ASSESSMENT OF THE CONSTRUCTION INDUSTRY PRACTICE IN PALESTINE BASED ON THE DESIGN FOR CONSTRUCTION SAFETY (DFCS) CONCEPT

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ABSTRACT

Construction industry is characterized by poor safety performance subjecting workers at sites to great risks. Safety risks can be minimized, not only by improving safety measures at site but also by considering safety issues throughout the project lifecycle; from the schematic design up to the operation and maintenance phases. Design for Construction Safety (DfCS) should be considered a main criterion in the design of engineering projects. In the DfCS most hazards would be designed out or minimized before reaching the construction phase. In Palestine, the construction industry has many safety accidents and risks caused by inadequate considerations to safety requirements in the early stages of the project lifecycle. The main aim of the undertaken research is to enhance the safety performance of the construction industry in Palestine. The characteristics of the construction industry in Palestine were assessed based on the DfCS concept. The positive characteristics are to be strengthened while the negative ones should be avoided, or at least proactive measures should be taken to minimize their effects. The DfCS concept was applied to five case study buildings already constructed in Gaza Strip, Palestine. The results from the case studies determined the safety risks in need for improvements; the main of which included: (1) Designing the exterior and interior building edges in such a way to ensure worker protection during the construction and maintenance phases, (2) Designing the formworks required for architecture, civil, mechanical and electrical works and (3) Selection of noncombustible durable building materials which can be also handled safely. In general, the results from the case studies highlighted the possibility and importance of considering the DfCS concept in the design of engineering projects in Palestine. For this purpose, it is recommended to develop a legal status to enforce the implementation of the DfCS concept. The awareness of designers should be raised to become cognizant that their design decisions can directly affect worker safety. The communication between designers and contractors should be enhanced to benefit from the lessons learned during construction.

KEYWORDS

Construction Industry, Worker Safety, DfCS, Design Phases.

INTRODUCTION

Construction industry has one of the highest accident incidence rates and the most demanding physical working conditions compared to other industries [1]. A lot of research was conducted and great efforts were made to improve construction worker safety; however statistics indicate that construction industry is still facing a safety problem [2]. The construction accident rate in Gaza Strip Palestine is nearly 20% of all industrial injuries and is higher than the other industry accident rates [3].

Since the accident rate in construction industry around the word including Palestine is higher than the other sectors, it is of paramount importance to address the DfCS concept. 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[4]. 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. Construction workers could benefit significantly from addressing DfCS concept since hazards would be designed out or minimized before reaching the construction phase. The most effective way for improving safety performance is to prevent accidents before they occur. Considering safety and ease of construction in the design phase would enhance safety of construction workers at site. It was found that design errors are significant factors in accidents [5]. Weak designs cannot be fully compensated in the construction phase.

Studies were conducted to quantitatively measure the magnitude of the relationship between design and construction safety [6]. It was found that 42% of reviewed fatality cases were linked to DfCS concept and that if the design for safety concept was considered; the associated risks could be reduced or eliminated [6]. Expert panel reviewed the fatality cases that were linked to DfCS concept and found that 71% of the fatality cases were linked to the DfCS principle [6].

SAFETY IN THE CONSTRUCTION INDUSTRY IN PALESTINE

The construction industry contributes 6% of gross domestic product (GDP) of all industries in West Bank and Gaza Strip [7]. The construction workers in Gaza Strip constitute 4% of the economic force. The accident rate in construction industry accounts for nearly 20% of all industrial injuries. Fatalities in construction industry constitute one third of all industrial fatalities. It was concluded that health and safety are not widely recognized as inherent characteristics of construction projects in Gaza Strip [7]. While contractors consider health and safety a legal requirement that cost them money without return, designers consider safety out of their responsibility. Although many researches were conducted on safety performance in Gaza Strip, there are still shortages in safety applications [8]. Most of available studies were directed on safety issues related to the construction phase [3, 7]. Safety issues related to planning and design phases are not adequately addressed yet. The DfCS concept is almost unknown in Gaza Strip.

