The Islamic University – Gaza

Higher Education Deanship

Civil Engineering Department
Master Program in
Construction Management

الجامعة الإسلامية - غزة

عمادة الدراسات العليا

قسم الهندسة المدنية

برنامج ماجستير إدارة المشاريع الهندسية

Addressing Construction Worker Safety through the Design Phase in Gaza Strip

اعتبار سلامة العمال خلال مرحلة التصميم في قطاع غزة

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In partial fulfillment of the requirement for the degree of
Master of Science in Civil Engineering. Construction Management

December , 2010

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LIST OF ABBREVIATIONS

ASCE	:	American Society of Civil Engineers
BC	:	British Columbia
CDM	:	Construction Design and Management
CHAIR	:	Construction Hazard Assessment Implication Review
CHPtD	:	Construction Hazard Prevention through Design
CRC	:	Cooperative Research Centre
DfS	:	Designing for Safety
DfCS	:	Design for Construction Safety
HVAC	:	Heating, Ventilation and Air Conditioning
NIOSH	:	National Institute for Occupational Safety and Health
NOHSC	:	National Occupational Health & Safety Commission
PPE	:	Personnel Protective Equipments
PtD	:	Prevention through Design
RfP	:	Request for Proposal
StD	:	Safety through Design
ToR	:	Terms of Reference
UK	:	United Kingdom
UNDP	:	United Nations Development Programme
UNRWA	:	The United Nations Relief and Works Agency
US	:	United States

DEDICATION

I would like to dedicate this work to:

My father and mother for their unlimited encouragement.

My husband and sons for their enduring support, trust, and patience.

Asmahan Jubeh

ACKNOWLEDGMENT

Above all, I would like to thank Allah for blessing me and enabling me to complete this thesis.

Indeed many people contributed time, knowledge, skill, and support to my research, and I am pleased to acknowledge their contributions. I would like to express my gratitude to my supervisor, Prof. Dr. Mohamed Ziara, who was abundantly helpful and offered invaluable assistance, support and guidance that enabled me to conduct my research.

I must also acknowledge the Construction Management Teaching Staff at the Islamic University for their support and encouragement. Special thanks to all my Friends and my Colleagues in the Civil Engineering Department for their friendship and assistance during my research study.

I wish to express love and gratitude to my beloved Parents, Husband and Sons; for their understanding and endless love, through the duration of my research study.

Finally, I must express my sincere thanks to the Contracting and Consulting firm personnel I interviewed for their cooperation and support.

ABSTRACT

Despite the remarkable efforts to enhance construction worker safety, the construction industry still suffer from poor safety performance. Although the burden of construction worker safety is usually the contractor responsibility, research studies have shown that design decisions made upstream is a factor in approximately forty to sixty percent of jobsite accidents. Design for construction safety (DfCS) concept is a collaborative process, where designers benefit from field experience, to produce designs that could be executed safely. While design decisions could enhance construction worker safety, designers are often ill-equipped to address this concept.

Since the DfCS concept is not a common practice in Gaza Strip, this research aims to enhance the safety performance of the construction industry by developing an approach that help designers involved in the design of building projects to address the concept in a proper and easy way. It aims also to investigate design professional awareness related to this concept.

A qualitative methodology was chosen to gain an in depth understanding of DfCS concept pertinent to Gaza Strip. DfCS suggestions appropriate to building construction in Gaza Strip were developed by researcher based on the study of literature reviews, researcher experience and knowledge of construction industry in Gaza Strip and the shortcomings of DfCS concept at the local and international levels. Also open interviews were conducted with owners, contractors and designers who were practitioners with hand on experience to investigate their knowledge of the subject and discuss relevant DfCS suggestions. Five case studies were carried out to contribute in verification of the developed approach.

A comprehensive approach for DfCS concept was developed for use in Gaza Strip. The approach is an easy tool that aids designers to consider DfCS concept in a systematic way. It considers design phases which are schematic, design development, construction documentation and work schedule phases. It also considers the four engineering specializations involved in building construction (architectural, civil, electrical and mechanical). It consists of DfCS suggestions classified as regulations or recommendations. The study showed the importance of protecting building edges; exterior or interior; during construction and maintenance phases. Also formworks related to the four engineering

specializations should be designed during design development phase. The selected materials for building construction related to the four engineering specializations should be as practicable as possible durable, safe to handle and non combustible.

The results from the five case studies highlighted the possibility and importance of considering the DfCS concept in Gaza Strip in order to minimize accident risks. The case studies also highlighted the important role of civil engineers in considering the DfCS concept. The study showed that the design professionals; architectural, electrical and mechanical engineers; are not cognizant with DfCS concept. Although professional civil engineer became recently cognizant of the concept, yet no reference document exist to facilitate applying the concept which highlights the importance of developing DfCS approach to aid designers to consider worker safety through their design decisions.

الخلاصـــــة

بالرغم من الجهود الكبيرة المبذولة لتحسين سلامة العمال، ما زالت صناعة الانشاءات تعاني من الأداء السيئ في مجال السلامة. المقاول عادة هو المسئول عن سلامة العمال إلا أن الدراسات أثبتت أن 40 - 60% من الحوادث بالموقع لها علاقة بالقرارات التي يتخذها المصمم خلال مرحلة التصميم. يعتبر مبدأ التصميم من أجل السلامة في الانشاءات عملية تعاونية حيث يستفيد المصممون من الخبرة العملية لإنتاج تصاميم يمكن تنفيذها بصورة آمنة. ومع أن القرارات التصميمية يمكن أن تحسن من سلامة عمال الإنشاء إلا أن المصممين يعانون من نقص الوسائل التي تمكنهم من أخذ هذا المبدأ بعين الاعتبار.

يعتبر مبدأ التصميم من أجل السلامة في الانشاءات غير ممارس بصورة شائعة في قطاع غزة، لذا فإن هذا البحث يهدف إلى تحسين أداء السلامة في صناعة الانشاءات عن طريق تطوير نهج يساعد التخصصات الهندسية ذات العلاقة بتصميم المباني على أخذه بعين الاعتبار خلال مرحلة التصميم بصورة مناسبة وسهلة. كما و يهدف للتحقق من مدى وعي المهندسين بهذا المبدأ.

وقد تم اختيار منهجية نوعية للحصول على فهم عميق لهذا المبدأ وعلاقته بقطاع غزة. وقد قامت الباحثة بتطوير اقتراحات التصميم من أجل السلامة المناسبة لانشاء المباني في قطاع غزة. وقد تم ذلك بناء على الدراسات السابقة، خبرة ومعرفة الباحثة في مجال صناعة الانشاءات في قطاع غزة وعلى نواحي القصور بما يختص بهذا المبدأ على المستوى المحلي والعالمي. تم عمل مقابلات مفتوحة مع ذوي الخبرة من المالكين والمقاولين والمصممين (عمارة. مدني. كهرباء ومكانيك) للتحقق من مدى معرفتهم بهذا الموضوع ومناقشة اقتراحات التصميم من أجل السلامة في الانشاءات. وقد طبق النهج الذي تم تطويره على خمس حالات دراسية للمساهمة في التحقق منه.

تم تطوير نهج شامل لاستخدامه في قطاع غزة. وهو عبارة عن أداة سهلة تهدف لمساعدة المصممين في اعتبار هذا المبدأ بصورة منتظمة وسهلة. ويتعامل هذا النهج مع مراحل التصميم الأربعة وهي مرحلة التصميم التخطيطي، مرحلة وضع التصاميم التفصيلية، مرحلة اعداد وثائق المشروع ومرحلة الجدول الزمني. ويتعامل هذا النهج مع التخصصات الهندسية الأربعة ذات العلاقة بتصميم المباني وهي عمارة، مدني، كهرباء و مكانيك. ويحتوي النهج على اقتراحات تم تصنيفها الى قوانين وتوصيات. أكدت الدراسة على أهمية حماية جوانب المنشآت سواء الداخلية أو الخارجية بصورة مناسبة خلال فترة التشييد والصيانة. كما أظهرت أهمية عمل تصميم لنظام السقالات والطوبار وجميع العناصر أو الأنظمة التي لها علاقة بالتخصصات الهندسية الأربعة خلال مرحلة التصميم. كذلك يجب ان يحرص المصممون من التخصصات الهندسية الأربعة على اختيار المواد المستخدمة في إنشاء المباني بحيث لا تتلف بسرعة ولا تحتاج الى صيانة مستمرة وان تكون امنة عند التعامل معها وغير قابلة للاشتعال.

وقد اظهرت الحالات الدراسية الخمسة امكانية وأهمية اعتبار هذا المبدأ لتقليل خطر الحوادث. وسلطت الضوء أيضا على أهمية اعتبار هذا المبدأ بالنسبة للمهندس المدني. بينت الدراسة أن المصممين (عمارة, كهرباء, مكانيك) لا يوجد عندهم معرفة بمبدأ التصميم من أجل السلامة في الانشاءات. بالنسبة للمهندس المدني فقد أظهرت الدراسة أنه بالرغم من معرفته الحديثة بهذا المبدأ إلا أنه لا يمتلك وسائل أو نهج يساعده على تطبيق هذا المبدأ مما يؤكد على أهمية تطوير نهج يساعد المصممين على اعتبار سلامة العمال خلال القرارات التصميمية.

Chapter 1: INTRODUCTION

1.1 Background

Construction industry has been identified as one of the most hazardous industries, due to the nature of the work resulting from integration of materials, tools, environment and various human factors (Haro and Kleiner, 2008). In recent years, the construction industry recognized the importance of ensuring worker safety and health in job site. The burden of construction site safety was placed on contractors, where best practices have been identified to help contractors to eliminate hazards and ensure safe work practices. Although the safety performance has been improved, additional efforts are needed to control the construction site hazards. A breakthrough idea suggests that risks and accidents could be reduced or eliminated by considering worker safety through the design phase where hazards could be designed out (cited by Behm, 2005a).

Designing for construction safety (DfCS) is defined as the consideration of construction site safety in the design phase of the construction project, with the goal of reducing or eliminating the inherent risks to construction worker (Toole et al., 2006). This concept is based on the principle that many safety and health hazards exist because they are designed into the permanent features of the project. An early initiative came in 1991, when a European Commission study found that 60 percent of construction accidents could have been eliminated, reduced or avoided if the worker safety has been addressed through the design phase (Gambatese et al., 2005). As a result, United Kingdom (UK) introduced the Construction Design and Management (CDM) regulations which became effective in 1995 that placed a duty on construction owners, designers and contractors to ensure safe workplace (Behm, 2005b). That was the first time to mandate designers to avoid foreseeable risks to construction worker. While designing for construction safety has become increasingly common in Europe, Australia and South Africa, until recently, a few large scale design for safety initiatives have been launched in the United States (US).

Despite of these efforts, it is believed that the DfCS concept has not been adequately addressed at international level. Most of research has been directed to limited number of engineering fields. Other engineering fields need also to be addressed, especially the structural design.

Bluff (2003) stated that the DfCS concept should be addressed early in the conceptual design phase. Design decisions related to design, methods of construction and materials used should incorporate the consideration of worker safety during construction and maintenance. The opportunities to address worker safety in this phase are considerable where it is possible to design out hazards and, or integrate risk control measures that comply with the original design concept and structural and functional requirements of a construction project (Bluff, 2003).

The success of DfCS concept depends upon the joint effort among all parties involved in project construction in addition to researchers and educators efforts.

1.2 Research Problem

The construction industry continues to give international poor safety performance. Injuries, diseases, permanent disabilities and ultimately loss of life occur during construction works. A round the world many studies have been conducted on diverse safety issues contributed to enhance safety performance during the construction phase but not to acceptable level. The studies mainly focused on the contractor role being the one responsible for the work place safety.

Since the designer is the sole party that is not responsible for worker safety, researchers began to investigate the link between design and accidents. There is growing evidence that designers can and should play a role in eliminating and reducing hazards before they appear in the job site if they address DfCS concept.

In Gaza Strip, there is a shortage in the construction industry safety applications. The construction accident rate is nearly 20% of all industrial injuries and is higher than the other industry accident rates (Abu Alqumboz, 2007). Contractors consider health and safety as a cost not investment but legally they are the responsible party. Designers consider safety as a topic that is not related to them. Addressing worker safety in project design is not currently part of standard design practice, nor it is a part of the design professional role due to perceived industry and project barriers.

Hassouna (2005), Abu Alqumboz (2007) and Al-Aqqad (2009) have conducted researches related to construction worker safety but none of them has investigated design decisions that could improve worker safety or in other words study the DfCS concept. Although the design for safety concept is gaining momentum around the world, it is not adequately addressed in Gaza Strip yet. To improve worker safety and reduce accident rate to be within acceptable level an initiative should be taken to introduce this concept, and hence contribute to the enhancement of safety performance of the construction industry in Gaza Strip.

The undertaken research addresses the concept of considering the construction worker safety during the design phase of buildings in Gaza Strip. The related fields of engineering have been considered for the development of a comprehensive approach that enables designers to address the DfCS concept in their designs easily.

1.3 Scope of the Research

1. The study tackles the problem of safety in the construction industry in Gaza Strip by considering the role of designers in eliminating or reducing hazards during the design phase. Safety measures during the construction phase are not considered within the scope of the study.
2. The design for safety concept is not a common practice in Gaza Strip, so this study concentrates on developing a general approach that guide designers to address the DfCS concept in their designs.
3. This study is devoted to cover the commonly used reinforced concrete buildings.
4. The study is concerned with architectural, civil, electrical, and mechanical engineering specializations that usually involved in building projects.
5. Although the study is directed to Gaza Strip, the findings could be applied to regions of similar conditions.
6. The study addresses normal working conditions in Gaza Strip. It does not consider the current situation (siege) because the construction industry is very slow.

1.4 Research Aim and Objectives

The main aim of this research is to enhance the safety performance of the construction industry by considering the DfCS concept in construction projects to reduce or eliminate the inherent risks to construction worker in Gaza Strip before the construction phase. This aim is intended to be achieved by accomplishing the following objectives:

1. Developing design for safety suggestions pertinent to building projects in Gaza Strip.
2. Developing a framework to place DfCS suggestions within it. The frame accounts for design phases considering the related design specializations.
3. Classifying the developed DfCS suggestion into regulations and recommendations.
4. Ultimately, developing an approach to account for addressing the DfCS concept in Gaza Strip.
5. Verification of the approach by conducting real life case studies.
6. Improving the awareness of DfCS concept.

1.5 Summarized Methodology

Diverse strategy will be adopted to achieve the research objectives which include:

1. Conduct a comprehensive review of literatures related to the DfCS concept. The objective of the review is to identify the DfCS suggestions appropriate to Gaza Strip buildings.
2. From the prevailing construction industry practices in Gaza Strip, identify shortcomings and areas for improvements related to DfCS concept.
3. Develop DfCS preliminary approach which is composed of suggestions adopted from international experience and local and international shortcomings.
4. Perform open interviews with engineering specialists to develop additional applicable DfCS suggestions.
5. Develop a proposed approach to address the DfCS concept in Gaza Strip.

6. Solicit expert opinion related to the proposed approach and conduct case studies to verify the developed approach.

7. Report conclusions and recommendations.

1.6 Research Deliveries

The outcomes of the undertaken research are summarized as follows:

1. A pool of design for safety regulations and recommendations appropriate for Gaza Strip building construction industry.

2. An approach for implementing the DfCS concept in Gaza Strip taking into account the design phases and the various engineering specializations, i.e. Architectural, Civil, Electrical and Mechanical engineering.

3. Recommendations for enacting new legislations to enforce applying this concept in the local practice and for further future researches.

1.7 Rationale

The DfCS concept is approximately unknown in Gaza Strip. Researches around the word concluded that between approximately 40%-60% of accidents in construction industry are related to design decisions. Since the accident rate in construction industry around the word including Gaza Strip is higher than the other sectors, it is of paramount importance to address the DfCS concept so that worker safety could be improved significantly and accident rate could be reduced to acceptable level. Construction workers could benefit significantly from addressing DfCS concept since hazards would be designed out or minimized before reaching the construction phase. Designers could be more innovative where each design represents a challenge that should comply with design requirement and at the same time be safe during execution. Finally, developing an approach for applying DfCS concept could form data base viable to be updated and communicated to engineers.

1.8 Thesis Organization

This thesis is composed of eight chapters and three Appendixes.

1. The first chapter is an introduction to the research. It includes research problem, scope of the research, research aim and objectives, summarized methodology, research deliveries and rationale.
2. The second chapter presents the literature review. It includes the findings of previous studies related to DfCS concept around the globe, why to design for construction safety, how to design for construction safety and DfCS suggestions.
3. The third chapter discusses the research methodology which includes the research design, target groups, field investigations (open interviews, expert final opinion regarding the proposed DfCS approach and case studies) and quality of research.
4. The fourth chapter displays the preliminary DfCS approach. It contains DfCS suggestions adapted from literature and from researcher experience in the related topic for each engineering specializations and each design phase.
5. Chapter five discuses the expert awareness of this concept and the additional DfCS suggestions developed through the conducted interviews for each engineering specializations and each design phase.
6. Chapter six discuses expert final remarks regarding the developed DfCS approach. It includes the respondent agreement on DfCS suggestions and the classification of these suggestions as recommendations or regulations.
7. The seventh chapter displays the implementation setup of the developed DfCS approach.
8. The eighth discusses the application of the developed DfCS approach on five case studies.
9. The ninth chapter displays the conclusions and recommendations of this research.
10. The three appendixes contained in the thesis are, open interview as Appendix A, questionnaires for the four related engineering specializations as Appendix B and the documentations that were obtained for each case study as Appendix C.

Chapter 2: LITERATURE REVIEW

2.1 Introduction

Construction in its nature is a problem in ergonomics. Construction sites are busy places with continuous working environmental changes. Usually construction workers are exposed to heavy manual material handling, repetitive movements, awkward postures, contact stress, vibration and forceful exertions (Kramer et al., 2009). Workers in the construction industry face a greater risk of fatality or injury than those in other industries.

Traditionally safety on the construction site is the responsibility of the contractor which reflects the contractor's control over the construction workers, project schedule, work methods and sequence, and the contractual relationships amongst the project team members (Gambatese et al., 2008). Although significant improvements in safety performance have been made in the past few decades, construction workplace accidents still occur with upsetting frequency (Aires et al., 2010). It was found that one of the most important sources of risk is the gap between expected working and real working (Fadier and Garza, 2006).

Designers are the party that has not been directly involved in the safety effort (Gambatese and Hinze, 1999). Many researchers suggest addressing DfCS concept by engaging designers to participate from the start in designing out risks (Gambatese et al., 1997; Gabbot, 2007; Behm and Kramer, 2008; Choudhry, 2009; Bansal, 2010). The origins of DfCS concept are not known (Mroszczyk, 2009). Gallagher in 1991 cited several sources from 1907 and 1926 that mention the concept (Mroszczyk, 2009).

Culvenor et al., (2007) contend that the objectives of design should include DfCS concept balanced with the other traditional design objectives including practicability, aesthetics, cost and functionality in a manner that does not compromise the safety and health of construction workers. Designers must be made aware of various means by which their designs and decisions improve the site safety conditions (Bansal, 2010). From ethical point of view designers should accept this responsibility to ensure the wellbeing of end user, third party and construction worker.

In Gaza Strip health and safety is not widely recognized as inherent characteristic of construction projects Al-Aqqad (2009). While contractors consider health and safety a legal requirement that cost them money without return, designers consider safety a topic that is not related to them. Such mindset and practice contribute significantly to the increased number of accidents (Al-Aqqad, 2009). Indeed construction industry is an inherently dangerous business, which call for all parties involved to take responsibility in order to reduce the risk of injuries and fatalities in construction projects.

2.2 Design for Construction Safety (DfCS) Concept

DfCS concept is related to the incorporation of site safety knowledge into design decisions in order to eliminate or reduce risks which could affect worker safety positively. Although the concept is applicable to all types of industries, construction industry is the one that dealt with in this research. The concept has many names, abbreviations and definitions as displayed in Table 2.1. Some of them are related to type of industry to which this concept is implemented. In this research the term design for construction safety (DfCS) as defined by Behm (2006) would be adopted.

Table 2. 1: Names, abbreviations and definitions of DfCS concept

Concept names and abbreviations	Researchers	Design for safety (DfCS) concept definition
Safe design	National Research Centre for Occupational Health and Safety Regulation (2002)	A strategic approach concerned with eliminating hazards and controlling risks to health and safety at the source, as early as possible in the life cycle of designed-products.
Safe design; Safety through design (StD)	Commonwealth of Australia (2006); Manuele (2007)	The integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed. It encompasses all design including facilities, hardware, systems, equipment, products, tooling, materials, energy controls, layout, and configuration.
Designing for construction safety (DfCS)	Behm (2006)	The consideration of construction site safety in the preparation of plans and specifications for construction projects.

Concept names and abbreviations	Researchers	Design for safety (DfCS) concept definition
Design for construction safety (DfCS)	CRC for Construction Innovation (2006); Behm (2005a)	The consideration of construction site safety in the design of project.
Prevention through Design (PtD)	Manuele (2007); Mroszczyk (2009)	Addressing occupational safety and health needs in the design and redesign processes to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials and equipment.
Construction hazard prevention through design (CHPtD)	Toole and Gambatese (2008)	The process in which designers explicitly consider the safety of construction workers during the design process.
Construction ergonomics	Smallwood (2007)	The application of scientific information concerning humans to the design of objects, systems and environment for human use in order to optimise human well-being and overall system performance ergonomics during the phases of construction, commissioning, maintenance and deconstruction.

2.3 Design for Construction Safety around the Globe

In the US, the American Society of Civil Engineers (ASCE) believes that improving construction site safety requires attention and commitment from all parties involved (Toole and Gambatese, 2008). The ASCE and the National Association of Professional Engineers state in their code of ethics that designers should have ethical obligation towards the safety, health, and welfare of the public and should take action even if the hazard is not imminent (Toole and Gambatese, 2008). The problem is that designers do not consider construction worker as part of the public (Toole et al., 2006). Gambatese et al. (2007) concluded that the barriers that preclude this concept from becoming a standard are: designers consider themselves responsible for the safety of the facility end-users; a lack of education, training and resources to assist designers to design for construction safety; fear of liability exposure to third-party lawsuits; the codes and standards to which designers prepare their designs; the customs and culture of the construction industry and finally the absence of a legal requirement to apply

DfCS principles for construction workers in the US. For this the US currently lags behind the European Union, the UK and Australia in efforts to reduce occupational injuries and fatalities by designers (Mroszczyk, 2009).

Toole and Gambatese (2008) concluded that DfCS will progress in the US through increasingly: facilitate prefabricated construction; choose materials and systems that are inherently safer than alternatives; perform construction engineering and apply spatial considerations to reduce construction hazards. In order to facilitate considering this concept the National Institute for Occupational Safety and Health (NIOSH) Construction Sector Council named CHPtD as one of its top 10 priority areas while the ASCE has recently established a CHPtD Committee within the Engineering Directorate of the Construction Institute (Toole and Gambatese, 2008).

In the European Union whilst designers previously had some responsibilities for reducing risk under common law provisions the Temporary and Mobile Construction Site Directive was the first explicit legislation that placed duties on designers (Aires et al., 2010). It was initiated in 1992 and adopted in the law of all member states of the European Union in 1994 (Frijters and Swuste, 2008). It requires designers to take working conditions during execution, maintenance and demolition work into account in their designs. Its key concern is planning and coordination of construction works through improved transfer of information between the different parties involved in the design and planning phase, and the construction phase of projects (Bluff, 2003).

In response to the Temporary and Mobile Construction Site Directive, the UK enacts the Construction Design and Management (CDM) Regulations which became effective in March 1995 (Behm, 2005b). The CDM regulations place duties for addressing construction worker safety and health on designers. It places a duty on the designer to ensure that any design should avoid unnecessary foreseeable risks to construction workers (Bluff, 2003; Toole et al., 2006; Toole and Gambatese, 2008). Nonetheless, Behm (2005a) and Gambatese et al. (2005) cited that the success of the CDM in reducing construction fatalities has been difficult to establish since designers in the UK has been slow in meeting their responsibility under the CDM regulations. Brace et al. (2009) found that after fifteen years of CDM many designers still believe it is not related to them. Even the small groups who want to engage are having difficulty doing this. Wright (2003) stated that designers in the UK often treated health and safety plans merely as a paperwork requirement.

In Australia, work on safe design commenced at a national level under the National Occupational Health and Safety Commission (NOHSC) in the late 1980. In 1994, the National Standard for Plant declared positive duties for designers, manufacturers, importers and suppliers of plant to eliminate or reduce risks and hazards (Creaser, 2008). Since 1998, this requirement has been mandatory for all state government construction projects having a value of 3 million Australian dollar or greater or even for lower price projects where the government agency determines there is a high safety risk (Behm, 2005b). Toole and Gambatese (2008) cited that Australia is moving toward mandating CHPtD and has demonstrated leadership in this area by making practical CHPtD resources for designers available on the Web. WorkCover (2009) has identified the following five principles for safe design: safe design is everyone's, it employs life cycle concepts, it implements risk management, requires knowledge and capability and finally it relies on information.

In South Africa designers are required to make available all relevant information about the design, communicate hazards to contractors and modify design or use a substitute material to improve worker safety (Smallwood, 2007).

2.4 Why Design for Construction Safety

Construction industry has one of the highest accident incidence rates and the most demanding physical working conditions compared to other industries (Laitinen, and Päivärinta, 2010). Construction workers are exposed to hazards that are difficult to quantify because the work location for any group of workers often change, even work site evolves as construction proceeds, changing the hazards workers face week by week and sometimes day to day and finally the incorporation of different trade groups work as a building project moves from site development to completion where they often overlap in time and physical proximity (McDonald et al., 2009).

Although many researches had been conducted to improve construction worker safety, statistics indicate that construction industry is still facing a safety problem. In the US construction employs 7% of the workers, but accounts for 21% of the injuries (Zarges and Giles, 2008). It accounts for just fewer than 200,000 serious injuries and 1200 deaths each year (Toole et al., 2006). Sa et al. (2009) stated that in the US while great efforts have been made toward a safe working environment in the construction industry, many companies' safety plans have not been effective.

In UK, construction and agriculture have the highest rates of fatal injury, accounting for 46% of fatal injuries to workers. Cooperative Research Centre (CRC) for Construction Innovation (2006) cited that in Australia 50 construction workers have been killed each year which is 50% higher than fatalities experienced in other sectors. These statistics are comparable to the US and Europe, but double that of the UK. Village and Ostry (2010) reported that although in British Columbia (BC) construction workers accounting for approximately 12% of all workers in the state, the overall injury rate in construction is more than twice the local average for all industries and higher than that reported in the US. Törner, and Pousette (2009) said that Swedens' rate of construction injuries still places construction industry among the top 10 occupational sectors for occupational accidents in the country.

In Gaza Strip the accident rate in construction industry is higher than the other industries. It accounts for nearly 20% of all industrial injuries (Abu Alqumboz, 2007). From these statistics and many others, endeavors to minimize or control construction industry hazards to be within acceptable levels did not succeed as required. Recent researches indicates that to reduce this trend designers should consider construction safety from the start of the design process (Cited in Behm, 2005a) where the most effective way for improving safety performance is to prevent accidents before they occur (Fung et al., 2010).

Lam et al. (2006) found that considering safety and ease of construction in the design phase would enhance safety of construction workers in site. Frijters and Swuste (2008) have conducted a study which showed that it is possible to reduce risks and accidents by addressing safety through the design phase. Rollenhagen (2010) found that design errors and design weaknesses are significant factors in accidents. Consequently, weak designs cannot be fully compensated in the construction phase.

Studies have been conducted to quantitatively measure the magnitude of the relationship between design and construction safety. A study by Behm (2005a) found that 42% of 224 fatality cases reviewed were linked to DfCS concept. Behm (2005a) concluded that if the design for safety concept been utilized the associated risk that contributed to the incident would have been reduced or eliminated. Gambatese et al. (2008) utilized expert panel to confirm the findings of Behm (2005a). The 224 fatality cases reviewed by Behm (2005a) were reviewed another time by expert panel to investigate whether the design was a factor in the incident causation. The previous research results and expert panel responses were in agreement for 71% of the cases reviewed.

CRC for Construction Innovation (2006) cited that a research conducted by Smallwood 1996 revealed that 50% of general contractors interviewed identified poor design features as affecting safety. Haslam et al. (2005) found that up to half of the 100 accidents examined could have been mitigated through design changes.

The Australian Government has concluded that design-related issues were involved in 40% of incidents in construction (Mroszczyk, 2009). Toole et al. (2006) and Weinstein et al. (2005) cited that a European study published in 1991 found that 60% of accidents studied could have been eliminated or reduced if DfCS concept was considered. Culvenor et al. 2007 research revealed that student engineers considered design related issues as contributing factor to accident causation. Kinnersley and Roelen (2007) showed that about 50% of the accidents and incidents in the aircraft and nuclear industries are with a root cause in design.

Researchers in the UK analyzed 100 construction accidents and found that design changes would have reduced the likelihood of 47% of 100 construction accidents studied (Cited in: Gambatese et al., 2008; Rwamamara and Holzmann, 2007). A more recent study revealed that seventy seven out of the 210 identified workplace fatalities definitely or probably had design-related issues involved in Australia (Driscoll et al., 2008; Creaser, 2008).

Gabbot, (2007) contend that hazards should be eliminated and reduced by design where practicable, and most benefit in this respect is usually achieved at the early conceptual design stage. Benjaoran and Bhokha (2010) concluded that risks and hazards inherent in designs or construction methods must be identified during the design phase and encourage safety activities to become visible through the project participants and have their own working time in the construction sequence.

Designers should be encouraged to address this concept. Frijters and Swuste (2008) study showed that applying DfCS concept does not seriously disrupt the design process and the designers' freedom is not impaired. On the contrary applying the concept has many benefits. The main benefit of considering DfCS concept is to improve worker safety by minimizing or decreasing hazards through decisions made upstream. Gambatese (2005) stated that in addition to reducing safety hazards on the construction site, designing for safety could lead to fewer injuries and lower workers' compensation costs, thus, over the long-term, cost savings may be achieved. In addition, Manuele (2008) stated that by applying DfCS concept the benefits that could be obtained are improved productivity, decreased operating costs, significant risk reduction and avoidance of expensive retrofitting.

2.5 How to Design for Construction Safety

The concept of designing for construction safety is consistent with the traditional "hierarchy of controls" approach used by safety professionals which calls for eliminating or minimizing a workplace hazard before relying on controlling them (Behm, 2006). Many DfCS processes have been developed to aid designers in considering safety during their design. The key component of these design processes is the consideration of site safety knowledge while making design decisions. The site safety knowledge should be provided from the beginning of the conceptual design phase to increase the possibility to influence project safety (Toole et al., 2006). White (2008) stated that safety and health professionals, and the affected workers must have a seat at the design, engineering, and procurement tables to provide the required safety knowledge. Mroszczyk (2009) contend that the DfCS process should begin with an assessment of hazards and their associated risks then the hierarchy of controls is applied.

Gabbot (2007) proposed DfCS process. It starts at the early conceptual design stage through structured brainstorm to identify hazards followed by a risk assessment process to quantify the worst likely consequence and associated likelihood. As the process develops, further risk assessments should be conducted to maintain the safety integrity of the design solutions.

Risk management is DfCS process that eliminates or controls any foreseeable hazards that may arise from the design of a building or construction. It consists of three main steps: hazard identification where it is important to think creatively and systematically about potential hazards in each life cycle phase, risk assessment to assess how likely workers could be harmed by each hazard and how serious the injury or illness and finally risk elimination or control according to hierarchy of control model in priority order (WorkCover, 2009). Fung et al. (2010) developed a Risk Assessment Model (RAM) for assessing risk levels at various project stages with various work trades. The developed RAM is found to be benefit for predicting high-risk construction activities and thus preventing accidents occurred based on a set of historical accident data. Benjaoran and Bhokha (2010) formulate the four dimensional CAD (4D CAD) model which combines two separated information sources, a construction schedule and a 3D CAD model to automatically detect any working at height hazards. It also indicates necessary safety measures in terms of activities and requirements. Gambatese et al. (1997) developed a computer program “Design for Construction Safety Toolbox”, to alerts designers to specific construction safety hazards and provides suggestions to eliminate or reduce them.

The Health and Safety Executive in the UK has developed several documents that help designers to comply with the CDM Regulations (cited in Behm, 2005b). Construction Hazard Assessment Implication Review (CHAIR) is a tool to assist all parties involved in the construction process to come together to reduce construction, maintenance, repair and demolition safety risks (WorkCover, 2001). CHAIR consists of three phases: CHAIR ONE is a review performed at the conceptual stage of a design, CHAIR TWO and CHAIR THREE are performed just prior to construction, when the full detailed design is known. CHAIR TWO focuses on construction and demolition issues and CHAIR THREE focuses on maintenance and repair issues. Gangolells et al.

(2010) conducted a quantitative research that supports designers by providing a way to evaluate the safety-related performance of residential construction designs using a risk analysis–based approach. Individual firms who currently have PtD processes in place also utilize design reviews, constructability reviews, checklists, and risk assessment processes and forms (Behm, 2006).

2.6 Design for Construction Safety Suggestions

The literature mentions many DfCS suggestions that if considered by designers through design phase could enhance worker safety during construction and maintenance phases. Hinze and Wiegand (1992), Gambatese et al. (1997), Bluff (2003), Behm (2005a), Gambatese et al. (2005), Weinstein et al. (2005), WorkSafe Victoria (2005), Behm (2006), CANBERRA (2006), European Federation of Engineering Consultancy Associations (2006), Toole et al. (2006), Rwamamara and Holzmann (2007), Workplace Health and Safety Queensland (2007), Hinze and Marini (2008), Zarges and Giles (2008) and Workcover (2009) display DfCS suggestions that cover different engineering fields and types of engineering projects. The DfCS suggestions are related to project position, project layout, material selection, contractor storage places, mechanical installations, electrical installations, falling from heights, trenches, communicating hazards to contractors, sequence of work and maintenance requirements regarding safety.

It was noted that many of DfCS suggestions mentioned in the literature were focused to reduce or eliminate falling hazards. This could be attributed to research results across the world where falling from height was found to be the main cause for major injuries and death of construction workers (Chi et al., 2005; Hassona, 2005; Haslam et al., 2005; Ale et al., 2008; López et al., 2008; Hyoung-June Im et al., 2009).

2.7 Conclusion

1. To improve safety performance it is very important to address the DfCS concept in the design phase.
2. The ideal time to influence construction safety is to consider worker safety from the schematic design phase, continuing through the life cycle of project.

3. Despite the presence of valuable design for safety processes and tools, designers around the globe, response very slow to them. The researcher attributes this partly to: deficiency in awareness and the considerable amount of work required for applying these processes and tools. In addition, the processes and tools do not take engineering specializations or design phases in consideration. It would be much easier and more possible to consider the concept if:

a) Construction projects categorized according to function such as buildings, industrial buildings route construction and so on where DfCS suggestions related to each type are identified.

b) DfCS suggestions related to different engineering specializations involved are identified.

c) Design phase divided to sub phases and identify the related DfCS suggestions for each phase.

4. Up to the knowledge of researcher, on the international level, the DfCS suggestions did not cover all engineering fields such as structural design.

5. Not all DfCS suggestions available in the literature suit the prevailing construction industry. Examples of DfCS suggestions not applicable to Gaza Strip are:

a) For modular construction assemblies built off-site, calculate the center of gravity and geometric center and design into the module the location of the lifting connections and rigging plan so that the modules are transported properly (Gambatese et al., 1997). This suggestion have no meaning to be addressed by designers in Gaza Strip because modular construction assemblies built off-site is not a familiar practice where investment in such expensive projects is considered not efficient.

b) For pre-cast concrete members, provide inserts or other devices to attach fall protection lines (Behm, 2006). Considering the prevailing methods and means in the construction industry this suggestion cannot be addressed in the Gaza Strip because of lack of pre-cast concrete technology.

c) Avoid or minimize construction work in or near health care facilities in which immunosuppressed patients are housed requires particular measures to minimize disturbance and dispersal of dust and dirt (European federation of engineering consultancy associations, 2006). This suggestion is not related to worker safety which is out of the scope of research.

6. Up to the knowledge of researcher no previous studies related to DfCS concept was conducted in the Arab Countries.

Chapter 3: Methodology

3.1 Introduction

This research aims to enhance construction worker safety by developing a comprehensive DfCS approach that could minimize or eliminate hazards incorporated in designer decisions. To accomplish the research objectives, a qualitative methodology was chosen to gain an in depth understanding of DfCS concept pertenent to Gaza Strip buildings.

A preliminary DfCS approach was developed taking in account design phases which are schematic, design development, construction documentation and work schedule phases. The four engineering specializations involved in building construction (architectural, civil, electrical and mechanical) were also considered. The DfCS suggestions appropriate to Gaza Strip buildings either adopted from the leterature reviews or developed by researcher were incorporated within the preliminary DfCS approach. Open interviews were conducted where new DfCS suggestions were developed and incorporated within the preliminary DfCS approach. The final DfCS approach was prepared by researcher and delivered to the same interviewees in the form of four types of questionnaires to get their final opinion related to the DfCS approach. Each type of questionnaire is related to engineering specialization. Five case studies were conducted to verify the proposed DfCS approach. Interview questions designed based on literature reviews and researcher experience. Different groups are interviewed owners, designers and contractors who were practitioners with hand on experience. The targeted group covers the four engineering specializations namely architectural, civil, electrical and mechanical engineers

3.2 Research Design

Diverse strategy has been adopted to achieve the research objectives. Figure 3.1 shows the methodology flowchart which includes:

1. Identify the aim of the study, define the problem and establish solid objectives.
2. Conduct a comprehensive literature reviews related to the design for safety concept.

3. From the literature reviews identify the DfCS suggestions appropriate to Gaza Strip and within the scope of the research.
4. Develop new DfCS suggestions appropriate to Gaza Strip buildings and covers the shortcomings in the international construction industry such as structural design.
5. The fifth phase is to develop a preliminary DfCS approach that contains DfCS suggestions adapted from step number three and those developed in step number four. The preliminary DfCS approach considers design phases and designers specializations in order to facilitate the analysis process and the future consideration by designers.
6. Distribute open interview to experts to find wither the interview is the suitable tool for this research and if the interview topics cover the required objectives.
7. Conduct open interviews with design professionals to develop additional DfCS suggestions applicable to Gaza Strip buildings and to investigate their awareness related to the DfCS concept.
8. Solicit expert final opinion related to the DfCS approach to reduce errors, ensure that the investigations made cover the subject and to get expert classification of developed DfCS suggestions to regulations and recommendations.
9. Apply the DfCS approach to local case studies to contribute in its verification and to foster recommendations and suggestions.
10. The final stage is the overall conclusion and recommendations.

