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## RESEARCH ARTICLE

### Factors Affecting Defects Occurrence in Structural Design Stage of Residential Buildings in Gaza Strip

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#### Abstract:

#### Background:

Residential buildings are an essential and significant satisfaction pillar for the human's life to ensure a safe and durable residence. In addition, due to the rapid development and population growth in the Gaza Strip, many residential buildings and housing projects are being implemented in a short period of time especially after Gaza conflict during the year 2014. Therefore, various errors and defects are anticipated to rise during the design stage.

#### Objectives:

The aim of this paper is to identify and rank the factors affecting the occurrence of the defects in the structural design stage of residential buildings in the Gaza Strip.

#### Methods:

A survey was conducted for 134 respondents randomly selected as engineers, working for engineering consultant offices as designers, supervisors and projects managers in Gaza Strip.

#### Results:

The study reveals that the three most effective groups of factors are; the consultant administration and staff group, the drawings preparation group and the structural design group respectively. The most important factors were; ignoring soil investigation or poor soil investigation, poor or lack of engineering supervision or unqualified supervision and conflicts between architectural and structural drawings. These are the most common issues overlooked by the engineers and the contractors in the Gaza Strip.

#### Conclusion:

The study recommends to apply a strict quality assurance and quality control (QA/QC) program during design phases, providing simple and readable drawings with sufficient details for contractors, raising the awareness of owners towards conducting soil inspections prior to the design process and paying more attention to the informal buildings sector from the related authorities.

**Keywords:** Structural design stage, Defects, Residential buildings, Gaza Strip, Soil investigation, Quality assurance, Quality control.

#### Article History

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## 1. INTRODUCTION

The fast growth in population and technological advancement in all lifestyles has made humans to adapt the environmental changes and ensure a better form of housing.

Today, people not only seeking the provision of housing facility but also interested in quality housing facilities, that addresses the aspects of both function and aesthetics. The functionality of the residential building and its envelopes is dependent on their ability to act as an air barrier, thermal barrier and weather barrier. This includes the building security and safety from fire, in addition to appearance and the structural stability [1 - 3].

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Many defects are anticipated to rise during the designing of residential buildings especially in structural design stage. It is because of informal design and construction of buildings unlike the formal construction projects, which are subjected to managerial conditions and technical specifications [4]. The higher number of defects are found in the construction stage [5 - 8]. Where these defects and faults cause unplanned and unwanted high maintenance cost and unsafe accommodation conditions, and sometimes could lead to building failure [7]. It is well known that the costs of correcting and avoiding errors while the building is at the design stage are considerably smaller as compared with the cost of correcting the same errors during the construction stage. Thus, the design changes affect the project cost by increasing it in all the phases of the project [9 - 11]. Design defects can be avoided if appropriate planning and enough knowledge are available during the structural design phase of the residential buildings. The focus of this study is to identify and rank the factors affecting the occurrence of the defects in the structural design stage of residential buildings in the Gaza Strip.

## 2. LITERATURE REVIEW

Sivanathan *et al.* [12] define building defects as a shortcoming or failing in the performance, function, user requirement or statutory of a building which might manifest itself within a fabric, services, structure, or other facilities of the exposed building. Whereas, urban areas have different vulnerability patterns for critical services [13].

There are four main building defects factors, which are inappropriate operational or usage not in accordance to design, lack of maintenance or inappropriate maintenance, inadequacies in the design, and inadequacies in construction. However, defects that are identified in existing residential buildings have risen through wear and tear because of the lack of adequate maintenance [14, 15].

According to Cogurcu [16], design errors (inadequate lateral rigidity, soft story, short column, irregularities in vertical and horizontal directions, strong-beam-weak-column joints, *etc.*) are among the reasons of earthquake damage related to defects. Bahadori [17] highlighted that slight parameters of integrated model limit the prospect of policy and decision making for earthquake risk and disaster mitigation.

Wear and tear, weather vandalism or accidents, impacts from occupants and loads, poor quality materials and moisture from wet areas were the top five causes of failure that resulted from the poor design. The design strategies could prevent these defects from triggering, where the failure reasons are further broken down to enable designers for better understanding of their effects [12, 18 - 20].

Defects in building design put a heavy burden on the rest of the building lifecycle and without any compensation. In such situations, the responsibility falls on the designer's shoulders which they must think carefully with full consideration and concentration towards the completion of the design project [21, 22]. Engineers and architects may design buildings that do not behave as expected or intended by the owner the property, for instance, a roof design that allows the intrusion of water could be attributed to a design defect [23].

The failure of the design engineers to produce accurate, complete and well-coordinated design causes defects occurrence, which may be classified under design errors, omission or a combination of both. The effectiveness of the building design is measured by its aesthetic values show how it would serve the required functions for accessibility and better performance for effective maintenance [8]. The performance of any building depends mainly on the decisions taken at the design and construction stages. Buildings maintenance could be negatively or positively influenced during the design stage. Therefore, there is a need to consider maintenance at the design phase of the projects to avoid unplanned maintenance during occupancy, as design defects are costly mistakes in terms of restoration cost and occupant's life [24 - 26].