DfCS APPROACH FOR PALESTINE

Researchers proposed a number of DfCS suggestions that if considered by designers through design phase would enhance worker safety during construction and maintenance phases [9-12]. The DfCS suggestions covered 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 is noted that some DfCS suggestions could be applicable anywhere in the world; however other suggestions are applicable to specific regions depending on the local construction industry practice. For each region, new DfCS suggestions must be developed to suit that region. DfCS suggestions appropriate to Palestine construction industry were developed to cover the design phases, i.e. schematic phase, design development, construction documentation and work schedule phase [13]. The developed DfCS suggestions addressed the main four engineering specializations (architectural, civil, electrical and mechanical) as shown in Figure (1). In order to avoid repetition, the developed suggestions are discussed within a following case study section.

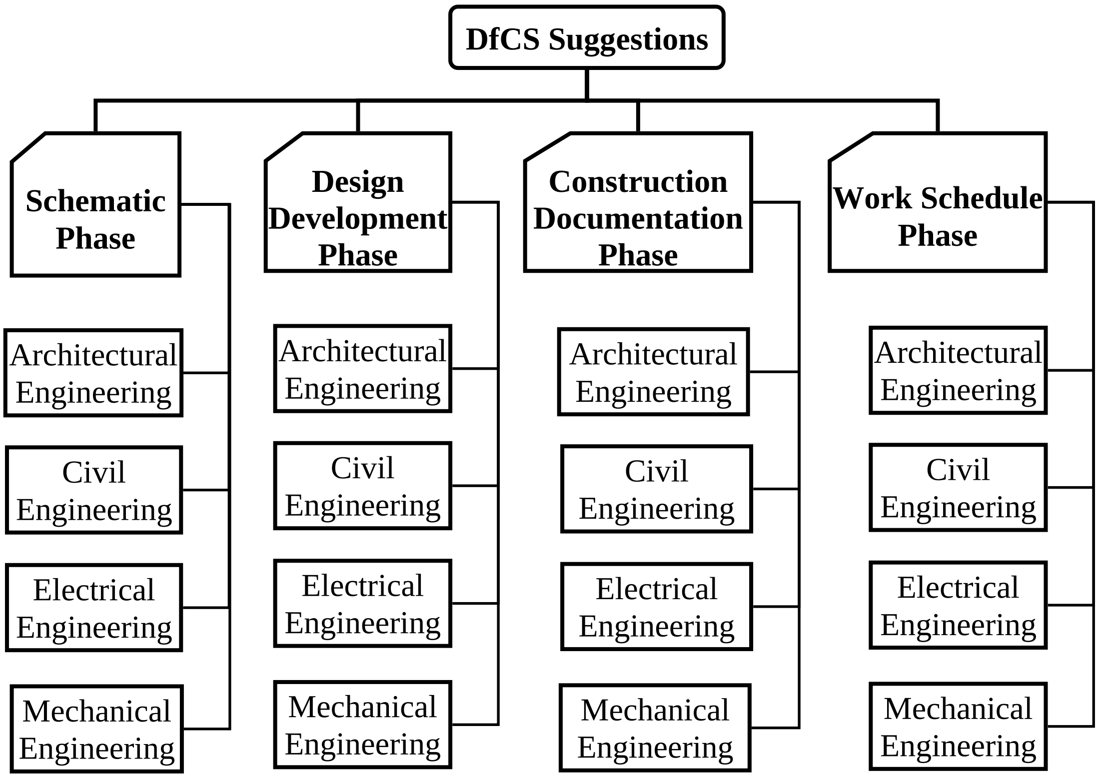


Figure (1): DfCS approach for Gaza Strip

ASSESSMENT OF THE DfCS IN DESIGN OF BUILDINGS IN PALESTINE

In order to assess the local practice of building construction industry in Palestine related to the DfCS approach, the approach was applied to five existing buildings in Gaza Strip as case studies. The ultimate aim was to enhance the construction worker safety by determining the safety risks in need for improvements during the design phase. The case study buildings were selected to represent all design and construction types used in Palestine; thus the assessment describes the local building industry.

