.4132	3.0673	2.00	3.50
40-49	2	2.3929	1.26269	.89286	-8.9520-	13.7377	1.50	3.29
50-59	2	3.0000	.20203	.14286	1.1848	4.8152	2.86	3.14
60 and more	2	2.8214	.55558	.39286	-2.1703-	7.8132	2.43	3.21
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.701	4	.175	.682	.611
Within Groups	6.418	25	.257		
Total	7.118	29			

T-TEST GROUPS=Gender (1 2) /MISSING=ANALYSIS /VARIABLES=t /CRITERIA=CI (.95).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
t	Equal variances assumed	.304	.586	-.236-	28	.815	-.04511-	.19084	-.43603-	.34580
	Equal variances not assumed			-.238-	21.444	.814	-.04511-	.18957	-.43886-	.34863

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
t	Male	19	2.8120	.50799	.11654
	Female	11	2.8571	.49590	.14952

ONEWAY t BY Career /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Onaway

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Academic	3	2.8571	.93405	.53927	.5368	5.1775	1.79	3.50
Supervisor	17	2.9160	.36267	.08796	2.7295	3.1024	2.00	3.36
Project Engineer	7	2.6735	.65186	.24638	2.0706	3.2763	1.50	3.21
Owner	3	2.6667	.41239	.23810	1.6422	3.6911	2.43	3.14
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.379	3	.126	.488	.694
Within Groups	6.739				
Total	7.118	29			

ONEWAY t BY experience /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	10	2.8571	.44032	.13924	2.5422	3.1721	1.79	3.29
6-10	9	2.8333	.54632	.18211	2.4134	3.2533	2.00	3.50
11-15	4	2.4643	.75930	.37965	1.2561	3.6725	1.50	3.07
16-20	3	3.0714	.18898	.10911	2.6020	3.5409	2.86	3.21
5.00	4	2.9286	.37796	.18898	2.3271	3.5300	2.43	3.29
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.756	4	.189	.743	.572
Within Groups	6.362	25	.254		
Total	7.118	29			

ONEWAY t BY Period /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. rror	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	15	2.8857	.47748	.12329	2.6213	3.1501	1.79	
re								

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.636	4	.409	1.865	.148
Within Groups	5.483	25	.219		
Total	7.118	29			

ONEWAY t BY Building /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1-5	16	2.9509	.42755	.10689	2.7231	3.1787	2.00	3.50
6-10	4	2.3750	.85391	.42696	1.0162	3.7338	1.50	3.14
16-19	2	2.7500	.15152	.10714	1.3886	4.1114	2.64	2.86
20 and more	8	2.8304	.39482	.13959	2.5003	3.1604	2.29	3.29
Total	30							

ANOVA

T

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.075	3	.358	1.541	.228
Within Groups	6.044	26	.232		
Total	7.118	29			

ONEWAY t BY Capital /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.

Descriptive

T

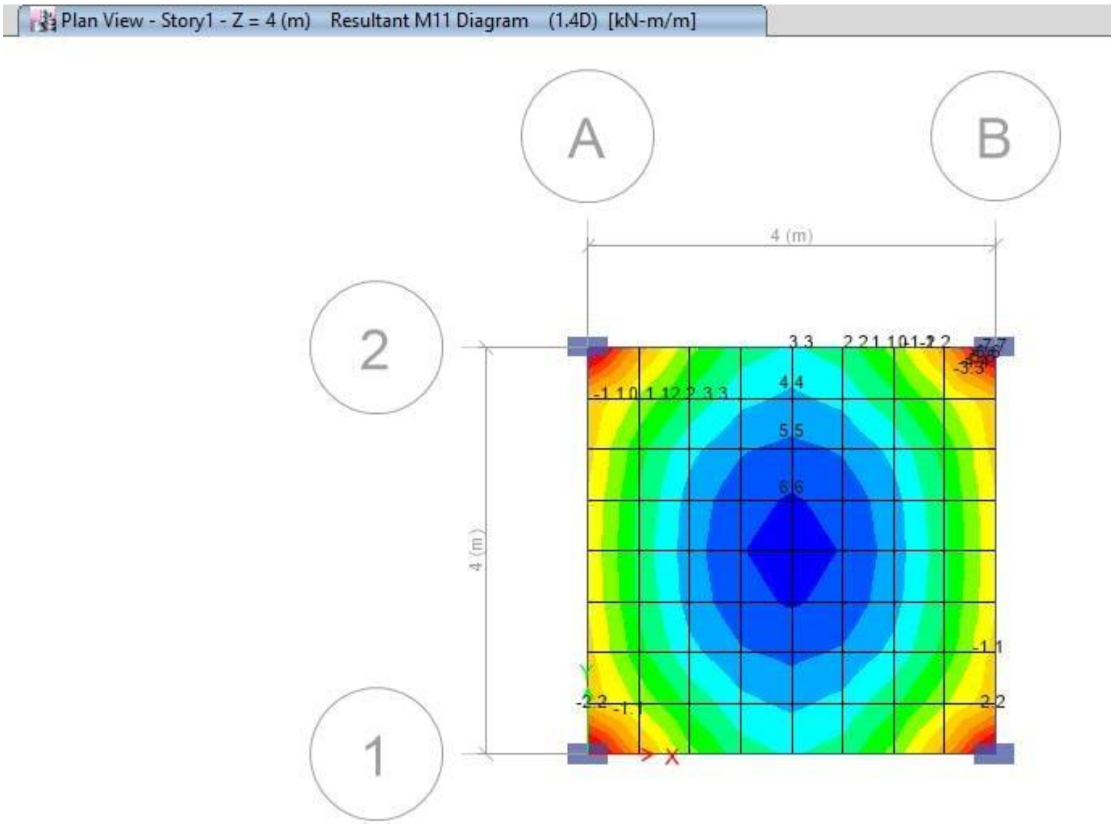
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Less than 100000	6	2.6310	.66611	.27194	1.9319	3.3300	1.50	3.29
100,000-150,000	7	2.6429	.47916	.18110	2.1997	3.0860	1.79	3.07
160,000-200,000	5	2.9429	.31703	.14178	2.5492	3.3365	2.43	3.21
300,000-400,000	9	2.8730	.46809	.15603	2.5132	3.2328	2.00	3.36
500000 and more	3	3.3333	.14869	.08585	2.9640	3.7027	3.21	3.50
Total	30	2.8286	.49544	.09045	2.6436	3.0136	1.50	3.50