According to Tayeh *et al.* [27], the defects in the design stage can be classified under three clusters; defects in civil design, defects due to administration and staff of consultant firms, and defects due to construction drawings. The breakdown of each group factors is as following:

**A. Defects in civil design:** Inadequate provisions for movement, ignoring the effects of weather condition and aggressive environment, ignoring biological effects, inadequate structural design such as foundation, ignoring variation in soil conditions, ignoring load impact on the stability of the structure, Exceeding the allowable deflection, ignoring wind effects on the structure, inadequate reinforcement concrete cover, and improper locating of pipe openings and conduits at critical structural locations.

**B. Defects due to administration and staff of consultant firms:** Lack of implementing QA/QC program during the design, Poor training for staff or poor technical updates, hiring unqualified designers, designer field of experience, designer technical background, designer ignorance of materials properties, misjudgment of climatic conditions, misjudgment of user's intended use.

**C. Defects due to construction drawings:** Lack of details, lack of references, and conflicting details.

Waziri [24] also recognized the defects encountered from design phase in eleven factors. The factors covered the architectural and structural design defects which can affect suitability of design for the existing technology. Also, the standards and specifications considering the maintainability and buildability in the design process were included [28].

## 3. METHODOLOGY

To achieve the research aim, a questionnaire survey was conducted by focusing on engineers who are working mainly in the structural design and supervision on construction projects. The study population was taken from formal statistics belongs to Engineering Association until 2016, which consists of 205 registered engineering offices in Gaza Strip [29]. The sample size was calculated from the following eq. (1) [30]:

$$n = \left( \frac{Z}{2m} \right)^2 \quad (1)$$

Where: Z: The standard value corresponding to a given level of significance (Z=1.96 for  $\alpha$  0.05). m: (margin error): expressed as decimal ( $\pm 0.05$ ).

The sample size is then corrected in the case of the final communities from the following eq. (2):

$$n = \frac{nN}{N + n - 1} \tag{2}$$

Where N is the sample size, and using the first equation it is found that the sample size is equal to:

$$n = \left( \frac{1.96}{2 \times 0.05} \right)^2 \cong 384$$

As the study population is N = 205, the size of modified sample using the second equation is equal to:

$$= \frac{384 \times 205}{205 + 384 - 1} \cong 134$$

The questionnaires were sent to 134 randomly selected engineers working in engineering offices by targeting more than one engineer in the same office to avoid the probability of low participation from all offices and to ensure higher reliability and benefits of the study. The response rate was 80.60% as shown in Fig. (1).

The questionnaire respondents were classified based on their job positions as shown in Fig. (2).

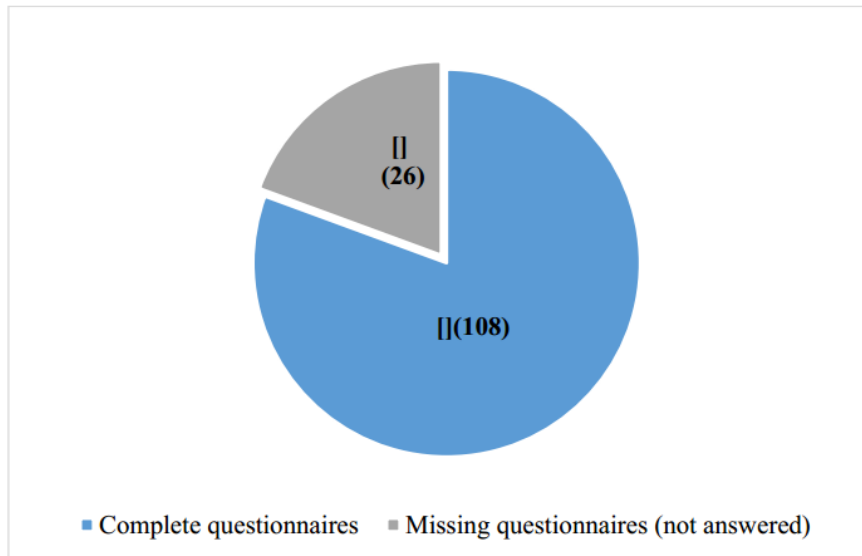


Fig. (1). Percentage of questionnaires responses.