3.3 Target Groups

An investigation was conducted to select the expert design professionals in building construction industry that could be able to enrich this research. The target groups consist of twenty interviewees with experience not less than 15 years in design and/or construction, and maintenance of buildings. They were fertile source to solicit first: design for safety suggestions that they already address and second: new ideas that could affect worker safety when addressed by designers. The participants were contacted via telephone to assure they have time to perform personal interviews with them and told that their responses would be kept confidential. The targeted groups consist of:

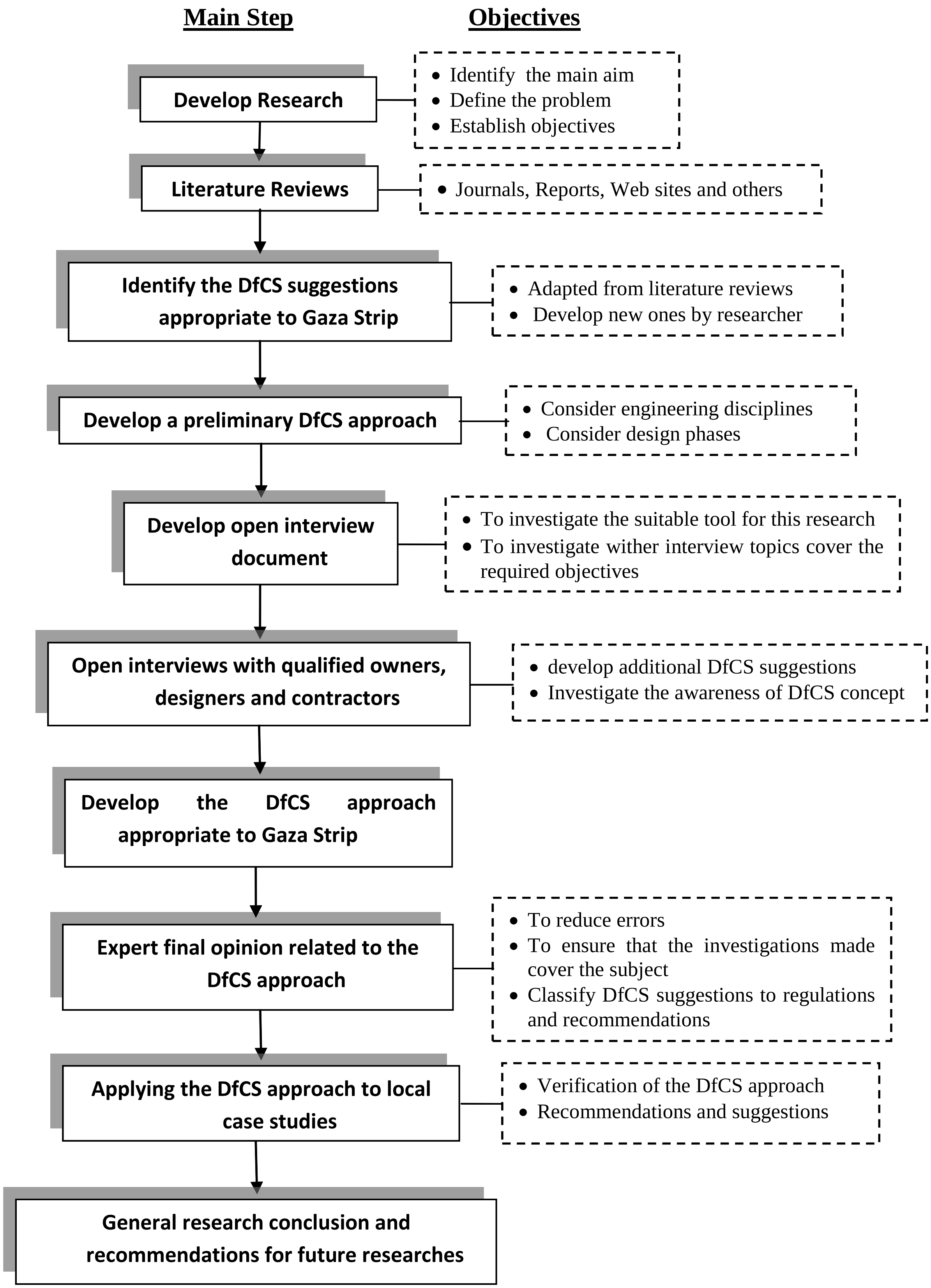


Figure 3. 1: Research methodology flowchart

1. Consultant engineers working in consulting companies as classified by the Committee of Offices and Engineering Companies. They practice design and supervision so they gain the expertise of identifying hazards inherent in design that expose workers to danger during construction or maintenance phase. Table 3.1 displays their qualification.

Table 3.1: Consultant qualification

Discipline	Architect	Civil	Electric	Mechanic
Number of interviewees	2	2	2	2
Position	Project manager	Project manager	Project manager, Supervisor	Project manager, Supervisor
Years of experience in design	30, 20	30, 22	35, 17	28, 16
Years of experience in construction	30, 20	30, 22	35, 17	28, 16

2. Client personnel were solicited from UNRWA, UNDP, Palestinian Housing Council, and Ministry of Public Works and Housing. Table 3.2 displays their qualification

Table 3. 2: Client qualification

Discipline	Architect	Civil	Electric	Mechanic
Number of interviewees	2	2	2	2
Position	Project manager	Head division manager	Head division manager	Project manager, Technical manager
Years of experience in design	31, 26	25, 23	20, 17	16, 15
Years of experience in construction	31, 10	25, 15	20, 17	6, 15

3. Contractors specialized in building construction class A (as classified by Palestinian Contractor Union) who were involved in large construction projects. Four contractors have been interviewed. All of them are civil engineers with construction experience more than 20 years. Their experience in design of constructing building projects is above 12 years for three contractors while the forth have just two years experience in design. Two of them are technical managers while the other two are supervisor and project manager.

3.4 Field Investigations

The DfCS concept is almost unknown in Gaza Strip. Qualitative methodology was adopted to have in depth investigation of DfCS concept. The field investigations were conducted after developing the preliminary approach. The field investigations consist of open interview, expert opinion related to the DfCS approach and case studies as shown in Figure 3.2.

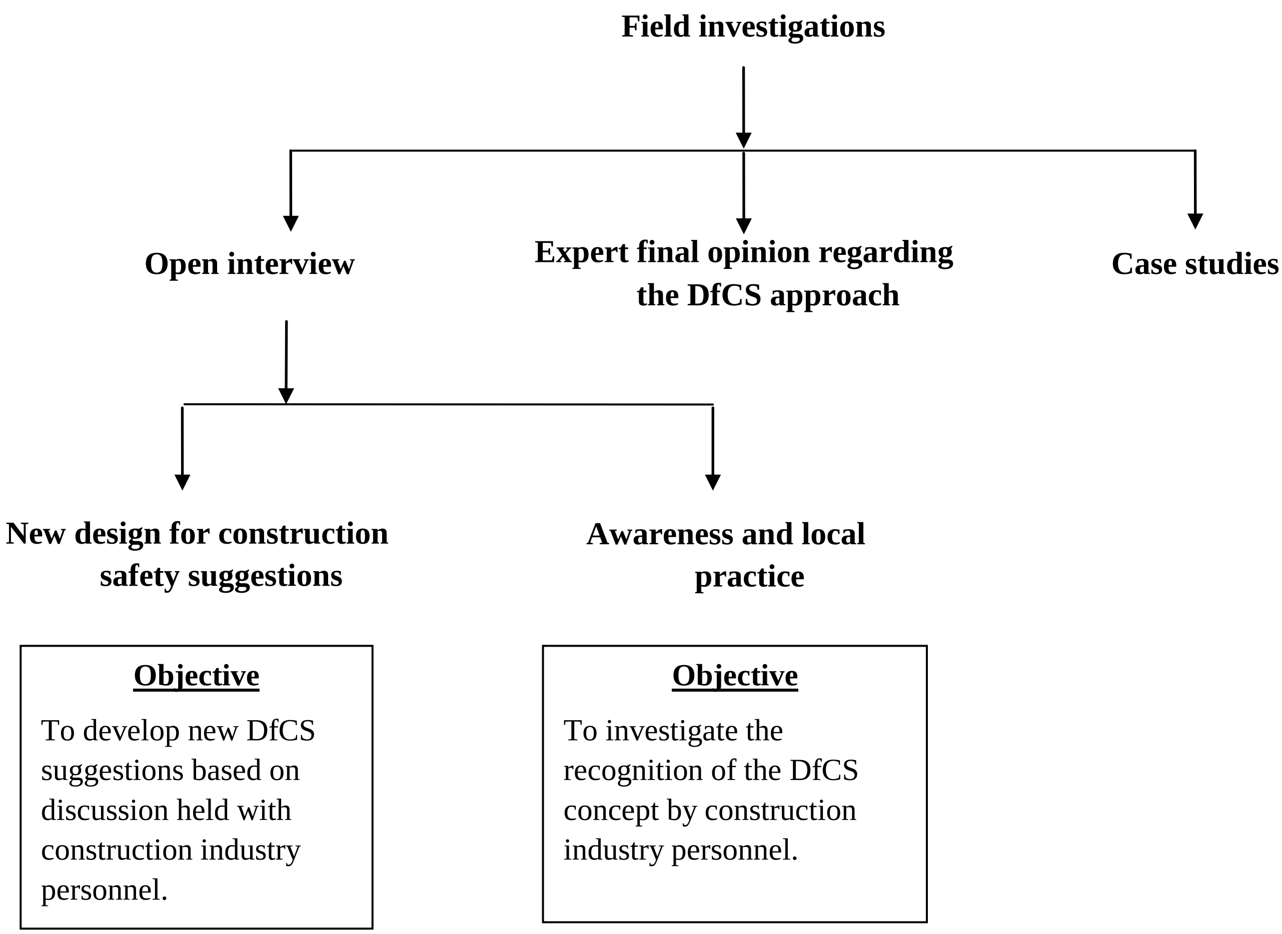


Figure 3. 2: Interview main sections and the objectives

3.4.1 Open interviews

The open interview is developed by researcher based on literature reviews and researcher experience in building construction industry. It is divided to two main sections as shown in Figure 3.2. The first section is related to the awareness of the DfCS concept by the construction personnel and local practices. It included recognition of the concept and current design practices (the DfCS suggestions that already addressed by designers). The second section is related to developing new DfCS suggestions that could improve construction worker safety based on discussion held with these experts. The preliminary approach was not shown to the experts, instead suitable guidewords and topics were prepared for each design phase and engineering discipline which assists the researcher to stimulate discussion with experts to identify DfCS suggestions that already addressed and to develop new ones. The open interview is attached as Appendix A.

3.4.2 Open Interview Document (pilot Interview)

The open interview document was conducted by distributing the open interview to two design professionals and one expert in statistics to have their remarks on the open interview. The two design professionals were asked to verify the open interview content regarding its ability to achieve the research objectives. The statistics expert was asked to verify if the open interview is the appropriate tool for the research. Expert comments and suggestions were collected and evaluated carefully where some minor changes, modifications and additions were considered in the final open interview.

3.4.3 Expert Final Opinion Regarding the DfCS Approach

In this stage experts were asked to display their opinion regarding the DfCS approach and to classify DfCS suggestions as recommendations or regulations. It consists of four types of questionnaires covering civil, architect, electrical and mechanical specializations and the four design phases. The analysis of each questionnaire would be qualitative. The questionnaires are attached as Appendix B.

3.4.4 Case Studies

The aim of conducting five case studies is to contribute in verification of the developed DfCS approach. This could be done by projecting DfCS suggestions on each case study to show that it is easy to identify weak designs related to safety issues and to give suggestions if addressed by designers could produce safer designs. Five case studies are attached as Appendix C.

3.5 Quality of Research

Although applying qualitative methodology is often labor-intensive, it contributes to a fuller understanding of the studied phenomenon (Törner and Pousette, 2009). Golafshani (2003) contend that both qualitative and quantitative researches need to be tested for their reliability and validity but that they need to be operationalized differently. Golafshani (2003) cited that the credibility in quantitative research depends on instrument construction but in qualitative research it depends on the ability and effort of the researcher. Unlike quantitative researches reliability and validity are not separated in qualitative researches. Instead, terminology that encompasses both, such as credibility is used. Mays and Pope (2000) proposed six criteria that must be met to improve credibility in qualitative research. The quality of this research is discussed in relation to these proposed six criteria.

1. Triangulation: compares the results from either two or more different methods of data collection or two or more data sources. This research utilizes different field investigation, namely: open interview, feedback and case studies with different groups as shown in the targeted group.
2. Respondent validation: reporting back the results to the participants of the study mainly to reduce errors and to ensure to some extent completeness. It is met in the research.
3. Clear exposition of the data collection and analysis methods. It is met in the research.
4. Reflexivity: sensitivity to the ways in which the researcher and the research process have shaped the collected data. The interviews were held in the offices of the target groups without pre-knowledge of researcher developed preliminary DfCS approach which minimize the possibility of bias.
5. Attention to negative cases: searching for data contradicting the emerging phenomena. It is apparent from discussion that experts oppose some suggestions.
6. Fair dealing: ensuring that the research design incorporates a wide range of different perspectives. This was assured by selecting design professionals and contractors with hand on experience.

Chapter 4: PRELIMENARY DFCS APPROACH

4.1 Introduction

The DfCS suggestions were gathered from the literature reviews. The applicability of these suggestions to buildings in Gaza Strip was investigated and the applicable ones were adapted. New DfCS were developed to cover the international shortcomings in different engineering fields such as structural design. Additional new DfCS suggestions were developed to comply with the prevailing practice in Gaza Strip construction industry.

The researcher considers the design process to start from the conceptual design till the start of construction commission. The possibility to design out hazards before construction phase is significant. Changes in design to eliminate or reduce hazards during construction phase are difficult, cost time and money and in some situations, controlling hazards become more practical than making changes in design which could compromise worker safety. The design process is divided into four phases, the schematic phase, design development phase, construction documentation phase (communicating hazards that were not eliminated to contractors) and work schedule phase. Since designing buildings require the collaboration of architectural, civil, electrical and mechanical engineers mainly, the preliminary DfCS approach take in account the four engineering specializations.

The preliminary DfCS approach is a tool aims to aid designers to consider DfCS concept easily. It is a systematic way for addressing DfCS concept regardless of engineering specializations or design phases. The preliminary DfCS approach consists of a framework that considers design phases and engineering specializations as shown in Figure 4.1. The adapted and developed DfCS suggestions were incorporated within the framework.

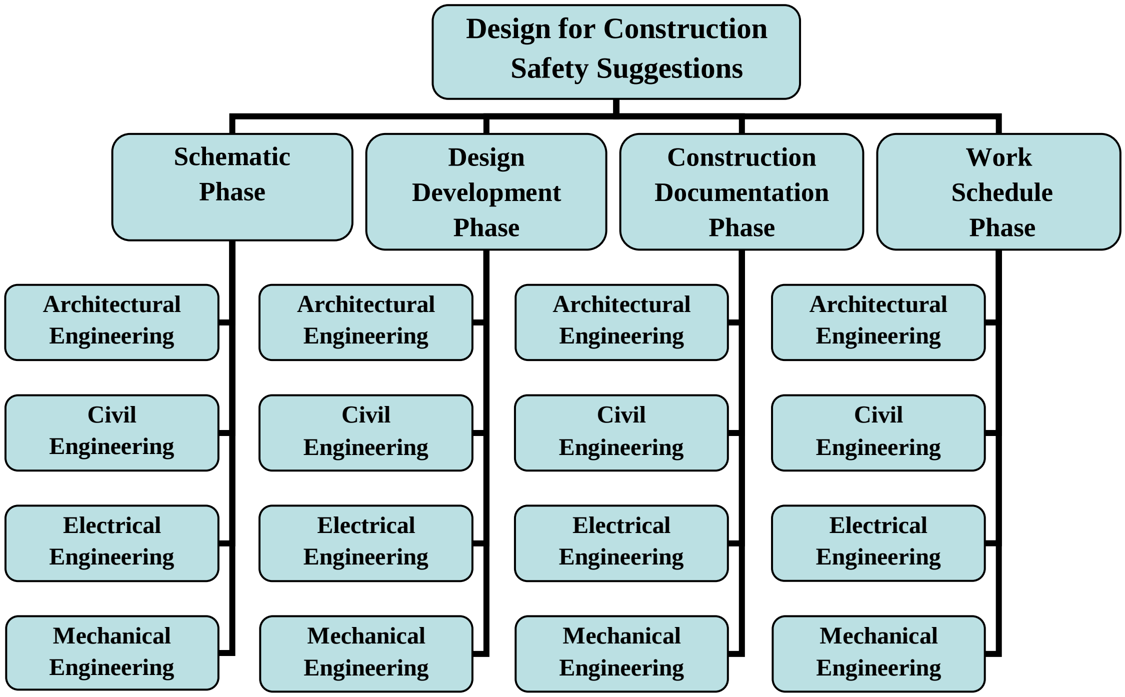


Figure 4. 1: Preliminary DfCS approach framework

4.2 Suggestions Incorporated within the Preliminary DfCS Approach

The developed DfCS suggestions that should or could be addressed by designers are discussed according to design phases and engineering specializations.

4.2.1 <u>Schematic Phase</u>

The developed DfCS suggestions related to schematic phase are discussed for the four engineering specializations as shown in Figure 4.2 and summarized in Table 4.1 followed by thorough discussion for each one.

4.2.1.1 Architectural Engineering

1. Provide storage places with enough capacity for contractor equipments and materials. Incorporating the need for adequate storage areas for contractor materials and equipments in the schematic phase increases the probability of providing them to contractors, on the contrary, delaying considering contractor storages until construction phase may decrease the probability of providing them as happened in one project where at the commission of the construction phase there was no place within the project to put contractor equipments and materials. By chance there was a nearby storage that could

be rent. If the capacity and the place of the storages are suitable then no material or equipment of no use would be in the site which facilitates job site housekeeping.

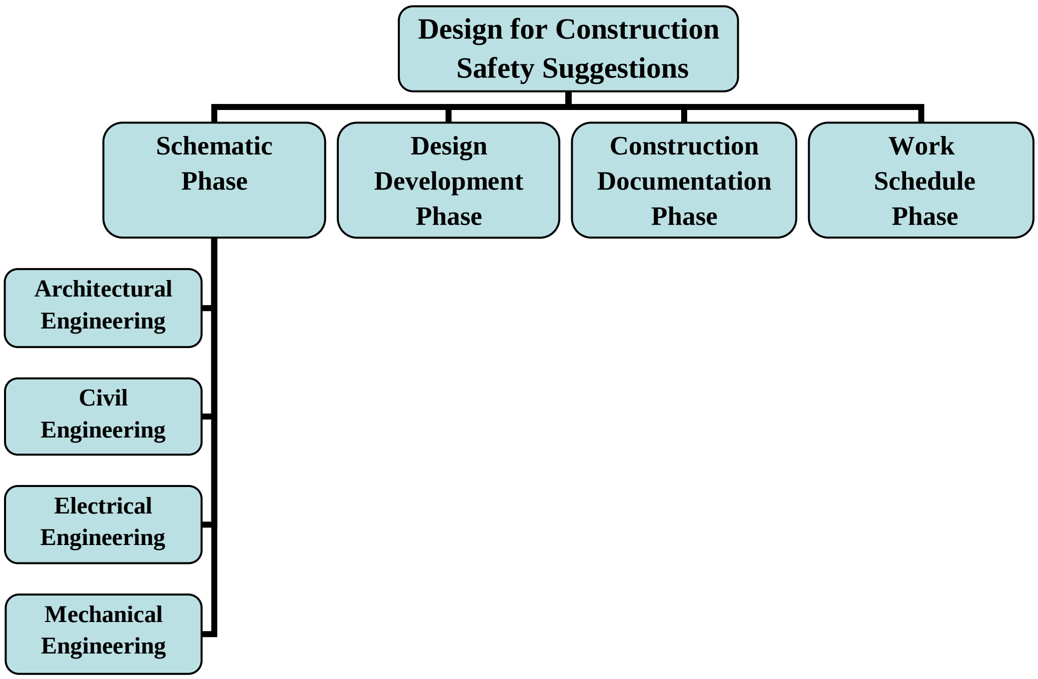


Figure 4.2 : Preliminary DfCS approach layout for schematic phase

Table 4. 1: DfCS suggestions incorporated in the schematic phase

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering	Mechanical Engineering
1	Provide storage places with enough capacity for contractor equipments and materials.	Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.	Choose project location to be away from overhead power lines.	Locate underground utilities in easily accessible places. Consider topographical survey within the criteria used to determine the location of these utilities.
2	Design the layout of project to ensure easy and safe access and regress of materials, equipments and personnel.	_________	Choose the location of contractor storage areas to be safe away from any power lines.	Position underground utilities away from workers passageways but in places easy to construct and maintain.
3	Choose project location to be away from factories.	_________	_________	Place the underground utilities away from existing structures.
4	Choose project location to be away from steep slopes.	_________	_________	_________

2. Design layout of project to ensure easy and safe access and regress of materials, equipments and personnel. Designers in the schematic phase must consider location of material storages, loading and unloading operations, suitable locations for equipments either those used for loading and unloading or for other purposes, safe access and regress of these equipment and personnel to the storages. As an example if a contractor was forced to put his storages in an unsuitable location where equipments cannot access suitable locations for loading and unloading, worker safety would be compromised since workers should do loading and unloading manually, walk long distances which could subject them to low back injury and fatigue that could affect negatively their concentration and alert from dangers.
3. Choose project location to be away from factories that produce dust which could harm the health of site workers. In general buildings should be placed away from factories because of the bad effect on workers and dwellers of these projects due to pollution caused by them. Factories that produce dust cause many diseases, among them lung diseases (Linch, 2002). Figure 4.3 shows the map of Gaza Strip where there are factories that produce high level of dust such as the crusher in Khan Younis and in Rafah. The dust of these crushers could reach up to one kilometre. Ready mix concrete factories also produce dust but less than the crusher machine. In case project location was predetermined to be near factories that produce dust, measurement for dust concentration should be conducted. If the measured dust concentration is within national standards then worker health would not be harmed, otherwise proactive measures should be considered to ensure that worker safety would not be compromised.

Figure 4. 3: Map of Gaza Strip

4. Choose project location to be away from steep slopes to prevent worker slippage across steep slopes. Normally in Gaza Strip, project location is usually predetermined and the topography of Gaza Strip is in general flat. Nevertheless, there are few locations that have considerable slopes such as those near the bridge street in Sheikh Redwan neighborhood of Gaza City. Also, sometimes it is possible to select the location of a project. If the decision is in the designer hand, safety of workers would be improved if locations are chosen away from steep slopes. In construction this suggestion is not of importance for most areas in Gaza Strip. However, in few locations it will be very important.

4.2.1.2 Civil Engineering

1. Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system. The aim of site investigation is to identify the existence of nearby structures that could affect and are affected by the new project and to determine necessary soil parameters through field and lab testing. Depending on soil type, the required depth of excavation and the existence of adjacent structures, the selected temporary shoring system and foundation system should be the safest and most economical. For example in one project while foundation (shallow foundation) was excavated, water from underground had flooded the project area, thus causing the site to be closed until proper soil investigation be performed. Such a

problem could lead to a disaster with many life losses if work continues. After conducting soil investigation the foundation system changed totally and a shoring system was required to ensure worker safety. If designers consider this suggestion then from the beginning proper shoring systems and foundation system could have been designed without having a chance of subjecting workers to such hazard.

4.2.1.3 Electrical Engineering

1. Choose project location to be away from overhead power lines to prevent the ability of having electrical shock accidents especially in the presence of tall equipments. Usually the location of projects are predetermined, but in case the designer has the decision, project location should chosen to be away from overhead power lines to minimize accidents related to electrocution. In cases where project location is predetermined and a nearby overhead power line exist, the designer should communicate the related body to disconnect or relocate the position of over head power lines before beginning any activity in the construction site. Also the designer should ensure that access and regress of equipment, materials and personnel are away from any power line, not only within project borders or around it but also on roads where tall equipments will be transported to the project.
2. Choose location of contractor's storage areas to be safe away from any power line to prevent or minimize the likelihood of a fire or electrical shocks caused by contactors equipment that get in contact with power lines. If contractor's storages placed away from any power lines, then the probability of having a fire in the storages or electrical shock due to power lines is minimized if not prevented. Hinze and Marini (2008) suggested that contractor's storages should be minimum16 meters away from any power line. The researcher believes that 16 meters as minimum is adequate and could enhance worker safety thus he recommend adopting it in Gaza Strip.

4.2.1.4 Mechanical Engineering

1. Locate underground utilities in easily accessible places. Consider topographical survey to be within the criteria used to determine the location of these utilities. This suggestion could enhance worker safety by choosing underground utility location in soil that requires low effort of excavation and cause low noise contamination. Gaza Strip soil

profile does not contain beds of rocks that require high effort, long time and produce high noise contamination. Nonetheless, there exist locations where excavation require considerable effort as happened in one project in Khan Younis. While excavating for underlying mechanical utilities for a project, the digging machine was unable to excavate because the soil was relatively hard. If a soil investigation was conducted, more suitable places for these utilities could be chosen that make the digging process easier. So when the designer has the decision to place underground utilities in different locations, topographical survey report should be important criterion in the decision making. Other criteria that should be considered while selecting underground utilities is to choose locations where there exist sufficient area around excavations for stockpiling and hauling the soil which could make work easy thus enhancing worker safety during construction .

2. Position underground utilities away from worker passageways in places easy to construct and maintain. Safe circulation of workers within project should always be ensured during construction and maintenance. Placing these utilities in worker passageways would compromise worker safety because of presence of trenches or holes. Also continuous circulation of workers around underground utilities that are under construction could decrease concentration of those who install underground utilities which might increase the probability of having accidents. In the maintenance phase having the location of these utilities in the passageways could also impede worker safety since even if guardrails are placed around them, working area might be confined and movement around them could distract workers concentration.

3. Place the underground utilities away from existing structures to prevent negative impact on adjacent existing buildings which could hamper worker safety. Placing excavations or trenches adjacent to existing buildings should be considered carefully to ensure the existing buildings would not affect excavation or affected by them. In addition, placing these utilities near adjacent existing buildings could hamper worker safety by forcing them to work in confined place which could subject them to accidents. Working in

confined places could increase the time required for work which in turn could increase the probability of having accidents.

4.2.1.5 General Comments Related to Schematic Phase

The schematic phase indicates that the role of architect in taking design decisions that could enhance worker safety is more significant than the role of the other engineering specializations. This comment is partially in agreement with literature reviews where Behm (2005a) found that Architects were more likely to have a positive impact on construction safety compared to other design engineers. Frijters and Swuste (2008) showed that architects and structural engineers have an influence on health and safety of employees and users during construction. This does not mean that the role of the other specializations is not significant noting that all literature reviews took the design phase as a whole without dividing it to four phases as conducted in this research. In addition this research deals with buildings in Gaza Strip while the literature reviews deal with this concept related to all types of engineering projects.

4.2.2 Design Development Phase

The DfCS suggestions that should or could be considered by designers in the design development phase were summarized in Table 4.2. The suggestions were displayed according to engineering specializations as shown in Figure 4.4 followed by thorough discussion for each one.

4.2.2.1 Architectural Engineering

1. Design height of parapets and guardrails to be 1.1m minimum above the roof or platform level to provide sufficient guardrail protection during construction or future maintenance. Some organizations in Gaza Strip already adopted the specification of having the height of guardrails to be within 90cm and 115cm above the platform to prevent construction workers from easily falling over them (International Labour Office, 1999R). Parapet heights could have the same specification because from safety point of view both have the same function as guardrails. In general the prevailing practice in Gaza Strip is to design parapets to have height of 1m to protect end user from falling. The literature specifies the height to be 1.1m as minimum (Gambatese et al., 1997) which is approximately the same as the prevailing one is. The 1.1m height

was adopted because it is logical and no need to change from what accepted globally especially if the difference is small.

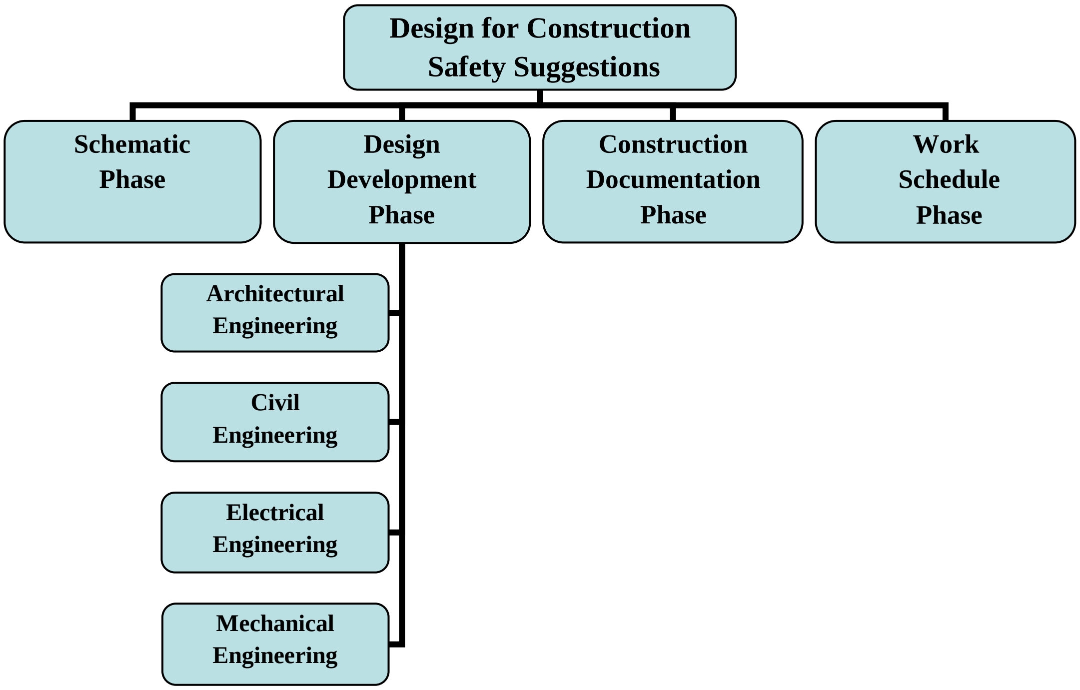


Figure 4. 4: Preliminary DfCS approach layout for design development phase

Table 4. 2: DfCS suggestions incorporated in the design development phase

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering	Mechanical Engineering
1	Design height of parapets and guardrails to be 1.1m minimum above the roof, floor or platform level.	When project site require shoring system, it should be considered in the design phase taking into account environmental conditions.	Using wall mounted lighting instead of ceiling mounted when possible.	Design to have hand excavation around existing underground utilities
2	Design height of window sills to be 1.1m minimum above the floor level.	Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.	Specify fiberglass sweeps for electrical conduit instead of steel sweeps.	Design sanitary installations to be placed in a way that facilitates their installation and maintenance.
3	In each stair riser, design tread and riser dimensions to be uniform from top to bottom.	Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.	Design temporary electrical system that can be installed and used safely during construction.	Locate all equipments such as HVAC equipment and water tanks away from a roof edges.

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering	Mechanical Engineering
4	Provide permanent guardrails around stairs and atrium.	Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance.	Design to place external lighting on places such as roof parapets that facilitate their installation and maintenance safely.	Place split unit (condenser) on roofs, ground or balconies.
5	Design skylights to be domed with elevated beams around them rather than flat ones.	Select building frame system in conjunction with shear walls rather than moment-resisting frame system.	When designing stairs, adequate lighting should be provided during construction and maintenance.	Choose durable material for mechanical installations.
6	Design floor and roof openings to be located away from readily accessed areas on the construction site.	Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enable workers to construct shear walls safely.	Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable labels on the main electrical distribution board	Choose light weight mechanical installations.
7	Specify non-slip tiles and avoid polishing tiles with slip material such as wax.	When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with dimensions of 25cm×25 cm maximum.	In case of ceiling lighting, specify light fittings that can be lowered when changing lamp or tube.	________
8	When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5m with oil-based paint and the remaining walls with water based paint.	Design members to be safe during construction and maintenance even if they are non structural members.	In mass construction avoid chasing walls by designing blocks to have ducts where electrical wires could be placed.	________
9	Design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components.	Design temporary guardrails around stairs and floor edges.	Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.	________
10	Design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.	Design to prefabricate components on ground or in factories where working environment is controlled.	In places where electrical installations require chasing, place material that could be chased easily.	________
11	Design buildings with	Choose quieter methods of	Increase electrical design	________

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering	Mechanical Engineering
	typical floor layout whenever possible.	construction.	load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installations.	
12	Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible.	Design the shuttering of slab to be continuous across the opening to prevent falling hazard and to facilitate working around it. Design a platform with chamfered edges to cover the opening.	Choose durable material for electrical installations.	________
13	Choose materials that are durable.	Select light weight materials such as hollow concrete blocks rather than solid ones.	________	________
14	Choose materials that are safe to handle.	Specify the use of small size concrete cubes of 100×100×100 mm3 instead of standard cylinder for testing concrete strength.	________	________
15	Choose materials that are non combustible.	Design the scaffolding system and specify the features of ground that should be prepared to place it safely.	________	________
16	Select elements such as windows, tiles etc. that are of consistent size, light weight, and easy to handle.	________	________	________
17	Avoid using hazardous materials or operations that emit hazardous materials in confined areas.	________	________	________

2. Design height of window sills to be 1.1m minimum above floor level to provide sufficient guardrail protection during construction or future maintenance. In general the

prevailing practice in Gaza Strip is to design window sills to have height of 1 meter to protect end user from falling. The discussion for height of parapets and guardrails is the same for height of window sills although frequency of being subjected to fall from window sill is less than that of parapets or floor edges.

3. In each stair riser, design tread and riser dimensions to be uniform from top to bottom during construction and maintenance. Any change in tread and riser dimensions could result in tripping or falling accidents. The prevailing practice in Gaza Strip is to consider this suggestion after tiling process to account for the safety of end users. During construction tread dimensions are usually made consistent but riser dimensions are not. The first step is usually made taller than the others while the last step is shorter to take in account embankment required on each slab before tiling process. After experts final opinion related to the proposed DfCS approach, the researcher proposes having a platform with some chamfered edges to be placed on stair flights so that uniform height of all steps is achieved during construction.

4. Provide permanent guardrails around stairs and atrium to protect workers from falling during maintenance. An emphasis on maintenance not on construction because usually during construction, temporary guardrails may be placed to protect workers from fall. The permanent guardrails are usually placed within the final activities to protect them from damages or becoming dirty during construction. In Gaza Strip, atrium and stair edges are usually protected by permanent guardrails because the safety of final user is an important criterion considered by designers during design phase. Considering the safety of end user is very important for designers because it affects their future work and reputation. Thus considering this suggestion embrace advantages other than improving worker safety.

5. Design skylights to be domed with elevated beams around them rather than flat ones so that workers can identify their presence from a distance that enable them to take suitable proactive measures. Being domed makes movement above them not easy so workers will not be encouraged to walk on them. On the contrary if the skylight is flat and not elevated above roof level, then workers would not note it and they may walk on it creating loads more than allowable which cause their failure where the injury most

times would be severe if not fatal. Addressing this suggestion not only improves worker safety but other advantages could be achieved such as the aesthetic scene in addition to increasing the surface area that will provide light to the space below. This suggestion could be recommendation because some situations may force architect to design flat one, yet the researcher recommend designing elevated beams around them to identify their presence from a distance.

6. Design floor and roof openings to be located away from readily accessed areas on the construction site to prevent falls or to prevent drop hazards from elevated work spaces. The circulation of workers within project should be studied so that floor openings are placed away from workers circulation. Floor opening usually placed near elevators and stair cases specifically near walls which could be considered away from workers passage especially if partitioning activity started as soon as possible. Falling from floor openings is a common source of accidents thus the researcher stressed on the importance of choosing floor opening to be away from workers passage.

7. Specify non-slip tiles and avoid polishing tiles with material such as wax that might increase slippage ability which might cause injuries that could be severe in some cases. Designers are conscious of the hazard incorporated in choosing slip tiles, yet owners in some cases insist on choosing slip tiles for the appearance. Even some end users make polishing with wax which increases the ability of slippage especially for slip tiles. The researcher believes that it is possible to choose alternatives which are none-slip tiles that acquire the satisfaction of end user. Indeed with the existence of sheer variety of tiles such as marble, terrazzo, porcelain, ceramic, terracotta, the architect could find alternatives that satisfy end user and cause non slippage or at least could advise end user to make polishing with a small amount of neutral detergent in warm water instead of wax. If not possible it is recommended to use non-slip additives.

8. When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5 meters (the height of hand reach) with oil-based paint and the remaining upper part of walls with water based paint. Although oil-based paint is a durable paint that has a high gloss, shiny finish and can be cleaned easily making it an excellent choice for areas that are susceptible to frequent use such as kitchens and corridors, its

smell is too strong and affects worker safety negatively especially if exposed to it long period (http://www.essortment.com). The oil-based paint is not required for the full height of walls, it is enough to have this paint to 1.5 meters because this height is the part of wall that usually subjected to dirt and need frequent cleaning. The upper part of the wall does not require durable paint that sustains frequent cleaning. The researcher believes that creative architect can benefit from having two types of paints for required walls to design beautiful decoration system and at the same time achieving enhancement of worker safety by decreasing the required time for painting with oil-based paint.

9. Design corridor dimensions, door heights and swing to ensure easy access and regress of long members and components. During designing corridors and doors, if designers did not consider easy access and regress of long members and components, workers would face a new challenge which could distract their concentration and expose them to hazard. For example, consider the painter who wants to enter a ladder to a corridor or through a door; if he face problems in entering the ladder, it is logical that he starts work with bad mood that could increase the probability of being subjected to accidents. Sometimes workers are forced to damage part of partitions to enable components to access across corridors or doors which could hamper worker safety. Thus considering this suggestion facilitates working and improves worker safety.

10. Design height of corridors to be suitable for making electrical and mechanical installations that covered by false ceiling. Service lines, such as air-conditioning systems and electrical wiring (used for computers or telephones) are sometimes installed above suspended false ceiling. Lighting systems could also be accommodated within the false ceiling. Installing the lighting system on false ceiling is easier than installing it on the original ceiling since it reduces work-related musculoskeletal disorders during construction and maintenance. Maintenance of service lines above false ceiling would be easier than impeding them in the slab, since suspended ceiling tile is easily removed to make the required repairs and all the service lines are apparent for the worker who could diagnose the problem and repair it easily without the need of chasing that produce harmful dust and impede worker safety.

11. Design buildings with typical floor layout whenever possible. When working in a floor, workers become familiar with the floor layout and they got good chance to identify sources of hazard and avoid them. If floor layout is not typical then there exists a probability that workers become confused. Workers perception to hazards in one floor might be project to a second floor causing worker safety to be compromised in case of none-typical floor layout. For example, if a column or door position is changed in the upper floor, worker who spent time on the lower floor and then moved to the upper one may collide accidently by the door or column when being tired and unable to concentrate. This can partly explain why in mass construction, productivity is high where workers became familiar with the work and their ability to avoid hazards increase which could decrease time waste due to accidents. Some opinions indicate that this suggestion could hamper architect creativity if it became as regulation. The researcher opinion is that this suggestion is important and should be considered whenever possible. Also the creativity of designers could be affected positively when more restrains are imposed on them.

12. Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible. Increasing the number of offsets in the plan could contribute first in having complicated one which makes work not easy and requiring more concentration, so as a result the worker safety would be compromised. Second, offsets are near the edges of buildings where working there incorporate danger of fall which could result in severe injuries or death. So by minimizing the number of offsets, worker safety could be improved. Designing offsets to have consistent size could minimize accidents by making workers circulation within the offsets to be the same. Besides making offsets as large as possible would facilitate workers circulation within the offsets which could decrease accidents such as colliding with guardrails that constructed around the offset edges as a result of small allowable distance for circulation.

13. Choose materials that are durable to minimize the maintenance needs. Durability and low maintenance often coincide which means that a durable material is often, low maintenance one. Durable material is one that has known brand and/or proven experience. It should pass the required tests. The importance of choosing durable

material increases in situations where the work incorporating hazards. As an example, choosing the paint of external facade to be durable will decrease the need to work at heights for maintenance. Besides, choosing window aluminum and glass to be of good quality would sustain higher period than ordinary types which could enhance worker safety and reduce accidents since any work related to facades incorporate hazard either by the ability to fall or being exposed to falling objects. In addition to law maintenance requirements needed when choosing durable material, the long run cost of project could be decreased.

14. Choose materials that are safe to handle in order to conserve worker health. Construction workers could be exposed to various hazardous materials. Excessive exposures to these materials may result in severe injury or even death. Poor health conditions affect worker concentration negatively which in turn could increase accidents. For example asbestos is unsafe material. Globally, it is agreed that installation of asbestos could lead to serious illness, including asbestosis, lung cancer and larynx cancer (http://english.vietnamnet.vn/tech). Another unsafe material is spirit-based paints which have strong smell and affect workers health. Designers could if applicable use water-based paints or search for a substitute in places that require durable material to minimize maintenance especially when working on heights. Another example is some types of tiles that produce hazardous dust (silica) when polished or during the cutting process. For many years, it has been known that breathing in fine dust containing crystalline silica can cause lung damage and cancer (General Secretary Derek Simpson, 2006). Designers should obtain information for hazard identification from the equipment and material manuals, supplier, site owners and principal contractors, and when choosing a substitute, they should always check that one hazard is not simply replaced by another.

15. Choose materials that are non combustible to avoid the likelihood of a fire. A non combustible material is one that is not capable of burning such as concrete, bricks and construction steel. Examples of combustible material that are used in construction are: wood, textiles, paper, plastics, etc. Fire accidents are very dangerous especially with the presence of materials that facilitate spread of fire thus causing injuries that might be severe or might cause death. One of the important criteria that should be considered by

designers while selecting construction material is to be with low combustibility. For example they could choose aluminum windows instead of wood ones. Considering this suggestion has been the cause to limit human and physical losses in major education building in Gaza Strip where the architect chose non combustible furniture and floor covering material. When the building has been subjected to fire, the chosen non combustible furniture and floor covering material was able to prevent its spread. Designers should first choose non combustible material or one with low combustibility; if not possible they should find a substitute which is less hazardous. Otherwise they should use fire-resistant material that could be sprayed over or applied on combustible materials to make them non-combustible.

16. Select elements such as windows, tiles, etc. that are of consistent size, light weight, and easy to handle to alleviate back pain. Manual handling is common in construction work and is a common cause of injury at work due to carrying out these operations for a long period. Also, materials may be heavy and/or inconsistently sized and shaped. This suggestion should be one of the criteria that considered in material selection to reduce the negative effect of worker safety due to material handling. For example choosing light weight tiles such as ceramic or porcelain tiles could enhance worker safety because these tiles have lighter weight than the other types. Also using small dimensions for tiles could enhance worker safety because small dimensions first have light weight and second working with tiles of small dimensions is easier than working with large ones. Another example is to design protection steel around window to be of light weight but within design codes and standards to make construction and maintenance process easier which could enhance worker safety.

17. Avoid using materials or operations that emit hazardous materials in confined areas. hazardous material can be defined as "a chemical or mixture of chemicals that is toxic, highly toxic, an irritant, a corrosive, a strong oxidizer, a strong sensitizer, combustible, flammable, extremely flammable, dangerously reactive, pressure generating" (http://www.noskidding.com). Making polishing for doors is an example of having hazardous material in confined area where the operation should be done within closed doors to avoid dust sticking. This action is unsafe since the smell is too strong and affects workers health. In such situation prefabrication is recommended where work

environment in factories is controlled. Another example is to practice welding in a confined place. This action should be minimized or approved in situations where high protective measures are used.

4.2.2.2 Civil Engineering

1. When project site requires shoring system in the schematic phase, it should be considered also in the design phase. Environmental conditions should be taken into account in its design. Ensuring safe design of shoring system would protect soil and nearby existing buildings from failure which in turn affects worker safety positively. In Gaza Strip the contractor most times is the one responsible for providing adequate shoring system. But the ideal case is to consider it in the design phase because designers are capable to design it properly taking into account the prevailing environmental conditions. The shoring system may be exposed to failure if rain was not considered in its design. An accident that was very bad for all parties of a project occurred because this suggestion was not considered in the design phase. The location of the project was adjacent to a building from one side and on the edge of a street from the other side. The contractor provided shoring system that he believed it would be safe for the required excavations. After heavy rain the shoring system collapsed leaving two killed persons who were walking nearby on the street and the adjacent building was subjected to severe cracks making it unsafe for dwelling. After investigations, it was found that due to the unsuitable dissipation of rain water that was gathered behind the shoring system, an additional horizontal hydraulic pressure was developed causing its collapse. Such accidents could be prevented or minimized by considering this suggestion.

2. Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process in order to protect workers from falling during construction and maintenance. Guardrails could be made of several materials such as concrete, wood or steel. The erection of guardrails depends on its material. Yet by designing for example inverted beams around the edges of skylights, stairs and atrium, and for all types of guardrails, safety could be improved. For concrete guardrails, blocks would be erected above it to make the height of guardrail to be 1.1 meters which is capable of preventing

worker falls. The presence of the inverted beam could enhance worker safety while working on roof, floor or atrium, by reducing time required for building blocks to the required level which decreases the time of exposure to falls. In addition the position of worker would be away from the edge which could impact worker safety positively. For steel or wood guardrails the design of elevated edge beams with certain connection placed above the elevated beam and erected at the same time with it could also enhance worker safety by eliminating the need to chase concrete to erect guard rail while standing on edges and also by reducing the time required for erection in hazardous situation. Sometimes, steel connection is designed and erected on edges to facilitate erection of guardrails as shown in Figure 4.5. Although such practice could reduce the time required for erection in a hazardous situation, it could increase the hazard of falling since the connection was placed outside the edge which could increase the probability of fall significantly. Such practice imposes significant hazard on workers while placing guardrails on inverted beam designed on edges could improve worker safety.

Figure 4. 5: Picture showing connection on edges of stairs

3. Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system. Perimeter beams and beams above floor openings are hazardous locations where workers are usually subjected to fall accidents causing severe injuries or even death. During construction or

maintenance, workers should be protected from fall when working near them. By designing these connection points, worker safety could be enhanced because in case of fall, these life lines if designed properly could eliminate or minimize the injury or death that result from falling. Since these connection points are not already addressed by designers, 25kN as minimum design load could be used as adopted from previous studies (Gambatese et al., 2005).

4. Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance. Usually in Gaza Strip, scaffolding erection is the contractor responsibility unless other parties specified in the contract. Usually there exist no tie-off points into the building facade that are considered as support points for scaffolding. In the absence of these points contractors are forced to use their experience in order to secure scaffolding erection. They try to make temporary supports in the facade and they benefit from the building windows where they erect steel props inside the building near the open window and tie scaffold to it. Although contractor experience is useful in the scaffold erection process, the non existence of scaffolding tie-off points into the building facade increase the probability of making faults in the erection process that cause its failure, subjecting workers to danger of fall. These faults may be due to the construction industry features where each site has its own characteristics and what is true for one site is not necessary true for another one. So designing these scaffolding tie-off points into the building facade facilitate the scaffolding erection process which could affect worker safety positively.

5. If the design requires earthquake and wind loads to be considered, whenever possible, select building frame system in conjunction with shear walls rather than moment-resisting frame system. Although there are many structural systems, the comparison was made between these two structural systems because the common practice in Gaza Strip is to use shear walls. While moment-resisting frame system is used for special cases such as halls with large spans and by some engineering institutions such as UNRWA. Although these institutions use moment resisting frame systems in the design, they have conducted recently a study to assess the possibility of designing shear walls instead of frames to improve worker safety. In general the shear wall construction is preferred than moment resisting frame system. This could be attributed to the fact

that shear walls are easier to install and could reduce work-related musculoskeletal disorders if compared to the construction of girder in moment resisting frame. Selecting shear walls not only could improve worker safety but are better from structural point of view since they are more rigid.

6. Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enables workers to construct shear walls easily and without being exposed to danger of fall. From structural point of view, the best location for shear walls is to be within few meters of the exterior part of the building. In case of placing shear walls on the exterior part of the building the construction and removal of shear wall forms incorporates significant danger, since workers are forced to work near the exterior edges which could increase the probability of being subjected to falling hazard. Shear walls should be placed, whenever possible, minimum 1.5 meters away from the exterior perimeter. Such a distance enables architect to benefit from the exterior parts and enables workers to work within adequate space that facilitate erection and removal of exterior shear wall forms.

7. When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with maximum dimensions of 25cm×25cm to provide a continuous walking surface free of tripping hazards. In the construction process, sometimes workers are forced to walk on reinforcement bars such as the grid of shrinkage steel in the slab or the upper reinforcement in the footing of retaining walls. This suggestion has little importance in the case of hollow block slab reinforcement where existence of blocks provides continuous support for workers while walking on it. Nonetheless, in such cases it is preferable to decrease the diameter of steel bars in order to decrease the spacing between them. So workers while walking on the grid are supported all the time by reinforcement bars which could eliminate or minimize the hazard of tripping. This suggestion is always considered in the design process in Gaza Strip. The dimension of 25 cm as maximum is adopted because workers foot size usually more than 25 cm.

8. Design members to be safe during construction and maintenance even if they are non structural members. Structural members are a constituent part of any structure or building as columns, slabs, etc. Non structural members such as those used to enrich the

aesthetic scene or to satisfy certain functions such as the covering of skylights. Each member in a structure should be designed to be safe during construction and maintenance regardless of being structural or non structural member. For example, skylights covering should be designed to be capable of supporting the workers who will construct or maintain them. Besides the amount of the downward deflection should also be checked to ensure it will not break the glass or the covering material which could cause failure of workers who construct or maintain these elements. In one project, an accident happened while workers were erecting decoration system above exterior door, the decoration system collapsed resulting in injuries. After investigation, it was found that the decoration system was not designed to sustain its own weight in addition to weight of workers. The researcher stresses on the importance of reviewing the loads and deflections that should be considered during design stage to ensure safe construction and maintenance for every member in the structure.

9. Design temporary guardrails around stairs and floor edges to minimize or eliminate the risk of subjecting workers to falling or being struck by falling objects. Facilitate the incorporation of these guardrails in the structural design. The permanent guardrails are usually placed within the final activities of the project to protect them from dirt or any damage. During work, temporary guardrails should be placed immediately on the edges that incorporate danger of fall. In Gaza Strip, the contractor is the one responsible for erecting these temporary guardrails. In the best situation, these guardrails are placed without any design but depending on contractor experience. It is not recommended to erect guardrails without design which could compromise the main function of these guardrails that is to protect workers from falling. Structural engineers should consider these guardrails regardless of being temporary or permanent in their design by designing for examples connections in the edges that facilitate erecting these guardrails easily and reduce the erection process duration.

10. When work incorporate danger such as a falling danger, design to prefabricate components on ground or in factories where working environment is controlled. In Gaza Strip, prefabrication in the construction industry is not a usual practice. Yet, it is very important to consider this suggestion especially when work incorporates significant danger. As an example many accidents happened while constructing beams

above windows where sometimes physical strength is needed to remove away shuttering of these beams which resulted in falls. Designing blocks of U shape for these beams where reinforcements would be placed inside the U shaped blocks and concrete is poured above reinforcement could eliminate such accidents. This alternative could be of great importance in mass construction where prefabrication became strategic choice that affects project cost positively in addition to its ability of enhancing worker safety.

11. Choose quieter methods of construction to improve communication between workers and enhance their safety. For example, mixing concrete in site causes lot of noise for over a higher range of time compared to premixed concrete. Using old method of mixing concrete in site could impede worker safety since it took much more time than premixed concrete while exposing workers to high noise. The high noise could distract workers concentration and hamper the communication between workers and with managers, affect workers health and finally increase work-related musculoskeletal disorders. This is because of the nature of the work where workers required holding materials to put on the mixer and then distribute the concrete to the required places. Recalling that premixed concrete could be afforded for most cases, considering this suggestion would not just has positive impact on worker safety but also the quality of premixed concrete.

12. Design slab shuttering to be continuous across floor openings to prevent falling hazard and to facilitate working around it. After removal of shuttering, design a platform with chamfered edges to cover the opening in order to facilitate working around it and to avoid struck of workers by platform edges. Otherwise, design temporary guardrails with coloured band to be placed around the opening before the removal of shuttering system. The prevailing practice in Gaza Strip is to extend reinforcement across the openings in both directions to protect workers from falls and facilitate working around it, but such practice has several disadvantages:

a. The slab reinforcement would be subjected to environmental conditions which would impede its strength.

b. The worker safety would be compromised while cutting the extended bars across the opening.

c. The cut bars would represent a real hazard if workers fall on them and they contribute to having untidy site.

13. Select light weight elements to reduce low back pain. One example is to use hollow concrete blocks rather than solid ones. Construction industry incorporates repetitive lifting, carrying, and laying concrete blocks which cause workers to suffer from low back injury and work-related musculoskeletal disorders. Lower weight decreases the forces exerted on the spine and other parts of the skeleton. Using light weight concrete block contribute in making work easy not tiring, decrease time required for work and could reduce the ability of being subjected to illness such as low back pain. In addition, fatigue would be reduced by performing the same task with less weight members that could enhance worker safety. Fatigue hamper worker safety since it could affect their concentration thus exposing them to accidents. Hollow blocks, also could affect design positively by decreasing the amount of dead load significantly and by increasing productivity of work which make the long run cost lower.

14. Specify the use of small size concrete cubes of 100×100×100 mm3 instead of standard cylinder for testing concrete strength. Using standard cylinder could cause low back pain and work-related musculoskeletal disorders since it is heavy. This practice is followed in most projects in Gaza Strip and it should be continued.

15. Design the scaffolding system and specify the features of ground that should be prepared to place the scaffolding system above it safely. The prevailing practice in Gaza Strip is that the scaffolding system is the responsibility of contractors who usually erect it according to their experience. Recalling that each construction project has its own unique characteristics, contractor experience is not enough at all to erect scaffolding system safely for all cases. Thus the scaffolding system should always be checked if it could sustain loads on it safely or not. Many accidents happened because the scaffolding system was erected according to contractor experience. These accidents are the result of either poor ground features underneath scaffolding system where partial settlement occurs or due to faults in the upper parts of the scaffolding system. Due to these both causes the result is collapse of scaffolding system with injuries that may be severe or fatal. Designers should understand the importance of this suggestion or at

least the erection of scaffolding system should always be preceded by approval from designer to ensure safety of workers.

4.2.2.3 Electrical Engineering

1. Using wall mounted lighting instead of ceiling mounted, wherever possible or when function permits, can reduce the hazard of falling from heights and reduce work-related musculoskeletal disorders during construction and maintenance. For installing lighting wither on walls or on ceilings a ladder is required. Working on ladders incorporate danger by its self, but when installing lighting on ceiling workers are required to ascend to higher level than that required for installing wall mounted lighting. In addition the manner of installing ceiling mounted lighting incorporates musculoskeletal disorders much more than that required for wall mounted and could increase the hazard of falling from heights. This suggestion cannot be addressed always by designers since functions enforce designers sometimes to use ceiling mounted lighting where lighting should be sufficient.
2. Specify fibreglass sweeps for electrical conduit instead of steel sweeps because of its light weight and flexibility. Installations of electrical conduit require repetitive bending as shown in Figure 4.6. The prevailing practice in Gaza Strip is to use fibreglass sweeps which have light weight and easy to handle. this contributes in simplifying work and decreasing the required time for installation which in turn could improve worker safety by reducing low back pain and musculoskeletal disorders.

Figure 4. 6: Picture showing worker during electrical installations

3. Design temporary electrical system that can be installed and used safely during construction. The temporary electrical system should be capable of providing adequate light and illumination for both exterior and interior work areas, especially at night. In addition, it should provide sufficient electricity for performing construction works safely. Since the permanent electrical system is connected to electricity within the last activities of construction process, a temporary electrical system is required. The contractor is the one responsible for providing the temporary electrical system in the prevailing practice in Gaza Strip. Contractors most of the times provide the electrical system without any design but depending on their previous experience. Many accidents happened because temporary electrical system was not designed which subject workers to be electrocuted causing severe injuries and death. This suggestion should be addressed in the design stage because of its importance in improving worker safety either by having safe electrical system or by providing adequate lighting and illumination.

4. Design to place external lighting on places that incorporate no or law danger on workers who install or maintain them. Usually designers avoid placing electrical installations on facades because the installing process is not easy and could expose workers to hazard of fall. When external lighting is required, designers should place it on roof parapet in case of low building as can be seen in Figure 4.7 so that workers could install and maintain it safely. For high buildings they should design it to be placed on short columns or on ground to eliminate or minimize workers exposure to danger of falls. If not possible they should try to place it in places that facilitate its installation and maintenance from inside building without the need to use scaffolding. In Gaza Strip designers consider this suggestion but in some cases they design connection for external lighting to be impeded in the slab to facilitate erection of the external lighting and improve worker safety by reducing the time required for erection. The researcher opinion is that such practice incorporate danger to workers while making the connection from the edges of the slab as can be seen in Figure 4.8. Also the installation and maintenance process still dangerous and require scaffolding system to

be erected in order to complete its erection or maintenance which could subject workers to danger of falls even if the required time for installation is reduced.

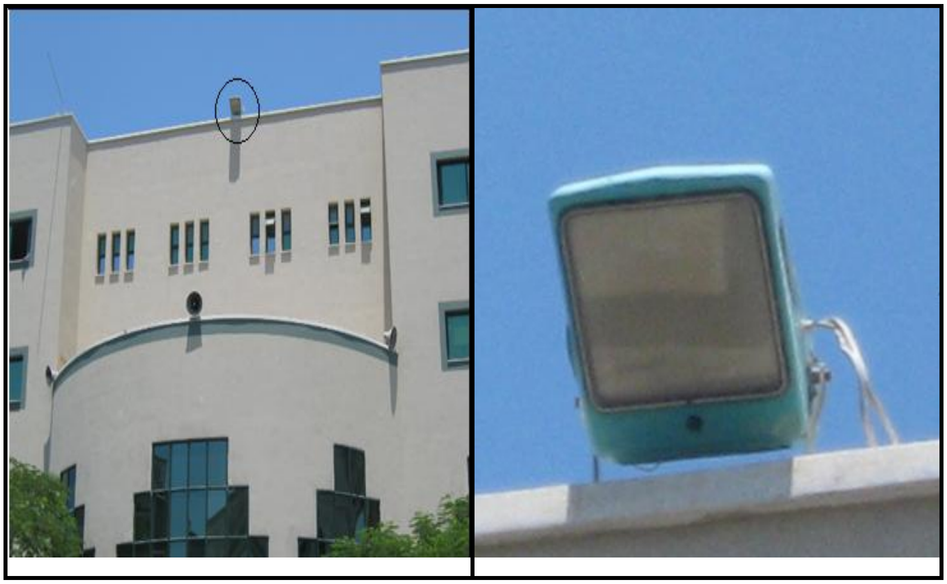


Figure 4. 7: Picture showing external lighting installed on roof parapet

Figure 4. 8: Picture showing impeding external edge lighting connection

5. When designing stairs, adequate lighting should be provided during construction and maintenance. Stairs are the passageways for workers to enter or leave the building,

workers keep moving on stairs all time of construction which require special care to be provided for stair lighting. In construction industry, workers are usually subjected to exhaustion. Any obstacle that is placed on stairs could form significant hazard if stair lighting is not adequate. This is because workers would not be able to see this obstacle which could cause their fall.

6. Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable labels on the main electrical distribution board. This suggestion is very important in the maintenance phase. The one who perform the electrical installations knows all the configuration of power sources and electrical distribution board. In case of maintenance if another worker comes, he could be subjected to electric shock unless consistent standards for power sources have been used and single line diagrams showing as built installations and identified by labels were present. The labels should be durable that is not affected by time to guide the worker who will perform maintenance in future. In Gaza Strip large projects this alternative is usually addressed but in small ones it depends on the owner request.

7. In case of ceiling lighting, specify light fittings that can be lowered when changing lamp or tube. When the function of the room requires placing lighting on ceiling the designer could choose light fitting that would be lowered as shown in Figure 4.9 to make the required maintenance easily. Although during installation, workers should ascend high on ladder which could subject them to fall and work-related musculoskeletal disorders, the maintenance process incorporate no hazard since these light fittings could be lowered to enable workers to change lamp or tube easily.

Figure 4. 9: Picture showing light fitting that could be lowered

8. In mass construction avoid ‘chasing’ walls by designing blocks to have ducts where electrical wires could be placed. This suggestion is difficult to apply in ordinary constructions were each project has its own electrical installation. It is difficult for workers to build these blocks with the direction of ducts the same as that required for electrical installation. The researcher opinion is that the construction process incorporate considerable amount of devastation. Workers build blocks then they chase these blocks to provide ducts for electrical installations. This process could affect worker safety negatively by first subjecting them to harm dust, low back pain and work-related musculoskeletal disorders , second by distracting their concentration due to exhausting work and third chasing produce large amount of waste which need continuous housekeeping otherwise it form tripping hazard for workers. This suggestion become of considerable value in mass construction where there exists repetition of design which enables workers to construct these blocks easily as required for installation process eliminating the need for chasing which affects worker safety positively. In mass construction addressing this suggestion could not only improve worker safety but also it could affect cost, productivity and project duration positively.

9. Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire. Sometimes while working, accidents happen that is not related to electricity such as a fire or being injured while working with cutting machine. In such situations electricity do not isolate automatically but require to be cut manually. If the isolator switch is not in an accessible location then worker safety would be compromised. Although contractors have experience but it is not sufficient to make them responsible for designing temporary electricity for the construction site or determining the best location for the isolator switches to cut electricity as quick as possible in case of accidents.

10. In places where electrical installations require chasing, place material that could be chased easily. Chasing is dangerous operation because it produces harmful dust, exposes workers to work-related musculoskeletal disorders and it is a hard job that could cause fatigue that affects their concentration and could expose them to accidents. This suggestion is considered by contractors in the case of electrical boxes that required to be placed in the slab. Designers specify the location of electrical boxes. The

contractors place material that could be easily removed after removal of slab forms to decrease the amount of work by eliminating chasing but not from worker safety point of view. This suggestion should be considered in the design phase and the type of material that could be chased easily should be specified so that contractors should address this suggestion whenever required.

11. Increase electrical design load to take into account the rapid technological advancement that invent new electrical equipments which could over load the electrical installations. Over loading the electrical system might cause damages to electrical installations that require maintenance which could hamper worker safety because of dust and work-related musculoskeletal disorders. In general, the design load for electrical installation is increased in case of public buildings and towers but in low rise buildings the design load is subjected to the request of the owner. Some owners request ordinary design load for electrical installations because either they don't have enough money or they think that they would not be able to have advanced electrical equipments such as HVAC equipment. Yet in many cases these owners became able to having these advanced electrical equipments thus causing damage to the electrical installations. In such cases maintenance is required and might include concrete chasings which could hamper worker safety.

12. Choose durable material for electrical installations. It is important for any selection of material during the design stage to be assessed on the bases if the installation or maintenance process incorporates danger or not. For example if the chosen electrical sweeps will not sustain long period then chasing slabs and walls will be required frequently which impede worker safety. By choosing these electrical sweeps to be of known brand and proven experience that pass successfully all required tests, designers could ensure long life utilization of these installations. The need for maintenance could be eliminated or decreased significantly which in turn could affect worker safety positively. Another example is the selection of electrical lamps which usually require a ladder to fix or replace, thus subjecting workers to hazard of fall. Choosing durable electrical lamps would decrease the frequency of changing these lamps which in turn reduces the ability of subjecting workers to hazards especially falling.

4.2.2.4 Mechanical and Plumbing Engineering

1. Design to have hand excavation around existing underground utilities to ensure no damage of utilities will occur during excavation. Any damage of underground utilities compromise worker safety by first subjecting worker life to danger such as being electrocuted. Second by requiring the worker to repair the damages while working in trenches which incorporate danger of soil failure. Depending on type of soil and on depth of excavation, sometimes hand excavation requires shoring system that should be designed.

2. Design sanitary installations to be placed in a way that facilitates their installation and maintenance. Sanitary installations could be placed on facades or impeded in walls as shown in Figure 4.10 case (a) and case (b) respectively which are a usual practice in the case of low rise building. In the case of high rise building sanitary installations usually installed inside risers. Placing these installations on the facade or impeded in walls incorporate significant danger on worker safety especially during maintenance but the later is more dangerous since it require chasing walls which could affect worker health because of dust emitted from chasing. In addition during construction scaffolding is used to install these sanitary installations which impede worker safety and subject them to falls or being struck by falling objects. During maintenance the prevailing practice in Gaza Strip is catastrophic where workers use rope ladder supported on roof parapets extending on the facade to descend on it till the level that require maintenance. This procedure is very dangerous and subject workers to falling which result in severe injuries or even death. For the case of high rise building the installation of these sanitary equipments could be safer than that of low rise building because if the risers are designed away of workers passageways with rectangular cross section of adequate size then the installation procedure and maintenance would be easy and safe. The researcher opinion is that sanitary installations should be designed to be in risers for all buildings regardless of the height to improve worker safety during construction and maintenance.

Case (a): placed on the facade | Case (b): Impeded in walls

Figure 4. 10: Picture showing sanitary installations

3. Locate all equipments such as HVAC equipment and water tanks away from roof edges to protect workers from falling during construction and maintenance. The prevailing practice in Gaza Strip is to place these equipments near the roof edge to minimize amount of installations. Even in the case of having roof parapets, any worker who needs to ascend on the top of these equipments could be subjected to hazard of fall. The researcher opinion is that although the amount of installations could be increased, placing these equipments away from roof edges could decrease the probability of subjecting workers to accidents such as fall from heights which most times produce severe injuries or death. The designers and owners should scarify additional cost in return to protect workers from dangerous accidents. Another point that should be considered during design is to place these equipments in a way that facilitates their construction and maintenance thus improving worker safety.

4. Place split unit (condenser) on roofs, ground or balconies to prevent or minimize falls during construction and maintenance. In low rise buildings the condenser could be placed on roofs away from edges or could be placed on ground so that the erection and maintenance process could be safe. In high rise buildings it is not economical to place the unit either on roof or on ground because this would increase the length of required pipes and increase loss of cold air which cost extra money. In such cases the common

practice in Gaza Strip is either to place the condenser on balcony wall so that the probability of subjecting workers to fall could be decreased during erection and maintenance, or near a window as shown in Figure 4.11 in cases where it is not possible to place the unit on balcony wall so that its erection would be from inside the building. The researcher recommend placing the condenser on balcony walls and oppose placing the condenser on facade near a window because it incorporates significant hazard on worker safety where workers could be exposed to fall in addition to work-related musculoskeletal disorders. If not possible, condenser could be placed near a window taking in account that all protective measures should be considered such as designing connections so that workers who install or maintain the condenser will be connected to them to eliminate or reduce the probability of falling.

Figure 4. 11: Picture showing split unit placed near a window

5. Choose durable material for mechanical installations that have long useful life and require low maintenance needs. Engineering require long life learning and following new inventions related to the discipline. Engineer should be able to know the useful life of each chosen mechanical installation in addition to the required tests that should be applied in order to check its quality. The mechanical installations are placed under tiles, in slabs, walls or subjected to weather conditions if placed on facade. Mechanical installations with no proven experience usually need continuous maintenance. Any maintenance process for those in slabs or walls requires chasing which could compromise worker safety by subjecting them to harmful dust and to work-related

musculoskeletal disorders. If the outside mechanical installations were not durable then the maintenance process incorporates significant danger to workers since they should work on heights. Many accidents happened while maintaining these installation and cause either severe injuries or death. For those under tiles, also any maintenance requires removal of tiles as the first step which could impedes worker safety by subjecting them to work-related musculoskeletal disorders, dust and low back pain.

6. Choose light weight mechanical installations which could enhance worker safety. For example choosing plastic pipes with a known brand and proven experience for mechanical installations could enhance worker safety because they have light weight which make their installation easier than other piping systems in addition of being ideal for long-life application. By choosing light weight pipes, the effort and time required for installing could decrease which reduce the probability of subjecting workers to law back pain and work-related musculoskeletal disorders thus improving worker safety.

4.2.2.5 General Comments Related to Design Development Phase

The number of DfCS suggestions related to architecture specialization is relatively more than those for civil specialization which in turn is relatively more than those for electrical specialization. The number of DfCS suggestions related to mechanical specialization is the least. In fact the mechanical engineers interviewed contend that the mechanical design package for buildings in Gaza Strip does not incorporate significant danger on workers as the architect and civil engineer design packages. This claim is not exact since for example till now in some projects mechanical installations are placed on facades which incorporate significant danger on workers during construction and maintenance. Electrical engineers have the same claim explaining that first: the dead work is the normal method of carrying out electrical installations and second: almost all electrical installations usually placed inside the buildings not on facade. Noting that the electrical installations require working while on ladder, chasing walls and slabs and incorporate lots of work above shoulders and below knees means that indeed the electrical design decisions affect worker safety significantly. The civil engineer role in improving worker safety is crucial since ten DfCS suggestions out of fifteen are related to falls which is a major cause of construction industry accidents.

4.2.3 Construction Documentation Phase (Communicating Hazards to Contractors)

This phase deals with the required information that if available in technical specifications and drawings, could communicate hazards to workers thus enhancing worker safety. The DfCS suggestions that should or could be considered by designers in the construction documentation phase were summarized in Table 4.3. The suggestions were displayed according to engineering specializations as shown in Figure 4.12 followed by thorough discussion for each one.

The four engineering specializations should address DfCS number three which state that the general condition of the contract documents should contain a term that obliged designers and construction supervisors to provide efficient and timely response to any contractor query for information. To enhance communication process between designers and contractors it is very important to respond to any query for information introduced by contractors. This response should be timely because any delay in responding could subject worker safety to danger. Designers and construction supervisors should understand that providing information to contractors when required could minimize or prevent accidents and enhance worker safety. This suggestion is very important especially in design-bid-contracts to ensure that worker safety be above the adversarial relation between designers and contractors.

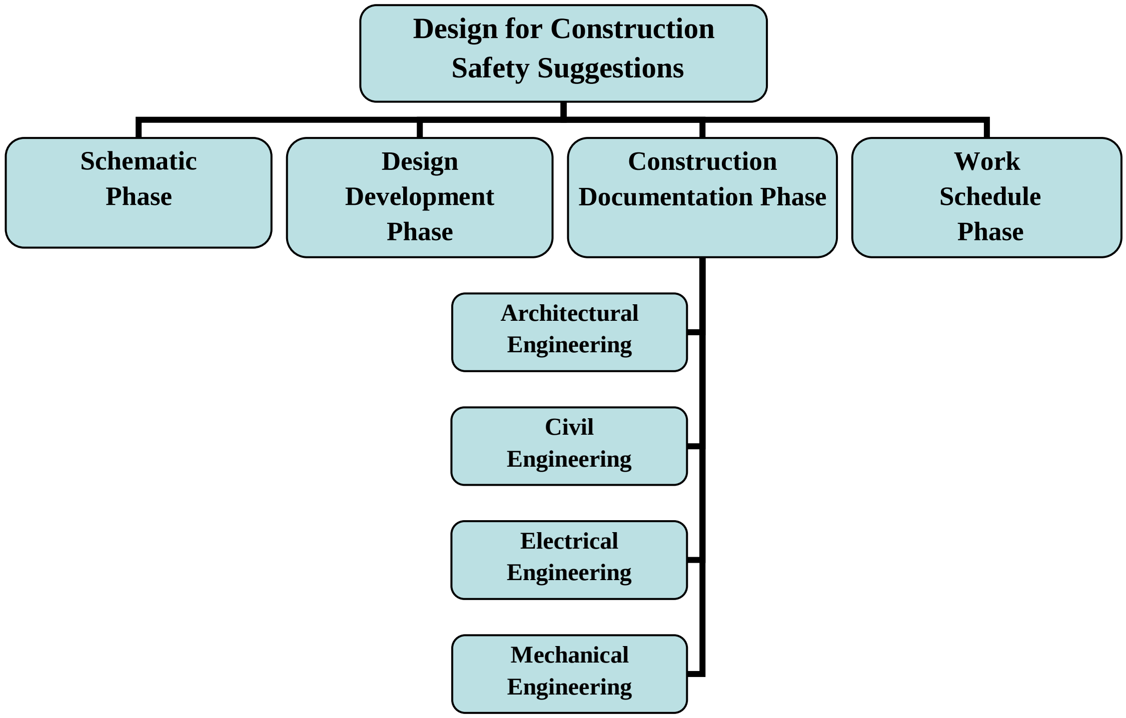


Figure 4. 12: Preliminary DfCS approach layout for construction documentation phase

Table 4. 3: DfCS suggestions incorporated in the construction documentation phase

Suggestion Number	Schematic phase	Design development phase	Construction documentation phase	Work schedule phase
1	Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and water supply locations on the drawings and technical specifications. Specify the involved personnel that should be communicated in case of emergency.	On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines.	On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information.	On the project drawings and specifications, identify the location and size of existing utilities including underground lines indicating the level of certainty and source of information.

Suggestion Number	Schematic phase	Design development phase	Construction documentation phase	Work schedule phase
2	Provide warning signs and notes colored in red on the drawings and technical specifications that incorporate hazards on workers, notes should be provided to alert workers of the existing hazards. Examples of hazards are floor openings and steep slopes.	Provide warning signs and notes colored in red on the drawings and technical specifications to alert workers to places of hazards such as excavation location and the required shoring system.	Provide warning signs and notes colored in red on the drawing and technical specifications when electrical systems incorporate hazards.	Warning symbols should be provided on drawings and technical specifications reminding workers that oxygen welding is not permitted in confined places.
3	The general condition of the contract documents should contain a term that obliged designers and construction supervisors to provide efficient and timely response to any contractor query for information.	Same as architecture specialization.	Same as architecture specialization.	Same as architecture specialization.

4.2.3.1 Architectural Engineering

1. Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and water supply locations on the project drawings and technical specifications. Specify the involved personnel that should be communicated in case of emergency. The number of hospitals in Gaza Strip is few and known for most workers, the drawings contain large amount of information and project site signs could be used to convey the required information. Nonetheless, not all workers know whom they should contact in the hospital to speed the injury rescue process, besides the number of health centres is not small and workers should know the location of the nearest to project. Finally, the inclusion of this information in the drawings could make this information cognizant to workers especially if they are placed in a standard place in the drawings. When accidents happen, the workers usually became confused and distracted for a short period of time. If workers became familiar with the required information then the response time would be decreased and the probability of taking the proper action could be increased. For example if they have an

injury they could immediately contact the nearest hospital or health centre to the project. In case of a fire they could specify the nearest location of water supply which could enhance the rescue process and minimize injuries or death situation.

2. Provide warning signs and notes colored in red on the drawings to draw observer attention and convey presence of danger such as floor opening, steep slopes or hazardous material. In case of technical specifications that incorporate hazards on workers, notes colored in red should be provided to alert workers of existing hazards to take suitable proactive actions. Workers usually deal with drawings; if recognized symbols or notes cognizant to workers were used on drawings to communicate hazards to workers then workers would be reminded all times of the presence and locations of these hazards which could decrease the probability of having accidents. Construction industry should have global warning symbols understood by worker that identify the type of hazard. As an example, if warning signs were provided on drawings showing the location of floor openings and convey the presence of falling hazards then workers will be conscious all time and their ability to avoid this hazard could be increased. In Gaza Strip this suggestion is not a usual practice.

4.2.3.2 Civil Engineering

1. On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines. Specify their number and locations. The beams designed to support lifelines are very important to protect workers from falls. If their locations and numbers are specified on the contract drawings then workers will always be aware of their presence and locations so the probability of benefiting from them could increase. This suggestion is not a common practice in Gaza Strip construction industry although most accidents are related to fall from heights. By considering this suggestion in the design stage the possibility of being subjected to falls could be decrease. Indeed designers can make a lot of difference in reducing the hazards associated with working at heights.
2. Provide warning signs and notes coloured in red on drawings to alert workers to places of hazards such as excavation location and the required shoring system. Provide in technical specifications notes in red colour to convey such hazards to enable workers to

take suitable proactive actions. Excavations are source of danger for workers which require being alert while performing or working near it. Excavations most times require shoring systems. By having these warning signs and notes, workers would be warned that the excavation is not a safe place to work in or adjacent unless having the specified shoring system thus the workers ability to avoid sources of hazards could be enhanced.

4.2.3.3 Electrical Engineering

1. On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information. In one project an accident happened because of lack of this information. The workers have predetermined safe access and regress for the project, but some workers came from a road that has over head power line because it is a short one. Their truck came in touch with the overhead power line causing death. If workers knew that the road they enter form danger on them, this accident could be prevented. If the location of this overhead power line was present on the map with warning signals then workers could be alert all the time about such hazard thus their safety could be improved. An important point is to specify the level of certainty on the map because in case of being certain the workers would consider this source of hazard seriously and be alert to avoid it.

2. Provide warning signs and notes coloured in red on the drawings. Provide red colour notes on technical specifications when electrical systems incorporate hazards. For example installing electrical system inside a riser which is a floor opening incorporate hazard of falling. Conveying location of hazard to workers could improve their alertness of such hazard. The architect should also communicate such hazard to workers. In general communicating such hazard to workers by all engineering specializations could keep workers alert all time and it could enhance worker safety.

4.2.3.4 Mechanical Engineering

1. On the project drawings and specifications, identify the location and size of existing utilities including underground lines and indicating the level of certainty and source of information. Although designers obtain the site utility plans from the local municipality or owner, existing utilities are often not shown on design drawings. From safety point

of view, all underground utilities should be identified on the drawings so that workers could benefit from them and could avoid spoiling them by making excavation that causes damage. Such excavations could subject worker safety to danger and enforce workers to fix damages which are also a dangerous work. Identifying the source and level of certainty could help workers to communicate with the source for more information and could keep them alert if the level of certainty is high. In general, whenever information about the existence and location of underground utilities is available hand excavation is conducted. On the contrary, with the absence of the required information, excavation may be performed using machines which result in underground utilities damages in addition to injuries or even death.