Case Studies

Table (1) includes general information about each of the five case study buildings. The case studies covered different locations, functions, owners, structural systems and foundation systems. All case studies are design-bid-built since this is the prevailing practice in Palestine. The material used was reinforced concrete. The case study buildings were designed by consulting firms and executed by contractors classified in the “Palestinian Contractor Union” as “Class A” in the “Building Construction Branch”.

Table (1): General information about each case study

Description	Sport hall	Hospital	School	Trade Centre	Bank
Location	North of Gaza Strip	Gaza City	South of Gaza Strip	Gaza City	Middle of Gaza Strip
Owner	NGO	Government	Private	Public/ Private	Private
Documents	Drawings and specifications	Drawings	Drawings	Drawings	Drawings
Soil	Sand	Sand	Sand	Rubbish replaced by sand	Sand
Foundation	Isolated	Mat	Combined	Mat	Isolated
Structural system	Building and moment resisting frames	Building frame with shear walls	Moment resisting frame	Building frame with shear walls.	Building frame

The five buildings of the case studies shown in Figure (2) are:

(1) Sport hall of $230m^2$ one floor area consists of two parts of 3m and 6m height for the administration part and sport hall, respectively.

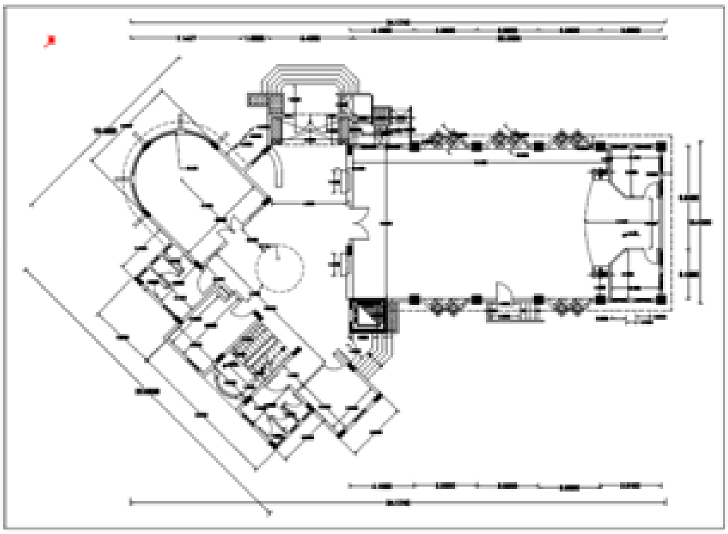
(2) Hospital of seven storey building that consists of one underground and six over ground floors. The first three floors are of $1800m^2$ each and the remaining floors have an area of $2000m^2$ each where the dimension of the floor increased by about *2m* in each direction. The height of the third slab from the ground in the extension area reached up to *8m*.

(3) School of three floor building of **U** shape. The area of the first floor is around $1100m^2$. The area of the upper floors was increased to $1400m^2$ each by increasing the dimension inside the U shape by about *1.9m*.

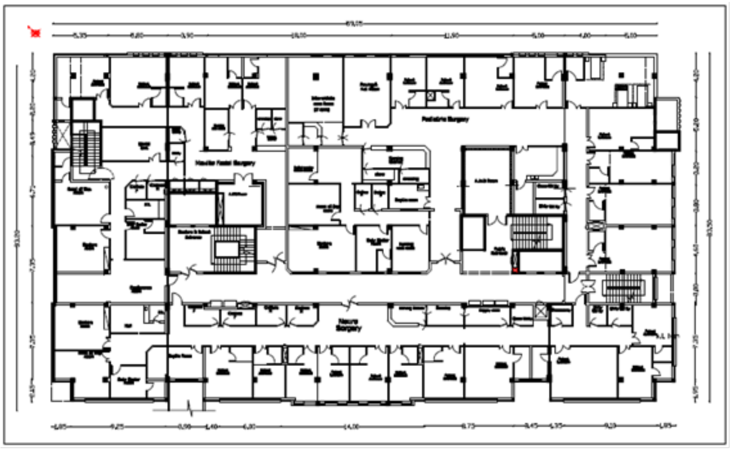
(4) Trade centre building of seventeen floors. The area of the first floor is $625m^2$. The area of the upper floors is $660\ m^2$.

