Research Article

Factors affecting defects occurrence in the construction stage of residential buildings in Gaza Strip

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Received: 26 September 2019 / Accepted: 3 January 2020 / Published online: 8 January 2020

Abstract
The building defects are always of great concern for construction industry as they cause delays before handing over and increase maintenance costs during occupancy of the buildings. Due to the rapid development and population growth in Gaza Strip, many residential buildings and housing projects are being constructed in a short space of time, especially after Gaza war in 2014. Therefore, many errors and defects are expected to arise during the construction stage. The aim of this paper is to identify and rank the factors affecting the defects occurrence in the construction stage of the residential buildings in Gaza Strip. A survey was conducted in 134 randomly selected engineers working for engineering offices as design engineers, supervisors and project managers in Gaza Strip. The study revealed five most effective main factors during the construction stage, namely construction materials, factors due to inspections, factors due to construction equipment, factors due to constructions and factors due to construction management, respectively. The most important factors in each group were poor soil compaction, exceeding the allowable limits of verticality of the structural elements, insufficient reinforcement concrete cover, owner's negligence of inspections, absence of engineer in most of construction phases, using expired material, material or component failure, using corroded or second-hand reinforcement steel, using materials not of acceptable quality and not conforming to the specifications or design and lack of required equipment. This research is the first attempt at identifying factors affecting defect occurrence in the construction stage of residential buildings of the developing countries. The findings will be useful for the construction firms and regulatory bodies to deal with the critical factors affecting defect occurrence and device such policies that improve the design and construction of residential buildings.

Keywords Factors · Construction stage · Defects occurrence · Gaza Strip

1 Introduction

The fast growth of population and technological advancement in all lifestyles have made human to adapt to the environmental changes and ensure a better form of housing to accommodate himself and his family [1]. Presently, humans are not seeking housing facilities only but are very interested in the provision of quality housing facilities for both function and aesthetics [2]. The functionality of the residential building and its coverings depend on its ability to act as an air barrier, thermal barrier and weather barrier. This includes the building security and safety from the fire in addition to the appearance and the structural stability [3].

There is enough evidence regarding the defects found in the new residential buildings; such defects demand

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SN Applied Sciences (2020) 2:167 | https://doi.org/10.1007/s42452-020-1959-1

significant attention [4]. Their occurrences have serious consequences for construction projects' parties and end users and contribute to low reputation for quality fulfillment in the housing sectors in many countries [5].

Different studies have been conducted to identify causes of defects through mathematical models; for example, [6] proposed a mathematical model to estimate the frequency and magnitude of conditions causing defects. [7] discussed factors contributing to poor workmanship and possible solutions to minimize them. Besides the final cost of product, defective building construction has implications throughout the life cycle of the building in the shape of maintenance cost [8], which can be substantial. Defective construction may lead to the failure of the structure completely in the end. The construction industry in whole of the world is getting modern, advanced and growing daily with the help of information technology systems [9]. Housing project represents a significant part of our society. Construction defects become a global issue faced by researchers and practitioners around the world. Defects can affect the success of construction project significantly. More specifically, it has a main impact on the construction time, construction cost, sustainability aspects, productivity and customer satisfaction [5].

Although there are many studies about defects in construction projects during design and construction phases, no one before in Gaza Strip in particular has taken the residential buildings' civil design and construction's defects into considerations. Design and construction defects can be avoided if there is an appropriate planning and sufficient knowledge during both phases of civil design and construction of the residential buildings. In order to achieve that, a study needs to be conducted in order to identify factors affecting civil design and construction and leading to defects occurrence in the residential buildings sector in Gaza Strips to help avoid them further.

The objective of this study is to identify and rank the factors affecting the defects occurrence in the construction stage of the residential buildings in Gaza Strip. Particularly, it investigates the factors related to civil construction, construction inspection, construction management, construction material and construction equipment.