ANOVA

T

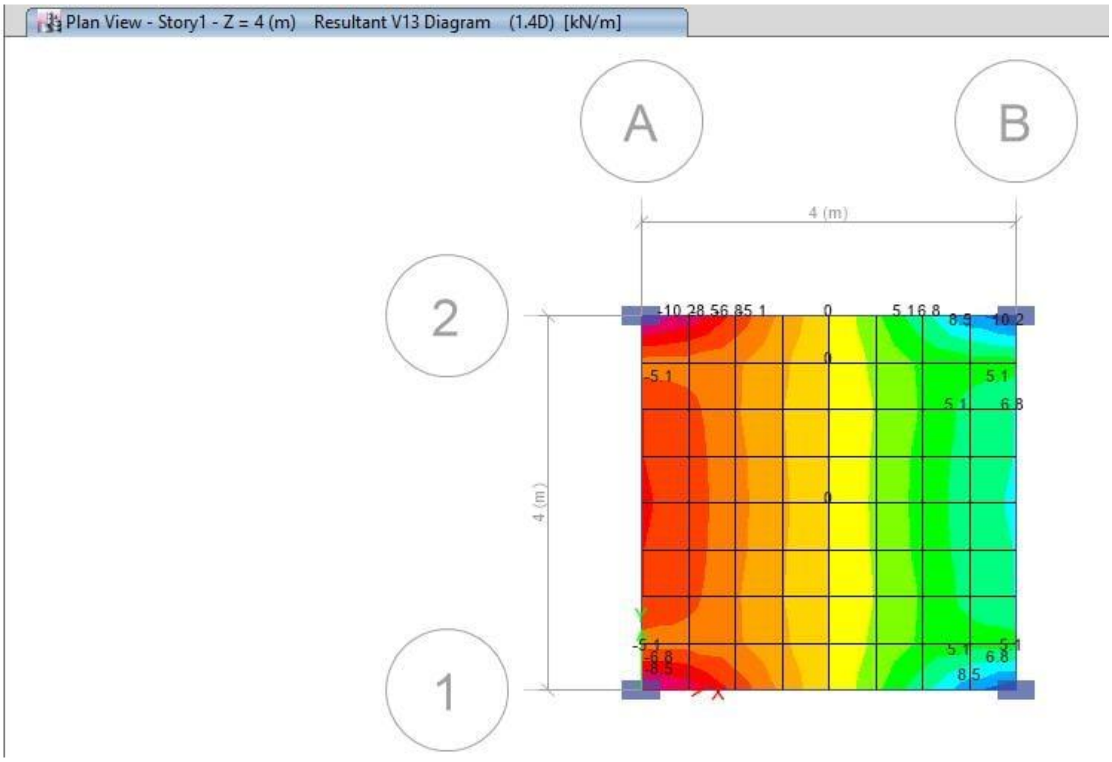
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.323	4	.331	1.427	.254
Within Groups	5.795	25	.232		
Total	7.118	29			