2. Warning symbols coloured in red should be provided on drawings reminding workers that for example oxygen welding is not permitted in confined places. Warning notes in red should be provided in technical specifications also. Oxygen welding should not be performed in confined areas to prevent or minimize the likelihood of a fire. When the design requires having oxygen welding such warning could keep workers all time alert of such hazard so that the probability of welding in confined areas could be decreased which in turn could improve worker safety.

4.2.3.5 General Comments Related to Construction Documentation Phase

The DfCS suggestions related to this phase are approximately identical for the four engineering specializations. They are summarized by identifying sources of danger, providing red colored signs and notes on contract drawing and technical specifications and finally efficient and timely response to any contractor query for information. A suggestion that was not adopted by researcher is to provide shop drawings with all required details represented in a clear way to perform construction and maintenance safely. Every design should fulfill this suggestion to be accepted and to enable workers to perform their work as required regardless of safety requirements. The researcher point of view is that this suggestion is fulfilled in all designs and for all engineering specializations and it is one of the requirements of any design so no need to address it or otherwise we are talking about bad design which is not the case. The researcher point of view is that the DfCS suggestions in this phase should be addressed by designers because of the ability of addressing them by all engineering specializations in addition to their importance in communicating hazards to workers.

4.2.4 Work Schedule Phase

The prevailing practice in Gaza Strip is that the civil engineer or sometimes the architectural engineer is the one responsible for preparing the project time schedule. For this, DfCS suggestions that related to project scheduling as a whole are summarized under civil engineering.

The DfCS suggestions that should or could be considered by designers in the work schedule phase were summarized in Table 4.4. The suggestions were displayed according to engineering specializations as shown in Figure 4.13 followed by thorough discussion for each one.

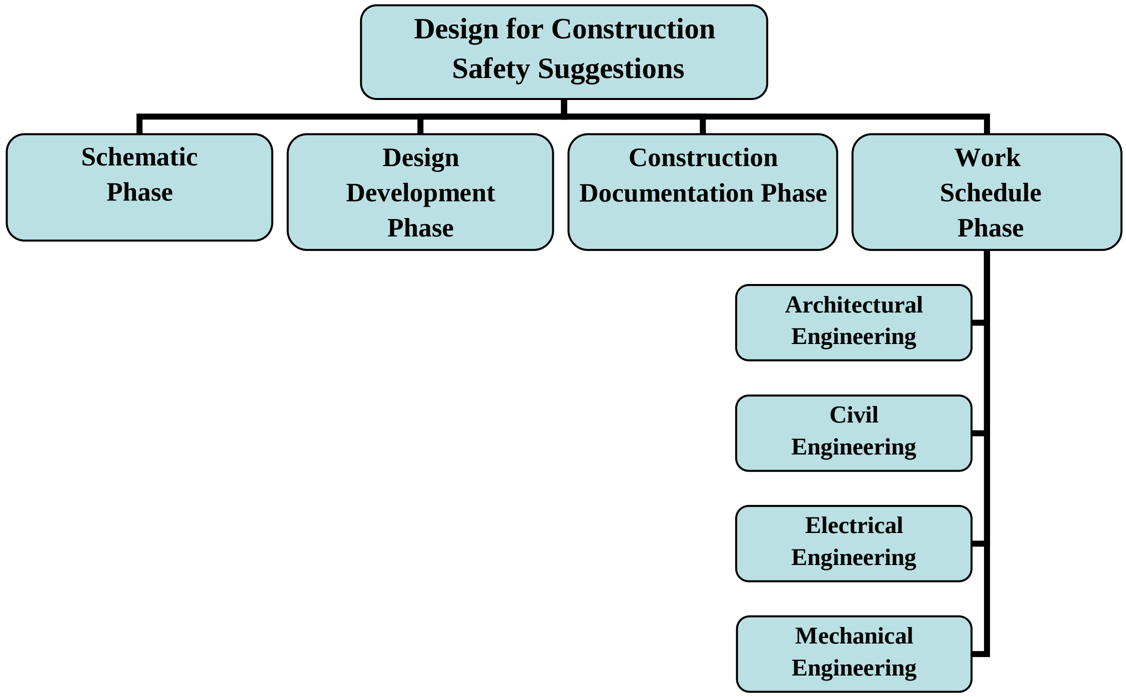


Figure 4. 13: Preliminary DfCS approach layout for work schedule phase

Table 4. 4: DfCS suggestions incorporated in the work schedule phase

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering
1	Schedule activities so that no welding activity is performed while painting.	Design permanent stairway to be constructed at the beginning or as close as possible to the start of construction of each floor.	After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging.
2	When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.	Before the removal of the steel props supporting slabs, satisfactory results of concrete cube tests are required.	________
3	Schedule sidewalks, ramps and roadways around project to be constructed as early as possible.	Schedule temporary guard rails with coloured band to be placed around edges and floor openings as soon as possible.	________
4	________	Design work schedule to minimize the need for overtime.	________
5	________	Design work schedule to minimize the need for night work.	________
6	________	The work schedule should contain daily housekeeping that keep site tidy all time.	________
7	________	Schedule to start partitioning activity as soon as possible especially at edges and floor openings.	________

4.2.4.1 Architectural Engineering

1. Schedule activities so that no welding activity is performed simultaneously with painting activity. While preparing the schedule, engineers should pay attention to activities that might subject workers to hazards if they took place at the same time.

Painting is considered a combustible material that should be carried out away from any activity that might cause a fire such as welding activity. Special care should be taken in case of carrying out painting in a confined place. All activities such as welding should be scheduled to be done either at different times or away from the painting place to ensure no fire would occur. By considering this suggestion such accidents could be eliminated which could affect worker safety positively.

2. When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible to reduce or prevent falls from heights. Globally the most frequent cause of fatal injuries in construction industry is falls from heights such as floor edges or stairs. To eliminate or minimize the effect of this major cause it is important to ensure that all sources of falls from heights are protected by guardrails and/or fall protection mechanisms all duration of the project. If any delay in erecting these proactive measures occurs, then the efficiency of these proactive measures decline significantly. The prevailing practice in Gaza Strip is not to consider this suggestion while scheduling. The permanent guardrails are delayed to be erected within the final activities in order to protect from any damage or dirt thus depriving workers to benefiting from them. Fall protection mechanisms are also not part of the prevailing practice. The reason for this is that designers and owners believe that erecting fall protection mechanisms cost too much and not practical. The researcher think that indeed it cost but in case of any falling accident that cause severe injury or fatality it will cost the company much more than the cost of erecting these proactive measures in addition, the reputation of the company would suffer a lot which affects its future work.

3. Schedule sidewalks, ramps and roadways around project to be constructed as early as possible to provide stable base for ladders, scaffolding and equipments. Many accidents happened because ladders or scaffolding or even equipments were placed on ground that has not been prepared to sustain loads on it and the result was injury and death in some situations. This suggestion is not a common practice in Gaza Strip although designers and contractors note from their expertise that workers could benefit much if this suggestion is considered. Although each construction project has its own

characteristics engineers could afford to schedule sidewalks, ramps and roadways around project to be within the earlier activities.

4.2.4.2 Civil Engineering

1. Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of the upper slab of each floor. The prevailing methods of erecting stairway is to pour concrete of one stair riser with columns, while the other riser is poured with the upper slab, or the two stair risers are poured with the upper slab. These prevailing methods for stairways construction deprive workers to benefit from permanent stairways. Workers are forced to walk on temporary stairs or scaffolding exposing them to danger of falling, slipping or even tripping. Civil engineers can easily choose position of columns and beams so that to enable the construction of stairway to be as early as possible which could enhance worker safety by eliminating or reducing hazards of falling or slipping.
2. Before removal of the form system of slabs, satisfactory results of concrete cube tests are required. The prevailing practice in Gaza Strip is that some of steel props that support slab forms is removed few days after concrete pouring then the slab forms are removed totally after fourteen or twenty one day depending on span length of slab and wither being cantilever or not. Removing steel props that support slab forms few days after concrete pouring is very dangerous since this period is not enough for concrete to gain the required strength. After fourteen days, engineers should ensure that 65% to 70% of the required concrete strength is gained before removing slab forms. After twenty one days, engineers should ensure that the strength gained is about 80% to 85% of the required strength before forms removal.
3. Schedule temporary guardrails with coloured band to be placed around edges and floor openings as soon as possible. Working near edges incorporates significant danger and could result in severe injuries or death. All edges should be protected during construction work to protect workers from falls. Since construction industry is not an easy one where workers could be distracted easily it is important to protect their life by all means. Considering this suggestion while scheduling could reducing accidents due to falls thus reducing severe injuries and death.

4. Design work schedule to minimize the need for overtime. The construction industry requires hard effort from construction workers which make the over time not recommended from safety point view in addition to productivity point view. At the end of workday, workers became exhausted which could affect their ability to avoid accidents. Any overtime could increase the probability of being subjected to accidents. It is impossible to eliminate the need for overtime. For example, workers became obliged to work extra time in case of concrete pouring to slabs where the whole slab should be finished. Nonetheless, this suggestion should be considered while scheduling to benefit from overtime as minimum as possible and to avoid using it for long time because workers became very exhausted and could be subjected to accidents easily.

5. Design work schedule to minimize the need for night work. Construction industry requires day light to identify hazards which could be hidden in night even if good lighting is introduced. In the night, workers are not able to distinguish between bars and their shadows. In general night work should be avoided whenever possible but sometimes the only practical option is to benefit from night work. If designers were obliged to benefit from night work then suitable precaution measures should be provided and the kind of work should not incorporate danger on workers.

6. The work schedule should contain daily housekeeping to keep site tidy and provide safe work place free from obstacles that cause accidents. Working in an untidy site as shown in Figure 4.14 could for sure affect workers concentration and mood negatively. On the contrary for tidy job sites, no equipment placed randomly in the worker passageway and every worker knows where to find the required equipments. No rubbish spread in the site that forms obstacles that could cause accidents. Workers mood could help them to perform work in comfortable condition where their concentration is totally focused on their work which could increase their safety significantly. Having a tidy work place could reduce also the time required for performing the work. This suggestion should be addressed because of its importance in improving worker safety in addition to improving productivity.

Figure 4. 14: Two pictures showing untidy job sites

7. Schedule to start partitioning activity as soon as possible especially at edges and floor openings to form guardrails on edges that protect workers from falling. Floor opening are placed near walls. Without partitioning these floor opening could be within passageway of workers while placing partitioning made these floor openings away from worker passageway that could decrease the probability of exposing workers to danger of fall from heights.

4.2.4.3 Electrical Engineering

After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging so as to decrease probability of chasing walls or slabs in maintenance process. In case of inserting electrical cables inside conduits before plastering activity, it is hard to check if these conduits are subjected to damage or to closure which could affect the maintenance process badly. In such situation the paint and plaster should be removed in addition to chasing walls and slabs which could subject workers to falls, dust and work-related musculoskeletal disorders.

4.2.4.4 General Comments Related to Work Schedule Phase

In this phase the scheduler should study the relationship between activities and hazards that result from their combination or sequence taking in account worker safety in addition to other criteria. The rule of civil engineer is crucial in this phase since the prevailing practice in Gaza Strip is that the civil engineer most times is the one responsible for preparing work schedule. In fact the civil engineer should be aware of all DfCS suggestions incorporated in the work schedule phase regardless of engineering specialization. The designers of other engineering specializations should be aware of DfCS suggestions related to their specializations in order to convey them to the one responsible for scheduling to ensure considering them.

4.3 General Comments

Every engineer practices his work in the area of his specialization. The preliminary approach that was proposed by researcher provides each engineering specialization with DfCS suggestions related to the discipline to make designers feel that this concept is related to their discipline thus accepting the responsibility. In addition, DfCS suggestions are identified for each design phase to help designer to feel that this concept is not vague and does not require lots of extra works. Another advantage is that each discipline could contribute in formulating new DfCS suggestions that could enhance worker safety and could consider this as part of their specialization development.

The amount of DfCS suggestions incorporated in the design development phase is the largest since all details would be designed in this phase and duration of this phase is much more than the other design phases. Many DfCS suggestions are related to fall from height which is a global cause of accidents in construction industry so that to aid in reducing accident rates of construction industry to allowable limit.

The DfCS suggestions placed within the preliminary approach are just the beginning were accumulation of new suggestion should be continued and made available for all designers.

Chapter 5: ADDITIONAL DFCS SUGGESTIONS BASED ON EXPERT PERSPECTIVE

5.1 Introduction

The open interview has two sections. The first section is related to designer recognition of the concept. The interviewees were experts in their work and they already address some DfCS suggestions voluntarily either to enhance workers safety or for other reasons such as protecting the third party or the end user which also could contribute in protecting workers from hazards. Nonetheless, most of them do not recognize the existence of such concept by the name while none of them have formal tool to aid. The second section is the core of the open interview. This section aims to develop new DfCS suggestions that are applicable to construction industry buildings in Gaza Strip. The thorough discussion that was held with the experts enabled the researcher to develop new DfCS suggestions applicable to buildings in Gaza Strip. These new DfCS developed suggestions are incorporated in the preliminary DfCS approach.

5.2 Recognition of the Concept and Current Design Practices

The discussion with the interviewees related to their recognition of the DfCS concept revealed the following:

1. Civil engineers regardless of being consultant or clients showed positive recognition and good understanding of the concept. This could be attributed to:

- In some projects, the Terms of Reference (ToR) included by clients in the Request for Proposal (RfP) require a safety engineer to be part of the consultant project team. The proposals are normally prepared by civil engineers and thus they became aware of the DfCS concept.

- Civil engineers from experience believe that they can to certain limit affect worker safety. They believe that the preparation of shop drawings enables them to ensure that the constructability is safe.

2. Architectures showed minimal knowledge of the concept regardless of being consultant or clients. They comment that although safety of workers is not their responsibility usually their designs for buildings are simple which means that they would be safe also workers are familiar to their designs.
3. The consultant electrical and mechanical engineers were not aware of the concept. They commented that although safety is the responsibility of contractors their designs do not form danger to worker safety. Half of electrical and mechanical engineers, as clients, were aware of the concept and they know it is a requirement in the foreign funded projects. Nonetheless, they believe their designs do not represent danger to worker safety and that safety is the responsibility of contractors.
4. Contractors lack the knowledge of the concept. Their knowledge is focused on the construction phase.

All interviewees did not have any academic or training background on the DfCS concept. They did not have a formal process to follow that allows for consideration of construction worker safety, nor hear of CDM regulations or CHAIR. None of them have worked with or hired a construction safety consultant in the design phase.

In general civil engineers have knowledge of the concept because recently they have been asked to address construction worker safety in the design phase. Nonetheless, they do not have solid materials or formal approach that aids them in applying the DfS concept. In fact experience is the only tool used to investigate if certain design represents danger to workers or not. Even hazards that are considered by them is limited and do not comprehend all real hazards that workers suffer in construction industry. For the other engineering specialization, when the concept was explained to them they mention that some of their decisions incorporate considering workers safety by common sense and experience.

5.3 Additional DfCS Suggestions Developed Based on the Open interviews

The new DfCS suggestions that developed by researcher based on the discussion held with experts are discussed in reference to the preliminary DfCS approach layout shown in Figure 4.1.

5.3.1 Schematic Phase

The following guidewords and topics were used to stimulate a thorough discussion with interviewees: project location, over head power lines, lay out of project, material access, and Piping and electrical controls. The developed new DfCS suggestions for this phase are summarized in Table 5.1 according to engineering specializations.

Table 5. 1: New developed DfCS suggestions incorporated in the schematic phase

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering
1	Place personnel protective equipments (PPE) as near as possible to the project entrance or in suitable place.	Design foundations to be positioned internally away from the exterior perimeter of proposed building if too close to existing ones.	Check the existence of exposed electrical wires in the nearby existing buildings around the site.
2	Provide sufficient utilities for workers to prevent the ability of using the job site.	________	________

5.3.1.1 Architectural Engineering

1. Place personnel protective equipments (PPE) as near as possible to project entrance or in suitable place to ensure that workers will use their PPE before being exposed to hazards. While in schematic phase there is a good probability of providing storage location as required, this probability decreases substantially if the decision is delayed until the construction phase. In general, many accidents could be prevented if this suggestion was considered in the schematic phase. Otherwise, in some situation, the only possibility left is to place contractor storages in a place where workers need to move through project before they get their PPE and hence exposing them to accidents such as falling object which may result in severe injuries if not death.

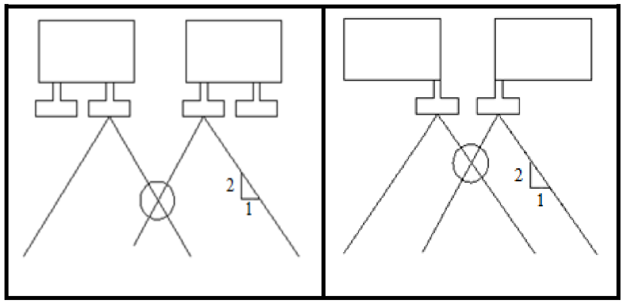
2. Provide sufficient utilities for workers to prevent the ability of using the job site which is hazardous. Considering this suggestion in the schematic phase, could facilitate the probability of affording these utilities to workers. In this phase designers should and can provide safe and adequate space for workers utilities such as toilet, sinks and a place to make tea or coffee and to have rest. An accident had occurred in one project

because in the schematic stage designers did not consider providing these utilities for workers during the construction stage. So at the construction stage workers used project rooms to satisfy these needs. While making coffee in a room where there exists paint material, a fire was launched causing severe injuries to workers in addition to cost loss. Considering this suggestion in the schematic phase is very important to afford these utilities to workers thus preventing such accidents.

5.3.1.2 Civil Engineering

1. In case of designing buildings too close to existing ones, if applicable, design foundations to be positioned internally away from the exterior perimeter of building under construction. This is to minimize the probability of affecting or being affected by adjacent foundations and to make work easier. This change of foundation location that affects the enclosed area of building under construction could be compensated by projecting offset cantilevers around its perimeter. Considering this suggestion could be suitable for some situations, but for other cases it might be not suitable. For all cases the design should be made according to design codes and standards. Although it is possible to design shuttering system and construct near the adjacent building, workers movement during constructing the shuttering system will be within confined areas which constrain workers movement subjecting them to accidents. Another cause of accidents is due to the time duration where in this case the duration would be longer than that required in the case of moving foundation locations few meters away from adjacent buildings. For example in some cases where the height of excavation for foundations is about 2-3 meters and the adjacent foundations were also within this range, designing foundations to be placed several meters away from the exterior perimeter of building would most times enhance worker safety by decreasing work time and facilitating workers movement. This suggestion has positive impact on design itself where it results in having an efficient foundation that dissipate loads to ground without affecting or being affected by adjacent foundation. Figure 5.1 shows two situations of adjacent buildings and the dissipation of loads to the earth. It is clear that in case (a) the intersection of line of dissipation of loads to earth is deeper than that of case (b), so the summation of stress from the two buildings at that point is less than that of (b). It is

apparent that such suggestion in addition to its ability to enhance worker safety it makes design more efficient.



Case (a) Case (b)

Figure 5. 1: Dissipation of loads to earth

5.3.1.3 Electrical Engineering

1. Check the existence of damage parts in electrical wires in the nearby existing buildings around the site to protect workers from electrical shocks that may occur if material or equipment by accident became in contact. It is not enough at all to check the existence of damaged electrical wires within project area, but adjacent buildings should be checked also, since accidents may occur while for example holding tall elements such as reinforcement bars that might come in contact with these damaged parts causing electrocution accidents. In such cases designers should contact the related parties to fix the wires that could subject workers to hazards. This suggestion when considered in the schematic phase enables proactive measures to be taken before commencement of construction phase thus in addition to its importance in enhancing worker safety it contribute in ensuring construction phase to be within the proposed time.

5.3.2 <u>Design Development Phase</u>

The new developed DfCS suggestions that should or could be considered by designers in the design development phase are summarized in Table 5.2. The suggestions were displayed according to engineering specializations.

5.3.2.1 Architectural Engineering

The following concepts and keywords were discussed with the interviewees to ensure the achievement of the open interview objectives: falling from roofs, floor openings, atriums, stairs, floor lay out, facade configuration, selection of materials and finishes (paints, tiles). The new developed DfCS suggestions are:

Table 5. 2: New developed DfCS suggestions incorporated in the design development phase

Suggestion Number	Architectural Engineering	Civil Engineering	Electrical Engineering	Mechanical Engineering
1	In mass construction, use modules to have length of 1.2 m or multiple.	Choose straight bars reinforcement rather than the bend-up ones.	Design the riser for electrical installation to be away from mechanical installation riser.	Design for placing water pump a way from electrical generator.
2	Design openings that are used to provide light and ventilation to be located at the exterior edges of buildings rather than inside the buildings.	Design slab shuttering to be minimum 0.5 meters over hanged from all direction with guard rails.	Avoid placing the main electrical distribution board under baths.	________
3	Design horizontal distance between two successive stair risers (stair nose) to be as small as possible.	Select small reinforcement diameters rather than larger ones.	Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined places and at suitable height.	________
4	Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length.	________	For underground electrical installations provide a warning tape to provide warning signal for workers who are digging in the area.	________
5	Design the door of the generator room to swing outward.	________	________	________

1. In mass construction, use modules to have length of 1.2 meters or multiple to reduce the need for cutting materials such as tiles. Using such module produce spaces with dimension that could be divided by 3 or 4 thus enabling designers to choose for example tiles of suitable dimensions that require no or minimum cutting. Cutting tiles is unsafe work, because it causes lots of noise, waste and dust. Using such module could improve worker safety by first reducing the requirement for cutting which subject workers to harmful dust. Second by reducing waste obstacles that could increase accidents due to falls of material and tripping accidents. Third by reducing noise contamination which hampered workers health and communication.

2. Design openings that are used to provide light and ventilation to be located at the exterior edges of buildings (external openings) rather than inside the buildings (internal openings) as shown in Figure 5.2. Although all edges should be protected by guard rails, accidents may occur. Workers by common sense feel cautious when moving near edges, while they feel free when moving inside the building which could increase the ability of being exposed to fall from internal openings. If an accident occur in an internal opening workers may not immediately note it and longer time is required to make evacuation of the injured person compared to that required in case of fall from external opening. For accidents that happen in external openings it is easy to note the occurrence of accidents by workers or by those moving around the project. This suggestion does not just have positive effects on workers health but also the acquired ventilation and light would be greater than that in the internal opening.

(a) Opening on exterior edge of building (b) Opening inside a building

Figure 5. 2: Types of floor openings

3. Design horizontal distance between two successive stair risers (stair nose) shown in Figure 5.3 to be as small as possible. If applicable, choose stair case location to have natural lighting and adequate ventilation. The stair nose dimension should be kept as small as possible to prevent workers from falling down until the ground level which could minimize the severity of falling accident and reduce death accidents. In the prevailing practice in Gaza Strip, designers consider this suggestion in schools to ensure end user safety which is students in schools. Considering this suggestion could for sure enhance worker safety during construction and maintenance in addition to student safety. Addressing this suggestion in buildings not just schools could improve worker safety significantly. Choosing stair case location to have natural lighting and adequate ventilation could enhance safety of workers during circulation on stairs. This usually

could be achieved by designing stairs to be near the external perimeter of buildings so that to have natural lighting and ventilation. This suggestion cannot be considered all times. Yet Architects should address it whenever possible.

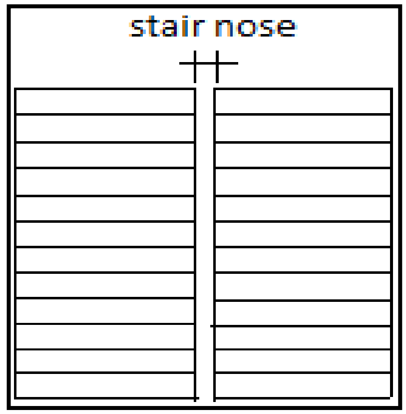


Figure 5. 3: Stair nose

4. Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length. Designing duct width to be as small as possible decrease the ability of falling through the floor opening. For example if floor openings are made square or rectangle with large width then the probability of falling through these ducts would be increased and workers will face a problem during the installation process. The reason is that some installations would be hidden behind others which could affect their installation negatively noting that the effect would be worse during maintenance. An opinion suggests that for Gaza Strip buildings, a duct of 50 cm would be enough for most required installations. This dimension if suitable for most buildings today it may not be sufficient in future as well. In general, the width dimension should be kept as small as possible while the duct length should be enough to perform installations in neat and comfortable way that could facilitate their construction and maintenance operation also.

5. Design door of generator room to swing outward as shown in Figure 5.4. Recently self contained generators are used without being placed in a room. Nonetheless, in some situations generators are required to be placed in rooms. Sometimes generators could be subjected to accidents such as a fire causing worker to try to escape from the room as fast as possible. If the generator room door swings inward, it could be closed and

require worker to open it which needs time. In accidents, duration to open a door is very important and it could prevent injury. On the contrary if the swing of the door is outward the worker can push it in rush and escape out without being injured.

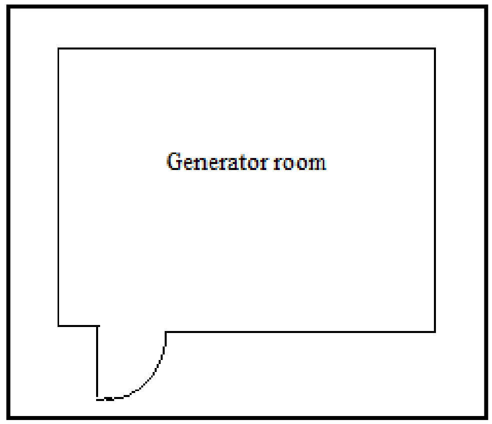


Figure 5. 4: Swing of generator room door to be outward

5.3.2.2 Civil Engineering

The following topics were discussed with the interviewees: structural systems for more than five stories, location of shear walls, moment resisting frames, buildings too close to existing ones, beams, slabs, stairs, reinforcement, foundation and falling from roofs and floor openings. The new developed DfCS suggestions are:

1. Choose straight bar reinforcement rather than bend-up ones. In Gaza Strip, structures are mainly composed of reinforced concrete which incorporates working with steel bars for long periods. It is known that reinforcement activity is not an easy one. If the time required for performing reinforcement decreased, then the worker safety could be improved. Although in the case of bend-up bar reinforcement, a machine is used to bend the bars up, sometimes special instrument is used to bend bars up while in their required locations. This instrument can bend small diameters easily, but for large diameters, bending requires strength and incorporates danger to workers. Using straight bar reinforcement eliminates the need to use such instrument thus contributes in improving worker safety. Also, transforming and handling straight bar reinforcement is easier and safer than the bend-up ones. Finally the time required for working with straight bar reinforcement is less than that required for bend-up ones.

2. Design slab shuttering to be minimum 0.5 meters over hanged from all directions with guardrails to give space for workers to work on slab edges while being protected from falling. The prevailing situation in Gaza Strip is to erect shuttering to cover just the size of the required slab without extra over hanged from edges. Yet some organizations already address this suggestion. Extending shuttering does not incorporate extra hazard during erection but it increases worker safety significantly. Some designers opposed this suggestion explaining that the extra over hanged shuttering compromise worker safety because workers feel safe which could reduce the alert from edges. The researcher opinion is that the o.5 meter is not a large distance that affect worker alert but its presence could increase the ability to perform work on edges easily and safely.
3. When possible, select small reinforcement diameters since small diameters are easier in handling than large ones. The cutting process and transporting from place to where required is easier and require less time than that for large diameters. It is important to note that this suggestion cannot be addressed in all cases since some elements require large amount of reinforcement that made it impossible to use small diameters. This is because spacing between bars become very small and prevent concrete from moving through these spacing which could hamper the strength of the element. This suggestion gain importance in cases where small distance between bars is suitable for concrete pouring. From structural point of view smaller diameters have larger bonding strength and more efficient in crack reduction.

5.3.2.3 Electrical Engineering

The following topics were discussed with the interviewees: stairs, sweeps, location of light system, electrical installation method, external lighting and selection of materials. The new developed DfCS suggestions are:

1. Design electrical installation riser to be away from mechanical installation riser. The importance of this suggestion is not during the construction phase where dead working is the normal method of carrying out electrical installations. Designing electrical installation to be in the same riser with mechanical installation could compromise worker safety because any fault or harm that happen in the mechanical installations could affect the electrical ones that could cause severe damages or fire. Designing

electrical installation riser to be away from mechanical installation one eliminate the ability of having these severe damages or fire thus eliminating the need for such maintenance which could affect worker safety positively.

2. Avoid placing the main electrical distribution board under baths. In one project an accident happened because the designer did not consider this suggestion. Leakage happened in one of the pipes in a bath placed above the main electrical distribution board causing water to inter electrical distribution board. The result was a fire and severe damages. Considering this suggestion could affect worker safety positively by eliminating the need for maintaining buildings subjected to such accidents. In the prevailing practice in Gaza Strip this suggestion is usually considered. This suggestion should be considered by designers because of the disastrous results in case of accidents and to eliminate the need for such maintenance.

3. Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height for ease of maintenance and construction. The main electrical distribution board should be first placed at suitable height that allow workers to perform work in a comfortable manner without the need to bending or working on ladder which incorporate danger of fall. This could aids in facilitating work, decreasing performance time and reducing work-related musculoskeletal disorders. The main electrical distribution board should be placed away from heavy passageways to allow workers to perform work without distraction that could increase probability of being subjected to accidents. In a school the maintenance process for the main electrical distribution board was forced to be performed after school because it was placed in the stair case. It is not always possible to delay the maintenance process especially when dealing with electricity.

4. For underground electrical installations provide a warning tape to provide warning signal for workers who are digging in the area. Avoid placing pipes that carry liquid above electrical installations to prevent the chance of electrical shock due to leaking pipes. Designers already consider this suggestion in their design and provide above the underground electrical installations a yellow warning tape about 10 cm wide with written identification of type of installation placed below it. This yellow warning tape is

placed 20cm below finished ground level. While digging for maintenance or for any other reason the warning tape warn workers to take care and to avoid damaging the installations under the tape which could affect their safety negatively by being subjected to electrocution.

5.3.2.4 Mechanical and Plumbing Engineering

Materials selection, sanitary installation, trenches and HVAC equipment were discussed with the interviewees to convey the following suggestions:

1. Design for placing water pump a way from electrical generator to avoid electrical shock or having a fire. For example any problem occur in the water pump could allow water to reach the electrical generator representing real hazard to worker safety especially in the maintenance phase. Many accidents in Gaza Strip happened such as having a fire or being electrocuted leaving lots of losses in human life and properties because this suggestion was not considered in the design phase. Designers benefited from such accidents and learnt to place water pump away in separate room from electric generator. What is noted here is that designers care about owner benefits more than anything, yet considering this suggestion conveys in the benefits of owner and worker safety at the same time.

5.3.3 Work Schedule Phase

The following topics where discussed with interviewees: sequence of activities, over time, night work, falling from roofs, floor openings and atriums, stairs, electrical system and mechanical system. The new developed DfCS suggestions according to engineering specializations are displayed in Table 5.3.

Table 5. 3: New developed DfCS suggestions incorporated in the work schedule phase

Suggestion Number	Architectural Engineering	Civil Engineering	Mechanical Engineering
1	Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.	Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times.	After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling.

Suggestion Number	Architectural Engineering	Civil Engineering	Mechanical Engineering
2	________	Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities.	________
3	________	Avoid scheduling pouring concrete activity to be simultaneous with compacting by vibration activity nearby the project.	________
4	________	In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint.	________
5	________	Avoid scheduling any activity related to work around the project while working on facade or lifting materials.	________
6	________	Schedule to avoid congestion of workers within limited area.	________

5.3.3.1 Architectural Engineering

1. Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint. Working with oil-base paint could affect worker safety negatively because of its strong smell. This suggestion could be addressed in mass construction efficiently where number of workers enables scheduler to place one by another so that duration of subjecting each worker to oil-based paint is decreased. In small scale projects usually job site is small and number of painters is limited so that this suggestion cannot be addressed efficiently. Also, the duration of subjecting workers to oil-based paint is less than that in mass construction.

5.3.3.2 Civil Engineering

1. Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times. This can be done by

excavating a group of piles and pour concrete without subjecting workers to hazard of fall. After finishing one pile group, another group could be started. In the case of large projects, the prevailing practice in Gaza Strip is to excavate two rows of piles so that workers could move safely, then immediately they place reinforcement which prevent soil from collapse if the above layer is for example sandy then they pour concrete as fast as possible. For small projects where the diameter of pile is relatively small and number of piles is limited then engineers should study either performing piles as groups or as a whole so that safe access and regress for personnel, material and equipment is satisfied all time.

2. Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities. If the form of slab was removed before 28 days then check if the developed slab strength is capable to sustain loads developed from these activities. The schedule should contain activities that ensure or improve worker safety. The prevailing practice in Gaza Strip is to move blocks or other material to slab and may start working with columns few days after slab pouring and before acquiring the required strength. In case of starting new activities with the existence of form system that is usually erected according to contractor experience without accurate calculation then if the load developed due to these activities cannot be sustained by the form system, the result is disastrous, falling of forms and slab could take place causing injuries or death. In case the form system was removed, a test should be conducted to check wither the developed strength could sustain such loads.

3. Avoid while scheduling to make pouring concrete activity simultaneous with a nearby compacting by vibration activity. Subjecting workers to vibration while pouring concrete could affect their concentration and increase the probability of having accidents. In a project the worker who held the concrete pump pipe lost concentration because of ground vibration due to compaction of nearby road. The concrete pipe slipped from the worker hand and concrete is poured on workers heads and eyes. Considering this suggestion while scheduling could eliminate or reduce such accidents and enable workers to work in a good mode without frustration which could improve worker safety.

4. In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint as shown in Figure 5.5. If this suggestion was not considered while scheduling then the difference in height between the two parts of expansion joints may be more than one story. Any fall from the higher part of expansion joint to the lower part could produce severe injuries or death. Thus considering this suggestion could improve worker safety by reducing the severity of falling accidents.

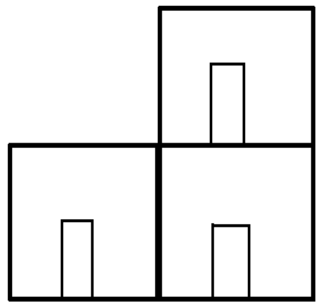


Figure 5. 5: One story difference in height between two parts of expansion joint

5. Avoid scheduling any activity related to work around the project while working on facade or lifting materials. When working on facade or lifting material the probability of having drop hazards from elevated work places increases thus subjecting workers moving or working around to be struck by these falling objects. In Gaza Strip the prevailing practice is that this suggestion is usually not considered, especially in projects which suffer from delay where these two activities could be held at the same time which cause accidents and could compromise worker safety.

6. Schedule to avoid congestion of workers because their concentration could be affected negatively thus affecting their ability to avoid hazards. Usually congestion occurs in projects suffering delays in order to fasten the rhythm of work. The construction industry involves different types of works. Many of these works could be held simultaneously such as electrical and mechanical installations. Scheduling work groups to work simultaneously could impede worker safety. This is because the communication between different work groups is much harder than within the same group. Also, the congestion of workers could impede workers concentration thus increasing the ability of having accidents. Workers hate congestion and each group

prefer working without interference from other groups. The researcher recommends scheduling to have the numbers of working groups within the same space to be minimize and to be below three groups if possible. If not possible, schedule to have number of workers within the same space to be as minimum as possible.

5.3.3.3 Mechanical Engineering

1. After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling to insure the installations are conducted without faults. If this test was delayed after tile activity then any fault in mechanical installations would result in tile removal which could subject workers to dust and work-related musculoskeletal disorders.

5.4 General Comments

1. Twenty six new DfCS suggestions applicable to Gaza Strip buildings are developed by researcher based on discussion with experts.
2. About half of the developed DfCS (14) are related to the design development and work schedule phases. This could be attributed to the fact that most design works are related to these two phases.
3. The role of civil engineer is very important in the work schedule phase. Civil engineer should be cognizant to all DfCS suggestions incorporated in this phase in case of being responsible of project scheduling.
4. No DfCS suggestion was developed related to construction documentation phase. Designer point of view is that safety is the responsibility of contractors.
5. The developed DfCS suggestions are minimal regarding electrical and mechanical engineering. This could be attributed to being incognizant of the concept. Once being cognizant the researcher opinion is that many new DfCS suggestions could be developed.

Chapter 6: EXPERT OPENION RELATED TO THE DEVELOPED DFCS APPROACH

6.1 Interpretation of Expert Answers

The final DfCS approach (the developed DfCS approach) consists of DfCS suggestions developed in Chapters four and five as shown in Table 6.1 to Table 6.4. Each DfCS suggestion is classified as recommendation or regulation by the researcher. In each discipline, a questionnaire was developed to solicit the expert final remarks regarding the developed DfCS approach taking in account that the classification conducted by the researcher is not given to the experts. The targeted group was the twenty experts that was interviewed to ensure efficient response to the questionnaire since they became familiar with the concept. Each questionnaire consists of the developed DfCS suggestions classified under the four design phases. The experts were required to convey on 5-Point likert scale the degree of their agreement to each DfCS suggestion and wither it could be regulation or recommendation. The researcher was keen to deliver questionnaires to experts by hand and was present all duration of questionnaire application to ensure that all requirements for explanation were satisfied. In general, the experts required little effort for explanation.

Table 6. 1: The developed DfCS approach for schematic phase

No	Schematic Phase
	Architectural Engineering
1	Provide storage places with enough capacity for contractor equipments and materials.
2	Design the layout of project to ensure easy and safe access and regress of materials, equipments and personnel.
3	Choose project location to be away from factories.
4	Choose project location to be away from steep slopes.
5	Place personnel protective equipments (PPE) as near as possible to the project entrance or in suitable place.
6	Provide sufficient utilities for workers to prevent the ability of using the job site.
	Civil Engineering
1	Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.
2	Design foundations to be positioned internally away from the exterior perimeter for proposed building if too close to existing ones.
	Electrical Engineering

No	Schematic Phase
1	Choose project location to be away from overhead power lines.
2	Choose the location of contractor storage areas to be safe away from any power lines.
3	Check the existence of exposed electrical wires in the nearby existing buildings around the site.
	Mechanical Engineering
1	Locate underground utilities in easily accessible places. Consider topographical survey within the criteria used to determine the location of these utilities.
2	Position underground utilities away from workers passageways but in places easy to construct and maintain.
3	Place the underground utilities away from existing structures.