2 Literature review

Ojo and Ijatuyi [31] defined defects as "faults, which may reduce the strength of a construction work, durability or usefulness". It is among the most common problems that construction projects suffer from [10–18]. Chong and Low [19] found that "most of the defects due to human factors were caused solely by 'forgetfulness and carelessness,' 29% by lack of knowledge, and a very small percentage were intentional. As for workmanship defects, lack of motivation dominated the costs, but the presence of risks directly increased the chance of defects."

Carelessness has been stated to be the most important cause of construction defects [20]. Jingmond and Ågren [21] conducted a study to identify primary root causes of defects and found that the causes of defects mainly reside in endogenous factors within the organizations. According to Waziri [22], it was noticed that many building defects could be explained entirely or partly because of readily identifiable errors in construction, which could have been foreseen and hence avoided. The importance of different defects arising from construction process has been established and identified as critical to the maintenance of residential building. The topmost defects have been determined to be: poor construction work supervision, use of defective construction materials, poor site quality control, defects due to specification and use of untested and new materials and incompetent workforce for construction. However, Ahzahar [23] found that low quality of construction materials is the most common factor that leads to the building defects and failures. Bakri and Mydin [24] divided the defects into two main categories; these categories are structural defect and nonstructural defect. Structural defect means any defect in a structural element of a building that is attributed to defective material, defective or faulty workmanship, defective design and sometimes any combination of these. The structure of building includes columns, earth retaining walls, flat slabs and beams.

Structural defects can be categorized as cracks in walls (superstructure), cracks in foundations (substructure) and cracks in floor or slabs (superstructure). These defects can result from inadequate soil analysis, use of defective materials and inappropriate site selection. However, nonstructural defect in a residential building is defined as a defect in a nonstructural element of the building because of defective residential building work. Nonstructural defect includes defect in plaster works, dampness in old structures and defects in brickwork.

According to Al-Farra [25], the other source of the high cost of maintenance process is the defaults in construction phase, which may be due to many factors such as contractor performance, nonuse of appropriate materials, poor supervision and ineffective use of equipment. As known, the construction environment is constantly changing, and the authorities' actions continuously give new conditions. Simultaneously, competition between companies may become a stronger factor that leads the contractor to accept the bid with low margin of profit. Studies show that the construction defects cost is in the range of 5–10% of the production cost. Therefore, knowledge of the causes of these defects is necessary for choosing adequate measures.

Construction defects due to Waziri [22] arise from several factors, which could be visible to the naked eye or deep hidden within the structure. Construction defects that affect directly the structure performance can be a result of defective design or defective construction. Generally, the construction can be as a design that fails to meet the professional standard and a decision that is not in accordance with codes, among others. Construction failures and defects also may result from poor and misguided decisions of the clients or failure of the design professional to produce complete and accurate design and construction documents, which provide sufficient information for the contractor for building construction. Sometimes, they can be due to the use of nonconforming materials, poor workmanship and design misinterpretation.

According to Assaf et al. [26], defects in the construction stage include (1) defects due to construction inspection based on unqualified inspector, lack of inspection, weakened inspection rule in implementing corrective actions during job execution and proponent (owner) negligence of the importance of inspection; (2) defects due to civil construction based on inaccurate measurement, damaged formwork, excavation tools close to the building, painting in unsuitable conditions or on unsuitable surface, inadequate waterproofing and drainage, insufficient reinforcement concrete cover, cold joints, loss in adhesion between materials, early formwork removal, poor soil compaction, inadequate curing and lack of communication; (3) defects due to specification based on unclear specification, not defining adequate materials, not specifying the QA/QC construction procedure, not specifying the allowable load limits and specifying inadequate concrete mix design; (4) defects due to contractor administration based on not complying with specification, insufficient site supervision, poor communication with the design firm and the owner, unqualified supervision, speedy completion or poor-quality work, unqualified workforce and multinational construction experience; (5) defects due to construction material based on differential thermal movements in dissimilar materials, selection of material that is unsuitable for existing climatic conditions, use of nondurable material, use of expired material and poor materials handling storage; and (6) defects due to construction equipment based on improper use of equipment, inadequate performance of equipment and lack of required items of equipment.