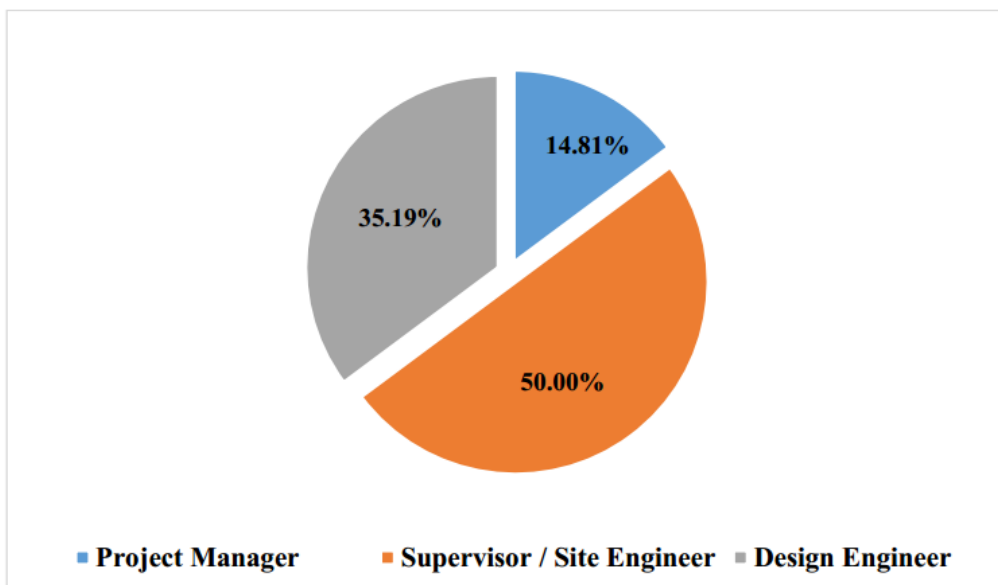


Fig. (2). Respondents percentage based on job title.

Based on literature review, 29 factors for structural design defects were considered in this study. The factors were categorized into three main themes and were derived after reviewing several previous studies including [1, 12, 16, 21, 23, 24, 31 - 38].

A pilot study considering ten expert consultants was conducted. The professionals for the pilot study were selected

based on their technical and managerial capabilities to ensure a qualitative review of the questionnaire. The ten respondents were asked to review the questionnaire to verify the validity and their relevance to the research objectives and to provide feedback. Indeed, significant comments and suggestions were collected and evaluated carefully. At the end of the pilot study, few modifications and additions were accommodated and incorporated to finalize the questionnaire as shown in Table 1.

**Table 1. List of factors from literature vs. selected factors after pilot study in design stage.**

Factors from Literature	Status	Selected Factors After Pilot Study
<b>A. Factors Due to Structural Design</b>		
1. Inadequate structural design	Modified	1. Non-compliance with the requirements of design codes and their updates
2. Ignoring the variation of soil types and conditions	Modified	2. Ignoring soil investigation or Poor soil investigation leads to the wrong selection of foundation type
3. Ignoring biological, chemical attacks, natural hazards and dampness effects.	Modified	3. Ignoring environmental, weather condition, biological and chemical attacks.
4. Ignoring aggressive environment and weather condition effects	Merged	
5. Ignoring the location of Building	Modified	4. Ignoring building locations such as buildings located near the sea.
6. Inappropriate site selection	Not Selected	
7. Ignoring lateral loads impact on structure stability (winds and earthquakes)	Modified	5. Ignoring lateral loads effects (winds and earthquakes).
8. Exceeding allowable deflection values	Selected	6. Exceeding allowable deflection limits
	Added	7. Ignoring dynamic loads impact on structure stability
9. Inadequate provisions for movement	Modified	8. Ignoring the design of expansion, contraction, settlement joint and special construction joint.
10. Inadequate concrete cover on reinforcement	Selected	9. Inadequate concrete cover on reinforcement
11. Improperly locating conduits and pipe openings at critical structural locations	Selected	10. Improperly locating conduits and pipe openings at critical structural locations
12. Insufficient sizing of structural elements (columns, Beams, walls...etc.)	Selected	11. Insufficient sizing of structural elements such as reducing the size of columns, the size of reinforcement bars and foundations.
13. Reducing the size of reinforcement bars and foundations	Merged	
14. Misjudgment in design leading to assumptions or decisions that are not consistent with the actual behavior of the structure	Selected	12. Misjudgment in design leading to assumptions or decisions that are not consistent with the actual behavior of the structure.
15. A roof design that allows water intrusion	Selected & Clarified	13. A roof design without inverted beams, which allows water intrusion.
	Added	14. Inadequate slab types and loading ways with no consideration for codes related rules especially in long spans and cantilevers.
16. Ignoring the consequence of thermal movement	Not Selected	
17. Lack of standardization	Modified	15. Designing residential buildings away from the municipality's conditions and engineering association rules.
18. Poor design of concrete mix	Modified	16. Lack of technical specification references for residential buildings.
19. Poor materials selection	Modified	17. Not defining adequate materials.
<b>B. Factors Due to Consultant Firms Administration and Staff</b>		
1. Lack of QA/QC program during design	Selected	1. Lack of QA/QC program during design.
2. Poor technical updating and poor staff training	Selected	2. Poor technical updating and poor staff training.
3. A decision that is not in accordance with codes	Selected	3. A decision that is not in accordance with codes.
4. Poor supervision	Modified	4. Poor or Lack of engineering supervision during construction of residential buildings or unqualified supervision
5. Hiring unqualified designers	Selected	5. Hiring unqualified designers.
6. Designer field of experience	Selected & Clarified	6. Poor field of experience and technical background for structural designers.
7. Designer technical background	Merged	

(Table 1) contd....