Table 6. 2: The developed DfCS approach for design development phase

No	Design Development Phase
	Architectural Engineering
1	Design height of parapets and guard rails to be 1.1m minimum above the roof, floor or platform level.
2	Design height of window sills to be 1.1m minimum above the roof, floor or platform level.
3	In each stair riser, design tread and riser dimensions to be uniform from top to bottom.
4	Provide permanent guardrails around stairs and atrium.
5	Design skylights to be domed with elevated beams around them rather than flat ones.
6	Design floor and roof openings to be located away from readily accessed areas on the construction site.
7	Specify non-slip tiles and avoid polishing tiles with slip material such as wax.
8	When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5 meters with oil-based paint and the remaining walls with water-based paint.
9	Design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components.
10	Design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.
11	Design buildings with typical floor layout whenever possible.
12	Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible
13	Choose materials that are durable.
14	Choose materials that are safe to handle.
15	Choose materials that are non combustible.
16	Select elements such as windows, tiles etc. that are of consistent size, light weight, and easy to handle
17	Avoid using hazardous materials or operations that emit hazardous materials in confined areas.
18	In mass construction, use modules to have length of 1.2 meters or multiple.
19	Design openings that are used to provide light and ventilation to be located at the exterior edges of buildings rather than inside the buildings.
20	Design horizontal distance between two successive stair risers (stair nose) to be as small as possible. choose stair case location to have natural lighting and adequate ventilation
21	Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length.
22	Design the door of the generator room to swing outward.

No	Design Development Phase
	Civil Engineering
1	When project site require shoring system, it should be considered in the design phase taking into account environmental conditions.
2	Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.
3	Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.
4	Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance.
5	Select building frame system in conjunction with shear walls rather than moment-resisting frame system.
6	Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enable workers to construct shear walls.
7	When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with dimensions of 25cm ×25cm maximum.
8	Design members to be safe during construction and maintenance even if they are non structural members.
9	Design temporary guard rails around stairs and floor edges.
10	Design if possible to prefabricate components on ground or in factories where working environment is controlled.
11	Choose quieter methods of construction.
12	Design the shuttering of slab to be continuous across the opening to prevent falling hazard and to facilitate working around it. Design a platform with chamfered edges to cover the opening.
13	Select light weight materials such as hollow concrete blocks rather than solid ones.
14	Specify the use of small size concrete cubes of 100×100×100 mm^3 instead of standard cylinder for testing concrete strength.
15	Design the scaffolding system and specify the features of ground that should be prepared to it safely.
16	Choose straight bars reinforcement rather than the bend one.
17	Design slab shuttering to be minimum 0.5 meters over hanged from all direction with guard rails.
18	Select small reinforcement diameters rather than larger ones.
	Electrical Engineering
1	Using wall mounted lighting instead of ceiling mounted when possible.
2	Specify fiberglass sweeps for electrical conduit instead of steel sweeps.
3	Design temporary electrical system that can be installed and used safely during construction.
4	Design to place external lighting on places such as roof parapets that facilitate their installation and maintenance in safe way.
5	When designing stairs, adequate lighting should be provided during construction and maintenance.
6	Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable labels on the main electrical distribution board.
7	In case of ceiling lighting, specify light fittings that can be lowered when changing lamp or tube.
8	In mass construction avoid chasing walls by designing blocks to have ducts where electrical wires could be placed.
9	Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.
10	In places where electrical installations require chasing, place material that could be chased easily.
11	Increase electrical design load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installation.
12	Choose durable material for electrical installations.
13	Design the riser for electrical installation to be away from mechanical installation riser.
14	Avoid placing the main electrical distribution board under baths.
15	Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height.

No	Design Development Phase
16	For underground electrical installations provide a warning tape to provide warning signal for workers who are digging in the area.
	Mechanical Engineering
1	Design to have hand excavation around existing underground utilities
2	Design sanitary installations to be placed in a way that facilitates their installation and maintenance.
3	Locate all equipments such as HVAC equipment and water tanks away from a roof edges.
4	Place split unit (condenser) on roofs, ground or balconies.
5	Choose durable material for mechanical installations.
6	Choose light weight mechanical installations.
7	Design for placing water pump a way from electrical generator.

Table 6. 3: The developed DfCS approach for Construction documentation phase

No	Construction documentation phase
	Architectural Engineering
1	Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and water supply locations on the drawings and technical specifications. Specify the involved personnel that should be communicated in case of emergency.
2	Provide warning signs and notes colored in red on the drawings and technical specifications that incorporate hazards on workers.
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.
	Civil Engineering
1	On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines.
2	Provide warning signs and notes colored in red on the drawings and technical specifications to alert workers to places of hazards such as excavation location and the required shoring system.
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.
	Electrical Engineering
1	On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information.
2	Provide warning signs and notes colored in red on the drawing and technical specifications when electrical systems incorporate hazards.
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.
	Mechanical Engineering
1	On the project drawings and technical specifications, identify the location and size of existing utilities including underground lines indicating the level of certainty and source of information.
2	Warning symbols should be provided on drawings and technical specifications reminding workers that oxygen welding

No	Construction documentation phase
	is not permitted in confined places.
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.

Table 6. 4: The developed DfCS approach for Work schedule phase

No	Work schedule phase
	Architectural Engineering
1	Schedule activities so that no welding activity is performed while painting.
2	When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.
3	Schedule sidewalks, ramps and roadways around project to be constructed as early as possible.
4	Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.
	Civil Engineering
1	Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor.
2	Before the removal of the steel props supporting slabs, satisfactory results of concrete cube tests were required.
3	Schedule temporary guard rails with colored band to be placed around edges as soon as possible.
4	Design work schedule to minimize the need for overtime.
5	Design work schedule to minimize the need for night work.
6	The work schedule should contain daily housekeeping that keep site tidy all time.
7	Schedule to start partitioning activity as soon as possible especially at edges and floor openings.
8	Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times.
9	Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities.
10	Avoid scheduling pouring concrete activity to be simultaneous with compacting by vibration activity nearby the project.
11	In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint.
12	Avoid scheduling any activity related to work around the project while working on facade or lifting materials.
13	Schedule to avoid congestion of workers within limited area.
	Electrical Engineering
1	After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging.
	Mechanical Engineering
1	After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling.

For each DfCS suggestion, the number of experts who agree and those who strongly agree was added together to convey the agreement on the suggestion (applicable to Gaza Strip and could improve worker safety). Also the number of experts who disagree and those who strongly disagree was added together to convey the disagreement on the suggestion.

Experts who strongly agree or agree on the suggestion are required to classify it as recommendations or regulations. For this, the number of experts who made classification for the DfCS suggestion may be less than four. For each suggestion if three or the four experts have the same classification of the DfCS suggestion then the suggestion is considered classified by experts otherwise it is considered not classified.

The researcher also classified these DfCS suggestions where the classification was based on the severity of possible accidents and the possibility of occurrence. Since fall from heights is a frequent cause for severe injuries and fatalities in construction industry it is considered an important criterion in DfCS suggestions classification. It should be mentioned that the classification was made by experts without previous knowledge of the researcher opinion related to the classification.

As the questionnaire has two parts where the first part related to experts agreement on DfCS suggestions and the second part related to classifying them as regulations or recommendations, each part is discussed separately for each design phase.

6.2 Schematic Phase

The responses of experts regarding their agreement on and classification to the developed DfCS suggestions in addition to researcher opinion related to classification of these suggestions are displayed in Table 6.5.

Table 6. 5: Schematic phase feedback in addition to researcher classification of DfCS suggestions

Number	Design for Construction Safety Suggestions for Schematic Phase	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Expert opinion		Researcher opinion	
							Regulation	Recommendation	Regulation	Recommendation
	Architectural Engineering									
1	Provide storage places with enough capacity for contractor equipments and materials.	1	3				4	0	√	
2	Design the layout of project to ensure easy and safe access and regress of materials, equipments and personnel.	2	2				4	0	√	
3	Choose project location to be away from factories.		3	1			0	3		√
4	Choose project location to be away from steep slopes.		3		1		0	3		√
5	Place personnel protective equipments (PPE) as near as possible to the project entrance or in suitable place.	1	2	1			1	2	√	
6	Provide sufficient utilities for workers to prevent the ability of using the job site.		4				0	4	√	
	Civil Engineering									
1	Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.	4					0	4	√	
2	Design foundations to be positioned internally away from the exterior perimeter for proposed building if too close to existing ones.	3	1				0	4		√
	Electrical Engineering									
1	Choose project location to be away from overhead power lines.	2	2				1	3		√
2	Choose the location of contractor storage areas to be safe away from any power lines.	2	2				2	2	√	
3	Check the existence of exposed electrical wires in the nearby existing buildings around the site.	3	1				2	2	√	
	Mechanical Engineering									
1	Locate underground utilities in easily accessible places. Consider topographical survey within the criteria used to determine the location of these utilities.	3	1				2	2		√
2	Position underground utilities away from workers passageways but in places easy to construct and maintain.	3	1				3	1		√
3	Place the underground utilities away from existing structures.	2	2				0	4		√

6.2.1 Expert Agreement on DfCS Suggestions

At least, three experts out of four, regardless of their specialization, agreed on (agree and strongly agree) the fourteen DfCS suggestions.

6.2.2 Classification of DfCS Suggestions as Recommendations or Regulations

The classification of DfCS suggestions by experts and researcher are the same for seven suggestions out of fourteen. Four DfCS suggestions have not been classified by experts while three DfCS suggestions classification are not the same. Each engineering specialization would be considered separately.

6.2.2.1 Schematic Phase Architectural Engineering

It is apparent from Table 6.5 that the architect classification for the DfCS suggestions in this phase agreed with that of the researcher except for suggestion numbers five and six. The researcher believes that these two suggestions must be regulations while experts prefer to have suggestion six as recommendation while suggestion five is considered not classified. The architects consider the contractor as the party that is responsible for providing and specifying the location of PPE and providing sufficient utilities for workers. Nonetheless, leaving these two DfCS suggestions until construction commission could decrease the probability of affording them to workers. In case of placing PPE away from project entrance where workers need to move in the project area before having their PPE then the probability of being subjected to accident such as falling hazard that could cause severe injury or fatality is not small. Also delaying providing utilities till construction phase could deprive workers from having them and enforcing them to use project buildings as their utilities which could cause accidents. Accordingly, these two DfCS suggestions should be regulations.

6.2.2.2 Schematic Phase Civil Engineering

The design group experts classified the two DfCS in the schematic phase as recommendations. The researcher and the contractor group experts classified the first as regulation while the second as recommendation. It is very important to conduct site investigation and to examine the need of shoring system. Because of the importance of the first suggestion and the possibility of conducting it, it must be classified as regulation.

6.2.2.3 Schematic Phase Electrical Engineering

Table 6.5 shows that the electrical engineers and researcher have the same classification for DfCS suggestion one. Although suggestion numbers two and three were not classified, the researcher classified them as regulation. This is because accidents that occur due to discarding these two suggestions could be fatal and usually construction industry incorporates dealing with long members that could easily get in touch with any nearby power line causing electrocution accident.

6.2.2.4 Schematic Phase Mechanical Engineering

DfCS suggestion one has not been classified by experts while classified as recommendation by the researcher. For suggestion number three the experts and researcher have consensus to classify it as recommendation. The experts classified suggestion number two as regulation while the researcher understand that in some projects where spaces limited then this suggestion could not be considered. Also analyzing severity and frequency of occurrence of accidents reveal that this suggestion could be classified as recommendation.

6.3 Design Development Phase

Table 6.6 displays the responses of experts regarding their agreement on and classification to the developed DfCS suggestions in addition to researcher opinion related to classification of these suggestions.

Table 6. 6: Design development phase feedback in addition to researcher classification of DfCS suggestions

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Design Development Phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
Architectural Engineering										
1	Design height of parapets and guard rails to be 1.1m minimum above the roof, floor or platform level.		4				0	4	√	

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Design Development Phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
2	Design height of window sills to be 1.1m minimum above the roof, floor or platform level.		4				0	4		√
3	In each stair riser, design tread and riser dimensions to be uniform from top to bottom.		1		2	1	0	1		√
4	Provide permanent guardrails around stairs and atrium.	2	2				1	3	√	
5	Design skylights to be domed with elevated beams around them rather than flat ones.		4				0	4		√
6	Design floor and roof openings to be located away from readily accessed areas on the construction site.		4				0	4		√
7	Specify non-slip tiles and avoid polishing tiles with slip material such as wax.		4				2	2		√
8	When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5 meters with oil-based paint and the remaining walls with water-based paint.	1	3				0	4		√
9	Design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components.	1	3				1	3		√
10	Design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.	3	1				1	3		√
11	Design buildings with typical floor layout whenever possible.		3	1			0	3		√
12	Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible		3		1		0	3		√
13	Choose materials that are durable.	2	2				2	2		√
14	Choose materials that are safe to handle.	3	1				2	2		√
15	Choose materials that are non combustible.	2	2				1	3		√
16	Select elements such as windows, tiles etc. that are of consistent size, light weight, and easy to handle	1	3				2	2		√
17	Avoid using hazardous materials or operations that emit hazardous materials in confined areas.	2	2				1	3		√
18	In mass construction, use modules to have length of 1.2 meters or multiple.		3	1			0	3		√
19	Design openings that are used to provide light and ventilation to be located at the exterior edges of buildings rather than inside the buildings.		4				0	4		√
20	Design horizontal distance between two successive stair risers (stair nose) to be as small as possible. choose stair case location to have natural lighting and adequate ventilation		4				1	3		√

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Design Development Phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
21	Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length.	1	3				0	4		√
22	Design the door of the generator room to swing outward.	4					4	0	√	
	Civil Engineering									
1	When project site require shoring system, it should be considered in the design phase taking into account environmental conditions.	1	3				0	4	√	
2	Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.	3	1				1	3	√	
3	Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.	3	1				2	2	√	
4	Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance.	2	2				1	3	√	
5	Select building frame system in conjunction with shear walls rather than moment-resisting frame system.	1	2		1		0	3		√
6	Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enable workers to construct shear walls.		3		1		0	3		√
7	When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with dimensions of 25cm ×25cm maximum.		4				0	4		√
8	Design members to be safe during construction and maintenance even if they are non structural members.	1	3				1	3		√
9	Design temporary guard rails around stairs and floor edges.	3	1				0	4	√	
10	Design if possible to prefabricate components on ground or in factories where working environment is controlled.		4				0	4		√
11	Choose quieter methods of construction.	1	1	2			0	2		√
12	Design the shuttering of slab to be continuous across the opening to prevent falling hazard and to facilitate working around it. Design a platform with chamfered edges to cover the opening.	3	1				1	3	√	
13	Select light weight materials such as hollow concrete blocks rather than solid ones.		3	1			0	3		√
14	Specify the use of small size concrete cubes of 100×100×100 mm^3 instead of standard cylinder for testing concrete strength.	3	1				1	3		√
15	Design the scaffolding system and specify the features of ground that should be prepared to it safely.		2	2			1	1	√	
16	Choose straight bars reinforcement rather than the bend one.		4				0	4		√

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Design Development Phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
17	Design slab shuttering to be minimum 0.5 meters over hanged from all direction with guard rails.	3	1				1	3	√	
18	Select small reinforcement diameters rather than larger ones.		4				0	4		√
	Electrical Engineering									
1	Using wall mounted lighting instead of ceiling mounted when possible.		4				0	4		√
2	Specify fiberglass sweeps for electrical conduit instead of steel sweeps.	2	2				2	2		√
3	Design temporary electrical system that can be installed and used safely during construction.	2	2				2	2	√	
4	Design to place external lighting on places such as roof parapets that facilitate their installation and maintenance in safe way.		4				0	4		√
5	When designing stairs, adequate lighting should be provided during construction and maintenance.	3	1				3	1	√	
6	Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable labels on the main electrical distribution board.	4					4	0	√	
7	In case of ceiling lighting, specify light fittings that can be lowered when changing lamp or tube.		2	2			0	2		√
8	In mass construction avoid chasing walls by designing blocks to have ducts where electrical wires could be placed.	1	2		1		0	3		√
9	Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.	3	1				3	1	√	
10	In places where electrical installations require chasing, place material that could be chased easily.	1	3				1	3		√
11	Increase electrical design load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installation.	2	2				3	1	√	
12	Choose durable material for electrical installations.	2	2				2	2		√
13	Design the riser for electrical installation to be away from mechanical installation riser.	4					3	1	√	
14	Avoid placing the main electrical distribution board under baths.	4					4	0	√	
15	Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height.	3	1				2	2		√

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Design Development Phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
16	For underground electrical installations provide a warning tape to provide warning signal for workers who are digging in the area.	4					4	0	√	
	Mechanical Engineering									
1	Design to have hand excavation around existing underground utilities	2	1	1			2	1	√	
2	Design sanitary installations to be placed in a way that facilitates their installation and maintenance.	3	1				3	1	√	
3	Locate all equipments such as HVAC equipment and water tanks away from a roof edges.	3	1				3	1	√	
4	Place split unit (condenser) on roofs, ground or balconies.	2	2				2	2		√
5	Choose durable material for mechanical installations.	2	2				1	3		√
6	Choose light weight mechanical installations.		2	2			0	2		√
7	Design for placing water pump a way from electrical generator.	3		1			2	1	√	

6.3.1 Expert Agreement on DfCS Suggestions

In the design development phase fifty eight DfCS suggestions were agreed upon by at least three experts as shown in Table 6.6. The remaining five suggestions that were not agreed upon are discussed according to expert specializations as follows.

For Architect experts, DfCS suggestion number three was rejected by three experts. A thorough discussion was stimulated regarding how to make it possible to have uniform height for step risers. One opinion is that by careful design of levels no need for embankment will be required. The researcher thinks it is very hard to control levels so that the need for embankment is to be overcome. Other opinion is that it is possible to construct step risers height to be uniform, and then floors in addition to stairs embankment could achieve the deigned levels. The researcher believes that this opinion is also not practical and it is not an easy job to conduct embankment for the whole staircase. Other opinion is to have a step on the entrance of each apartment if possible to enable designer to have uniform step risers height since the embankment required would be within the apartment and not affecting the landing level of stairs. This idea was opposed by architects who contend that it is not right to have a step on the entrance of an apartment. Designing stairs to have uniform height for step risers is very important for construction worker safety and it could be done and should be done regardless of solution adopted to ensure considering this suggestion. The researcher proposed having a platform with some chamfered edges to be placed on stair landings so that uniform height of all steps is achieved during construction.

Two of the civil group experts (design group) were undecided for DfCS suggestion numbers eleven and fifteen. For electrical engineering, DfCS suggestion number seven was agreed upon by two electrical engineers while the other two were undecided. The mechanical engineer experts were undecided by two experts for DfCS suggestion six. It could be concluded that there is no rejection for the DfCS suggestions. Such feedback empowers the developed DfCS suggestions.

6.3.2 Classification of DfCS Suggestions as Recommendations or Regulations

The design development phase contains sixty three DfCS suggestions under the four engineering specializations. The discussion of the classification of DfCS suggestions by the experts in relation with the researcher opinion is as follows.

6.3.2.1 Design Development Phase Architectural Engineering

Table 6.6 shows that the architect classification for the DfCS suggestions agrees with that of the researcher except for seven DfCS suggestions. Suggestion numbers three, seven, thirteen, fourteen and sixteen were not considered classified. These suggestions are related to material selection such as being durable or safe to handle or even kind of tiles where experts believe that other criteria than safety could affect their selection such as availability, cost or owner demands. For DfCS suggestion numbers one and four the architects classify them to be recommendation while the researcher classified them as regulation. In case permanent guardrails around stairs and atrium was not provided or provided with heights less than 1.1 meters then the job site would became dangerous place where workers could be subjected to falls from height. It is not ethical to deprive workers from these guardrails; in fact it is the prevailing practice that makes designers believe they are not the party responsible for worker safety. If the designer mindset changed so that they accept the concept and believe that their design decisions could affect worker safety then these guardrails could become a usual necessary practice.

6.3.2.2 Design Development Phase Civil Engineering

Table 6.6 shows that the design group experts classified fifteen DfCS suggestions as recommendations. The remaining three were not classified. The designer group did not classify any suggestion as regulation even they did not disagree on any of them. This could be attributed to their fair of liability. The contractor group experts and the researcher have the same classification for fourteen DfCS suggestions. DfCS suggestion numbers one, eight and seventeen have not been classified by contractor group experts. The researcher classified suggestion numbers one and seventeen as regulations since any fault in the shoring system could cause severe injuries and fatalities. Also designing shuttering to be minimum 0.5 meters over hanged from all directions with guardrails have significant effect on the ability of preventing or minimizing falls from height. Due to the frequency of their occurrence in the construction process and the severity of resulting accidents, these two DfCS suggestions should be regulations. Contractor group experts classified suggestions related to fall from heights such as DfCS suggestion numbers two, four, nine and twelve as regulations since many accidents have occurred because these suggestions were not considered during design phase.

6.3.2.3 Design Development Phase Electrical Engineering

Eleven DfCS suggestions have the same classification by at least three electrical engineers and the researcher. The remaining five suggestions have not been classified by electrical engineers. It could be concluded that there is no contradiction between researcher and the expert classification.

6.3.2.4 Design Development Phase Mechanical Engineering

The researcher and mechanical engineers have the same classification for suggestion numbers two, three and five as shown in Table 6.6. For the remaining four

DfCS suggestions, although two mechanical engineers classified them the same as the researcher did, they are considered not classified.

6.4 <u>Construction Documentation Phase</u>

Table 6.7 displays the responses of experts regarding their agreement on and classification to the developed DfCS suggestions in addition to researcher opinion related to classification of these suggestions.

Table 6. 7: Construction documentation phase feedback in addition to researcher classification of DfCS suggestions

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Construction Documentation Phase (communication between designers and contractors)**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
	Architectural Engineering									
1	Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and water supply locations on the drawings and technical specifications. Specify the involved personnel that should be communicated in case of emergency.	3	1				2	2	√	
2	Provide warning signs and notes colored in red on the drawings and technical specifications that incorporate hazards on workers.	3	1				3	1	√	
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	2	2				2	2	√	
	Civil Engineering									
1	On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines.		4				0	4	√	
2	Provide warning signs and notes colored in red on the drawings and technical specifications to alert workers to places of hazards such as excavation location and the required shoring system.	3	1				2	2	√	
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	1	3				0	4	√	
	Electrical Engineering									

							Expert opinion		Researcher opinion	
Number	**Design for Construction Safety Suggestions for Construction Documentation Phase (communication between designers and contractors)**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
1	On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information.	3	1				1	3	√	
2	Provide warning signs and notes colored in red on the drawing and technical specifications when electrical systems incorporate hazards.	3	1				3	1	√	
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	1	3				2	2	√	
Mechanical Engineering										
1	On the project drawings and technical specifications, identify the location and size of existing utilities including underground lines indicating the level of certainty and source of information.	4					1	3	√	
2	Warning symbols should be provided on drawings and technical specifications reminding workers that oxygen welding is not permitted in confined places.	2	2				2	2	√	
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	1	2	1			1	2	√	

6.4.1 Expert Agreement on DfCS Suggestions

At least, three experts out of four, regardless of their specialization, agreed the three DfCS suggestions. Although experts value the importance of communicating hazards to contractors the type of contract (design-bid-build) causes the relationship between designers and contractors to be adversarial on behalf of workers safety.

6.4.2 Classification of DfCS Suggestions as Recommendations or Regulations

The researcher classified the DfCS suggestions in this phase as regulations. This is because the DfCS suggestions included in this phase are very important and they communicate hazards to contractors who should take suitable precaution measures to avoid subjecting workers to these hazards.

For the four engineering specializations, the expert classification of DfCS suggestions incorporated in the construction documentation phase is discussed as follows.

6.4.2.1 Construction Documentation Phase Architectural Engineering

The construction documentation phase contains three DfCS suggestions as shown in Table 6.7. The first and the third one have not been classified while the architectural engineers classified DfCS suggestion number two as regulation.

6.4.2.2 Construction Documentation Phase Civil Engineering

The design group experts classified the first and the third DfCS suggestions within this phase as recommendations and did not classify suggestion number two. The contractor group experts classified all the suggestions within this phase as regulations because of their importance in communicating hazards inherent in the design to contractors.

6.4.2.3 Construction Documentation Phase Electrical Engineering

The electrical engineers classified the first DfCS suggestion to be recommendation, the second to be regulation and the third was not classified. The real contradiction between researcher and electrical engineer opinions is in suggestion number one. Electrical engineers believe that there is no need to identify location of existing electrical utilities in technical specifications and drawings. This suggestion is an effective type of communicating places of hazards to contractors. Otherwise, the contractor either being subjected to hazards or if having good experience he starts searching for such information where sometimes get fault one thus subjecting workers to hazards. For this, suggestion number one should be regulation.

6.4.2.4 Construction Documentation Phase Mechanical Engineering

The mechanical engineers classified the first as recommendation while the second and the third were not classified as shown in Table 6. 7. Designers fear liability because these three suggestions place burden on designers to consider worker safety within design criteria. To improve worker safety, designers should be able to identify hazard locations in order to communicate them to contractors and response timely and efficiently to contractor query for information.

6.5 Work Schedule Phase

Table 6.8 displays the responses of experts regarding their agreement on and classification to the developed DfCS suggestions in addition to researcher opinion related to classification of these suggestions.

Table 6. 8: Work schedule phase feedback in addition to researcher classification of DfCS suggestions

							Expert opinion		Researcher opinion	
Number	**Design for Construction safety suggestions for Work schedule phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
	Architectural Engineering									
1	Schedule activities so that no welding activity is performed while painting.	3	1				4	0	√	
2	When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.	1	3				1	3	√	
3	Schedule sidewalks, ramps and roadways around project to be constructed as early as possible.	1	3				1	3		√
4	Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.		4				0	4		√
	Civil Engineering									
1	Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor.	1	1		2		0	2		√
2	Before the removal of the steel props supporting slabs, satisfactory results of concrete cube tests were required.		4				0	4	√	
3	Schedule temporary guard rails with colored band to be placed around edges as soon as possible.	2	2				1	3	√	
4	Design work schedule to minimize the need for overtime.		4				0	4		√
5	Design work schedule to minimize the need for night work.	2	2				0	4		√
6	The work schedule should contain daily housekeeping that keep site tidy all time.	1	3				0	4	√	
7	Schedule to start partitioning activity as soon as possible especially	4					0	4		√

							Expert opinion		Researcher opinion	
Number	**Design for Construction safety suggestions for Work schedule phase**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**	**Regulation**	**Recommendation**	**Regulation**	**Recommendation**
	at edges and floor openings.									
8	Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times.	4					2	2	√	
9	Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities.	2	2				1	3	√	
10	Avoid scheduling pouring concrete activity to be simultaneous with compacting by vibration activity nearby the project.	3	1				1	3		√
11	In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint.	1	3				0	4		√
12	Avoid scheduling any activity related to work around the project while working on facade or lifting materials.	2	2				2	2	√	
13	Schedule to avoid congestion of workers within limited area.		4				0	4		√
	Electrical Engineering									
1	After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging.	3	1				3	1	√	
	Mechanical Engineering									
1	After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling.	4					3	1	√	

6.5.1 Expert Agreement on DfCS Suggestions

At least, three experts out of four, regardless of their specialization, agreed on a nineteen DfCS suggestions. The only DfCS suggestion that was rejected by experts is number one in the civil engineering work schedule phase. DfCS suggestion number one was agreed upon by two experts and rejected by two. To design and schedule stairway to be constructed close to the start of construction of each floor is not the prevailing practice in Gaza Strip. For this, two experts disagreed upon it, but if the prevailing practice changed then this DfCS suggestion would become possible and could increase worker safety. Most contractors and some engineers interviewed were against this suggestion because they think that erecting stairs at the beginning of the project would result in leakage of water through the construction joint. The researcher believes that the civil engineer is able to deal with construction joint and prevent leakage through construction joint.

6.5.2 Classification of DfCS Suggestions as Recommendations or Regulations

The work schedule phase contains nineteen DfCS suggestions under the four engineering specializations. The discussion of the classification of DfCS suggestions by the experts in relation with the researcher opinion is as follows.

6.5.2.1 Work Schedule Phase Architectural Engineering

In this phase the architects and the researcher have the same classification for DfCS suggestion numbers one, three and four as shown in Table 6.8. On the contrary suggestion number two is classified by experts to be recommendation while the researcher classified it as regulation. The architects believe that providing these guardrails in the design development phase should be recommendation which reflect its shadow on their classification of scheduling the guardrails to be erected as soon as possible, to be also recommendation. The researcher consider providing guardrails very important and should be erected as soon as possible to benefit from it as early as possible in protecting workers from falls, so suggestion two should be regulation.

6.5.2.2 Work Schedule Phase Civil Engineering

The design group experts classified ten DfCS suggestions within this phase as recommendations and did not classify suggestion numbers one, eight and twelve. Eight DfCS suggestions have the same classification by contractor group experts and the researcher as shown in Table 6.8**.** Suggestion numbers seven, eight and nine have not been classified by the contractor group experts while the researcher classified number eight and nine as regulations. This is because without recognizing this concept the designers and contractors consider these suggestions in some project executions which are a strong clue of their importance. In case of having activities on slab before it acquire the suitable strength then the forming system may not sustain loads caused by these activities which could cause collapse of slab and forming system thus causing severe injuries and fatalities. Due to the frequency of occurrence and the severity of accidents, the researcher classified both as regulation. For suggestion numbers six and twelve the contractor group experts classified them as recommendations while the researcher classified them as regulations. For suggestion number six, daily housekeeping is important in having tidy job site without tipping hazards or causes for distracting workers attention. Each work place should contain daily housekeeping to improve environment of work, this is the least thing that should be done to improve worker safety. For suggestion number twelve, scheduling any activity related to work around the project while working on facades or lifting materials could cause severe accidents.

6.5.2.3 Work Schedule Phase Electrical Engineering

This phase contain one suggestion where researcher and three electrical engineers classified it as regulation.

6.5.2.4 Work Schedule Phase Mechanical Engineering

This phase contains one DfCS suggestion that classified as regulation by three mechanical engineers in addition to the researcher.

6.6 General Comments

The DfCS suggestions within the proposed approach has been agreed upon by at least three experts out of four except for suggestion numbers three in the design development phase (architectural engineering requirement) and number one in the work schedule phase (civil engineering requirement) .

The classification of DfCS suggestions by architects and researcher are the same for twenty three suggestions out of thirty five. Eight DfCS suggestions have not been classified by experts. The experts and researcher have different opinions in classifying four DfCS suggestions.

Although the civil engineer design group experts agreed on most DfCS suggestions, twenty nine DfCS suggestions have been classified as recommendations by at least three experts. The remaining seven DfCS suggestions have not been classified. From this result it is clear that civil designers fear the consequences of having any DfCS suggestion as regulation. They encourage addressing the concept voluntary.

Three or more of the civil engineer contractor group experts classified twelve of DfCS suggestions as regulations. Six of DfCS suggestions have not been classified. The researcher classified eighteen DfCS suggestions as regulations.

The classification of DfCS suggestions by electrical engineers and researcher are the same for fourteen suggestions out of twenty three. Eight suggestions were not classified. One suggestion has different classification by electrical engineers and researcher.

Researcher and mechanical engineers have consensus on the classification of six DfCS suggestions. Six suggestions have not been classified. The experts and researcher have different opinions in classifying two DfCS suggestions.

In general, the researcher and the respondent classification were in harmony for most DfCS suggestions. The contractors classification was the nearest to the researcher since they are the ones that suffer from not considering the concept in the design phase.

In the construction documentation phase the suggestions have some similarities for the four specializations since they are related to communicating hazards to contractor. Providing warning symbols on drawings and technical specification to alert workers of hazards was classified as regulation by two or more experts in addition to researcher which reveal the importance of this suggestion. Suggestion number three in this phase was not classified as regulation by any engineering discipline; in the best situation it is not classified. The reason for this is fear from liability.

Chapter 7: IMPLEMENTATION SETUP OF DFCS APPROACH

7.1 Implementation Setup Requirements

The implementation of the developed DfCS approach needs additional efforts and actions from relevant decision makers, specialists, legislation bodies, engineering syndicates, ministries, etc. Seminars, workshops, awareness campaigns, etc. may be held to specialized engineers to make them aware of the DfCS concept and suggestions wither in recommendation or regulation forms.

As for regulations, legislations or bylaws need to be enacted to force design engineering firms to apply the suggestions in form of regulations. Bodies such as Engineering Syndicate, Ministry of Public Works and Housing, UNRWA, UNDP, Palestinian Housing Council, etc. should be responsible on the inclusion of DfCS concept as one of the technical requirements and contracts to be fulfilled in order to gain approval of building permits.

For this purpose the developed DfCS approach has been re-structured as shown in Figure 7.1 and detailed in Tables 7.1 to 7.4 to differentiate between the recommendations (Recom.) and the regulations (Regul.)

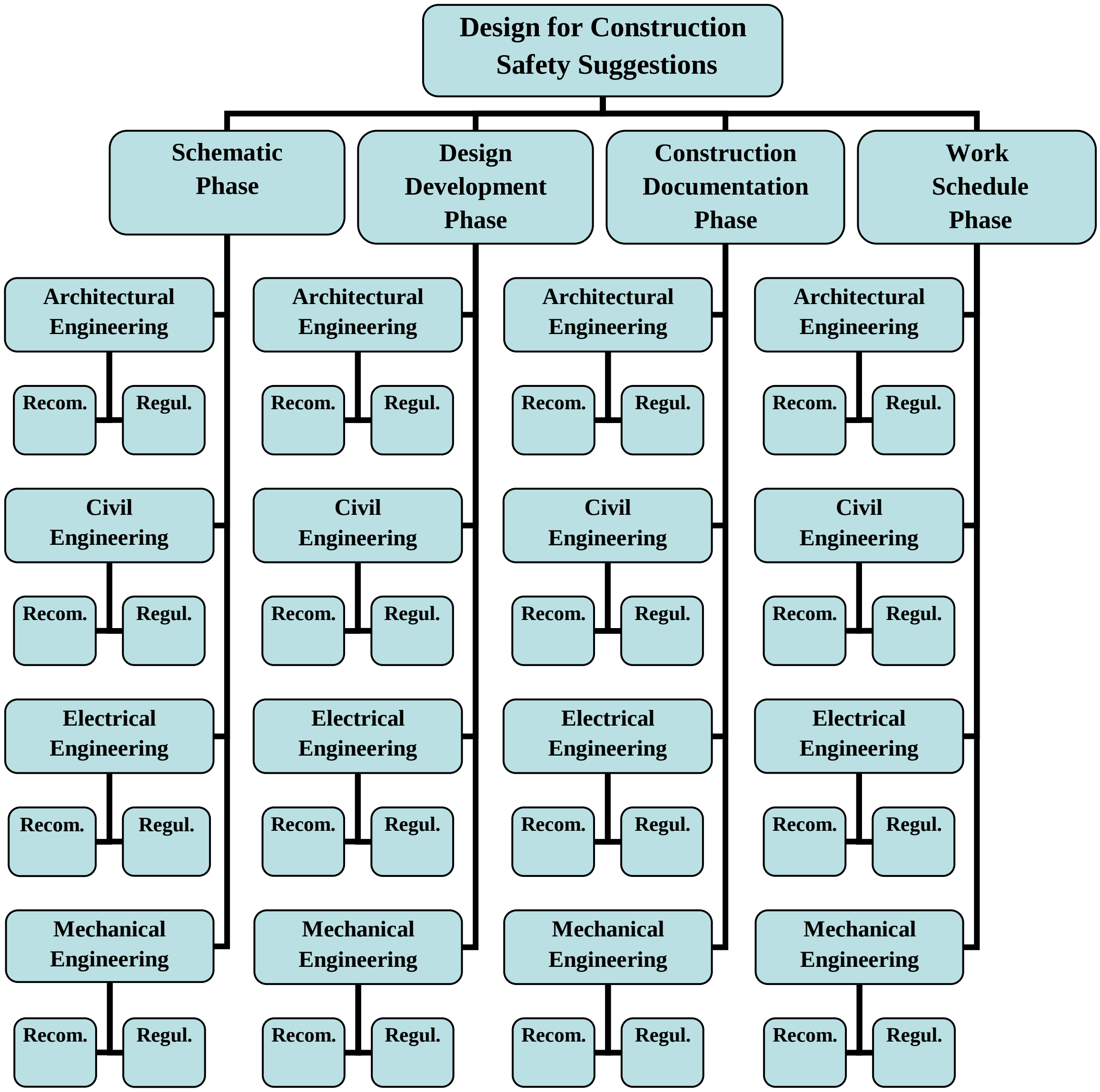


Figure 7. 1: The DfCS approach framework

The engineer should satisfy the regulations because they were developed to reduce or eliminate hazards of frequent occurrence that could produce severe injuries or even fatalities. For the recommendations the engineer should consider them if possible, otherwise the related hazard should be communicated to contractors to take proactive actions in order to reduce or eliminate them.

7.2 Schematic Phase Proposed DfCS Approach

The proposed DfCS approach for schematic phase consists of seven regulations and seven recommendations as shown in Table 7.1.

Table 7. 1: Proposed DfCS approach for schematic phase

Schematic phase	
Regulations	***Recommendations***
Architectural engineers	
1. Provide storage places with enough capacity for contractor equipments and materials. 2. Design the layout of projects to ensure easy and safe access and regress of materials, equipments and personnel. 3. Place personnel protective equipments (PPE) as near as possible to the project entrance or in suitable place. 4. Provide sufficient utilities for workers to prevent the ability of using the job site.	1. Choose project location to be away from factories. 2. Choose project location to be away from steep slopes.
Civil engineers	
1. Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.	1. Design foundations to be positioned internally away from the exterior perimeter for proposed building if too close to existing ones.
Electrical engineers	
1. Choose the location of contractor storage areas to be safe away from any power lines. 2. Check the existence of exposed electrical wires in the nearby existing buildings around the site.	1. Choose project location to be away from overhead power lines.
Mechanical engineers	
	1. Locate underground utilities in easily accessible places. Consider topographical survey report within the criteria used to determine the location of these utilities. 2. Position underground utilities away from workers passageways but in places easy to construct and maintain. 3. Place the underground utilities away from existing structures.

7.3 Design Development Phase Proposed DfCS Approach

The proposed DfCS approach for design development phase consists of twenty three regulations and fourty recommendations as shown in Table 7.2.