(5) Bank building of three floors of $326m^2$, $340m^2$ and $107m^2$ areas starting from the ground floor to the roof, respectively.

Building 1



Building 2



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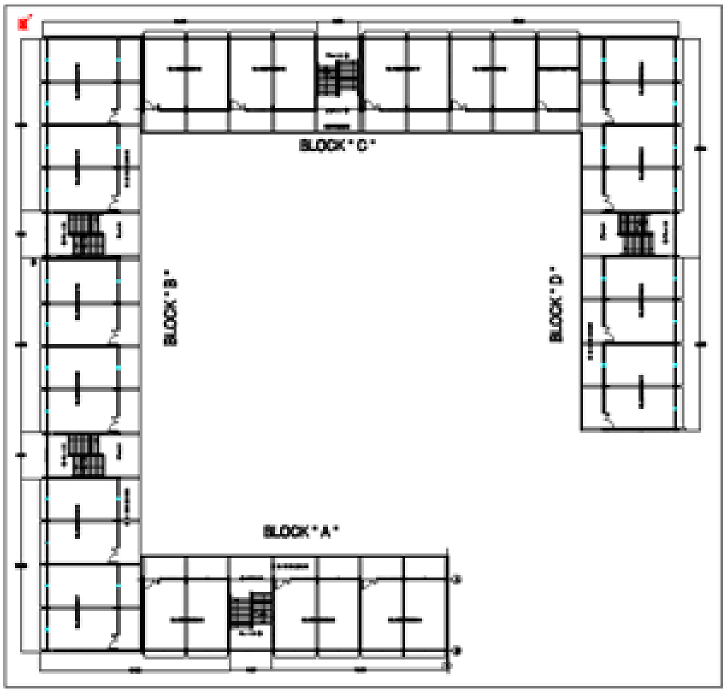

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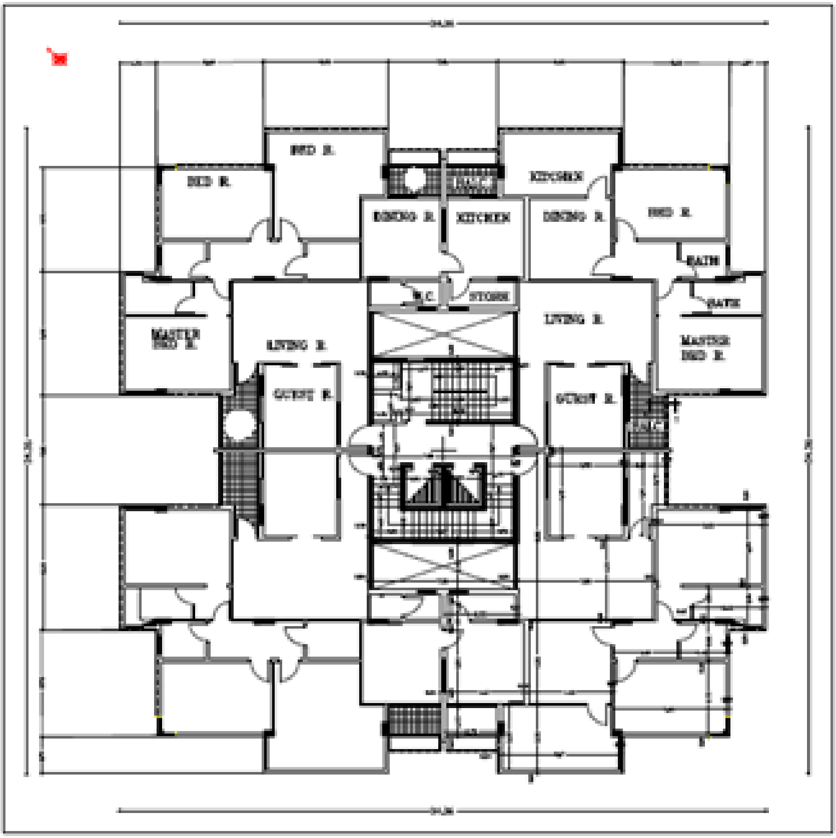