Appendix C: Structural Analysis and Design



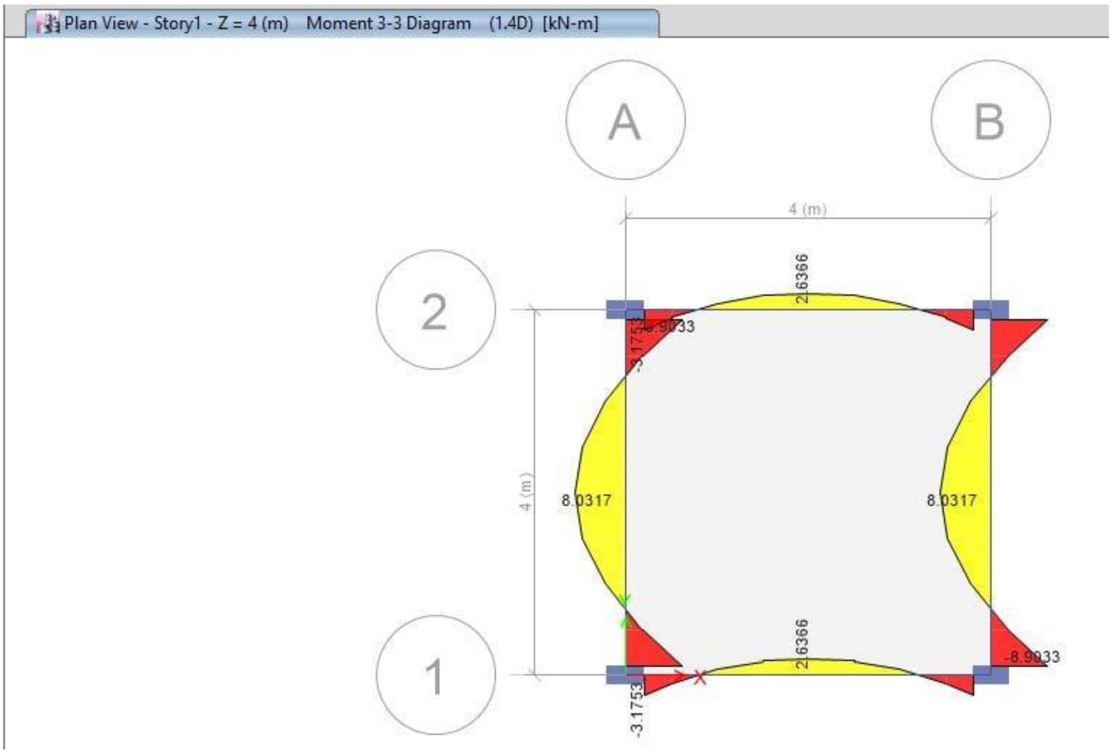
Moment =7 kN/m for slab

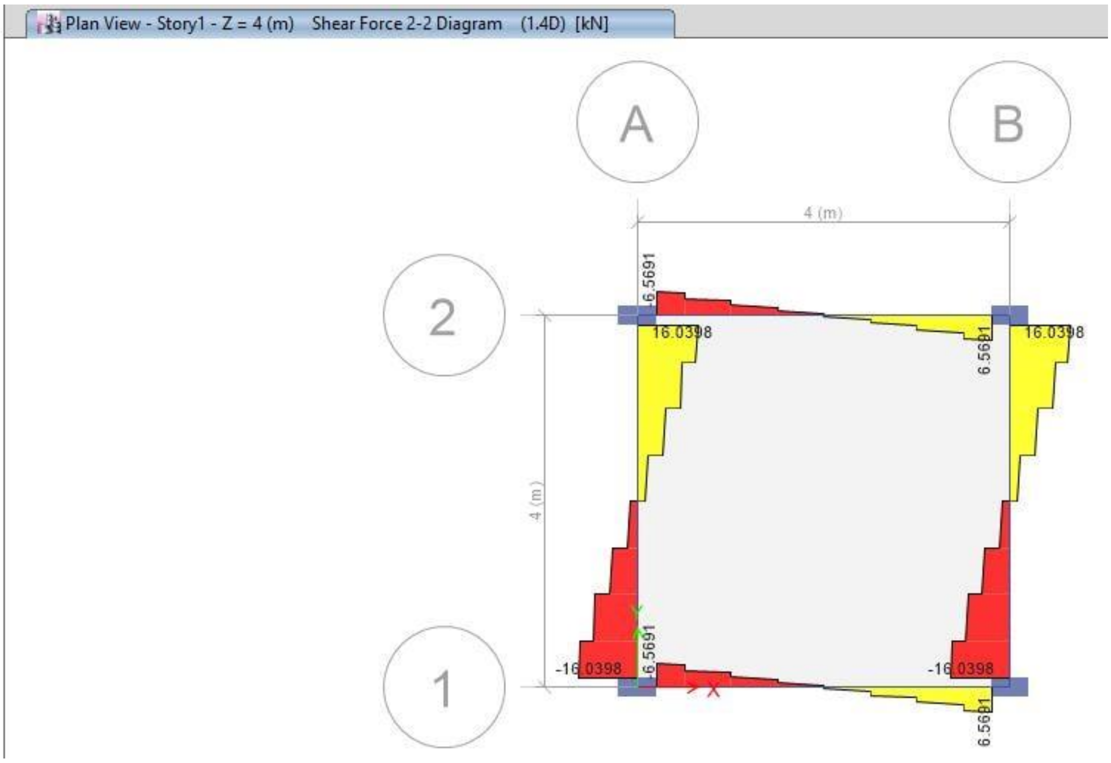
7*0.52= 3.64 kN



Shear for slab =7kN/m

7*0.52= 3.64 kN





Plan View - Story1 - Z = 4 (m) Shear Force 2-2 Diagram (1.4D) [kN]
A
B
2
1
4 (m)
4 (m)
6.5691
16.0398
16.0398
-16.0398
-16.0398