Table 7. 2: Proposed DfCS approach for design Development phase

Design development phase	
Regulations	***Recommendations***
Architectural engineers	
1. Design height of parapets and guard rails to be 1.1m minimum above the roof, floor or platform level. 2. Provide permanent guardrails around stairs and atrium. 3. Design the door of the generator room to swing outward.	1. Design height of window sills to be 1.1m minimum above the roof, floor or platform level. 2. In each stair riser, design tread and riser dimensions to be uniform from top to bottom. 3. Design skylights to be domed with elevated beams around them rather than flat ones. 4. Design floor and roof openings to be located away from readily accessed areas on the construction site. 5. Specify non-slip tiles and avoid polishing tiles with slip material such as wax. 6. When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5m with oil-based paint and the remaining walls with water-based paint. 7. Design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components. 8. Design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling. 9. Design buildings with typical floor layout whenever possible. 10. Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible. 11. Choose materials that are durable. 12. Choose materials that are safe to handle. 13. Choose materials that are non combustible. 14. Select elements such as windows, tiles, etc. that are of consistent size, light weight, and easy to handle. 15. Avoid using hazardous materials or operations that emit hazardous materials in confined areas. 16. In mass construction, use modules to have length of 1.2m or multiple. 17. Design openings that are used to provide light and ventilation to be external rather than internal ones. 18. Design horizontal distance between two successive stair risers (stair nose) to be as small as possible.

Design development phase	
Regulations	***Recommendations***
	Choose stair case location to have natural lighting and adequate ventilation. 19. Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length.
Civil engineers	
1. When project site requires shoring system, it should be considered in the design phase taking into account environmental conditions. 2. Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process. 3. Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system. 4. Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance. 5. Design temporary guard rails around stairs and floor edges. 6. Design the shuttering of slab to be continuous across the opening to prevent falling hazard and to facilitate working around it. Design a platform with chamfered edges to cover the opening. 7. Design the scaffolding system and specify the features of ground that should be prepared to erect it safely. 8. Design slab shuttering to be minimum 0.5 m over hanged from all direction with guard rails.	1. Select building frame system in conjunction with shear walls rather than moment-resisting frame system. 2. Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enable workers to construct shear walls safely. 3. When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with dimensions of 25cm×25cm maximum. 4. Design members to be safe during construction and maintenance even if they are non structural members. 5. Design if possible to prefabricate components on ground or in factories where working environment is controlled. 6. Choose quieter methods of construction. 7. Select light weight materials such as hollow concrete blocks rather than solid ones. 8. Specify the use of concrete cubes with dimensions 100×100×100 mm^3 instead of standard cylinder for testing concrete strength. 9. Choose straight bars reinforcement rather than the bend ones. 10. Select small reinforcement diameters rather than larger ones.
Electrical engineers	
1. Design temporary electrical system that can be installed and used safely during construction. 2. When designing stairs, adequate lighting should be provided during construction and maintenance. 3. Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable	1. Using wall mounted lighting instead of ceiling mounted when possible. 2. Specify fiberglass sweeps for electrical conduit instead of steel sweeps. 3. Design to place external lighting on places such as roof parapets that facilitate their installation and maintenance in safe way. 4. In case of ceiling lighting, specify light fittings that

Design development phase	
Regulations	***Recommendations***
labels on the main electrical distribution board. 4. Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire. 5. Increase electrical design load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installation. 6. Design the riser for electrical installation to be away from mechanical installation riser. 7. Avoid placing the main electrical distribution board under baths. 8. For underground electrical installation provide a warning tape to provide warning signal for workers who are digging in the area.	can be lowered when changing lamp or tube. 5. In mass construction avoid chasing walls by designing blocks to have ducts where electrical wires could be placed. 6. In places where electrical installations require chasing, place material that could be chased easily. 7. Choose durable material for electrical installations. 8. Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height.
Mechanical engineers	
1. Design to have hand excavation around existing underground utilities 2. Design sanitary installation to be placed in a way that facilitates their installation and maintenance. 3. Locate all equipments such as HVAC equipment and water tanks away from a roof edges. 4. Design for placing water pump a way from electrical generator	1. Place split unit (condenser) on roofs, ground or balconies. 2. Choose durable material for mechanical installations. 3. Choose light weight mechanical installations.

7.4 Construction Documentation Phase Proposed DfCS Approach

The proposed DfCS approach for construction documentation phase consists of nine regulations as shown in Table 7.3.

Table 7. 3: Proposed DfCS approach for construction documentation phase

Construction documentation phase	
Regulations	***Recommendations***
Architectural engineers	
1. Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and	

Construction documentation phase	
Regulations	***Recommendations***
water supply locations on the drawings and technical specifications. Specify the involved personnel that should be communicated in case of emergency. 2. Provide warning signs and notes colored in red on the drawings and technical specifications that incorporate hazards on workers. 3. In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	
Civil engineers	
1. On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines. 2. Provide warning signs and notes colored in red on the drawings and technical specifications to alert workers to places of hazards such as excavation location and the required shoring system. 3. In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	
Electrical engineers	
1. On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information. 2. Provide warning signs and notes colored in red on the drawings and technical specifications when electrical systems incorporate hazards. 3. In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	
Mechanical engineers	

Construction documentation phase	
Regulations	***Recommendations***
1. On the project drawings and technical specifications, identify the location and size of existing utilities including underground lines indicating the level of certainty and source of information. 2. Warning symbols and motes should be provided on drawings and technical specifications reminding workers that for example oxygen welding is not permitted in confined places. 3. In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.	

7.5 Work Schedule Phase Proposed DfCS Approach

The proposed DfCS approach for work schedule phase consists of ten regulations and nine recommendations as shown in Table 7.4.

Table 7. 4: Proposed DfCS approach for work schedule phase

Work schedule phase	
Regulations	***Recommendations***
Architectural engineers	
1. Schedule activities so that no welding activity is performed while painting. 2. When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.	1. Schedule sidewalks, ramps and roadways around project to be constructed as early as possible. 2. Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.
Civil engineers	
1. Before the removal of the steel props supporting slabs, satisfactory results of concrete cube tests are required. 2. Schedule temporary guard rails with colored band to be placed around edges as soon as possible. 3. The work schedule should contain daily housekeeping that keep site tidy all time.	1. Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor. 2. Design work schedule to minimize the need for overtime. 3. Design work schedule to minimize the need for night work. 4. Schedule to start partitioning activity as soon as

Work schedule phase	
Regulations	***Recommendations***
4. Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times. 5. Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities. 6. Avoid scheduling any activity related to work around the project while working on facades or lifting materials.	possible especially at edges and floor openings. 5. Avoid scheduling pouring concrete activity to be simultaneous with compacting by vibration activity nearby the project. 6. In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint. 7. Schedule to avoid congestion of workers within limited area.
Electrical engineers	
1. After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging.	
Mechanical engineers	
1. After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling.	

7.6 General Comments

Addressing DfCS concept using the proposed DfCS approach is easy. It does not need much effort to understand how to address the principle. Categorizing the DfCS suggestions to account for design phases and engineering specializations facilitate the consideration of the concept since each discipline has limited DfCS suggestions classified as recommendations or regulations for each design phase. Identifying the DfCS suggestions for each engineering discipline empowers the probability of considering the concept by designers.

The architectural discipline consists of twelve regulations and twenty three recommendations. The civil engineers while designing should consider eighteen regulations and eighteen recommendations. The electrical engineers should consider fourteen regulations and nine recommendations. The mechanical engineers should consider eight regulations and six recommendations should be considered whenever possible.

Although the proposed DfCS approach of architects and civil engineers contains approximately the same number of DfCS suggestions (35 for architect, 36 for civil), the civil engineer should consider eighteen suggestions while the architect should consider twelve suggestions. In fact the electrical engineers should consider fourteen regulations, which is more than the architects. This indicates that civil engineer decisions incorporate hazards more than design decisions of other engineering specializations. This indicates the importance of considering the concept by civil engineers.

This Chapter can be represented to concern bodies as a manual for the implementation of the DfCS approach.

Chapter 8: VEREFICATION OF DFCS APPROACH (CASE STUDIES)

8.1 Introduction

The aim of the re-structured DfCS approach is to help designers to produce designs which could be executed safely. In other words by the aid of the re-structured DfCS approach it is possible to identify hazards incorporated in design decisions where the ability to alter design to safer one for construction workers is significant. To show that the aim was fulfilled, five case studies were conducted on building projects already constructed in Gaza Strip. The re-structured DfCS approach is applied to each of the five case studies. The DfCS suggestions that were considered and those that were not considered in the case study are identified for each engineering discipline and design phase. In addition the regulations and recommendations were also identified. Thus the DfCS suggestions that were not considered could alarm designers of hazards incorporated in their decisions and provide suggestions to reduce or prevent the related hazards. In case the DfCS suggestions not considered were regulations, then the design incorporates significant hazards and should be changed to safer one. If the DfCS suggestions not considered are recommendations then the design should be changed to safer one if possible, otherwise hazard should be communicated to contractor. It should be emphasized that the case studies consists of buildings already constructed and the application of the DfCS suggestions is a theoretical one.

Table 8.1 displays general information about each case study. The case studies cover different: locations, functions, owner, structural systems and foundation systems. The case studies are design-bid-built since this is the prevailing practice in Gaza Strip. The material used was reinforced concrete. The researcher was keen to choose projects designed and executed by professionals, to eliminate problems related to weak design and focus only on DfCS concept. For this, the case studies were designed by consulting firms and executed by contractors classified as class A in building construction according to Palestinian Contractor Union. The required documentation for projecting the developed DfCS approach are civil, architectural, electrical and mechanical drawings in addition to technical specification, soil investigation and general project location. The documentations that were obtained for each case study were displayed in Appendix C. It should be mentioned that it was difficult to obtain all required documentations for each case study due to the sensitivity of the subject. However, for the sport hall and hospital case studies the missing documentations were compensated by conducting interviews with the consultant engineer that was in charge for their execution. For the school, the trade centre and the bank the researcher made interviews with civil, architectural, electrical and mechanical engineers who designed the project.

Three of the case studies suffered from accidents which analyzed to investigate if designer decisions contribute to accident causation by studying the link between accident and DfCS suggestions that were not considered.

Table 8. 1: General information about each case study

	Sport hall	**Hospital**	**School**	**Trade centre**	**Bank**
Location	North of Gaza Strip, predetermined location where there were no nearby buildings or power lines.	Gaza, predetermined location with no adjacent buildings.	South of Gaza Strip, predetermined location with no adjacent buildings.	Gaza, predetermined location with adjacent building from one side.	Middle of Gaza Strip, predetermined location with no adjacent buildings.
Owner	Nongovernmental organization.	Ministry of health	Private	Half public and half Private.	Private
Obtained document	One plan, civil engineering drawings, technical specifications.	Plans, facades, sections and some civil drawings.	Plans, facades, sections and civil and electrical drawings.	Architectural and civil drawings.	Architectural, civil, electrical and mechanical drawings.
Soil	Sand	Sand	Sand	Rubbish that moved away and replaced by sand.	Sand
Type of foundation	Isolated footing with maximum excavation of 2m.	Mat foundation	Combined footing with maximum excavation of 2m.	Mat foundation	Isolated footing with maximum excavation of 2m.
Structural system	Continuous beams resting on columns for the administration part and moment resisting frame system for the sport hall.	Building frame system in conjunction with shear walls.	Moment resisting frame system.	Building frame system in conjunction with shear walls.	Continuous beams resting on columns

8.2 Case Study One (Sport Hall Project)

The project consists of one floor building. The area of the floor is 230m^2. The floor has two parts with different heights, three meters for the administration part and six meters for the sport hall. Figure 8.1 shows the plan of case study one.

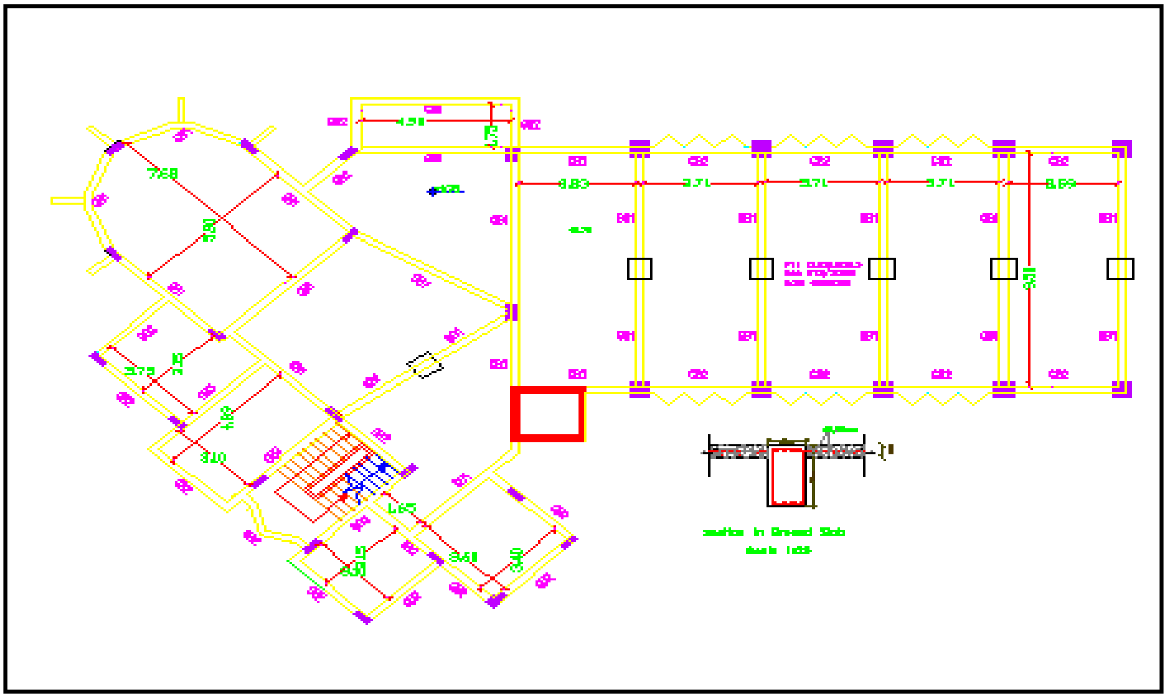


Figure 8. 1: First floor Plan

8.2.1 Applying the Re-structured Approach on the Sport Hall Project

For case study one, the DfCS suggestions were applied to each engineering discipline for each design phase. The numbers of DfCS suggestions (regulations and recommendations) that were considered and those that were not considered by designers are displayed in Table 8.2.

Table 8. 2: applying the re-structured approach on sport hall case study

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Schematic Phase	**Architectural Engineering**	Regulations		1,2,3,4
		Recommendations		

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
	Civil Engineering	Regulations	1	
		Recommendations		
	Electrical Engineering	Regulations		1
		Recommendations		
	Mechanical Engineering	Regulations		
		Recommendations	1,2	
Design development Phase	Architectural Engineering	Regulations	2	1
		Recommendations	1,3,4,5,7,8,10,11,14,18	2,9,12,13,15,19
	Civil Engineering	Regulations	2	3,4,5,7,8
		Recommendations	3,6,7,8,10	9
	Electrical Engineering	Regulations	2,3,7,8	1,4,5
		Recommendations	2,3,6,7,8	
	Mechanical Engineering	Regulations	1,2	
		Recommendations	2,3	
Construction documentation Phase	Architectural Engineering	Regulations		1,2,3
		Recommendations		
	Civil Engineering	Regulations		1,2,3
		Recommendations		
	Electrical Engineering	Regulations		1,2,3
		Recommendations		
	Mechanical Engineering	Regulations		1,2,3
		Recommendations		
Work schedule Phase	Architectural Engineering	Regulations	1	2
		Recommendations		1
	Civil Engineering	Regulations	1,6	2,3,5
		Recommendations	2,3,7	1
	Electrical Engineering	Regulations	1	
		Recommendations		
	Mechanical Engineering	Regulations	1	
		Recommendations		

Identify regulations and recommendations that were considered and those that were not considered give the ability to designers according to their specializations to modify their designs. All regulations should be satisfied while recommendations considered whenever possible. The designers regardless of their specializations considered forty one suggestions composed of fourteen regulations and twenty seven recommendations. At the same time they did not consider thirty nine suggestions composed of thirty regulations and nine recommendations. In the schematic phase the architects did not consider the four regulations which are more than the other engineering specializations. The civil engineer did not consider five out of eight regulations in the design development phase which is more than the other specializations. In the work schedule phase the civil engineer did not consider more regulations than the other engineering disciplines. In general, the civil engineer did not consider the maximum number of regulations, i.e. eleven ones followed by architect, i.e. nine. It could be concluded that the design of this case study incorporates significant hazard on worker safety.

8.2.2 Accident Description and Discussion

While constructing the sport hall roof forms, the construction supervisor noted that the roof form is not safe. An order was submitted to the contractor requiring the contractor to replace the roof form with safe one in order to continue working. The contractor abandoned the stop order and starts lifting blocks and steel up, and places them on roof forms. The roof form collapsed leaving two workers with severe injuries and three with moderate injuries.

This accident could be avoided if designers provided adequate design for the roof form and impeded it as an activity that should be priced during procurement phase. Once the contractor prices this activity in the bid, then the probability to abide to form design increases.

Another point is that leaving the roof form design to contractors; give them the confidence that their experience is adequate to construct any one. This might result in disobeying the construction supervisor which could lead to accidents as happened in this case. The right attitude of the contractors is to collaborate with engineers to design out hazards, not to be in adverse relationship. Finally the work schedule did not contain activity that requires checking form system before lifting material.

Referring to Table 8.2 it is clear that the civil engineer design decisions contribute to accident causation. The civil engineer did not consider DfCS regulation number six and eight in the design development phase where designers are required not just to design slab forms but also to extend it on edges 0.5 meters and to be continuous across slab openings (in this case study there is no floor opening) to prevent falling hazard and to facilitate working around edges. This case study shows that there is a link between cause of accident and DfCS suggestion number eight in the design development phase that was not considered in this project. The accident also could be related to regulation number five in the work schedule phase where it is required to check the capability of the form system to sustain loads caused by activities such as lifting material.

Another important point is the communication between contractors and designers. If they both beer responsibility of worker safety and make it a priority then the contractor would never scarify the worker safety in order to keep in schedule. For this the three regulations in the construction documentation that were not considered in this case study have contribution to accident. If designer knew the DfCS concept and identify that these suggestion are regulations that should be satisfied then this accident might not occur.

The case study shows the importance of considering DfCS suggestions especially the regulations and empowers classifying these suggestions as regulations. Although many DfCS suggestions classified as regulations did not considered in this case study and did not contribute to accident causations, this does not mean that they would not cause accidents in other projects.

8.3 Case Study Two (Hospital Project)

The project consists of seven floor building. One floor is under ground level and six above it. The area of each of the first three floors is 1800 m^2. An offset of approximately two meters was started around the third slab and continued on the upper slabs so that the area of the above four floors is 2000 m^2 for each of them. The height of the third slab offset from ground level is maximum eight meters (western direction). Figure 8.2 shows the fourth floor plan of case study two.

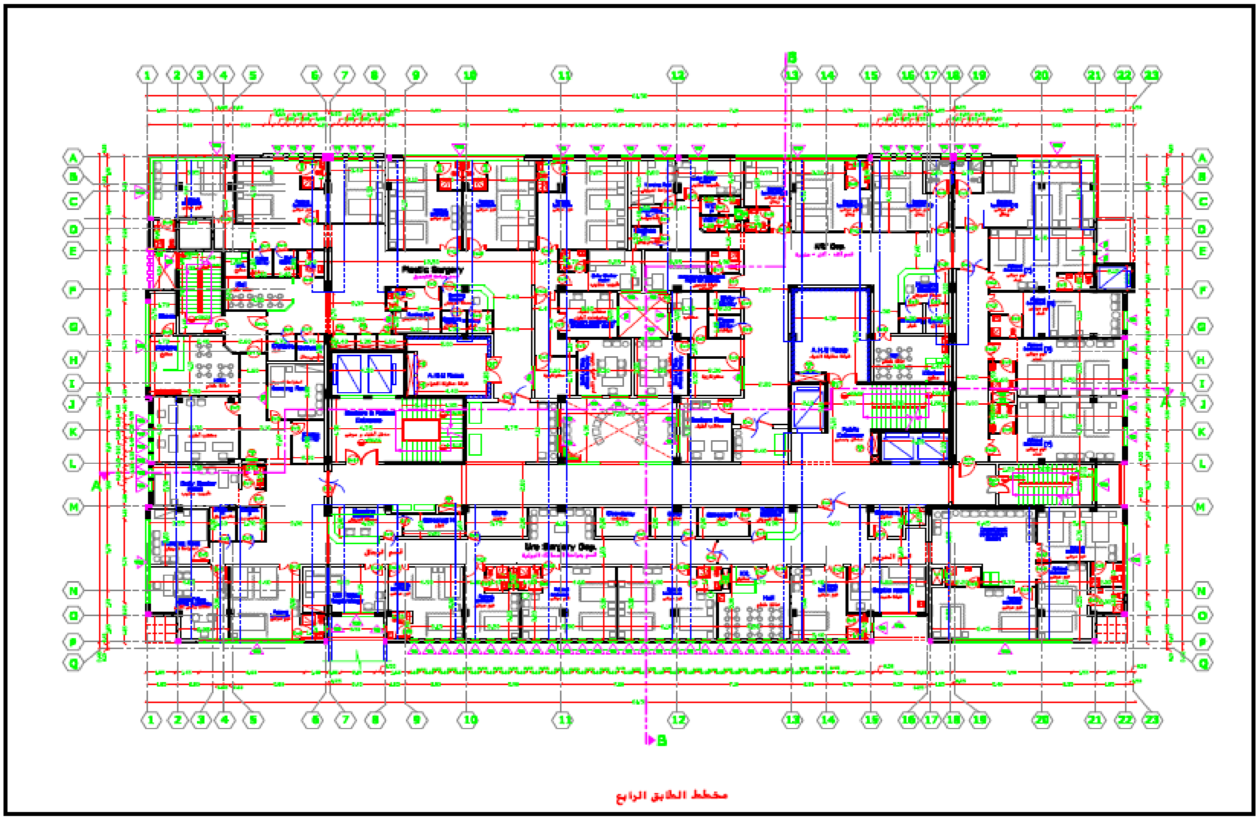


Figure 8. 2: Fourth floor plan

8.3.1 Applying the Re-structured Approach on the Hospital Project

For case study two the DfCS suggestions were applied to each engineering specialization for each design phase as shown in Table 8.3. The application of the developed DfCS approach on the hospital case study is done easily and shows clearly the weak design related to safety issues. In the schematic phase the architects did not consider three regulations out of four which is more than the other engineering specializations. The civil engineer did not consider six out of eight regulations in the design development phase which is more than the other specializations. In the work schedule phase the civil engineer did not consider more regulations than the other engineering disciplines. In general, the designers considered fifty four suggestions composed of twenty five regulations and twenty nine recommendations. At the same time they did not consider forty one suggestions composed of twenty seven regulations and fourteen recommendations. The civil engineer is the one who did not consider maximum number of regulations, i.e. twelve ones followed by architect, i.e. seven. It could be concluded that the design incorporates significant risk on workers.

Table 8. 3: Applying the re-structured approach on hospital project case study

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Schematic Phase	Architectural Engineering	Regulations	2	1,3,4
		Recommendations		
	Civil Engineering	Regulations	1	
		Recommendations		
	Electrical Engineering	Regulations	2	1
		Recommendations		
	Mechanical Engineering	Regulations		
		Recommendations	1	2,3
Design development Phase	Architectural Engineering	Regulations	1,2,3	
		Recommendations	1,3,5,6,7,8,10,11,12,14, 18	2,4,13,17,19
	Civil Engineering	Regulations	1,2	3,4,5,6,7,8
		Recommendations	1,2,3,4,6,7,10	5,9
	Electrical Engineering	Regulations	2,3,4,5,6,7,8	1
		Recommendations	2, 6,7,8	3
	Mechanical Engineering	Regulations	2,3,4	1
		Recommendations	2,3	
Construction documentation Phase	Architectural Engineering	Regulations		1,2,3
		Recommendations		
	Civil Engineering	Regulations		1,2,3
		Recommendations		
	Electrical Engineering	Regulations		1,2,3
		Recommendations		
	Mechanical Engineering	Regulations		1,2,3
		Recommendations		
Work schedule Phase	Architectural Engineering	Regulations	1	2
		Recommendations		1,2
	Civil Engineering	Regulations	1,4,6	2,3,5
		Recommendations	2,3,4,7	1,5
	Electrical Engineering	Regulations	1	
		Recommendations		

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
	Mechanical Engineering	Regulations	1	
		Recommendations		

8.3.2 Accident Description and Discussion

While erecting the form system for the third slab, the construction supervisor noted that the form system in the western part of the building under the offset, where the height of the proposed slab is eight meters above ground level, is not safe. The construction supervisor did not give approval for the forming system. Despite of this, the contractor continued working and started to pour concrete on the third slab. As the worker pouring concrete reached the western offset where the height of forms above ground level is eight meters, a collapse occurred leaving this worker with severe injuries.

This accident is another example of the prevailing practice in Gaza Strip where contractor experience is used in form erection. It should be mentioned that from the ethical point of view, the construction engineer committed an error, since no order to stop work was submitted. It seems that the disproval of the form system is a protective action from any expected liability in case of form collapse. Designers are the party that has suitable education that enables them to design the form system. If designers became obliged to design the forming system then a change in the contractor mindset would occur so contractors might become able to comply with the submitted design of the forming system.

This accident is approximately similar to the one occurred in the sport hall case study with some difference in the way accident occur. In the hospital project case study the collapse happened while pouring concrete but in the sport hall case study it occurred while lifting materials. The discussion to investigate designer decisions contribution to accident causation is the same as sport hall accident discussion. In fact, during the interview many similar accidents were mentioned. Although this accident is the same as the one in case one, it empowers the importance of considering this concept and empowers the classification to DfCS suggestions made by researcher into regulations and recommendations where violation of regulations was the main cause for accident causation.

8.4 Case Study Three (School Project)

The project consists of three floor building that has U shape. The area of the first floors is 1091 m^2. An offset of approximately 1.9 m was designed on the inner part of the

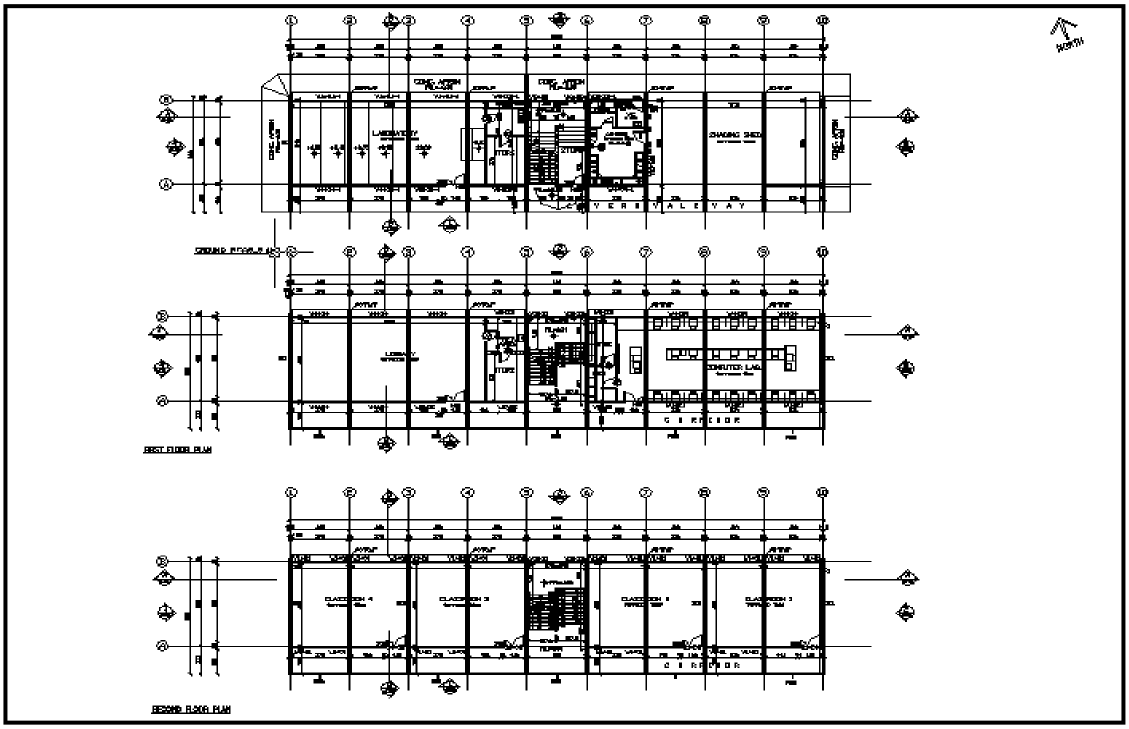


Figure 8. 3: Ground floor plan, first floor plan and second floor plan

U shape. It started from the first slab and continued on the upper slabs so that the area of the above two floors is 1400 m^2 for each of them. Figure 8.3 shows the ground floor plan, first plan and second plan of the school project.

8.4.1 Applying the Re-structured Approach on School Project

For the school case study the DfCS suggestions were applied to each engineering specialization for each design phase. The numbers of DfCS suggestions (regulations and recommendations) that were considered and those that were not considered are displayed in Table 8.4. The regulations and recommendations that were considered and those that were not considered are easily identified. In the schematic phase the architects did not consider the four regulations which are more than the other engineering specializations. The civil engineer did not consider seven out of eight regulations in the design development phase which is more than the other specializations. In the work schedule phase the civil engineer did not consider more regulations than the other engineering disciplines. In general, the designers considered forty nine suggestions composed of sixteen regulations and thirty three recommendations. At the same time they did not consider forty one suggestions composed of thirty two regulations and nine recommendations. The civil engineer is the one who did not consider maximum number of regulations, i.e. fourteen ones followed by architect, i.e. eight. This reveals that the design decisions compromise worker safety.

Table 8. 4: Applying of re-structured approach on school case study

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Schematic Phase	Architectural Engineering	Regulations		1,2,3,4
		Recommendations		
	Civil Engineering	Regulations	1	
		Recommendations		
	Electrical Engineering	Regulations		1,2
		Recommendations		
	Mechanical Engineering	Regulations		
		Recommendations	1,2	
Design development Phase	Architectural Engineering	Regulations	1,2	
		Recommendations	1,4,5,6,7,8,9,10,11,12,14,15,18,19	2,13
	Civil Engineering	Regulations	2	1,3,4,5,6,7,8
		Recommendations	3,4,6,7,8,9,10	1,5
	Electrical Engineering	Regulations	2,3,6,7,8	1,4,5
		Recommendations	2,3,6,7	9
	Mechanical Engineering	Regulations	1,2	
		Recommendations	2,3	
Construction documentation Phase	Architectural Engineering	Regulations		1,2,3
		Recommendations		
	Civil Engineering	Regulations		1,2,3
		Recommendations		
	Electrical Engineering	Regulations		1,2,3
		Recommendations		
	Mechanical Engineering	Regulations		1,2,3
		Recommendations		
Work schedule	Architectural Engineering	Regulations	1	2
		Recommendations		1,2

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Phase	Civil Engineering	Regulations	6	1,2,3,5
		Recommendations	3,4,6,7	1,2
	Electrical Engineering	Regulations	1	
		Recommendations		
	Mechanical Engineering	Regulations	1	
		Recommendations		

8.4.2 Accident Description and Discussion

While working near the edge of the slab a worker fall from the second floor on a block placed on the ground. The worker suffered from severe injuries that caused Permanente disabilities thus preventing him from work.

This accident is a common one not just in Gaza Strip but globally. Analyzing the accident prevail that the slab did not have temporary guardrails around edges which could prevent falling. In addition the work schedule did not contain daily housekeeping activity which results in untidy job site. The severity of the injury was due to fall from height and hitting block on the ground. Finally the work schedule contains lots of overtime which affect worker concentration and was one of the causes of fall.

Investigation of accident causation reveals that the civil engineer did not consider DfCS suggestion number five (regulations) in the design development phase where designers are required to design temporary guardrails around stairs and floor edges. As a result suggestion number two (regulations) in work schedule phase where these guardrails should be placed around edges as soon as possible was not considered also. DfCS suggestion number three (regulation) in the work schedule phase related to having daily housekeeping was not considered which cause untidy job site and contribute to the severity of injuries. Finally DfCS suggestion number two (recommendation) in the work schedule phase related to minimizing over time was not considered. If designers considered these suggestions, this accident could be avoided. It should be mentioned that although many suggestions have not been considered by the four specializations and did not contribute to the accident causation in this project, the ability of causing accidents in other projects could be significant which highlight the importance of addressing this concept by designers.

The school case study shows that three suggestions classified as regulations are linked to the accident causation while one recommendation is linked to accident causation. This result empowers the classification of these suggestions into regulations and recommendations made by researcher.

8.5 Case Study Four (Trade Centre Project)

The project consists of seventeen floor building. The area of the first floors is $625m^2$. The area of the upper floors is typical and equal 660 m^2. Figure 8.4 shows the typical floor plan.

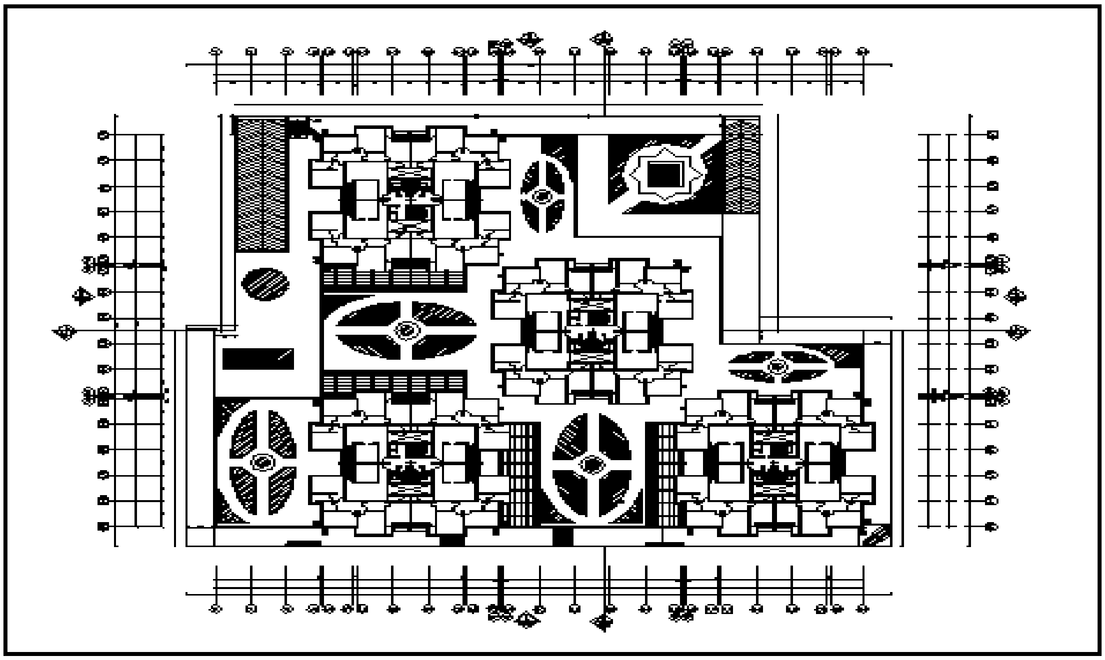


Figure 8. 4: Typical Floor plan

For case study number four the DfCS suggestions were applied to each specialization for each design phase as shown in Table 8.5. The regulations and recommendations that were considered and those that were not considered are identified for the trade centre. In the schematic phase the architects did not consider the four regulations which is more than the other engineering specializations. The civil engineer did not consider seven out of eight regulations in the design development phase which is more than the other specializations. In general, the designers considered sixty eight suggestions composed of twenty four regulations and forty four recommendations. At the same time they did not consider thirty four suggestions composed of twenty six regulations and eight recommendations. The civil engineer is the one who did not consider maximum number of regulations, i.e. eleven ones followed by architect, i.e. seven. Although no accident was reported to occur in this project, the accident risk is considered to be high.

Table 8. 5: Applying the re-structured approach on trade centre project case study

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Schematic Phase	Architectural Engineering	Regulations		1,2,3,4
		Recommendations		
	Civil Engineering	Regulations	1	
		Recommendations		1
	Electrical Engineering	Regulations	2	1
		Recommendations	1	
	Mechanical Engineering	Regulations		
		Recommendations	2,3	
Design development Phase	Architectural Engineering	Regulations	1,2,3	
		Recommendations	1,3,5,6,7,8,9,10,11,12,13,14,15,17,18,19	2,4
	Civil Engineering	Regulations	1	2,3,4,5,6,7,8
		Recommendations	1,2,3,4,6,7,8,9,10	5
	Electrical Engineering	Regulations	3,4,5,6,7,8	1,2
		Recommendations	2,3,5,7,8	1,8
	Mechanical Engineering	Regulations	2,4	1
		Recommendations	1,2,3	
Construction documentation Phase	Architectural Engineering	Regulations		1,2,3
		Recommendations		
	Civil Engineering	Regulations		1,2,3
		Recommendations		
	Electrical Engineering	Regulations		1,2,3
		Recommendations		
	Mechanical Engineering	Regulations		1,2,3
		Recommendations		

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Work schedule Phase	Architectural Engineering	Regulations	1,2	
		Recommendations	1	2
	Civil Engineering	Regulations	1,3,4,5,6	2
		Recommendations	2,3,4,5,6,7	1
	Electrical Engineering	Regulations	1	
		Recommendations		
	Mechanical Engineering	Regulations	1	
		Recommendations		

8.6 Case Study Five (Bank Project)

The project consists of three floor building. The area of the ground floor is 326 m^2. Due to offsets, the area of the first floor is 340 m^2 and the area of the second floor (roof) is 107 m^2. Figure 8.5 shows ground floor slab.