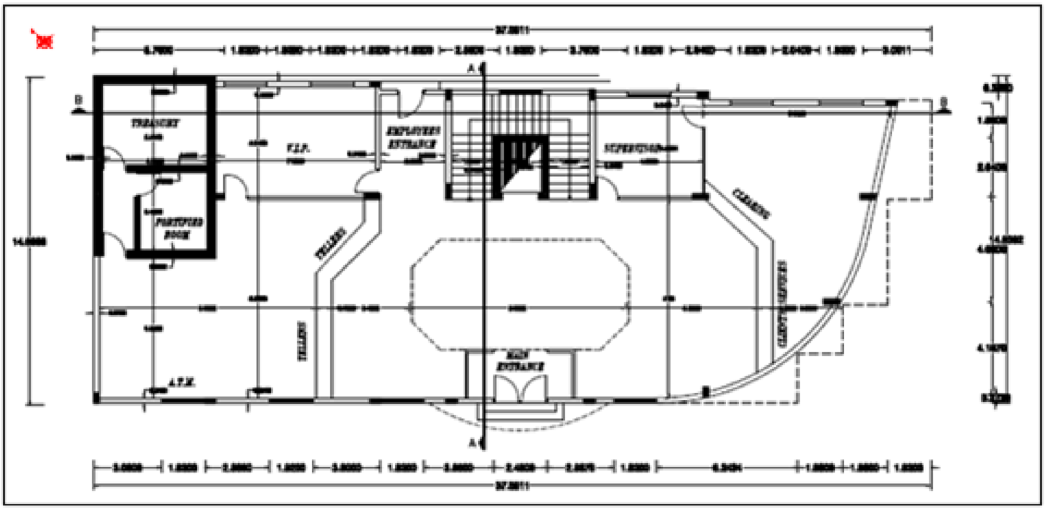

Building 5

Figure (2) (continues): Plans for the five case study

Application of the DfCS Approach

The developed DfCS approach was applied to each of the five case studies. The application of the DfCS suggestions for each engineering discipline was investigated to determine how the design accounted for the safety risks that will be faced during the construction and maintenance phases. Accordingly, the weakness and strength of the design characterizing the building industry in Palestine related to each of the four engineering specialization were assessed. DfCS suggestions that were implemented by at least three out of the five cases were considered as "*design strength*", while DfCS suggestions that were not considered by at least three out of the five cases were considered "*design weakness*"

Assessment Results

Tables (2-5) include a summary of the assessment results from the five case studies for Architecture, Civil, Electrical and Mechanical design specializations, respectively. For simplicity, the shown DfCS suggestion results cover the four phases (Schematic, Design Development, Construction Documentation and Work Schedule Phases) within each specialization.

Table (2): Assessment of Architecture Engineering

DfCS Suggestions	Case Study #					Assess.
	1	2	3	4	5	
1. Height of parapets and guardrails to be 1.1m minimum above the roof, floor or platform level.	no	yes	yes	yes	yes	Strength
2. Permanent guardrails around stairs, edges and atrium.	yes	yes	yes	yes	yes	
3. Skylights to be domed with elevated beams around them rather than flat ones.	yes	yes	NA	yes	NA	
4. Non-slip tiles and avoid polishing tiles with slip material such as wax.	yes	yes	yes	yes	no	
5. If possible, paint about 1.5 meters with oil-based paint and the remaining walls with water based paint.	NA	yes	yes	yes	NA	
6. Corridors dimensions and door height and swing are to ensure easy access and regress of long members and components.	yes	yes	yes	yes	yes	
7. Height of corridors to be suitable for making electrical and mechanical installations covered by false ceiling.	yes	yes	yes	yes	yes	
8. Distance between two successive stair risers to be as small as possible. Choose stair case location to have natural lighting and adequate ventilation.	yes	yes	yes	yes	no	
9. Use durable materials.	yes	yes	yes	yes	yes	
10. Use materials that are safe to handle.	no	yes	yes	yes	yes	
11. Use elements such as windows, tiles, etc. that are of consistent size, light weight, and easy to handle.	yes	yes	yes	yes	yes	
12. Use door of the generator room to swing outward.	NA	yes	NA	yes	yes	
13. Schedule activities so that no welding activity is performed while painting.	yes	yes	yes	yes	yes	
1. Consideration of the DfCS concept in the schematic and the construction documentation phases.	no	no	no	no	no	Weakness
2. Step risers are designed to be consistent from top to bottom during construction.	no	no	no	no	no	
3. Materials that are non-combustible	no	no	no	yes	no	
4. Schedule guardrails and/or fall protection mechanisms to be erected as soon as possible.	no	no	no	yes	no	
5. Schedule sidewalks, ramps and roadways around project to be constructed as early as possible.	no	no	no	yes	no	
6. Consideration for scheduling the duration of subjecting workers to oil-base paint to be as short as possible.	NA	no	no	no	NA	