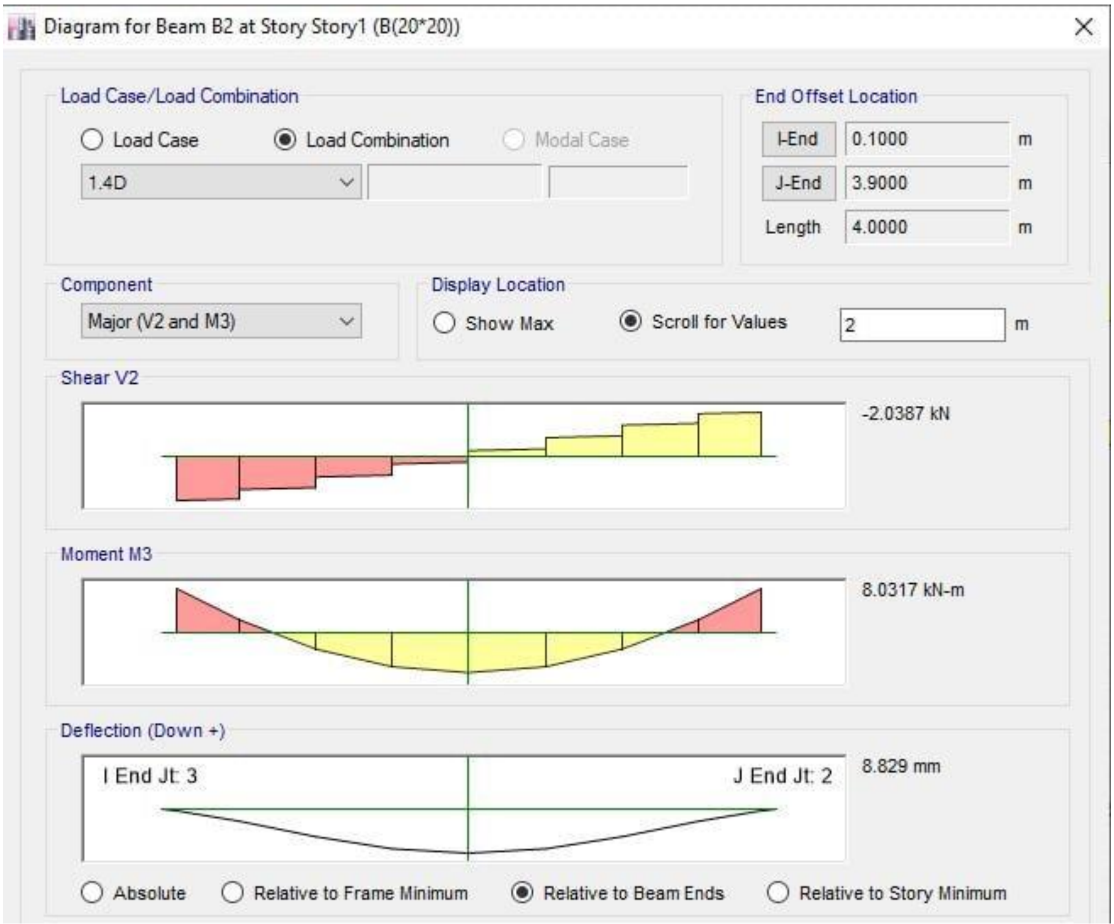
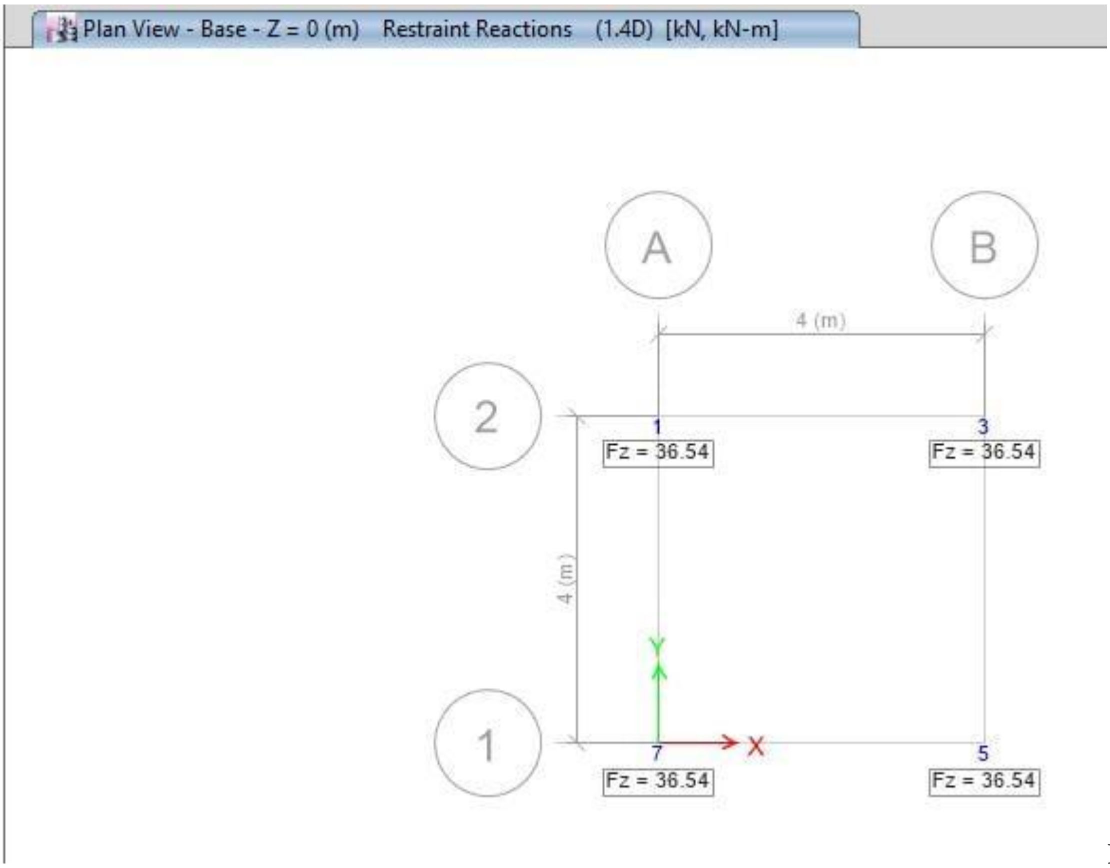