3 Methodology

To achieve the research objective, a questionnaire survey was conducted by focusing on engineers who are working mainly in the field of structural design and supervision on construction of engineering projects. The study population was taken from formal statistics belonging to Gaza Engineering Association which consists of 205 registered engineering offices in Gaza Strip. The study sample was selected based on the equation [27]. The sample size was calculated from Eq. 1:

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

where Z is the standard value corresponding to a given level of significance ($Z = 1.96$ for α 0.05). m (margin error) is expressed as decimal (± 0.05).

The sample size is then corrected in the case of the final communities from Eq. 2:

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

where N is the sample size, and using the first equation, we find that the sample size is found by Eq. 3:

$$n = \left(\frac{1.96}{2 \times 0.05}\right)^2 \cong 384 \tag{3}$$

Since the study population is $N = 205$, the size of the modified sample using Eq. 2 is equal to:

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

Although the calculated sample size was 134 engineering offices, the questionnaires were sent to 134 randomly selected engineers working in engineering offices by targeting one engineer in each office to overcome the risk of low participation from offices and to ensure higher reliability and benefits of the study. One hundred eight completed questionnaires were returned, representing a response rate of 80.60%. Fifty percent of job titles of the respondents were supervisors/site engineers, 35.19% were design engineers and remaining 14.81% were project managers. Therefore, the majority of the questionnaire respondents were supervisors or engineers in the first rank, the second were design engineers and the rest of them were project managers, which was useful as an indicator to how these respondents dealt before with residential buildings design and construction process in Gaza Strip.

Based on literature review, 44 factors for construction defects were derived after reviewing several previous studies [3, 22–26, 28–34]. These factors were categorized under five main groups and are shown in Table 1. A pilot study was conducted with the ten experts (i.e., consultant engineers) [35–37]. These experts were selected based on their technical and managerial capabilities to ensure quality review of the questionnaire. All experts' proposals have been taken into account preparing the basic data to

Table 1 List of factors from the literature versus selected factors after pilot study

Factors from the literature	Status	Selected factors after pilot study
Civil construction-related factors		
Misinterpretation of design	Selected and clarified	Misinterpretation of the design leading to wrong construction
Inaccurate measurement	Modified	Inaccurate dimension projection and measurement
Damaged formwork	Modified	Damaged or weak formwork due to multiuse of formwork timber
	Added	Exceeding the allowable limits of verticality of the structural elements
Poor installation method	Not selected	
Excavation tools close to the building	Not selected	
Painting in unsuitable conditions or on unsuitable surface	Modified	Ignoring isolation works for buried parts of concrete (footings, ground beams and walls)
Inadequate waterproofing and drainage	Modified	Poor roof water drainage system or without foam concrete for water drainage slopes and without isolation works for roof
Insufficient reinforcement concrete cover	Selected	Insufficient reinforcement concrete cover
Cold joints	Selected and clarified	Cold joints, especially in concrete casting, due to late concrete arrival
Loss in adhesion between materials	Modified	Loss in adhesion between concrete and finishing materials due to oil painting of formworks timber or soft faces
Early formwork removal	Selected	Early formwork removal
Poor soil compaction	Modified	Poor soil compaction or backfilling without compaction and layers
Inadequate curing	Modified	Inadequate water curing of different concrete and finishing works
Overloading	Modified	Overloading of building during the construction stage
Moisture penetration through the building envelope	Not selected	
Lack of communication	Not selected	
Improper roof installation	Not selected	
Specifying inadequate concrete mix design	Not selected	
Construction inspection-related factors		
Lack of inspection	Modified	Lack of inspection and material testing
Unqualified inspector	Selected and clarified	Unqualified inspector, especially in concrete cube preparation
Proponent (owner) negligence of the importance of inspection	Selected	Proponent (owner) negligence of the importance of inspection
Weakness of inspection rule in implementing corrective actions during job execution	Modified	Neglecting inspection results and their recommendations in implementing corrective actions during job execution
Construction management-related factors		
Lack of documentation, standardization, knowledge and motivation	Added	Lack of QA/QC program during construction
Poor workmanship	Modified	Poor or unqualified workmanships
Inability to read drawings	Selected	Inability to read the drawings
Competition between companies may become a stronger factor that leads the contractor to accept the bid with a low margin of profit	Selected	Competition between companies that leads to accept the bid with low margin of profit, which affects the quality of construction
Not complying with specification	Modified	Not complying with specification and engineer instructions
Communication gap between contractors and design professionals	Selected	Communication gap between contractors and design professionals
Corruption	Selected	Corruption
Insufficient knowledge on construction/fixing of building element/components	Modified	Ignorance or insufficient knowledge of the methods of implementation and supporting of high slabs, drop beams and concrete walls