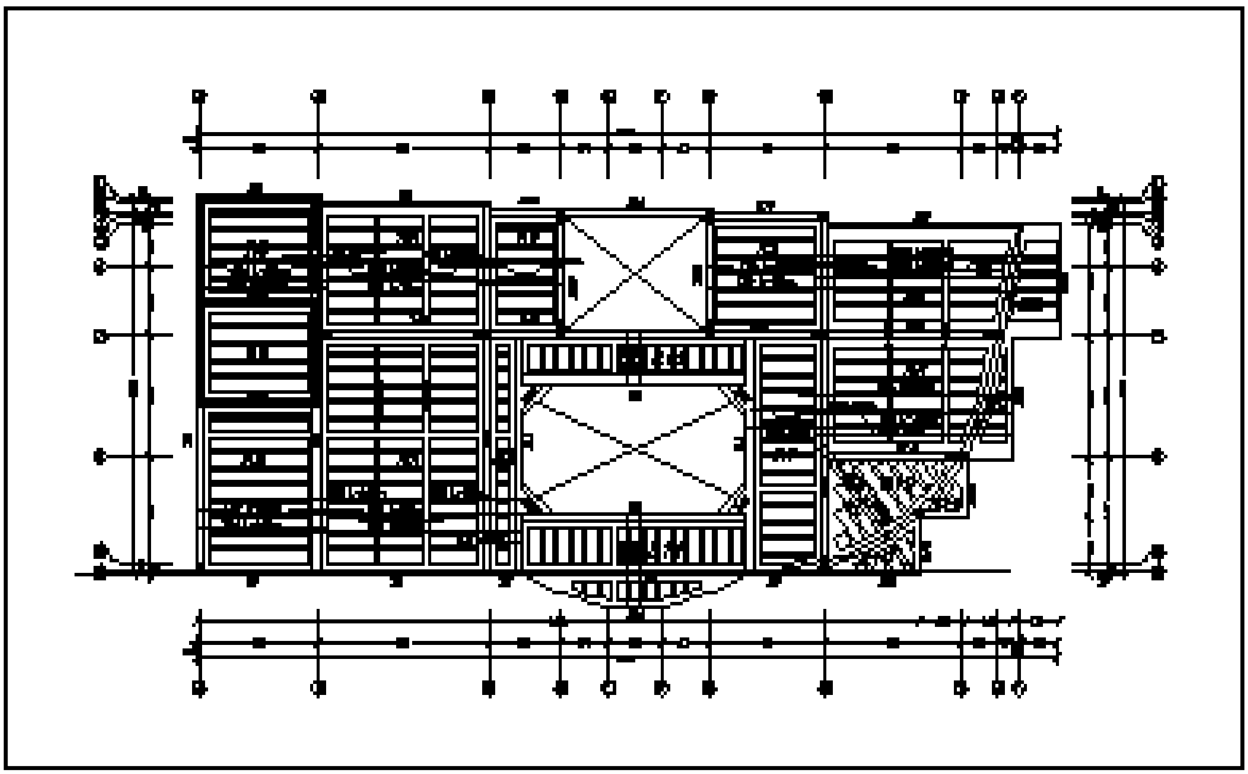


Figure 8. 5: Ground floor slab

For case study number five the DfCS suggestions were applied to each specialization for each design phase as shown in Table 8.6. The regulations and recommendations that were considered and those that were not considered are identified for the trade centre project. In the schematic phase the architects did not consider the four regulations which is more than the other engineering specializations. The civil engineer did not consider seven out of eight regulations in the design development phase which is more than the other specializations. In the work schedule phase the civil did not consider four regulations. For all engineering specializations, the suggestions that were considered are thirty six suggestions composed of fifteen regulations and twenty one recommendations. At the same time, forty four suggestions composed of thirty three regulations and eleven recommendations were not considered. The civil engineer is the one who did not consider maximum number of regulations, i.e. thirteen ones followed by architect, i.e. ten. For the bank case study, the accident risk is considered to be high despite no accident was reported to occur.

Table 8. 6: Applying the re-structured approach on bank project case study

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Schematic Phase	Architectural Engineering	Regulations		1,2,3,4
		Recommendations		
	Civil Engineering	Regulations	1	
		Recommendations		
	Electrical Engineering	Regulations		2
		Recommendations		
	Mechanical Engineering	Regulations		
		Recommendations	2	1
Design development Phase	Architectural Engineering	Regulations	1,2	3
		Recommendations	1,7,8,11,12,14,15	2,5,9,10,13
	Civil Engineering	Regulations		2,3,4,5,6,7,8
		Recommendations	3,7,8,10	6,9
	Electrical Engineering	Regulations	3,5,7,8	1,2,4
		Recommendations	2,3,6,7	8
	Mechanical Engineering	Regulations	1,2,3,4	
		Recommendations	1,2,3	

Design phase	Engineering specialization	Classification of DfCS suggestions	DfCS suggestions (considered)	DfCS suggestions (not considered)
Construction documentation Phase	Architectural Engineering	Regulations		1,2,3
		Recommendations		
	Civil Engineering	Regulations		1,2,3
		Recommendations		
	Electrical Engineering	Regulations		1,2,3
		Recommendations		
	Mechanical Engineering	Regulations		1,2,3
		Recommendations		
Work schedule Phase	Architectural Engineering	Regulations	1	2
		Recommendations		1
	Civil Engineering	Regulations	6	1,2,3,5
		Recommendations	2,3	1,4
	Electrical Engineering	Regulations	1	
		Recommendations		
	Mechanical Engineering	Regulations	1	
		Recommendations		

8.7 Discussion of Possible Relations between the Five Case Studies

The data of the five case studies is rearranged in order to investigate the weakness and strength of each engineering specialization related to DfCS concept. DfCS suggestions that were considered by three cases out of five cases are considered strength of design related to DfCS concept, while DfCS suggestions that were not considered by three cases out of five cases are considered weakness of design related to DfCS concept.

8.7.1 Architectural Engineering

Table 8.7 displays the application of the proposed DfCS approach on case studies according to architectural engineering.

Table 8. 7: applying the architectural engineering re-structured DfCS approach on the case studies

Design phase		Case 1		Case 2		Case 3		Case 4		Case 5	
		Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered
Schematic	Regul.		1,2,3,4	2	1,3,4		1,2,3,4		1,2,3,4		1,2,3,4
	Recom.										
Design development	Regul.	2	1	1,2,3		1,2		1,2,3		1,2	3
	Recom.	1,3,4,5 ,7,8,10, 11,14, 18	2,9,12, 13,15, 19	1,3,5,6 ,7,8,10, 11,12, 14, 18	2,4,13 ,17,19	1,4,5,6 ,7,8,9, 10,11,12, 14,15,18 ,19	2,13	1,3,5,6, 7,8,9,10 ,11,12,13 ,14,15,17 ,18,19	2,4	1,7,8, 11,12, 14,15	2,5,9, 10,13
Construction documentation	Regul.		1,2,3		1,2,3		1,2,3		1,2,3		1,2,3
	Recom.										
Work schedule	Regul.	1	2	1	2	1	2	1,2		1	2
	Recom.		1		1,2		1,2	1	2		1

i. Strength of design related to DfCS concept:

1. Architects design height of parapets and guardrails to be 1.1m minimum above the roof, floor or platform level.
2. Architects provide permanent guardrails around stairs, edges and atrium.
3. Architects design skylights to be domed with elevated beams around them rather than flat ones.
4. Architects specify non-slip tiles and avoid polishing tiles with slip material such as wax.
5. When required, architects design to paint about 1.5 meters with oil-based paint and the remaining walls with water based paint.
6. Architects design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components.

7. Architects design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.
8. Architects design distance between two successive stair risers (stair nose) to be as small as possible. Choose stair case location to have natural lighting and adequate ventilation.
9. Architects choose materials that are durable.
10. Architects choose materials that are safe to handle.
11. Architects select elements such as windows, tiles etc. that are of consistent size, light weight, and easy to handle.
12. Architects design the door of the generator room to swing outward.
13. Architects schedule activities so that no welding activity is performed while painting.

ii. Weakness of design related to DfCS concept:

1. The DfCS concept is not considered by architects in the schematic phase and in the construction documentation phase.
2. Designers do not design step risers to be uniform from top to bottom during construction.
3. Designers do not choose materials that are non combustible
4. Designers do not schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.
5. Designers do not schedule sidewalks, ramps and roadways around project to be constructed as early as possible.
6. Architects do not consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.

8.7.2 Civil Engineering

Table 8.8 displays the application of the proposed DfCS approach on case studies according to civil engineering.

Table 8. 8: Application of civil engineering re-structured DfCS approach on case studies

Design phase		Case 1		Case 2		Case 3		Case 4		Case 5	
		Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered
Schematic	Regul.	1		1		1		1		1	
	Recom.								1		
Design development	Regul.	2	3,4,5,7,8	1,2	3,4,5,6,7,8	2	1,3,4,5,6,7,8	1	2,3,4,5,6,7,8		2,3,4,5,6,7,8
	Recom.	3,6,7,8,10	9	1,2,3,4,6,7,10	5,9	3,4,6,7,8,9,10	1,5	1,2,3,4,6,7,8,9,10	5	3,7,8,10	6,9
Construction documentation	Regul.		1,2,3		1,2,3		1,2,3		1,2,3		1,2,3
	Recom.										
Work schedule	Regul.	1,6	2,3,5	1,4,6	2,3,5	6	1,2,3,5	1,3,4,5,6	2	6	1,2,3,5
	Recom.	2,3,7	1	2,3,4,7	1,5	3,4,6,7	1,2	2,3,4,5,6,7	1	2,3	1,4

i. Strength of design related to DfCS concept:

1. Designers conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.
2. Designers design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.
3. Designers design steel bars as a grid pattern with dimensions of 25cm *25cm maximum when workers are required to walk on reinforcement bars.
4. Designers design non structural members to be safe during construction and maintenance.
5. Designers choose quieter methods of construction.
6. Designers select light weight materials such as hollow concrete blocks rather than solid ones. Select concrete cubes of 100*100*100 mm3 instead of standard cylinder for testing concrete strength.

7. Designers select small reinforcement diameters rather than larger ones.
8. Designers get satisfactory results of concrete cube tests before the removal of the steel props supporting slabs.
9. Designers avoid scheduling any activity related to work around the project while working on facades or lifting materials.
10. Designers design work schedule to minimize the need for overtime.
11. Designers design work schedule to minimize the need for night work.
12. Designers schedule to avoid congestion of workers within limited area.
13. Designers schedule to start partitioning activity as soon as possible especially at edges and floor openings.

ii. Weakness of design related to DfCS concept:

1. The DfCS concept is not considered by civil engineers in the construction documentation phase.
2. Designers do not design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.
3. Designers do not design scaffolding tie-off points into the building facade.
4. Designers do not design temporary guardrails around stairs and floor edges.
5. Designers do not design permanent guardrails around skylights, stairs and atrium to be built as soon as possible.
6. Designers do not design slab shuttering to be minimum 0.5 meters over hanged from all direction with guardrails.
7. Designers do not design the shuttering of slab to be continuous across the opening.
8. Designers do not design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor.
9. Designers do not check the capability of the form system to sustain loads caused by activities such as lifting material.

10. Designers do not schedule temporary guardrails with colored band to be placed around edges as soon as possible.
11. Designers do not consider daily housekeeping in work schedule.

8.7.3 Electrical Engineering

Table 8.9 displays the application of the proposed DfCS approach on case studies according to electrical engineering.

Table 8. 9: Application of electrical engineering re-structured DfCS approach on case studies

Design phase		Case 1		Case 2		Case 3		Case 4		Case 5	
		Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered
Schematic	Regul.		1	2	1		1,2	2	1		2
	Recom.							1			
Design development	Regul.	2,3,7,8	1,4,5	2,3,4,5, 6,7,8	1	2,3,6,7,8	1,4,5	3,4,5,6, 7,8	1,2	3,5,7,8	1,2,4
	Recom.	2,3,6,7,8		2, 6,7,8	3	2,3,6,7	9	2,3,5, 7,8	1,8	2,3,6,7	8
Construction documentation	Regul.		1,2,3		1,2,3		1,2,3		1,2,3		1,2,3
	Recom.										
Work schedule	Regul.	1		1		1		1		1	
	Recom.										

i. Strength of design related to DfCS concept:

1. Designers specify fiberglass sweeps for electrical conduit instead of steel sweeps.
2. Designers design to place external lighting on places such as roof parapets that facilitate their installation and maintenance in safe way.
3. Designers provide, adequate stair lighting during construction and maintenance
4. Designers use consistent standards for power sources to identify them.
5. Designers design the riser for electrical installation to be away from mechanical installation riser.

6. Designers avoid placing the main electrical distribution board under baths.
7. Designers choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height
8. Designers increase electrical design load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installation.
9. Designers provide a warning tape to provide warning signal for underground electrical installation.
10. Designers choose durable material for electrical installations.
11. Designers check electrical conduits after plastering activity to ensure construction activities such as plastering did not affect the conduits or cause any plugging.

ii. Weakness of design related to DfCS concept:

1. The DfCS concept is not considered by electrical engineers in the schematic phase and in the construction documentation phase.
2. Designers do not design temporary electrical system that can be installed and used safely during construction.
3. Designers do not provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.

8.7.4 Mechanical engineering

Table 8.10 displays the application of the proposed DfCS approach on case studies according to mechanical engineering.

Table 8. 10: application of mechanical engineering re-structured DfCS approach on case studies

Design phase		Case 1		Case 2		Case 3		Case 4		Case 5	
		Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered	Considered	Not considered
Schematic	Regul.										
	Recom.	1,2		1	2,3	1,2		2,3		2	1
Design development	Regul.	1,2		2,3,4	1	1,2		2,4	1	1,2,3,4	
	Recom.	2,3		2,3		2,3		1,2,3		1,2,3	
Construction documentation	Regul.		1,2,3		1,2,3		1,2,3		1,2,3		1,2,3
	Recom.										
Work schedule	Regul.	1		1		1		1		1	
	Recom.										

i. Strength of design related to DfCS concept:

1. Designers locate underground utilities in easily accessible places. Consider soil investigation report within the criteria used to determine the location of these utilities.
2. Designers design to have hand excavation around existing underground utilities
3. Designers design for placing water pump a way from electrical generator.
4. Designers position underground utilities away from workers passageways but in places easy to construct and maintain.
5. Designers design sanitary installation to be placed in a way that facilitates their installation and maintenance.
6. Designers choose durable material for mechanical installations.
7. Designers choose light weight mechanical installations.
8. Designers conduct test on completed mechanical installations before performing new activities such as tiling activity.

ii. Weakness of design related to DfCS concept:.

1. The DfCS concept is not considered by mechanical engineers in the construction documentation phase.

8.8 Concluded Remarks

Comparing the five cases to each other several notes could be concluded:

1. The professional designers consider DfCS concept while designing not because they recognize the concept but because they know how their designs would be executed.
2. The prevailing practice is that safety is not considered during schematic phase especially by architects.
3. During construction documentation phase all specializations pay no attention to communicating hazards to contractors.
4. The case studies provide strong clue that by considering the developed DfCS approach accidents could be reduced and worker safety could be improved.
5. Civil engineer should hold the responsibility of designing shuttering systems, scaffold systems, form systems and tie off points for scaffolding. They should ensure that guardrails designed and scheduled to be placed around edges, stairs or atriums as soon as possible to minimize the probability of falls.
6. Electrical engineer should make design for temporary electrical system and don't leave it to contractors.
7. Daily housekeeping should be standard practice in all projects work schedule because of its importance in having tidy job site.
8. Although accidents did not occur in some case studies, the risk of accidents still exists in these projects.

Chapter 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

The DfCS concept is one element of a holistic approach that aims to improve worker safety. Collaboration between all parties involved in the project construction (designers, construction supervisors, contractors, owners, etc.) is required to enhance worker safety. Each party or even each specialization should fulfill its responsibility regarding worker safety.

To fulfill designer responsibility regarding worker safety, the construction industry should implement the DfCS concept as a standard practice. Designers are required to develop techniques, construction methods or to use substitute materials that comply with the design requirement and at the same time imply no risk to workers during construction or maintenance phase.

Although contractors play a traditional role as being responsible for worker safety, they must adhere to design specification, have a seat in design phase because their knowledge is essential to identify work hazards before commission of construction phase which could increase the ability to modify design to ones that could be executed safely.

9.2 Conclusions

1. A comprehensive approach for DfCS concept was developed for use in Gaza Strip. It is based on the findings from the literature reviews, researcher knowledge of the local construction industry and its shortcomings related to DfCS concept and the shortcoming of the concept at international levels. The approach is an easy tool that aids designers to consider DfCS concept. This is because it considers design phases which are schematic phase, design development phase, construction documentation phase and work schedule phase. It also considers the four engineering specializations involved in building construction.

2. The approach is directed to engineering fields involved in building constructions. Structural design which is not considered at the international levels is taken into account in this approach.
3. A further step is conducted in this research where DfCS suggestions incorporated in the developed DfCS approach are classified to regulations and recommendations. Regulations imply that the suggestions are too important and should be implemented, since ignoring them increase significantly the accident risk.
4. It is very important to assure that all edges (exterior or interior) are protected properly during construction and maintenance phase. Scaffolding system, form system or any element or system related to the four engineering specializations should be designed during design development phase. Designers should consider maintenance process and assure that worker safety would not be compromised. Selected materials should be as practicable as possible durable, safe to handle and non combustible.
5. The developed DfCS approach reveals that the civil engineer should consider eighteen regulations in comparison with architectural engineer (twelve), electrical engineer (nine) and mechanical engineer (eight). The civil engineer design decisions were a primary cause to accidents which is in disagreement with (Behm, 2005a) where architects decisions were found to have positive impacts on worker safety more than other engineering specializations. This could be attributed to the way of conducting the research. This research consider DfCS concept related to buildings in Gaza Strip taking engineering specializations and design phases in account while Behm (2005a) consider engineering accidents in general without restriction and did not relate the concept to engineering specializations and design phases.
6. The conducted five case studies highlight the importance and possibility of considering the DfCS concept easily. The case studies highlight the important role of civil engineers in considering the DfCS concept.
7. Designers do not consider worker safety during schematic design phase where the ability to enhance worker safety is the best. Most their experience and common sense was implemented in the design development phase then in the work schedule phase.

Designers do not communicate hazards to contractors by any mean which contribute to accident causation.

8. In general the design professionals in Gaza Strip are not cognizant with DfCS concept. Recently professional civil engineers became cognizant of the concept because this concept is included as a term that should be fulfilled in large project contracts. Nonetheless, civil engineers do not have solid materials or formal DfCS approach that aids them in applying the DfCS concept. Engineering common sense and experience in design and construction is used to investigate if certain design could form danger on construction workers during execution or not.

Finally the researcher encourages the application of the DfCS approach. It can provide a foundation for implementing the concept. This proposed DfCS approach provides an effective means that helps designers to explicitly consider construction worker safety during the design process. It is especially worthwhile for less-experienced designers who lack the knowledge of how their designs are transformed to physical objects and how their design decisions could affect worker safety. The application of the DfCS approach will minimize the accident risk which in turn improves workers safety.

9.3 Recommendations

1. To enhance construction safety performance, it is recommended to apply the DfCS approach.
2. Develop legal status for the approach.
3. Conduct activities to encourage the DfCS approach implementation.
4. The awareness of designers should be raised to become cognizant that their design decisions can directly affect worker safety.
5. The communication between designers and contractors should be increased.
6. Professional codes of ethics, building codes, and legislative actions such as regulations should stipulate the importance and the need to consider DfCS concept.
7. Encouraging relevant institutions such as Palestinian Housing Council, Ministry of Public Works and Housing, Engineering Syndicate, etc. to consider the inclusion of

DfCS concept as one of the technical requirements to be fulfilled in order to gain approval of a building proposal (permits).

8. Contract language is required to incorporate DfCS concept without affecting safety duties of the other parties especially contractors.

9. To create an organization whose duty is to gather accidents related to construction industry so that to provide data base for further studies such as investigating the link between accidents and design in order to derive more DfCS suggestions.

10. Designers should not maintain a distance from construction worker safety and from the construction process. This can be achieved by:

i. Incorporating safety-related topics in engineering curricula so that the graduated engineers can become more responsive to the safety needs of construction workers.

ii. Providing professional engineers with regularly updated construction safety training sessions followed up by site visits to gain a direct insight of how their designs transferred to physical objects and hazards incorporated in their decisions.

9.4 Further Researches

1. Investigate the economical viability of addressing DfCS concept. This can be achieved by investigating the economic impact of implementing the design for safety concept to all parties involved in construction projects.

2. Expand the research to other types of structures such as industrial buildings and route construction.

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Appendix A

Open interview

Part one (Awareness and local practice):

1. Have you had any discussions with contractors or designers that include the method of constructing designed elements or connections in order to increase worker safety?
2. Do you ever make design decisions or proposed ideas or recommendations that could improve construction worker safety? Provide specific examples.
3. When design incorporates certain hazard, do you communicate it to the contractors in the form of warning and information about the hazard on the contract drawings (consultant, client)?
4. Are you familiar with design for safety concept? Describe your understanding of the concept?
5. Do you have a formal process to follow that allows for consideration of construction worker safety? Describe the process.
6. Specify sources that aid you in addressing construction worker safety during design phase?
7. Did you hear of the Construction Design and Management (CDM) regulations?
8. Did you hear of the Construction Hazard Assessment Implication Review (CHAIR)?
9. Have you ever worked with or hired a construction safety consultant in the design phase?
10. Have you ever been asked to address construction worker safety in the design phase?
11. Have you had any academic or training background that included addressing construction worker safety?
12. Are you aware of any design firms (besides your firm, if applicable) that address construction worker safety in the design phase? Give names.
13. Did you or your company participate in designing or supervising construction projects that suffered from accident during construction or maintenance phase?
14. Give detail description related to how each accident had occurred.

15. Can you suggest design modification that could prevent or minimize the severity of the accident?

Part two (design for construction safety suggestions):

This section aims to solicit ideas or recommendation that when addressed by designers could improve construction worker safety.

The interviewer is required to give ideas and recommendations that could be considered by designers to enhance construction worker safety for the topics and subtopics listed below. Give rationale for each proposed idea or recommendation. Also rationale for each idea is required.

1. Schematic design phase (for the four engineering specializations)
    a) Project location.
    b) Lay out of project.
    c) Falling from roofs, floor openings.
    d) Contractor storages.
    e) Workers utilities.
    f) Material access.
    g) Piping and electrical controls.
    h) Over head power lines.
    i) Adjacent existing buildings.
    j) Soil investigation.
2. Design development phase (Architectural requirement)
    a) Stairs.
    b) Falling from roofs, floor openings and atrium.
    c) Floor lay out and facade configuration.
    d) Selection of materials.

e) Finishes (paints, tiles).

f) Ducts.

3. Design development phase (Civil Engineering requirements)

a) Structural systems for more than five stories.

b) Location of shear walls.

c) Moment resisting frames.

d) Buildings too close to existing ones.

e) Beams.

f) Slabs.

g) Stairs.

h) Reinforcement.

i) Foundation.

j) Falling from roofs, floor openings.

k) Soil investigation.

4. Design development phase (Electrical Engineering requirements)

a) Stairs.

b) Sweeps.

c) Location of light system.

d) Electrical installation.

e) External lighting.

f) Selection of materials.

g) Underground utilities.

h) Main distribution board.

5. Design development phase (Mechanical Engineering requirements)

a) Selection of materials.

b) Trenches.

c) HVAC equipment.

d) Sanitary installations.

e) Generators and water pumps.

f) Underground utilities.

6. Construction documentation phase (communication between designers and contractors for the four engineering specializations)

   a) The required information on contract drawings and technical specifications.

   b) Falls from height.

7. Work schedule phase:

   a) Sequence of activities.

   b) Over time.

   c) Night work.

   d) Falling from roofs, floor openings and atrium.

   e) Stairs.

   f) Paint.

   g) Welding.

   h) Piles.

   i) Concrete tests.

   j) Housekeeping.

   k) Partitioning.

   l) Electrical system.

   m) Mechanical system.

8. Do you want to add design suggestions that could prevent or minimize the severity of accidents in construction of buildings?

Appendix B

Cover Page

Dear Sir:

This questionnaire is a follow up of the open interview that was held with you.

The questionnaire contains design for safety suggestions categorized according to schematic phase, design development phase, construction documentation phase and work schedule phase.

For each design for safety suggestion:

- Please insert√ opposite to the suitable degree of agreement within 5- point likert scale.
- Please insert√ to support classifying suggestions as either regulation or recommendation.
- Feel free to add any note.

The results of the study will be of great help to the construction industry. The information provided by you will be used for the scientific research purpose only without mentioning your name or the name of your organization.

We appreciate your cooperation in answering this questionnaire.

Thank you for your valuable time.

Best regards.

Yours Sincerely,

Eng. Asmahan Jubeh

Architectural Engineering Questionnaire

Number	Design For Safety suggestion For Architectural Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
Schematic phase									
1	Provide storage places with enough capacity for contractor equipments and materials.								
2	Design the layout of project to ensure easy and safe access and regress of materials, equipments and personnel.								
3	Choose project location to be away from factories.								
4	Choose project location to be away from steep slopes.								
5	Place personnel protective equipments (PPE) as near as possible to the project entrance or in suitable place.								
6	Provide sufficient utilities for workers to prevent the ability of using the job site.								
Design development phase									
1	Design height of parapets and guard rails to be 1.1m minimum above the roof, floor or platform level.								
2	Design height of window sills to be 1.1m minimum above the roof, floor or platform level.								
3	In each stair riser, design tread and riser dimensions to be uniform from top to bottom.								
4	Provide permanent guardrails around stairs and atrium.								
5	Design skylights to be domed with elevated beams around them rather than flat ones.								
6	Design floor and roof openings to be located away from readily accessed areas on the construction site.								
7	Specify non-slip tiles and avoid polishing tiles with slip material such as wax.								
8	When choosing oil-based paints in places that need to be cleaned frequently, design to paint about 1.5 meters with oil-based paint and the remaining walls with water-based paint.								

Number	Design For Safety suggestion For Architectural Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
9	Design corridors dimensions and doors height and swing to ensure easy access and regress of long members and components.								
10	Design height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.								
11	Design buildings with typical floor layout whenever possible.								
12	Minimize the number of offsets in the building plan. Design offsets to have a consistent size and as large as possible								
13	Choose materials that are durable.								
14	Choose materials that are safe to handle.								
15	Choose materials that are non combustible.								
16	Select elements such as windows, tiles etc. that are of consistent size, light weight, and easy to handle								
17	Avoid using hazardous materials or operations that emit hazardous materials in confined areas.								
18	In mass construction, use modules to have length of 1.2 meters or multiple.								
19	Design openings that are used to provide light and ventilation to be located at the exterior edges of buildings rather than inside the buildings.								
20	Design horizontal distance between two successive stair risers (stair nose) to be as small as possible. choose stair case location to have natural lighting and adequate ventilation								
21	Design ducts (floor openings) that are used for mechanical or electrical installations to have width as small as possible and enough length.								
22	Design the door of the generator room to swing outward.								

Number	Design For Safety suggestion For Architectural Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
Construction documentation phase (communication between designers and contractors)									
1	Include the name, address, and telephone number of nearest local utility institutions such as hospitals, health centres, fire fighting and water supply locations on the drawings. Specify the involved personnel that should be communicated in case of emergency.								
2	Provide warning signs and notes colored in red on the drawings and technical specifications that incorporate hazards on workers.								
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.								
Work schedule phase									
1	Schedule activities so that no welding activity is performed while painting.								
2	When designing an atrium, floor edge or a stair in a building, schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.								
3	Schedule sidewalks, ramps and roadways around project to be constructed as early as possible.								
4	Whenever possible consider while scheduling the ability to decrease duration of subjecting workers to oil-base paint.								

Civil Engineering Questionnaire

Number	Design For Safety suggestion For Civil Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
Schematic phase									
1	Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.								
2	Design foundations to be positioned internally away from the exterior perimeter for proposed building if too close to existing ones.								
Design development phase									
1	When project site require shoring system, it should be considered in the design phase taking into account environmental conditions.								
2	Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.								
3	Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.								
4	Design scaffolding tie-off points into the building facade to prevent falls during construction and maintenance.								
5	Select building frame system in conjunction with shear walls rather than moment-resisting frame system.								
6	Place shear walls symmetrically in both directions, far away from the centre of the building but away from the exterior perimeter a distance that enable workers to construct shear walls.								
7	When workers are required to walk on reinforcement bars, design steel bars as a grid pattern with dimensions of 25cm ×25cm maximum.								
8	Design members to be safe during construction and maintenance even if they are non structural members.								
9	Design temporary guard rails around stairs and floor edges.								

Number	Design For Safety suggestion For Civil Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
10	Design if possible to prefabricate components on ground or in factories where working environment is controlled.								
11	Choose quieter methods of construction.								
12	Design the shuttering of slab to be continuous across the opening to prevent falling hazard and to facilitate working around it. Design a platform with chamfered edges to cover the opening.								
13	Select light weight materials such as hollow concrete blocks rather than solid ones.								
14	Specify the use of small size concrete cubes of 100×100×100 mm3 instead of standard cylinder for testing concrete strength.								
15	Design the scaffolding system and specify the features of ground that should be prepared to it safely.								
16	Choose straight bars reinforcement rather than the bend one.								
17	Design slab shuttering to be minimum 0.5 meters over hanged from all direction with guard rails.								
18	Select small reinforcement diameters rather than larger ones.								
Construction documentation phase (communication between designers and contractors)									
1	On the project drawings and technical specifications identify beams (perimeter beams and beams around floor openings) that designed to support lifelines.								
2	Provide warning signs and notes colored in red on the drawings and technical specifications to alert workers to places of hazards such as excavation location and the required shoring system.								
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.								
Work schedule phase									

Number	Design For Safety suggestion For Civil Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
1	Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor.								
2	Before the removal of the steel props supporting slabs, satisfactory results of concrete cube tests were required.								
3	Schedule temporary guard rails with colored band to be placed around edges as soon as possible.								
4	Design work schedule to minimize the need for overtime.								
5	Design work schedule to minimize the need for night work.								
6	The work schedule should contain daily housekeeping that keep site tidy all time.								
7	Schedule to start partitioning activity as soon as possible especially at edges and floor openings.								
8	Schedule the sequence of pile excavation to be done in a way that ensure safe site access and regress for personnel, material and equipment all times.								
9	Before starting any activity on slabs that are supported by forms check the capability of the form system to sustain loads caused by these activities.								
10	Avoid scheduling pouring concrete activity to be simultaneous with compacting by vibration activity nearby the project.								
11	In case of having expansion joint, schedule activities in such a way to have no more than one story difference in height between the two parts of expansion joint.								
12	Avoid scheduling any activity related to work around the project while working on facade or lifting materials.								
13	Schedule to avoid congestion of workers within limited area.								

Electrical Engineering Questionnaire

Number	Design for safety suggestions for Electrical Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
Schematic phase									
1	Choose project location to be away from overhead power lines.								
2	Choose the location of contractor storage areas to be safe away from any power lines.								
3	Check the existence of exposed electrical wires in the nearby existing buildings around the site.								
Design development phase									
1	Using wall mounted lighting instead of ceiling mounted when possible.								
2	Specify fiberglass sweeps for electrical conduit instead of steel sweeps.								
3	Design temporary electrical system that can be installed and used safely during construction.								
4	Design to place external lighting on places such as roof parapets that facilitate their installation and maintenance in safe way.								
5	When designing stairs, adequate lighting should be provided during construction and maintenance.								
6	Use consistent standards for power sources to identify them. Design the main distribution board to have places for single line diagrams showing as built installations. Choose durable labels on the main electrical distribution board.								
7	In case of ceiling lighting, specify light fittings that can be lowered when changing lamp or tube.								
8	In mass construction avoid chasing walls by designing blocks to have ducts where electrical wires could be placed.								
9	Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.								

Number	Design For Safety suggestion For Electrical Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
10	In places where electrical installations require chasing, place material that could be chased easily.								
11	Increase electrical design load to take in account the rapid technological advancement that invent new electrical equipments which could over load the electrical installation.								
12	Choose durable material for electrical installations.								
13	Design the riser for electrical installation to be away from mechanical installation riser.								
14	Avoid placing the main electrical distribution board under baths.								
15	Choose the place of the main electrical distribution board to be away from heavy movement such as stairs in schools or in confined spaces and at suitable height.								
16	For underground electrical installations provide a warning tape to provide warning signal for workers who are digging in the area.								
Construction documentation phase (communication between designers and contractors)									
1	On the project drawings and technical specifications, identify the location of existing electrical utilities such as overhead power lines indicating the level of certainty and source of information.								
2	Provide warning signs and notes colored in red on the drawings and technical specifications.								
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.								
Work schedule phase									
1	After plastering activity check electrical conduits to ensure construction activities such as plastering did not affect the conduits or cause any plugging.								

Mechanical Engineering Questionnaire

Number	Design For Safety suggestion For Mechanical Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
Schematic phase									
1	Locate underground utilities in easily accessible places. Consider topographical survey within the criteria used to determine the location of these utilities.								
2	Position underground utilities away from workers passageways but in places easy to construct and maintain.								
3	Place the underground utilities away from existing structures.								
Design development phase									
1	Design to have hand excavation around existing underground utilities								
2	Design sanitary installations to be placed in a way that facilitates their installation and maintenance.								
3	Locate all equipments such as HVAC equipment and water tanks away from a roof edges.								
4	Place split unit (condenser) on roofs, ground or balconies.								
5	Choose durable material for mechanical installations.								
6	Choose light weight mechanical installations.								
7	Design for placing water pump a way from electrical generator.								
Construction documentation phase (communication between designers and contractors)									
1	On the project drawings and technical specifications, identify the location and size of existing utilities including underground lines indicating the level of certainty and source of information.								

Number	Design For Safety suggestion For Mechanical Engineering	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	Regulation	Recommendation	Notes
2	Warning symbols should be provided on drawings and technical specifications reminding workers that oxygen welding is not permitted in confined places.								
3	In the general condition of the contract documents designers and construction supervisors should provide efficient and timely response to any contractor query for information with its safety requirement.								
Work schedule phase									
1	After completing the mechanical installations activity conduct test on these installations before performing new activities such as tiling.								

Appendix C

Case Study One (Hall Sport Project)

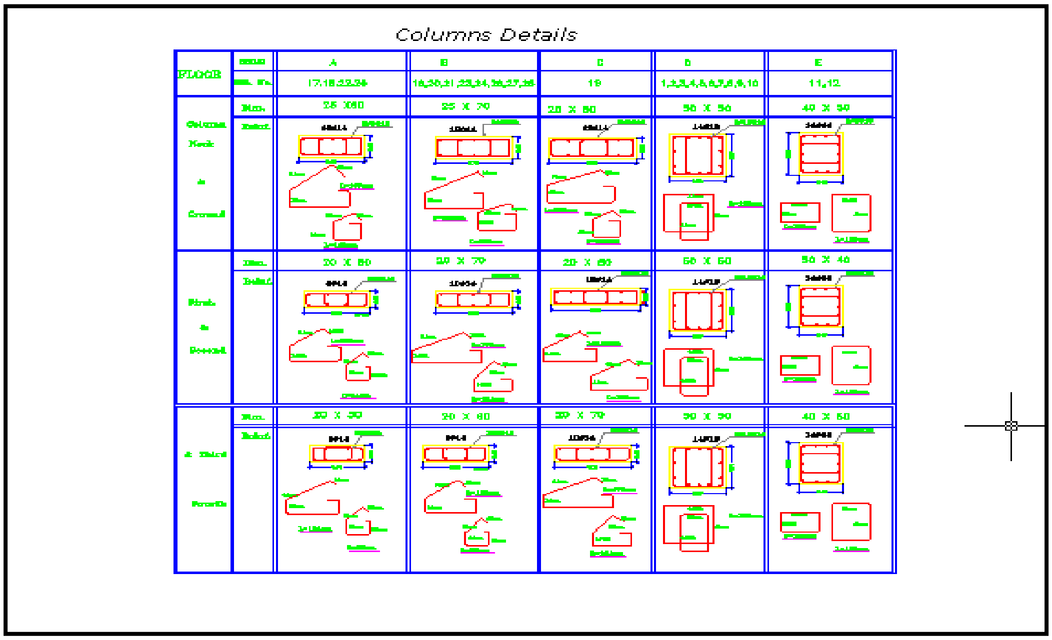

Figure C1. 1: Columns details

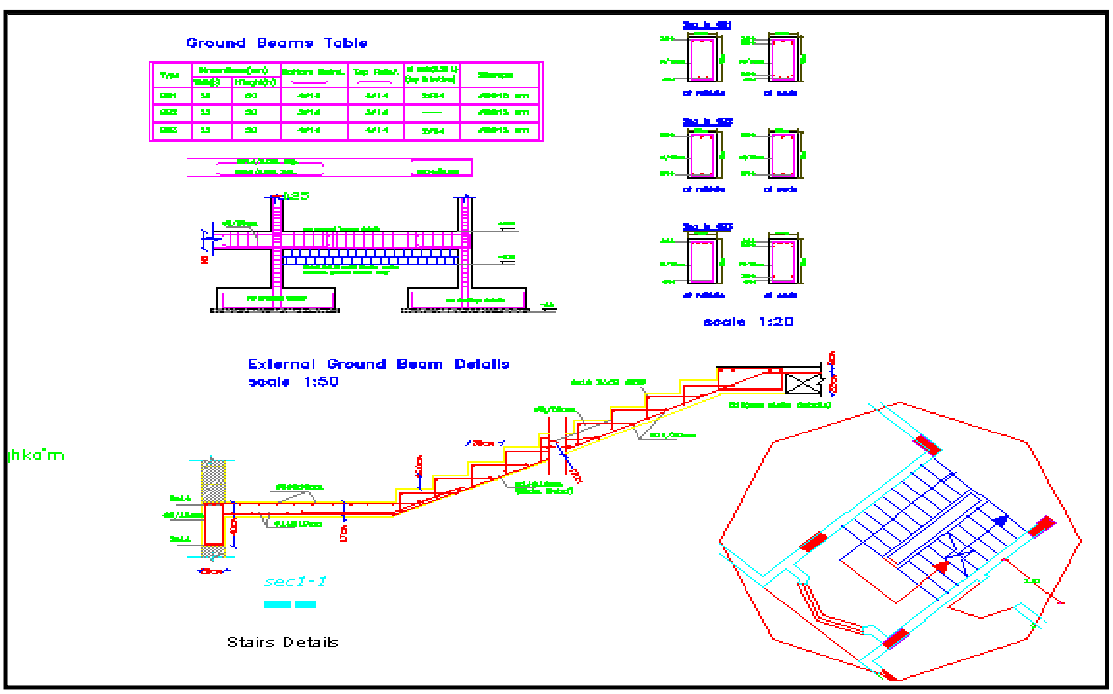

Figure C1.2: Ground beams and staircase reinforcement

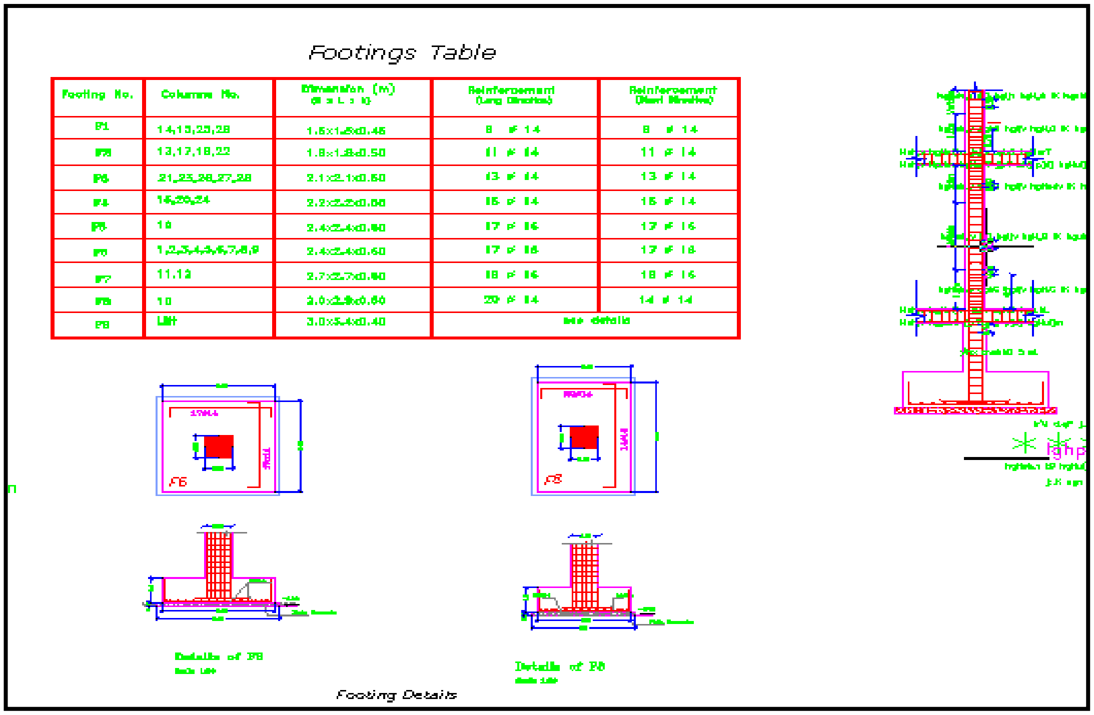

Figure C1. 3: Footings details

Case Study 2 (Hospital project)