Table (3): Assessment of Civil Engineering

DfCS Suggestions	Case Study #					Assess.
	1	2	3	4	5	
1. Conduct site investigation to examine the need of shoring system for temporary excavations and the appropriate foundation system.	yes	yes	yes	yes	yes	Strength
2. Design permanent guardrails around skylights, stairs and atrium to be built as part of the erection process.	yes	yes	yes	NA	NA	
3. Design steel bars as a grid pattern with dimensions of 25cm × 25cm maximum when workers are required to walk on reinforcement bars.	yes	yes	yes	yes	yes	
4. Design nonstructural members to be safe during construction and maintenance.	no	yes	yes	yes	no	
5. Choose quieter methods of construction.	yes	yes	yes	yes	no	
6. Select lightweight materials such as hollow concrete blocks rather than solid ones. Select 100mm concrete cubes instead of standard cylinders for testing concrete strength.	yes	yes	yes	yes	yes	
7. Select small reinforcement diameters.	yes	yes	yes	yes	yes	
8. Obtain satisfactory concrete cube results before the removal of the steel props supporting slabs.	yes	yes	no	yes	no	
9. Avoid scheduling any activity related to work around the project while working on facades or lifting materials.	yes	yes	yes	yes	yes	
10. Design work schedule to minimize the need for overtime.	yes	yes	no	yes	yes	
11. Design work schedule to minimize the need for night work.	yes	yes	yes	yes	yes	
12. Schedule the work to avoid congestion of workers within limited area.	yes	yes	yes	yes	no	
13. Schedule the start of the partitioning activity as soon as possible, especially at edges and floor openings.	no	yes	yes	yes	no	
1. Consider the DfCS concept in the construction documentation phase.	no	no	no	no	no	Weakness
2. Design safety connection points along perimeter beams and beams above floor openings to support lifelines or other protection system.	no	no	no	no	no	
3. Design scaffolding tie-off points into the building facade.	no	no	no	no	no	
4. Design temporary guardrails around stairs and floor edges.	no	no	no	no	no	
5. Design the scaffolding system and specify the features of ground that should be prepared to erect it safely.	no	no	no	no	no	
6. Design permanent stairway to be constructed at the beginning, or as close as possible to the start of construction of each floor.	no	no	no	no	no	
7. Design slab shuttering of minimum 0.5 m over hanged from all direction with guardrails.	no	no	no	no	no	
8. Design the shuttering of slab to be continuous across the opening.	NA	no	no	no	no	
9. Check the capability of the form system to sustain loads caused by activities such as lifting material.	no	no	no	yes	no	
10. Schedule temporary guardrails with colored band to be placed around edges as soon as possible.	no	no	no	no	no	
11. Consider daily housekeeping in work schedule.	no	no	no	no	no	