Table 1 (continued)

Factors from the literature	Status	Selected factors after pilot study
Insufficient site supervision	Modified	Absence of engineer in most of the construction phases
Speedy completion or poor-quality work	Selected	Speedy completion or poor-quality work
Multinational construction experience	Selected	Multinational construction experience
Poor decisions	Modified	Poor or wrong decisions
Poor rectification work processes	Modified	Poor rectification processes of wrong works and failed concrete elements
Human intervention	Modified	Human-side interventions and expression of opinion without knowledge
Remedial work	Modified	Cumulative errors
Unqualified supervision	Not selected	
Faulty construction	Not selected	
Unqualified work force	Not selected	
Construction material- related factors		
Material failure or component failure	Selected	Material failure or component failure
Differential thermal movements in dissimilar materials	Not selected	
Poor materials handling storage	Modified	Poor storage of construction materials and exposure to weather conditions
Selection of material that is unsuitable for existing climatic conditions	Selected	Selection of material that is unsuitable for existing climatic conditions
Materials not of acceptable quality	Selected	Using materials not of acceptable quality and not conforming to the specifications or design
Using materials not conforming to the specifications or the design brief	Merged	
Use of expired material	Selected & clarified	Using of expired material (cement)
Steel corrosion	Modified	Using of corroded steel or second-hand reinforcement steel
Erosion of mortar joint in mason works	Selected	Erosion of mortar joint in mason works
Sulfate attack of ordinary Portland cement in walls and floors	Modified	Lack of using sulfate resistance cement in areas, which is exposed to sulfate attack
Use of new and untested materials	Modified	Using inadequate concrete mix design for structural elements
Metal fatigue in fixings	Not selected	
Use of nondurable materials	Not selected	
Construction equipment-related factors		
Improper use of equipment	Modified	Improper use of equipment (compactor, concrete pump, vibrator, concrete mixer, drill, plumb bob…etc.)
Inadequate performance of equipment	Modified	Inadequate performance of equipment (compactor, concrete pump, vibrator, concrete mixer, drill…etc.)
Lack of required items of equipment	Modified	Lack of required equipment (vibrator, drill, mixer, compactor, cutting disk, plumb bob…etc.)

be used in this survey to construct the first version of this questionnaire. This involved deleting, adding, merging or modifying many variables to develop the final version of the questionnaire.

The ten respondents were asked to review the questionnaire and to verify the validity of the questionnaire topics and their relevance to the research objective and to give their advice. Important comments and suggestions were collected and evaluated carefully. At the end of the pilot study, a few minor changes, modifications and additions were accommodated to finalize the questionnaire. The questionnaire was validated by the criterion-related reliability test, which measures the correlation coefficients between the factors selected for in one group and the whole group, and structure validity test (Spearman test).

The collected raw data were first sorted, edited, coded and then entered into computer software. Two softwares were used, the Excel sheet and SPSS. The ordinal scale is a rating datum, which uses integers in ascending or descending order. The relative important index (RII) was used for the analysis of data. Also analysis of variance (ANOVA) tests, frequencies and percentiles were used. The RII method has been widely used in construction research for calculating and formulating attitudes with respect to surveyed variables.