Factors from Literature	Status	Selected Factors After Pilot Study
8. Designing buildings and systems that do not work as intended or as expected by an owner	Selected	7. Design buildings that do not work as intended by the owner (making drop beams, place and size of columns, etc.) which lead to change in design without consulting the engineer.
9. Misjudgment of user's intended use	Merged	
	Added	8. Poor communication between the design firms and the owner.
10. Misjudgment of climatic conditions	Not selected	
11. Designer ignorance of materials properties	Not selected	
<b>C. Factors Due to Drawings</b>		
1. Lack of references	Selected & Clarified	1. Lack of references and details in drawings (cross sections, detailed sections and incomplete detailed drawings).
2. Conflict and discrepancies in details	Selected & Clarified	2. Conflicts and discrepancies between architectural and structural drawings.
3. Lack of details	Modified	3. Discrepancies in construction drawings (dimensions, scales, reinforcement bars diameters, conflict details...etc.).
4. Inability to read the drawings	Selected & Clarified	4. Inability to read the drawings due to language, symbols and scales.

The questionnaire was validated by the criterion-related reliability test, which measures the correlation coefficients between the factors selected for one group compared to the whole groups, and structure validity test (Spearman test).

The relative weight technique has been widely used in construction research for measuring attitudes concerning to surveyed variables. The respondents were asked to gauge the factors on a five-point Likert scale (1 for the strongly disagree to 5 for the strongly agree) based on their perceptions and experience [39, 40].

**4. RESULTS**

Based on the responses of the survey, the results are represented and discussed the factors affecting the structural design of residential buildings in Gaza Strip, where three main groups for design-related factors were derived after reviewing the literature and the pilot study as:

- 1- Factors due to structural design
- 2- Factors related to administration and staff of consultant firms
- 3- Factors due to drawings

Each group of factors has a list of sub-factors in which the respondents have expressed their opinions and perceptions about the significance of each factor in contributing of defects occur during the design stage of residential buildings in Gaza Strip. In this context, the T-test was used to determine the average response to all questionnaires sections. The results are shown in the following tables.

In Table 2, the factors due to the structural design were presented. It is obvious that the arithmetic mean of all factors was larger than the overall average value (3), therefore, all sub-factors have significant differences. The total relative weight was 73.9%, and the mean was 3.69 with a standard deviation of 0.74. The statistical characteristics for each sub-factor related to structural design are tabulated in Table 1.

**Table 2. Statistical characteristics for the main factor and its sub-factors due to structural design.**

No	Factors Due to Structural Design	Mean	Standard Deviation	The Relative Weight (%)	The Value of the Test	P- Value	Rank
1-	Non-compliance with the requirements of design codes and their updates.	3.73	1.27	74.60	4.41	0.00	11
2-	Ignoring soil investigation or Poor soil investigation leads to a wrong selection of foundation type.	4.22	1.00	84.40	9.36	0.00	1
3-	Ignoring environmental, weather condition, biological and chemical attacks.	3.00	1.17	60.00	0.00	1.00	17
4-	Ignoring building locations such as buildings located near the sea.	3.27	1.13	65.40	1.85	0.07	14
5-	Ignoring lateral loads effects (winds and earthquakes).	3.39	1.05	67.80	2.85	0.01	13
6-	Exceeding allowable deflection limits.	3.91	1.01	78.20	6.87	0.00	6
7-	Ignoring dynamic loads impact on structural stability.	3.00	1.11	60.00	0.00	1.00	16
8-	Ignoring the design of expansion, contraction, settlement joint and special construction joint.	3.88	0.97	77.60	7.01	0.00	9
9-	Inadequate concrete cover on reinforcement.	4.07	1.02	81.40	8.08	0.00	2
10-	Improperly locating conduits and pipe openings at critical structural locations.	3.90	0.98	78.00	7.06	0.00	7
11-	Insufficient sizing of structural elements such as reducing the size of columns, the size of reinforcement bars and foundations.	3.98	1.20	79.60	6.31	0.00	3
12-	Misjudgment in design leading to assumptions or decisions that are not consistent with the actual behavior of the structure.	3.64	0.89	72.80	5.58	0.00	12
13-	A roof design without inverted beams, which allows water intrusion.	3.86	1.14	77.20	5.84	0.00	10

(Table 2) contd....