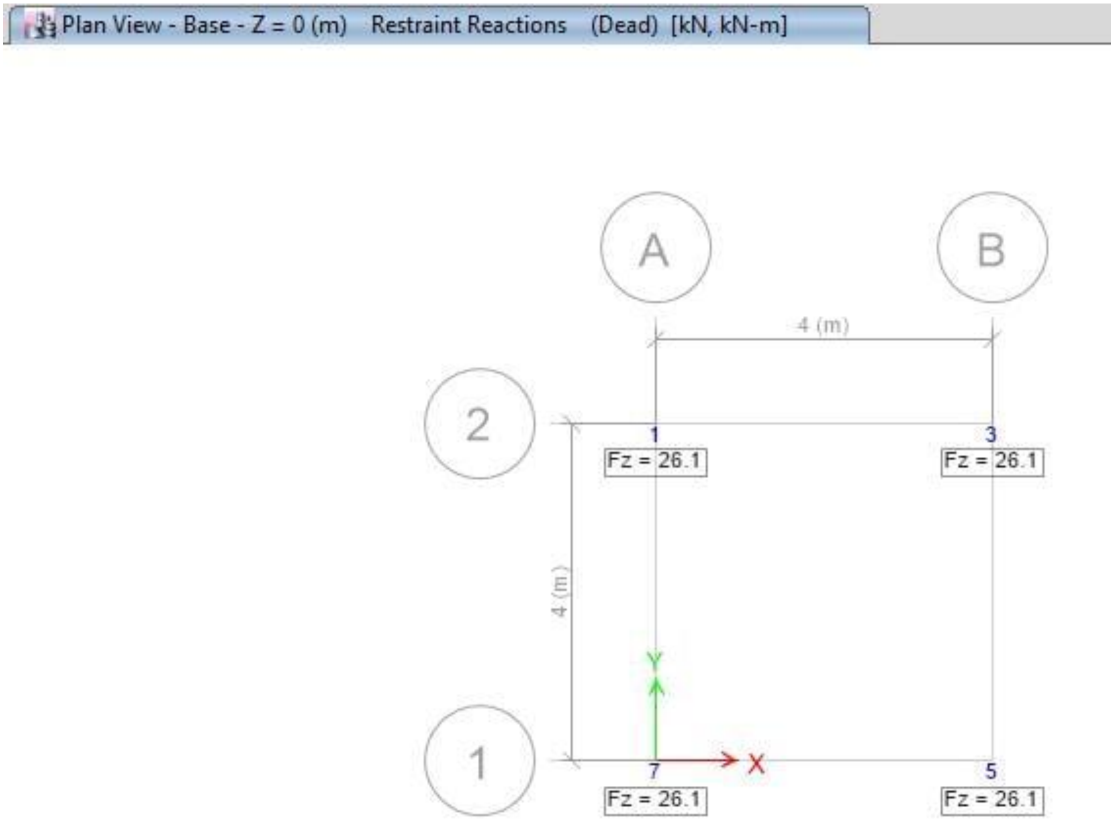
Diagram for Beam B2 at Story Story1 (B(20*20))
Load Case/Load Combination
Load Case
Load Combination
Modal Case
1.4D
End Offset Location
I-End 0.1000 m
J-End 3.9000 m
Length 4.0000 m
Component
Major (V2 and M3)
Display Location
Show Max
Scroll for Values
2 m
Shear V2
-2.0387 kN
Moment M3
8.0317 kN-m
Deflection (Down +)
I End Jt: 3
J End Jt: 2
8.829 mm
Absolute
Relative to Frame Minimum
Relative to Beam Ends
Relative to Story Minimum