The relative importance index method (RII) was used to determine the ranks of all factors. The relative importance index was computed using the following formula (Eq. 4):

$$\bar{X}_W = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (4)$$

where W is the weight given to each factor by the respondents (ranging from 1 to 5), A the highest weight (i.e., 5 in this case), N the total number of respondents, n_1 number of respondents who strongly agreed, n_2 number of respondents who do not agree, n_3 number of respondents who are neutral, n_4 number of respondents who agree, n_5 number of respondents who strongly agreed).

The RII value had a range from 0 to 1 (0 not inclusive); the higher the value of RII, the more is the impact of that attribute. RII value ranges between 0 and 1. The analyzed data were finally presented using descriptive methods for easy interpretation and comparisons. Further, the relative weight % was calculated by dividing the mean by the number of response options (i.e., 5 in the study) (Eq. 5):

$$\text{RII} = (\text{Mean} \div 5) \times 100\% \quad (5)$$

Respondents were asked to rate each factor on a rating scale (five-point Likert scale) that required a ranking (1–5), where 1 represented "the lowest scale" and 5 represented "the highest scale," as the case might be. The numerical rating scale (five-point Likert scale) was chosen to format the questions of the questionnaire with some common sets of response categories called quantifiers. Those quantifiers were used to facilitate understanding as RII = (20–36%) not important at all, (36–52%) not important, (52–68%) moderately important, (68–84%), important and (84–100%) very important.

Additionally, one-sample t test was used to determine whether the mean of a factor is significantly different from a hypothesized value 3 (middle value of Likert scale). If the P value (Sig.) is smaller than or equal to the level of significance $\alpha = 0.05$, then the mean of a factor is significantly different from a hypothesized value 3. The sign of the test value indicates whether the mean is significantly greater or smaller than hypothesized value 3. On the other hand, if the P value (Sig.) is greater than the level of significance $\alpha = 0.05$, then the mean a factor is insignificantly different from a hypothesized value 3.

4 Results and discussion

Under this section, the results of analysis are supposed to achieve the aim of the study in addition to the second and third objectives of the research, which are the factors affecting the defects occurrence in the construction stage of the residential buildings in Gaza Strip, and degree of effect of those factors in the construction stages of residential buildings in Gaza Strip.

Five main groups of factors affecting the construction stage were derived after reviewing the literature and the pilot study, which are: (1) civil construction-related factors, (2) construction inspection-related factors, (3) construction management-related factors, (4) construction materials-related factors and (5) construction equipment-related factors. Each main factor has a list of subfactors in which the respondents put their opinions about the importance of each one in contributing defects occurrence during the construction stage of residential buildings in Gaza Strip.

4.1 Civil construction-related factors affecting the defects occurrence in the construction stage

From Table 2, it is clear that the arithmetic mean of all the factors was larger than the overall average (3). Therefore, there were significant differences between the civil construction-related factors. The total axis relative weight reached 82.4%, the mean was 4.12 and the standard deviation was 0.74.

From Table 2, it can be seen that poor soil compacting factor was in the first rank with a relative weight of 88.20% and this is very logical because most of the backfilling processes in the construction stage of residential buildings in Gaza Strip are executed without real compaction or with poor compaction, which lead to unwanted settlement in the future.

Exceeding the allowable limits of verticality of the structural elements factor was in the second place with a relative weight of 87.60%. Proper verticality of the structural elements is very important to prevent cumulative exceeded deviation about the vertical axis to more than the allowable limits, which appears in the figure of the building and may generate a destructive moment causing overturning of the tall building.