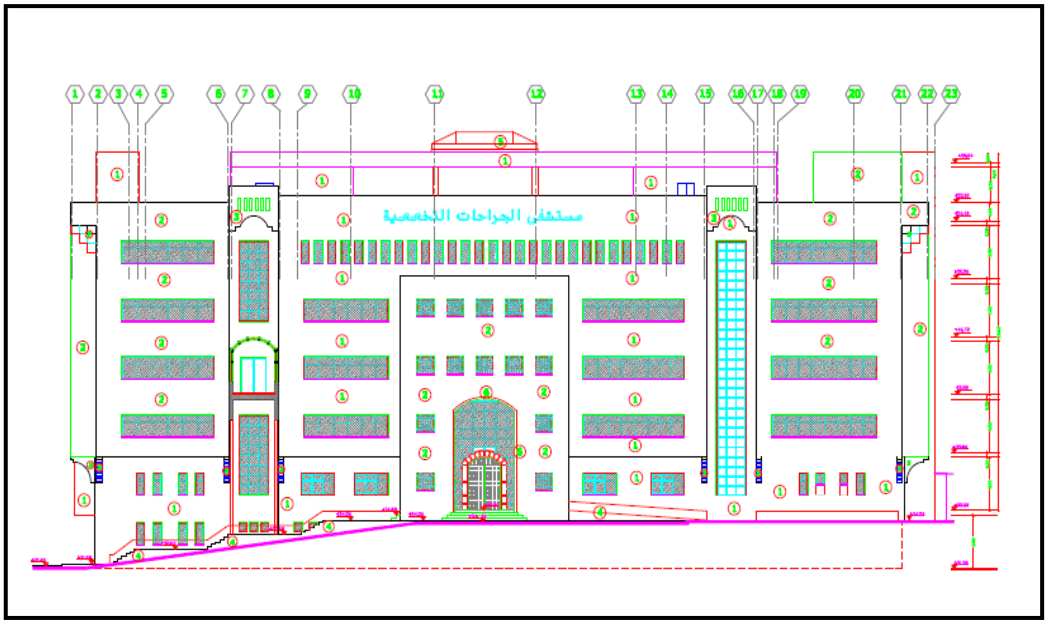

Figure C2. 1: Southern elevation

Figure C2. 2: East elevation

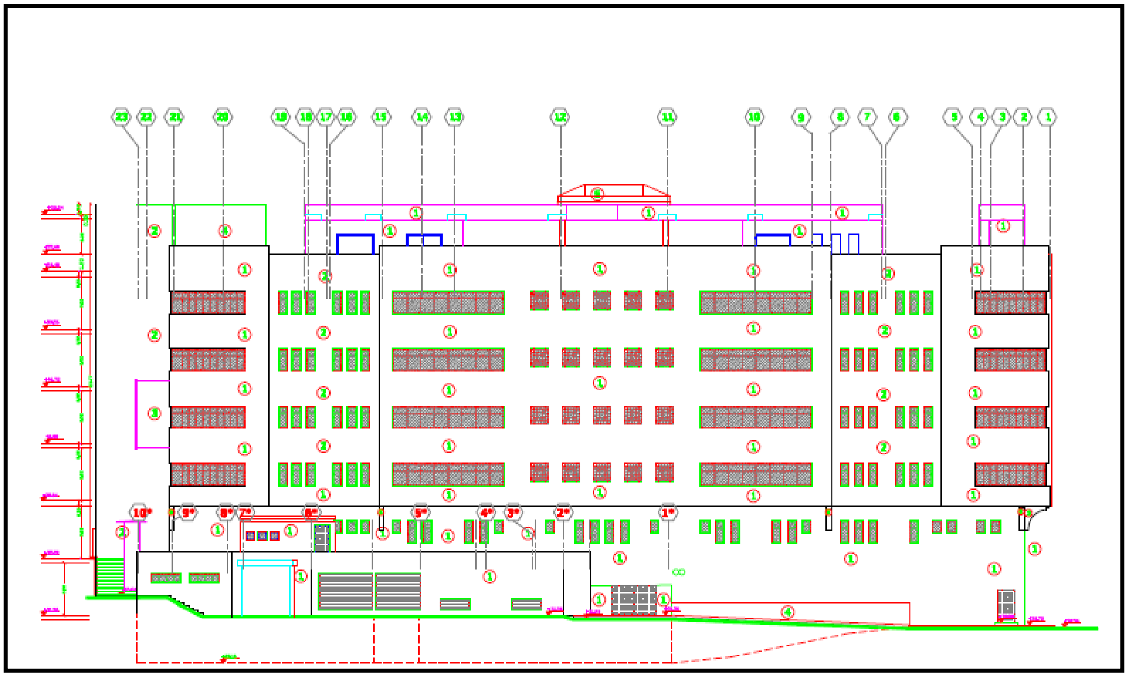

Figure C2. 3: Northern elevation

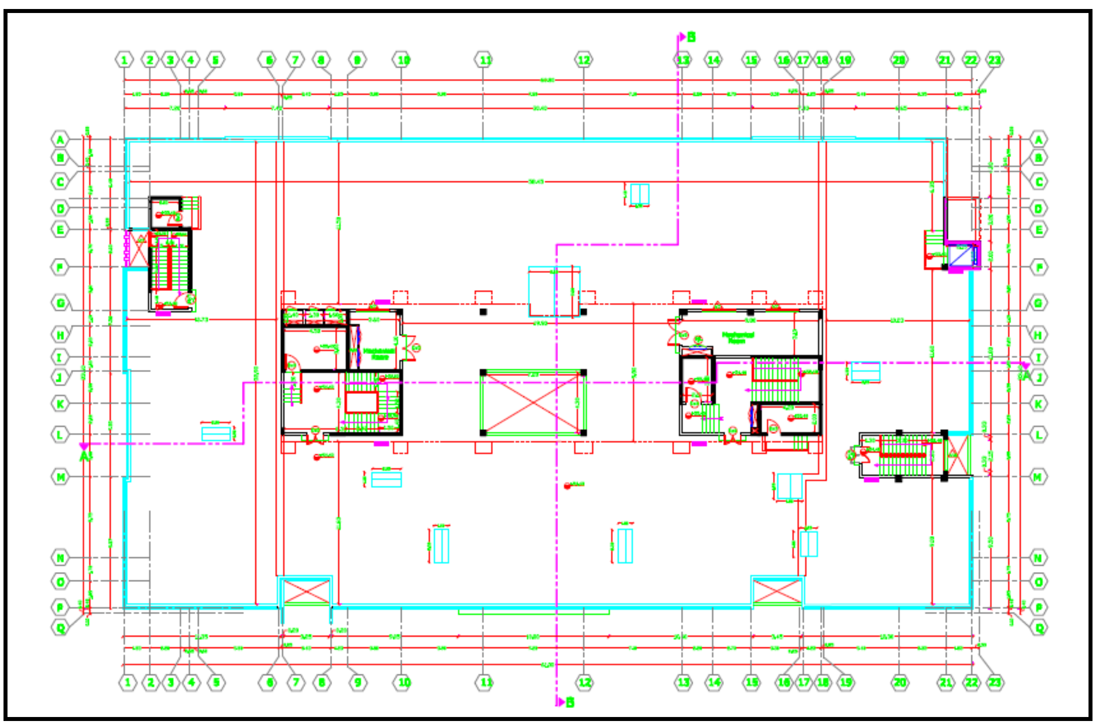

Figure C2. 4: Roof plan floor

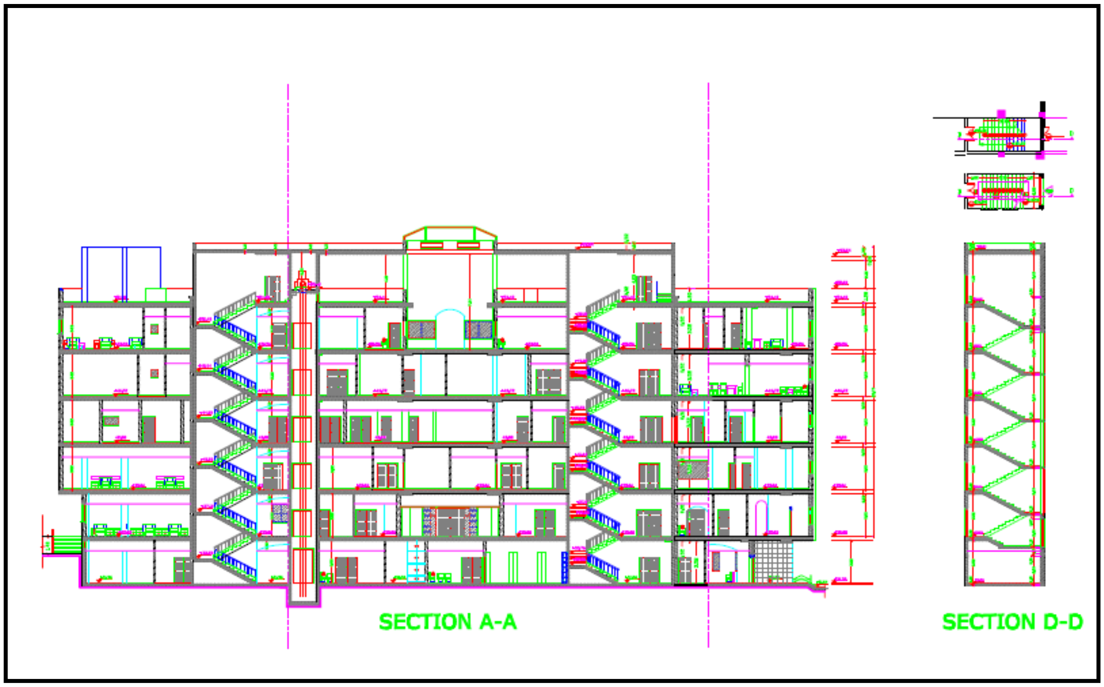

Figure C2. 5: Section A.A

Case Study 3 (School project)

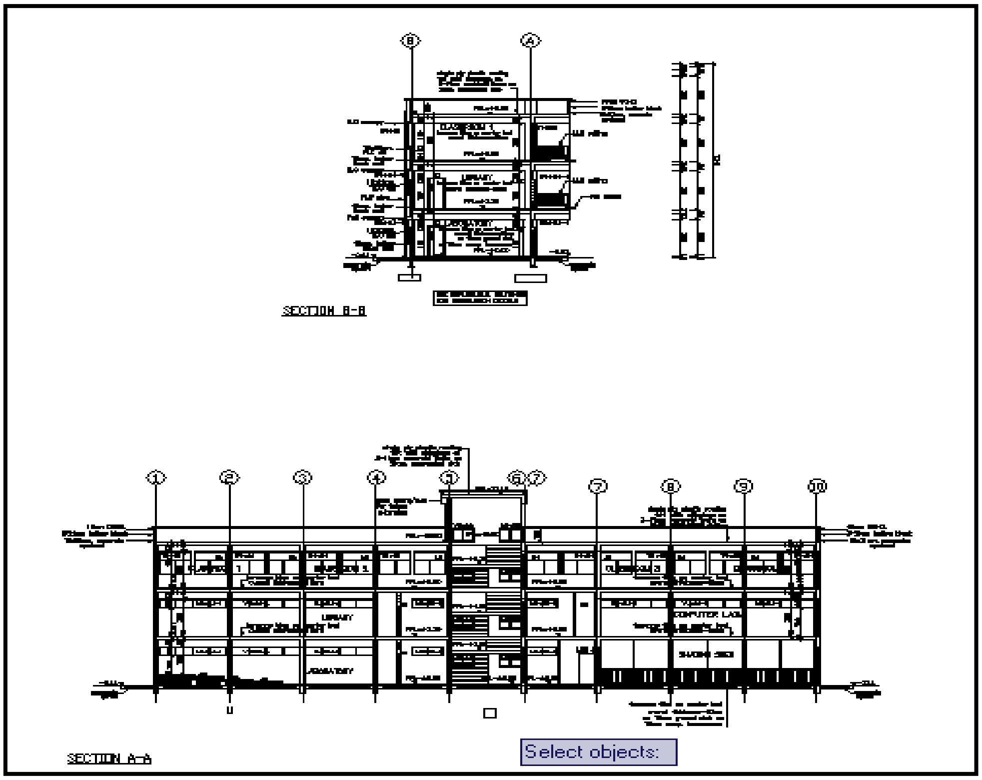

Figure C3. 1: Section D.D

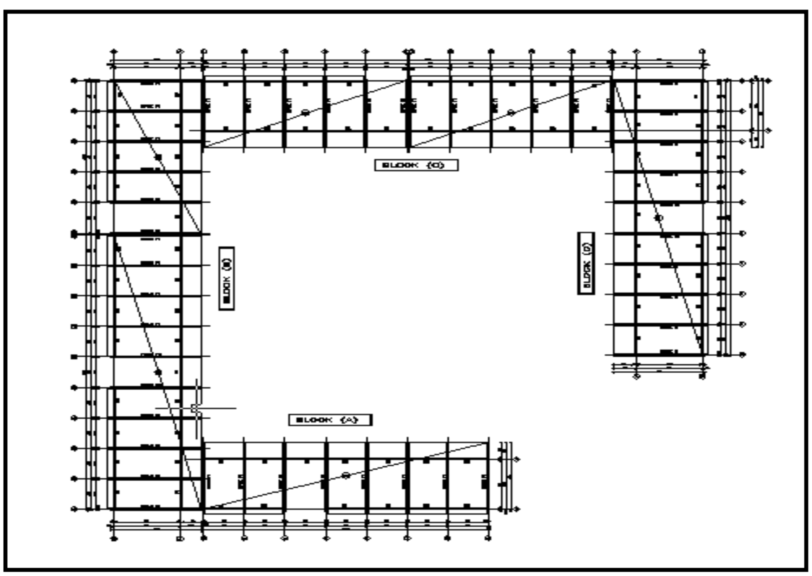

Figure C3. 2: General arrangement of structural elements for ground floor

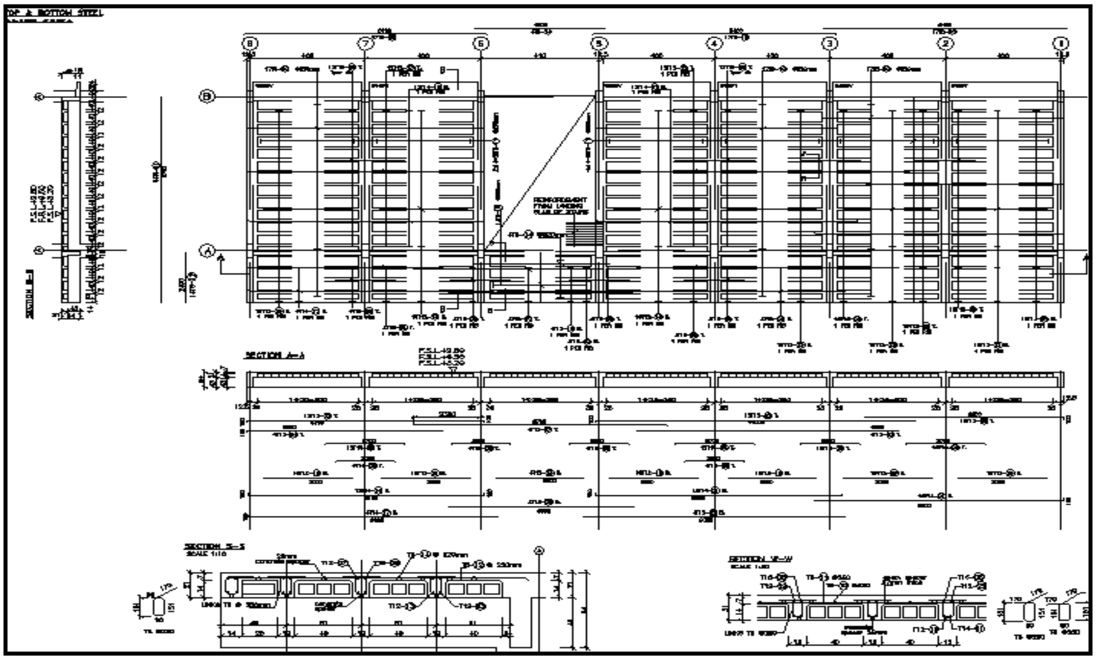

Figure C3. 3: Slab reinforcement

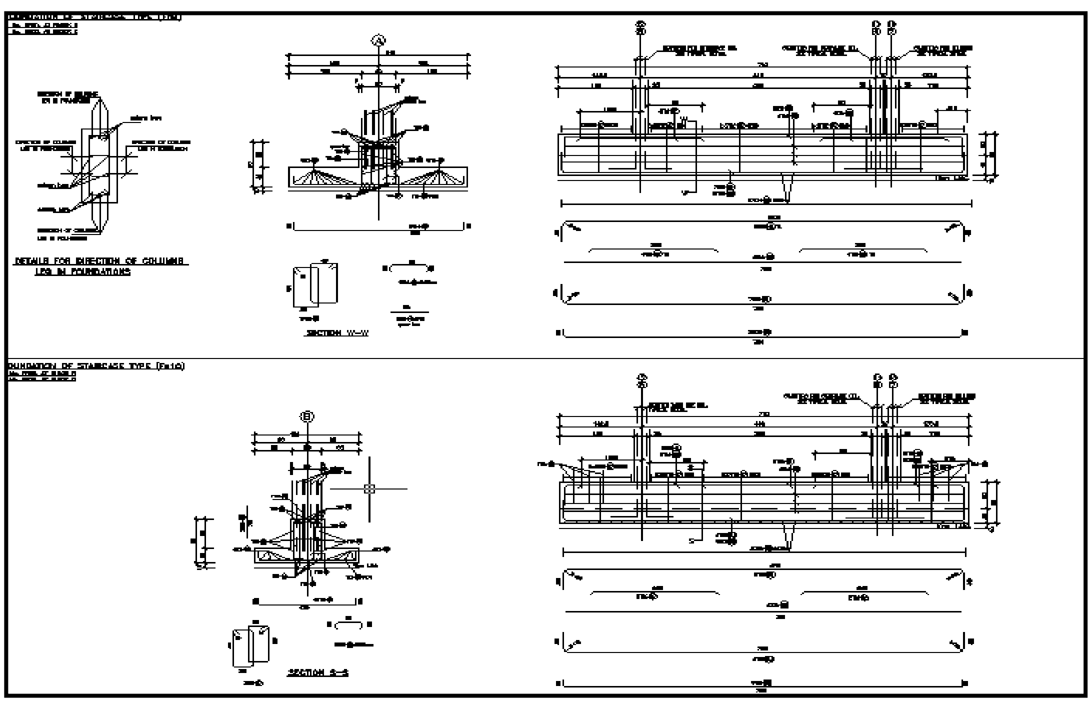

Figure C3. 4: Reinforcement details of foundations

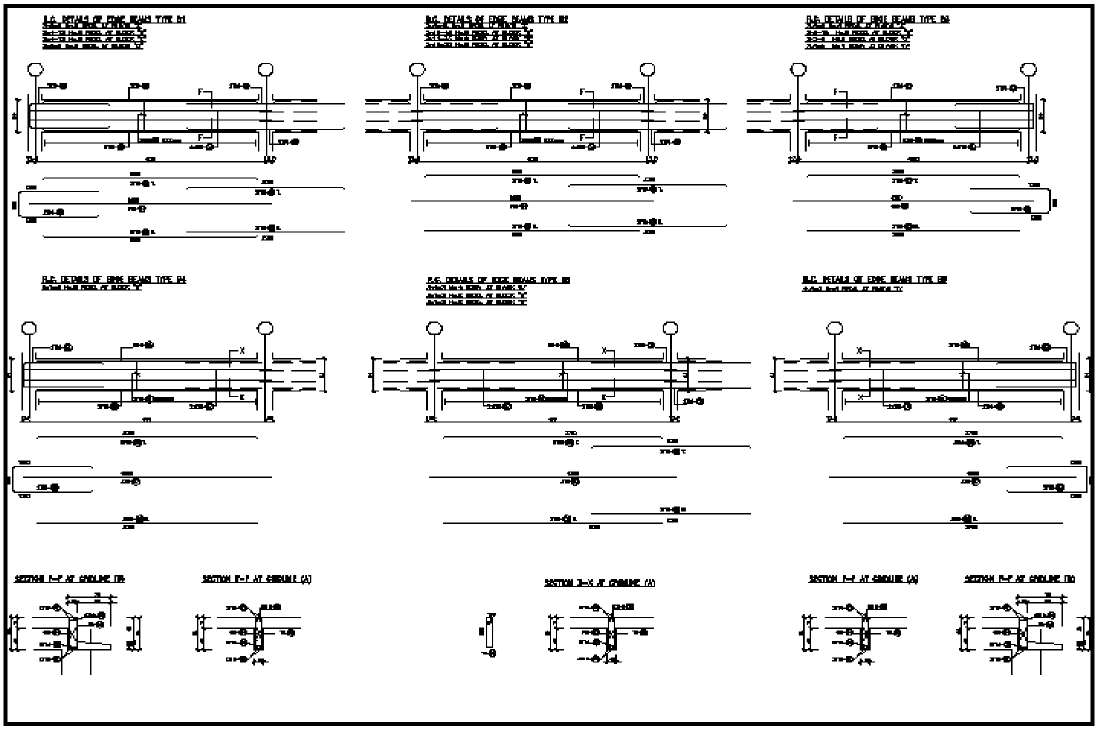

Figure C3. 5: Reinforcement details of edge beams

<u>**Case Study 4 (Trade Center Project)**</u>

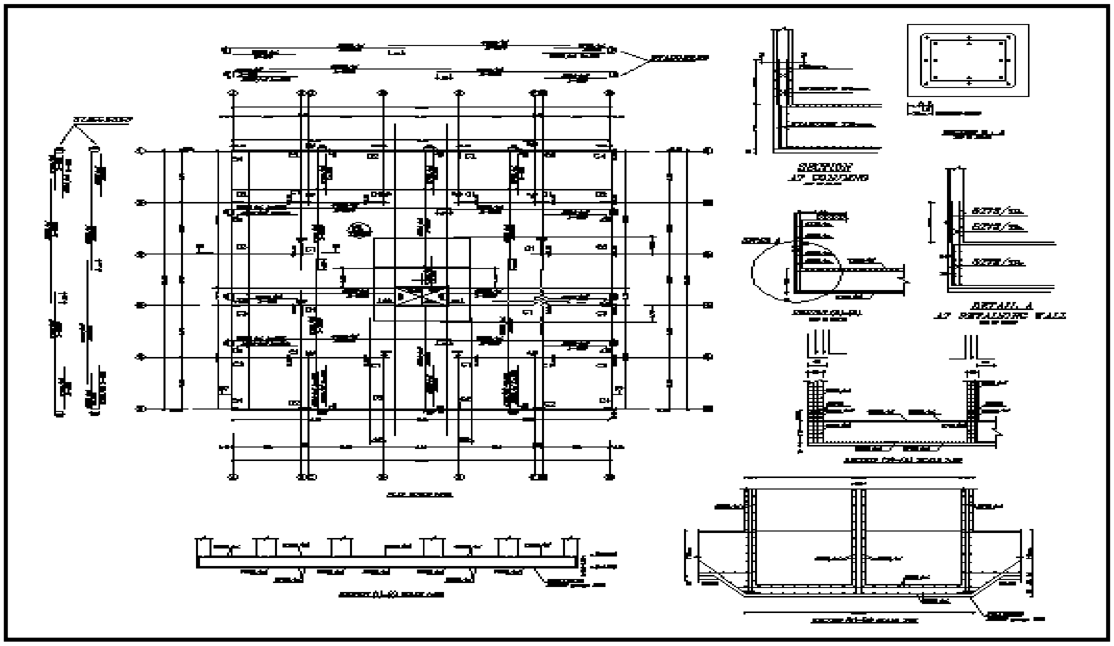

Figure C4. 1: Raft details

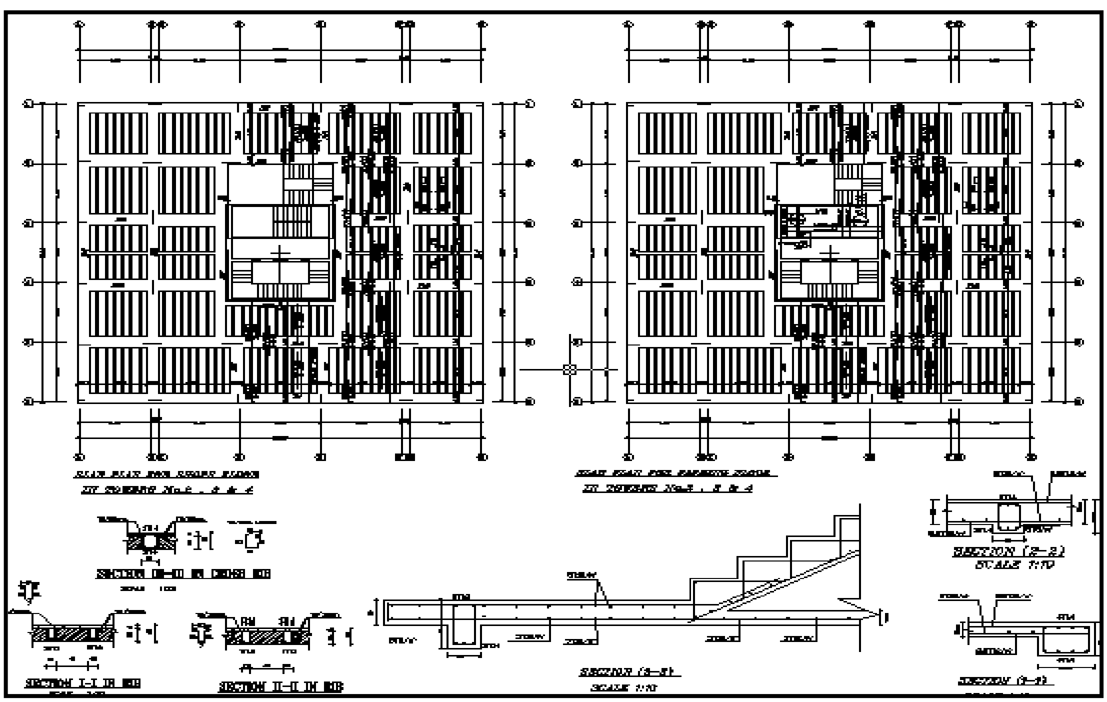

Figure C4. 2: Slab Plan for shops and parking

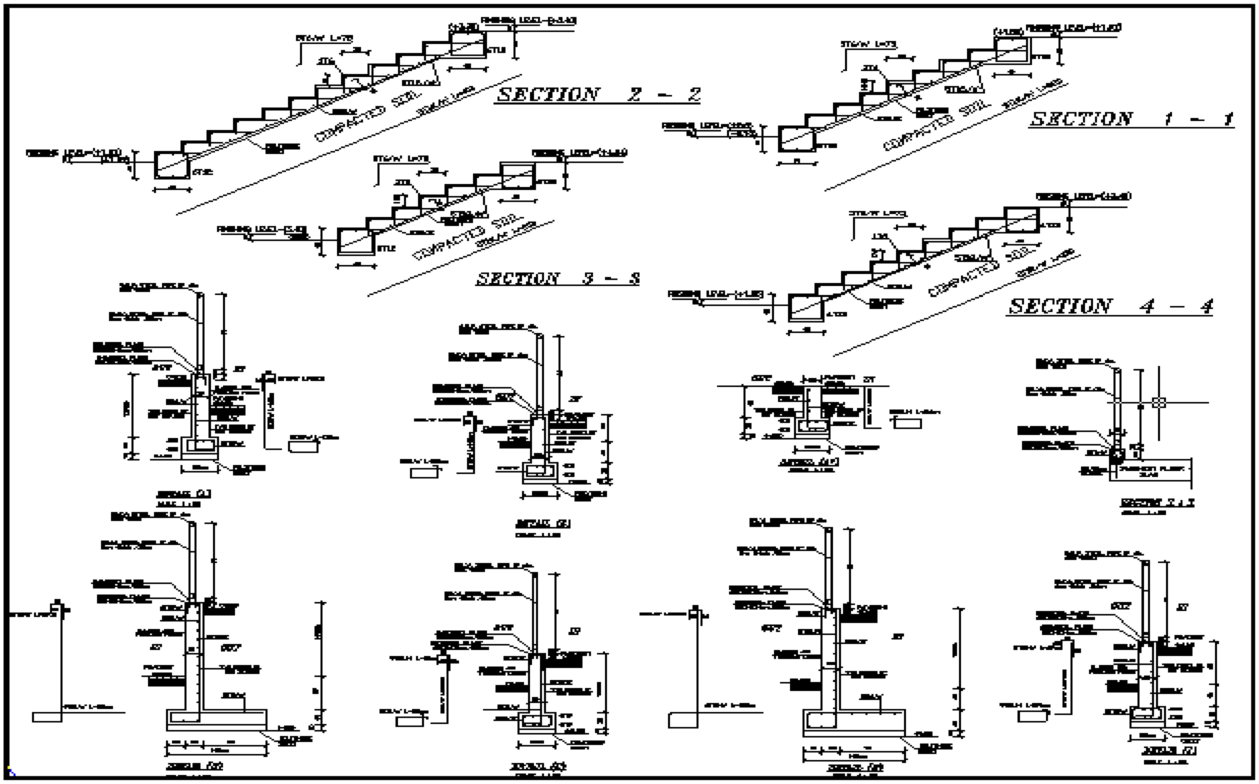

Figure C4. 3: Steps and Retaining walls details

<u>**Case Study 5 (Bank project)**</u>

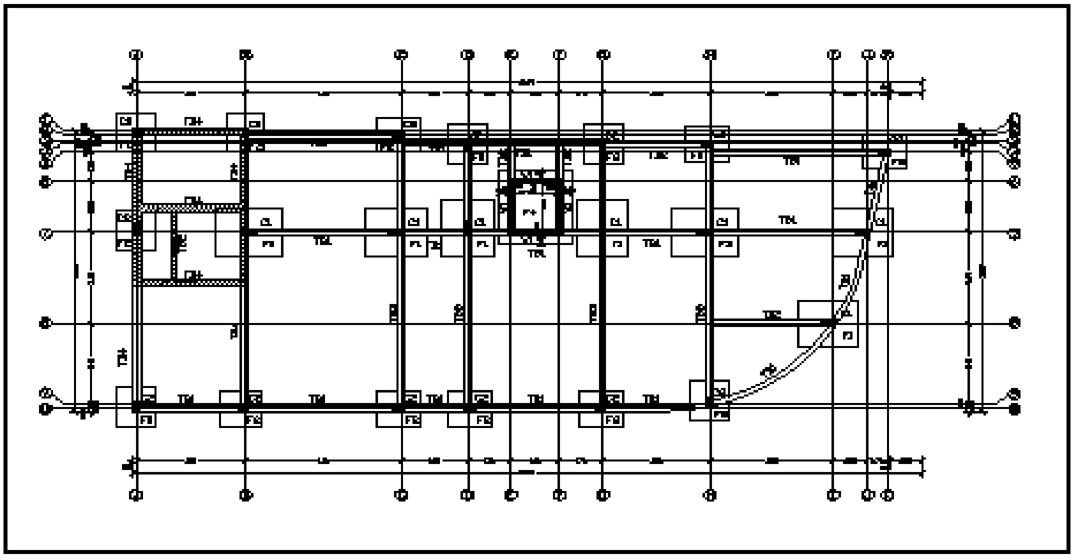

Figure C5. 1: Foundation details

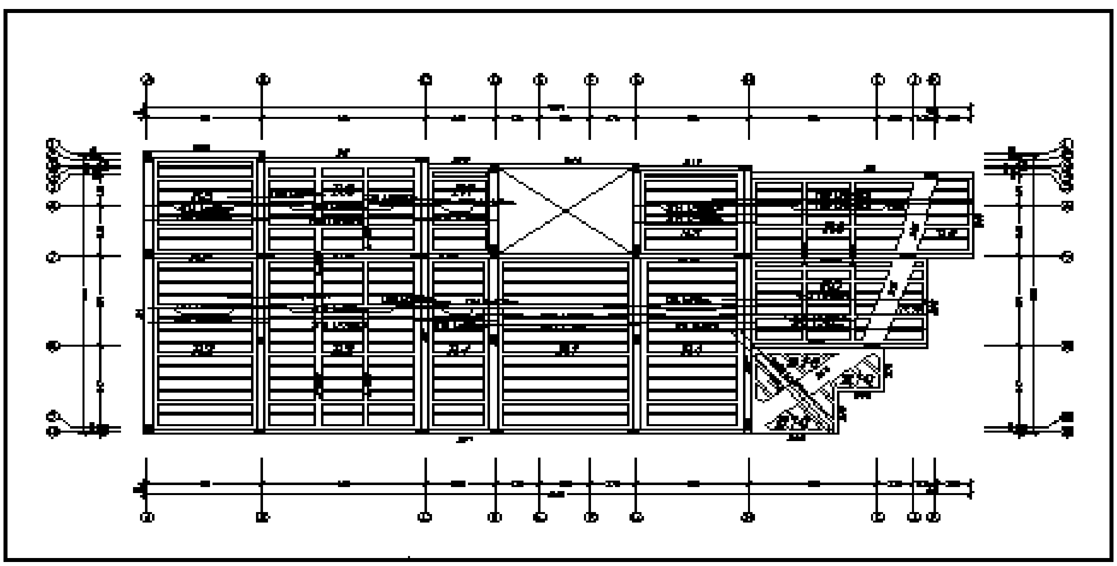

Figure C5. 2: First Floor Slab

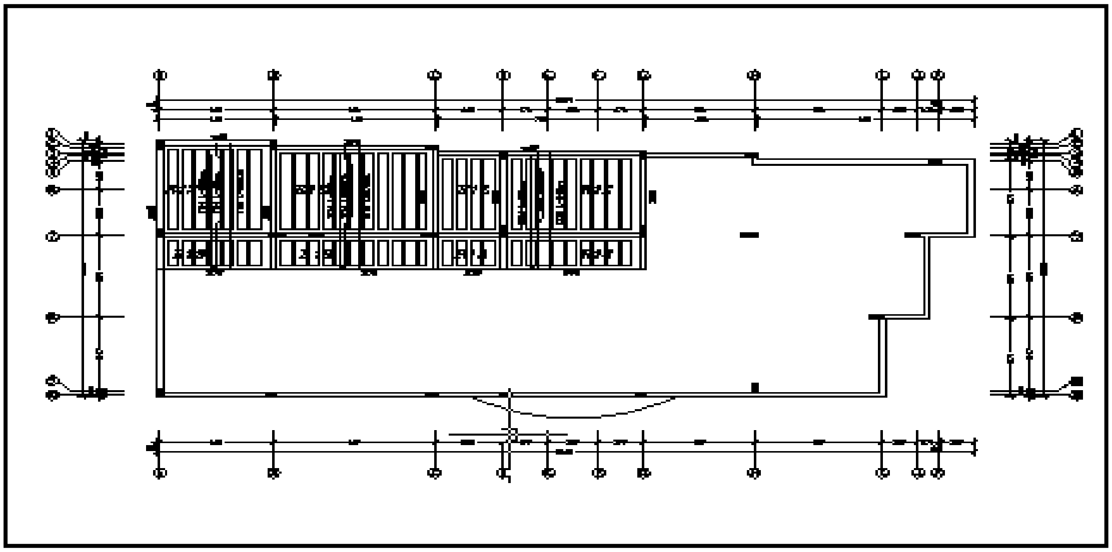

Figure C5. 3: Roof Floor Slab

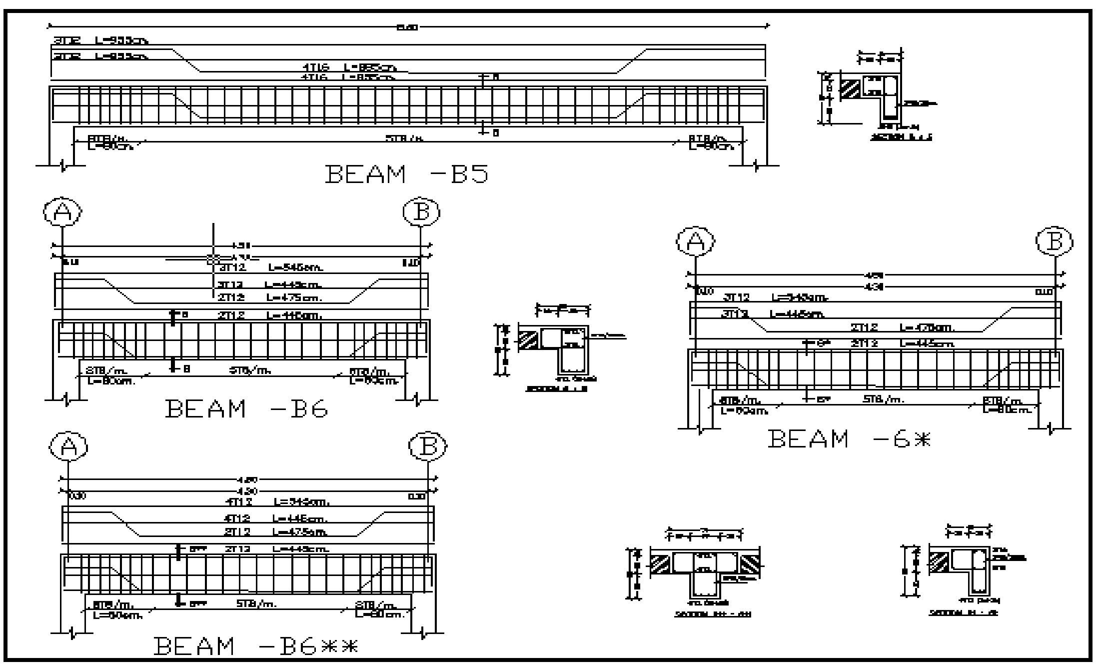

Figure C5. 4: Slabs Beams Details