Table (4): Assessment of Electrical Engineering

DfCS Suggestions	Case Study #					Assess.
	1	2	3	4	5	
1. Specify fiberglass sweeps for electrical conduit instead of steel sweeps.	yes	yes	yes	yes	yes	Strength
2. Place external lighting on accessible locations such as roof parapets that facilitate installation and maintenance in safely.	yes	no	yes	no	yes	
3. Provide adequate stair lighting during construction and maintenance	yes	yes	yes	no	no	
4. Use consistent standards for power sources to identify them.	yes	yes	yes	yes	yes	
5. Design the riser for electrical installation to be away from mechanical installation riser.	no	yes	yes	yes	no	
6. Avoid placing the main electrical distribution board under baths.	yes	yes	yes	yes	yes	
7. Choose the place of the main electrical distribution board away from heavy movement such as stairs in schools or in confined spaces and at suitable height	yes	yes	no	yes	no	
8. Increase electrical design load to take in account the rapid technological advancement.	no	yes	no	yes	yes	
9. Provide a warning tape to provide warning signal for underground electrical installation.	yes	yes	yes	yes	yes	
10. Choose durable material for electrical installations.	yes	yes	yes	yes	yes	
11. Check electrical conduits after plastering to ensure against damage or plugging.	yes	yes	yes	yes	yes	
1. Consider the DfCS concept in the schematic phase and in the construction documentation phase.	no	no	no	no	no	Weakness
2. Design temporary electrical system that can be installed and used safely during construction.	no	no	no	no	no	
3. Provide local isolator switches in accessible places to enable workers to isolate electricity manually in case of accident such as a fire.	no	yes	no	no	no	

Table (5): Assessment of Mechanical Engineering

DfCS Suggestions	Case Study #					Assess.
	1	**2**	**3**	**4**	**5**	
1. Locate underground utilities in easily accessible places. Consider soil investigation report within the criteria used to determine the location of these utilities.	yes	yes	yes	no	no	**Strength**
2. Design to have hand excavation around existing underground utilities	yes	no	yes	no	yes	
3. Design for placing water pump away from electrical generator.	no	yes	no	yes	yes	
4. Position underground utilities away from worker passageways but in places easy to construct and maintain.	yes	no	yes	yes	yes	
5. Design sanitary installation to be placed in a way that facilitates their installation and maintenance.	yes	yes	yes	yes	yes	
6. Choose durable material for mechanical installations.	yes	yes	yes	yes	yes	
7. Choose light weight mechanical installations.	yes	yes	yes	yes	yes	
8. Conduct tests on completed mechanical installations before performing new activities such as tiling activity.	yes	yes	yes	yes	yes	
1. Consider the DfCS concept in the construction documentation phase.	no	no	no	no	no	**Weakness**

The implementation of the DfCS approach to the case studies succeeded in identifying the design strength and weakness in the building industry in Palestine related to worker safety during the construction and maintenance. The assessment results indicate clearly that the DfCS concept is not considered in the building construction industry. The design strengths are the results of common sense and practical experience rather than following a known approach that minimize accident risks. The prevailing practice is that safety is not considered during schematic phase especially by architects. During construction documentation phase all disciplines pay no attention to communicate hazards to contractors. To minimize the probability of falls, civil engineer should hold the responsibility of designing shuttering systems, scaffold systems and tie off points for scaffold form systems. Also they should ensure that guard rails designed and scheduled to be placed around edges, stairs or atriums as soon as possible. Daily housekeeping should be standard practice in each time schedule because of its importance in having tidy job site.

The main safety risks in need for improvements include: (1) Designing the exterior and interior building edges in such a way to ensure worker protection during the construction and maintenance phases, (2) Designing the formworks required for architecture, civil, mechanical and electrical works and (3) Selection of noncombustible durable building materials which can be also handled safely. Communication between contractors and designers need also be strengthened to benefit from practical experience and lesson learned during construction. It is believed that enhancement in current practice related to construction safety can be achieved if the developed DfCS concept was adopted by the professional and legal bodies.

CONCLUSIONS AND RECOMMENDATIONS

1. It is important to consider DfCS concept to enhance safety performance in building construction industry. The strength and weakness of design related to DfCS concept should be identified. The design decisions that could improve workers safety would become cognizant to designers. On the other hand design decisions that impair workers safety became also cognizant and should be avoided whenever possible. Otherwise they should be communicated to contractors to take necessary precaution measures.
2. All exterior or interior edges should be protected properly during construction and maintenance phase. Scaffolding 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. Materials should be durable, safe to handle and noncombustible. Daily housekeeping should be standard practice in all projects work schedule because of its importance in having tidy job site.
3. It is recommended to develop legal status that assures the implementation of the developed DfCS approach in Palestine.
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 to benefit from contractors experience in designing out hazards before construction phase.

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