No	Factors Due to Structural Design	Mean	Standard Deviation	The Relative Weight (%)	The Value of the Test	P- Value	Rank
14-	Inadequate slab types and loading ways with no consideration for codes related rules especially in long spans and cantilevers.	3.97	1.03	79.40	7.18	0.00	4
15-	Designing residential buildings away from the municipality's conditions and engineering association rules.	3.90	1.30	78.00	5.32	0.00	8
16-	Lack of technical specification references for residential buildings.	3.93	1.09	78.60	6.50	0.00	5
17-	Not defining adequate materials.	3.16	1.17	63.20	1.01	0.32	15

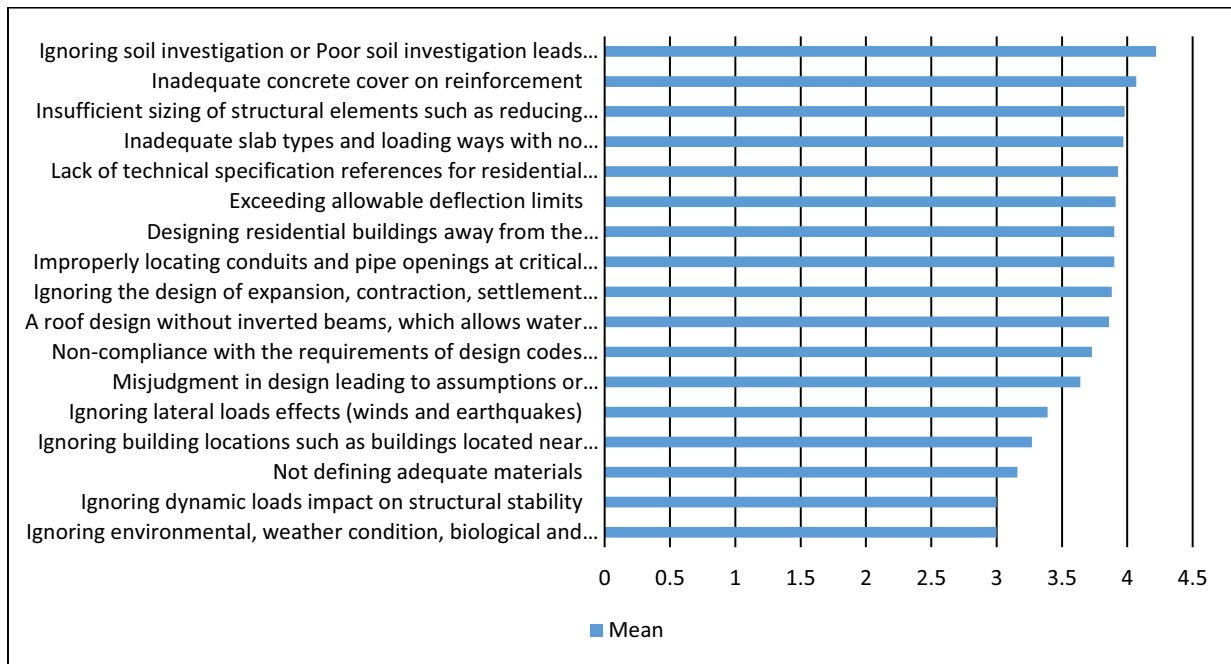


Fig. (3). Ranking of factors due to structural design.

From the above Table 2, the highest mean was recorded for the second sub-factor which is ignoring soil investigation or poor soil investigation, which leads to a wrong selection of foundation type of the building. This was ranked as the first factor, as shown in Fig. (3), with a relative weight of 84.4%, indicates the higher importance of soil investigation for the residential building site before commencing the design process of the building especially for foundation design considerations.

To ensure an adequate and appropriate selection of foundation type for the building, the unwanted settlement, cracking and unseen behavior of the building can be prevented. Also, it is observed that the soil investigation culture is almost absent in most building's projects in the Gaza Strip due to its cost and absence of regulations that oblige the owners to perform it. Whereas, poor soil condition factor according to [24, 41], is considered with other two factors as most significant, affecting the building maintenance from the consultant perspective.

The second highest rank was recorded for the factor of inadequate concrete cover on reinforcement with a relative weight of 81.40%. This is also a significant factor during the design stage. Where in practice, sometimes the designers ignore the adequate concrete cover for the structural elements

in order to achieve the required area of reinforcement and diameters. The result of this factor is in line with their study [27] which was considered as one of the most critical causes for severe defects during the civil design stage.

The third notable ranking was of the factors insufficient sizing of structural elements, such as reducing the size of columns, the size of reinforcement bars and foundations. The fourth-ranked factor was inadequate slab types and loading ways with no consideration for codes related rules, especially in long spans and cantilevers. The relative weights for the third and fourth factors were 79.60% and 79.40%, respectively, which can be summarized in a factor of inadequate structural design. This has the same level of agreement with the study conducted by [27] that emphasized on civil design defects as it was ranked as the second most severe of all defects by the owners. In addition [24], showed that poor structural design is considered one of the most significant factors due to the consultants and the clients.