Beam details

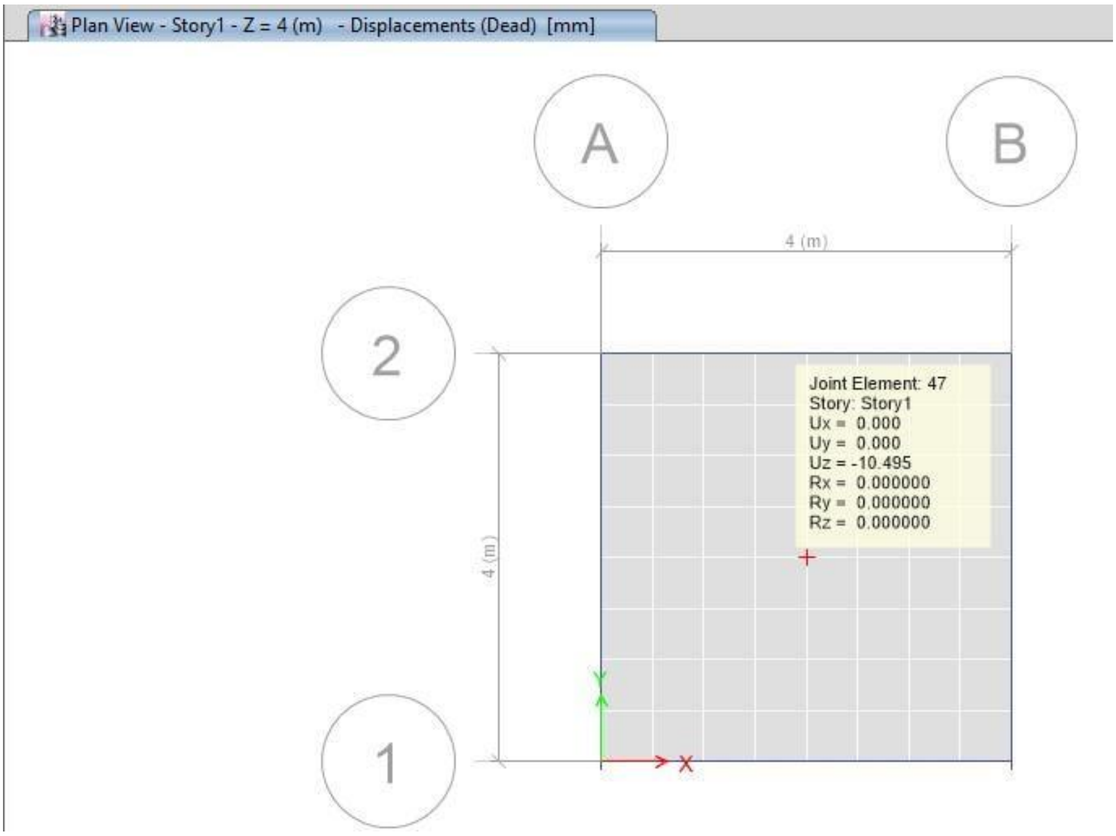


R

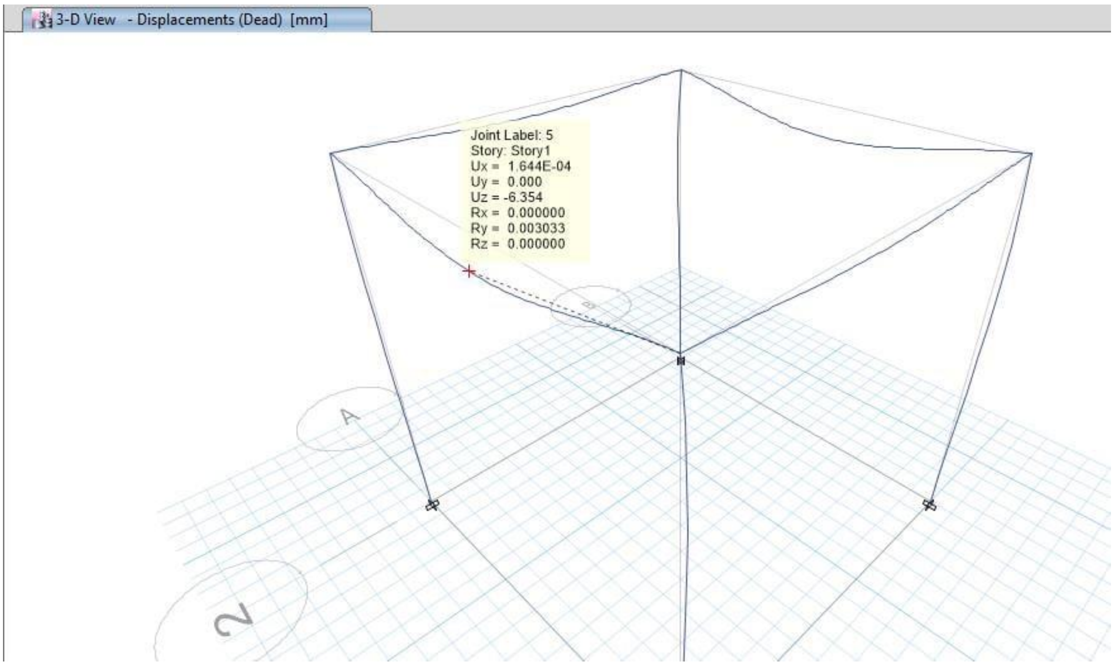
eaction 1.4 D



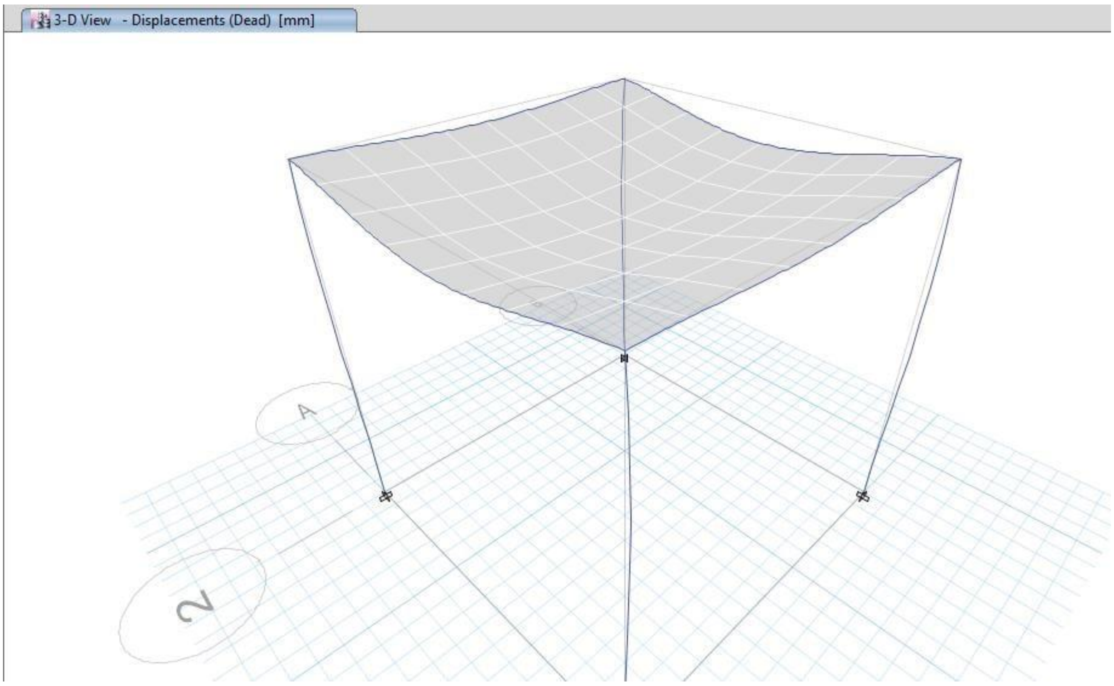
Reaction for dead load



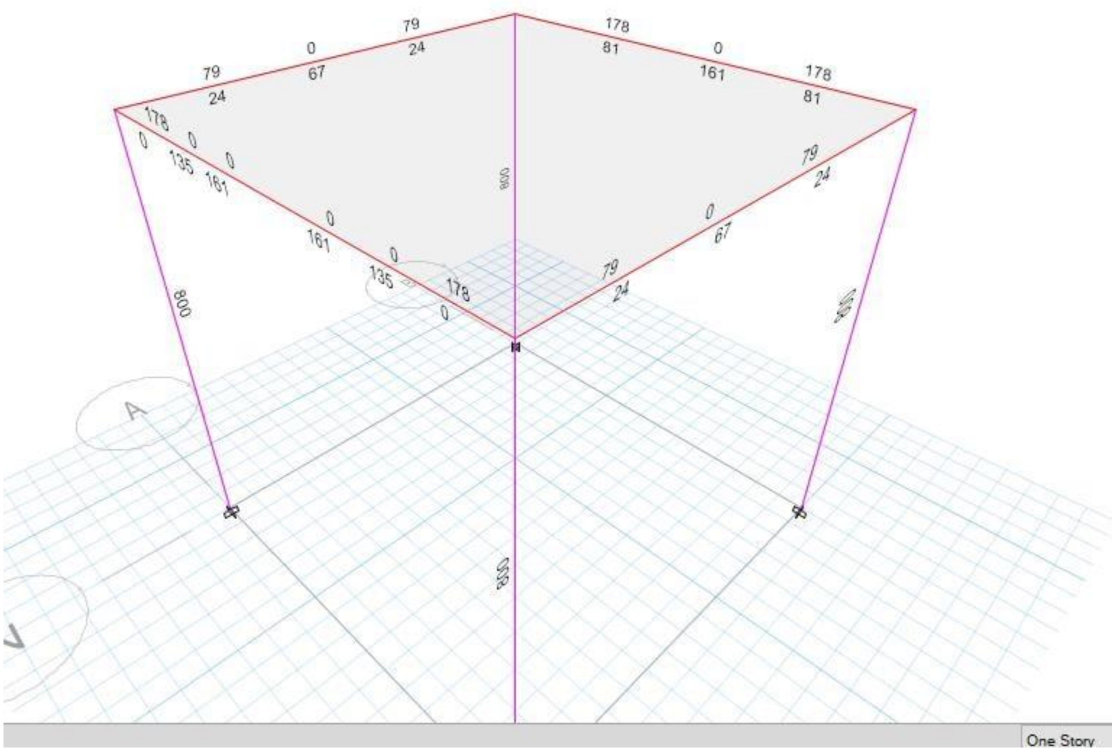
Deflection for slab =10.5 mm



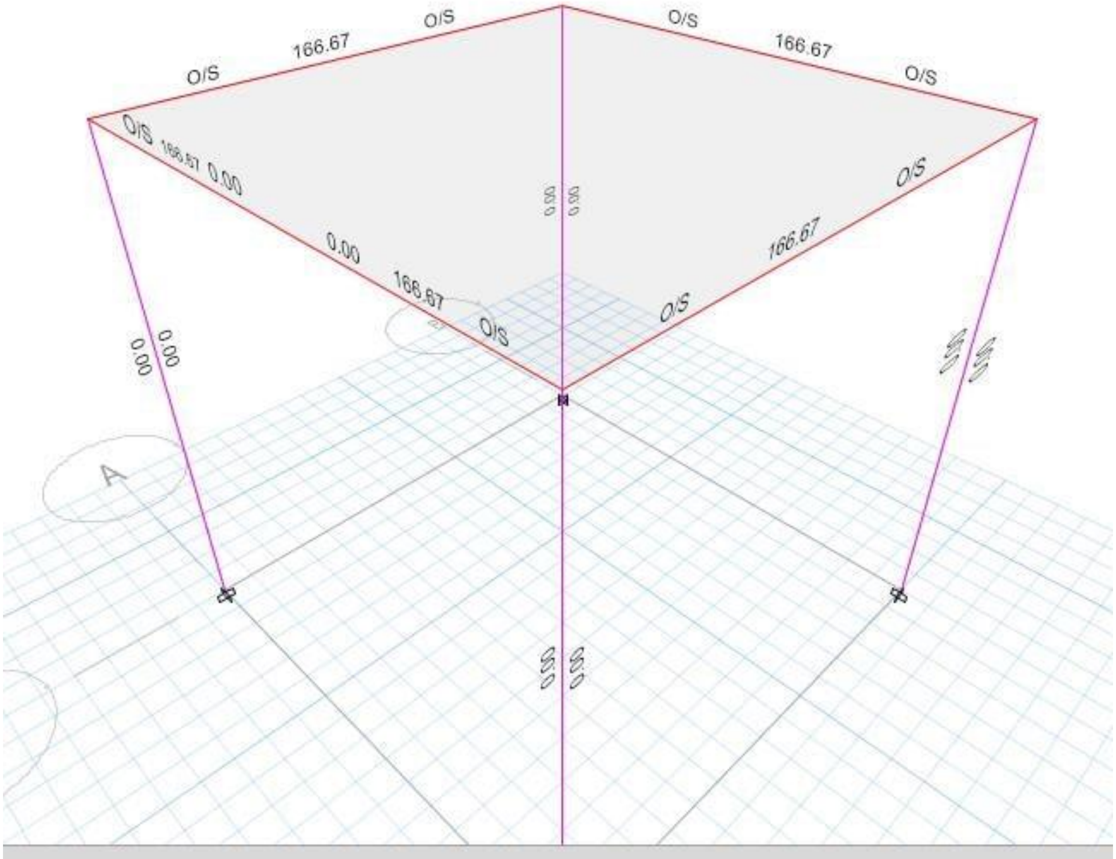
Deflection for beam = 6.35 mm



Shear stress



Area of steel for beams and columns



Shear steel for beams

o/s means over of stress

Note that the shear calculated above is from allowable loads

جامعة النجاح الوطنية

كلية الدراسات العليا

التحقيق في أسباب إنهيار بعض المباني قيد الإنشاء في الضفة الغربية

إعداد

عوني خليل عبد الكريم الدوده

إشراف

د. رياض عوض