Another considerable factor ranked as fifth with a relative weight of 78.60%, is the lack of technical specification references, technical specifications and standards for residential buildings as they do not exist in the Gaza Strip.

Designing residential buildings away from the municipality’s conditions and engineering association rules is another notable factor with a relative weight of 78%. This is classified as a significant factor mainly because any design process performed away from the engineering associations and municipality rules and regulations will lead to defects occurrence during the construction phase. However, previous studies have not considered this factor.

The last ranking factors in this group were, ignoring environmental, weather condition, biological and chemical attacks with a relative weight of 60.0%. This indicates that this factor does not have a significant effect from Gazans engineer's perspectives mainly due to the reason that there is no extreme or severe environmental, weather condition, as well as biological and chemical attacks occur particularly in Gaza Strip. Whereas [12] and [27] considered these factors as an important factor affecting buildings maintenance.

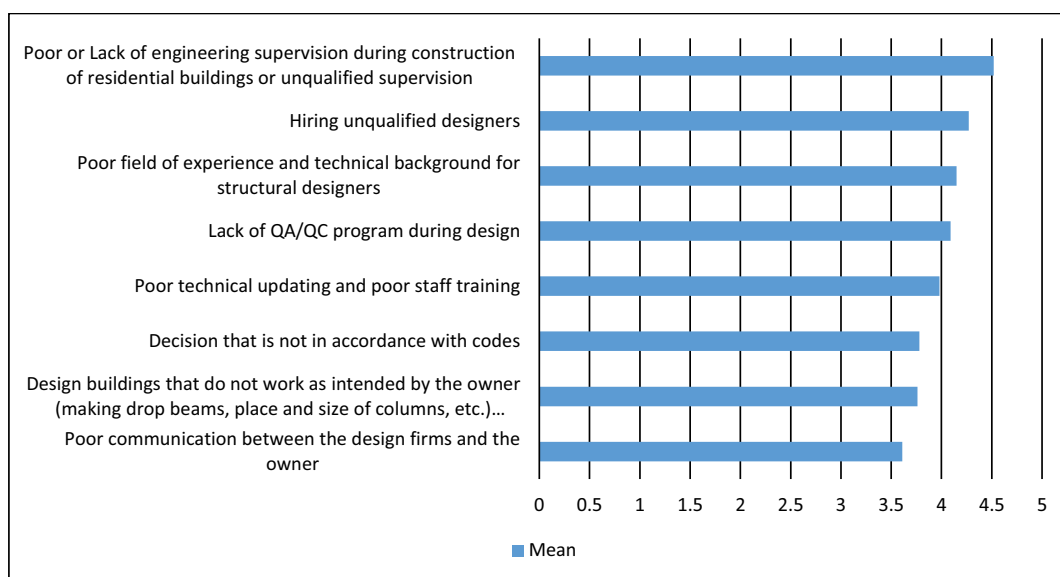
On the other hand, the rest of the factors were ranked according to their importance for residential buildings. Where

some of them appear less important as; ignoring design of expansion, contraction, settlement joint and special construction joint, misjudgment in design leading to assumptions or decisions that are not consistent with the actual behavior of the structure. Similarly, ignoring lateral loads effects such as winds and earthquakes as well as the dynamic loads impact on structure stability, such as; generators, air conditions and elevators, is mainly because the prevalent form of residential buildings in Gaza Strip tends to be very simple. The basic design trend is to utilize a small limited area that often consists of five to six-story building and not permissible to be higher. However, undoubtedly, these factors are axial and very essential for other huge and tall buildings projects.

Factors related to consultant firm's administration and staff are tabulated in Table 3. It is definite that the arithmetic mean of all the related sub-factors was larger than the overall average value (3) and therefore, have significant differences. The total relative weight was 80.27%, mean 4.01 and a standard deviation of 0.74.

**Table 3. Statistical characteristics for factors due to consultant firms administration and staff.**

No	Factors Due to Consultant Firms Administration and Staff Firms	Mean	Standard Deviation	The Relative Weight (%)	The Value of the Test	P- Value	Rank
1-	Lack of QA/QC program during design.	4.09	0.96	81.80	8.61	0.00	4
2-	Poor technical updating and poor staff training.	3.98	0.92	79.60	8.22	0.00	5
3-	Decision that is not in accordance with codes.	3.78	1.04	75.60	5.79	0.00	6
4-	Poor or Lack of engineering supervision during construction of residential buildings or unqualified supervision	4.52	0.82	90.40	14.06	0.00	1
5-	Hiring unqualified designers.	4.27	0.78	85.40	12.45	0.00	2
6-	Poor field of experience and technical background for structural designers.	4.15	0.93	83.00	9.57	0.00	3
7-	Design buildings that do not work as intended by the owner (making drop beams, place and size of columns, etc.) which lead to change in design without consulting the engineer.	3.76	1.07	75.20	5.46	0.00	7
8-	Poor communication between the design firms and the owner.	3.61	1.03	72.20	4.53	0.00	8



**Fig. (4).** Ranking of factors due to consultant firms administration and staff firms.

Based on Table 3, there is no uncertainty that the first ranked factor was the poor or lack of engineering supervision on the construction of residential buildings or unqualified supervision with a relative weight of 90.4%. The ranking of the factors is shown in Fig. (4).

This implies the crucial importance of existing qualified supervision from the consultant team to make sure a proper and efficient construction process complying with the specifications. This factor indicates the absence of supervision in most residential building’s projects in Gaza Strip. The results agree with many researches such as conducted by [24, 35, 37], etc.

The second, third and fifth-ranked factors were related to the hiring of unqualified designers, poor field experience and technical background for structural designers and poor technical updating and poor staff training with relative weights of 85.40%, 83%, 79.6%, respectively. Based on the results, the factors are considered very important. Similarly, the results confirm that unqualified and less experienced engineers working in building’s design result in poor design [27].

Another critical element ranked as the fourth factor is the lack of QA/QC policy during the design phase. It was notable that QA/QC systems and programs were not implemented in most engineering offices and consultant’s organizations in the

Gaza Strip. The existence of QA/QC systems not only contributes to preventing the defects and errors occurrence during the design process of buildings but also enhances the overall design process.

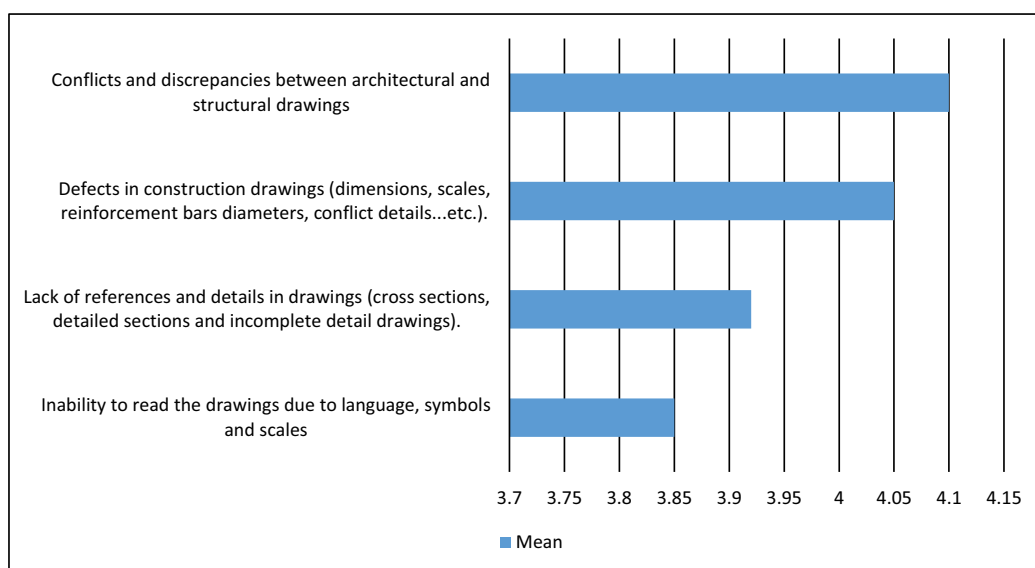
The last ranked factor in this group was poor communication between the design firm and the owner with a relative weight of 72.2%. From Gazans engineer’s perspective, poor communication was considered the less significant factor which implies that there are an appropriate platform and medium for communication between design firms and owners [42].

The rest of factors in this group were ranked according to their importance for residential buildings, which were the decision that is not in accordance with codes and designing of the buildings in a way that does not work as intended by the owner. Sometimes designer’s decisions conflict with design code conditions and rules, which could lead to an improper design with the possibility of defects occurrence [43].

For the factors due to drawings shown in Table 4, the arithmetic mean of all the sub factors was larger than the overall average value (3), thus; listed factors were classified as significant. The total relative weight was 79.58%, mean 3.98 with a standard deviation of 0.92.

**Table 4. Statistical characteristics for factors due to drawings.**

No	Factors Due to Drawings	Mean	Standard Deviation	The Relative Weight (%)	The Value of the Test	P- Value	Rank
1-	Lack of references and details in drawings (cross sections, detailed sections and incomplete detail drawings).	3.92	1.02	78.40	6.88	0.00	3
2-	Conflicts and discrepancies between architectural and structural drawings.	4.10	1.05	82.00	8.09	0.00	1
3-	Defects in construction drawings (dimensions, scales, reinforcement bars diameters, conflict details...etc.).	4.05	1.02	81.00	7.88	0.00	2
4-	Inability to read the drawings due to language, symbols and scales.	3.85	1.13	77.00	5.78	0.00	4



**Fig. (5).** Ranking of due to drawings.



**Table 5. Statistical characteristics for factors leading to defects occurrence in structural design of residential buildings.**

No	Factors Leading to Defects Occurrence in Structural Design Stage of Residential Buildings.	Mean	Standard deviation	The Relative Weight (%)	The Value of the Test	P- Value	Rank
1-	Factors due to structural design	3.69	0.74	73.90	7.26	0.00	3
2-	Factors due to consultant firms administration and staff	4.01	0.74	80.27	10.50	0.00	1
3-	Factors due to drawings	3.98	0.92	79.58	8.20	0.00	2

As shown in Table 3, it is noticed that the most important factor in related drawing factors group was; conflicts and discrepancies between architectural and structural drawings, which has the highest mean with a relative weight of 82%. The overall ranking of drawing factors group is shown in Fig. (5).