قدمت هذه الأطروحة استكمالاً لمتطلبات الماجستير في الإدارة الهندسية بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس.

2021

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إعداد
عوني خليل عبد الكريم الدوده
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د. رياض عوض

الملخص

عملية البناء مهمة لكل البلدان والبشر، المباني تزود الاشخاص بواحدة من اهم الاحتياجات للانسانية، هناك العديد من حالات الانهيار للمباني التي حدثت في الضفة الغربية مؤخرا وبعضها كان خلال عملية الانشاء، دراسة مستفيضة لاسباب الانهيار تم تنفيذها خلال الرسالة، طريقة بحثية مدمجة تم تطبيقها لتحديد العوامل الاساسية التي تؤثر على انهيارات المباني خلال عملية الانشاء، استبيانة منتقاة تم توزيعها على المهندسين والخبراء في مجال الانشاءات، تم تنفيذ تحليل احصائي للبيانات التي تم تجميعها من خلال اجابات الخبراء، وتمت دراسة حالات خاصة من خلال عمل مقابلات واستشارات مع خبراء في هذا المجال، ومن هذه الحالات تم تحليل حالتين بشكل مستفيض باستخدام البرامج والاكواد الهندسية ذات العلاقة، النتائج اشارت الى ان الانهيارات في الانشاءات يجب ان تكون ذات موضع اهتمام في الضفة الغربية، والاسباب الاكثر تاثيرا على انهيار المباني تحت الانشاء في الضفة الغربية هي نوعية التربة المقام عليها المبنى والتدعيم والطوبار الغير مناسبين والاخطاء التنفيذية وعدم الالتزام بالمخططات والمواصفات المطلوبة، وتوصي الرسالة بعمل مراجعات دورية على المخططات واعمال التنفيذ من خلال البلديات ونقابة المهندسين – فرع القدس قبل واثناء تنفيذ الاعمال.