Discrepancies and conflicts between drawings are usually defecting causative especially in the structural elements and it is a common problem facing engineers during the construction phase. The results reveal that there is a level of agreement between this study and the study carried out by [27], that the defects may result from discrepancies and conflict in details drawings. This is considered as the most severe factor from the owner's perspective. Furthermore, this factor is categorized as the most significant defect from the contractor's perspectives according to a study by [24].

The second and third-ranked factors were defects in construction drawings (dimensions, scales, reinforcement bars diameters, conflict details, *etc.*) and lack of references and details in drawings (cross sections, detailed sections and incomplete detail drawings). For sure, those factors are very important and directly affecting defects occur due to the reason that any conflicts in structural drawings, if not resolved during implementation, will result in defects during the construction phase. Also, the lack of details in the drawings causes confusion to the contractors when implementing these drawings and may result in the wrong anticipation of details, which leads to defects occurrence [27, 24].

The last ranked factor was inability to read the drawings due to language, symbols and scales, in spite of this factor ranked as last according to Gazans engineers, but it is an essential factor due to the reason that contractors who construct and build the residential buildings are classified as traditional and simple contractors and they are not always a formal company contractors. So, it is necessary that designers produce a simple and readable drawings in order to accommodate and address this class of contractors [44].

By comparing the relative weights of the three main groups of the related factors affecting the occurrence of the defects in the structural design stage of the residential buildings in Gaza Strip as represented in Table 5. It is remarkable that the arithmetic mean of all the sub factors of each group was larger than the overall average value of (3). Therefore, the three group related factors were significant. The rank of the importance for each main related factor from the most to the less important group are as follows:

1. Factors due to consultant firm's administration and staff
2. Factors due to drawings
3. Factors due to the structural design

The study reveals that factors due to consultant firm's administration and staff were ranked first with a relative weight of 80.27%. This is logical because a qualified staff and effective and efficient administration lead to good products and better performance. On the other hand, the drawings related factors were ranked as the second with a relative weight of 79.58%. Undoubtedly the design drawings are significant due to the reason that the details drawings are seen and recognized as the final product of the design process in which the contractors construct buildings according to the drawings [45]. However, the structural design related factors were ranked as the third with a relative weight of 73.90% based on the respondent's perceptions and perspectives as summarized in Table 5.

## CONCLUSION

Based on the data analysis of the obtained results on defect's factors for the residential building, it can be concluded that the main findings of the study have achieved the objective of this study. The research findings identified three groups of factors which were derived after reviewing the literature and conducting the pilot study. These factors were ranked based on the respondent's opinions and perceptions on the relative weights.

1. The first group of factors are due to consultant firm administration and staff. This main group consists of eight sub factors, ranked according to their importance. The second group of factors are due to drawings which consist of four sub factors, ranked according to their importance. The third group of factors are due to a structural design containing seventeen sub factors ranked according to their significance by respondents

2. It was cleared that the factors stated in the questionnaire were the most related and important, facing structural design and construction defects in Gaza strip through the respondents. Where the consultant firms and their staff play an important role in eliminating the structural design defects *via* well planning and designing of the project and producing plain and errors-free drawings to the contractors.

3. For the first ranked group (consultant firm) eight factors were ranked, where the most important factor was the poor or lack of engineering supervision during the construction of residential buildings or unqualified supervision. The supervision by engineers is almost absent in most of the residential building's construction processes due to the associated finance issues or owner negligence.

4. For the second ranked group (drawings preparation), four factors were ranked according to the degree of effect of each sub factor on defects occurrence. The most important

factor was the conflicts between architectural and structural drawings where this problem is common, faced by engineers and contractors in projects in Gaza Strip.

5. For the third ranked group (Related factors due to structural design) seventeen factors were ranked according to the degree of effect of each sub factor on defects. The most important factor was ignoring soil investigation or poor soil investigation that leads to wrong selection of foundation type where it is a common problem in the Gaza Strip.

It is strongly recommended to apply a strict quality assurance and quality control (QA/QC) program for the designers and contractors to ensure the commitment of the specifications, standards, conditions and instructions. Simple and readable specifications and drawings should be available for the construction of residential building projects.

#### CONSENT FOR PUBLICATION

Not applicable.

#### AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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None.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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