Insufficient reinforcement concrete cover factor was in the third place of importance, which agreed with Al-Farra [25] and Assaf et al. [26] results. Sometimes, during construction of the residential buildings and in the absence of engineers, the reinforcement concrete cover of different structural elements is neglected from the

Table 2 Statistical characteristics of the main civil construction-related factors

No.	Civil construction-related factors	Mean	SD	Relative weight %	Value of the test	*P* value	Rank
1.	Misinterpretation of the design leading to wrong construction	4.10	0.96	82.00	8.82	0.00	9
2.	Inaccurate dimension projection and measurement	4.32	0.84	86.40	12.10	0.00	5
3.	Damaged or weak formwork due to the multiuse of formwork timber	4.34	0.84	86.80	12.20	0.00	4
4.	Exceeding the allowable limits of verticality of the structural elements	4.38	0.72	87.60	14.56	0.00	2
5.	Ignoring isolation works for buried parts of concrete (footings, ground beams and walls)	3.76	1.32	75.20	4.45	0.00	11
6.	Poor roof water drainage system or without foam concrete for water drainage slopes and without isolation works for roof	4.00	1.19	80.00	6.46	0.00	10
7.	Insufficient reinforcement concrete cover	4.39	1.02	87.80	10.49	0.00	3
8.	Cold joints, especially in concrete casting, due to late concrete arrival	4.27	0.91	85.40	10.77	0.00	8
9.	Loss of adhesion between concrete and finishing materials due to oil painting of formworks timber or soft faces	3.56	1.13	71.20	3.79	0.00	12
10.	Early formwork removal	4.31	0.92	86.20	10.83	0.00	7
11.	Poor soil compaction or backfilling without compaction and layers	4.41	0.93	88.20	11.61	0.00	1
12.	Inadequate water curing of different concrete and finishing works	4.31	0.79	86.20	12.64	0.00	6
13.	Overloading of building during the construction stage	3.47	1.13	69.40	3.15	0.00	13
	Civil construction-related factors	4.12	0.74	82.40	11.60	0.00	

contractors or labors for the sake of putting their reinforcement bars well, which causes corrosion in steel reinforcement due to its exposure to environment.

In the fourth and fifth places were factors of damaged or weak formwork due to multiuse of formwork timber, and inaccurate dimension projection and measurement with relative weights of 86.80% and 86.40%, respectively. Damaged formwork factor was one of the least important factors according to Waziri [22] and Assaf et al. [26]; however, it was considered significant according to Dahanayake amd Ramachandra [30], where most of the defects such as alignment issues and bulging of columns, beams and slabs are due to inadequate formwork according to their research findings. Inaccurate or wrong projecting of measurements and dimensions, as columns axis will cause defects.

Other factors ranked in the top were inadequate concrete curing, early formwork removal and the cold joints with relative weights of 86.20%, 86.20% and 85.40%, respectively. These factors are also important during the construction stages; concrete will not be reaching the intended strength without proper curing. In addition, the too early formwork removal may cause failure of the structure, especially for long-span beams, or cause unwanted deflection, and the cold joint during concrete casting results in improper adhesive between fresh concrete and casted concrete causing cracks or water leakage problems further. These factors were the least important factors according to Assaf et al. [26].

The rest of factors were ranked as less important by respondents as shown in Table 2, but there was an important factor that ranked in the tenth place which is poor roof water drainage system or absence of foam concrete for water drainage slopes and absence of isolation works for roof. Inadequate waterproofing and drainage factor was considered by Assaf et al. [26] results as a moderately severe factor from the owners' and contractors' perspectives. In the most of residential buildings in Gaza Strip, the roof isolation is neglected by the owners due to finance issues or due to construction of the whole building in multiple stages.

The least important factor was overloading of building during the construction stage with a relative weight of 69.4%. Overloading is not a significant factor during construction process of residential buildings because all the loads during construction are normal and within the allowable loads range.

4.2 Construction inspection-related factors affecting the defects occurrence in the construction stage

It can be seen that the arithmetic mean of all the factors was larger than the largest overall average (3) (Table 3). Therefore, there were significant differences between the construction inspection-related factors. The relative weight of the total axis reached 84.75%, the mean was 4.24 and the standard deviation was 0.80.

Table 3 Statistical characteristics of the main construction inspection-related factors

No.	Construction inspection-related factors	Mean	SD	Relative weight %	Value of the test	*P* Value	Rank
1.	Lack of inspection and material testing.	4.24	0.84	84.80	11.35	0.00	3
2.	Unqualified inspector, especially in concrete cube preparation.	4.02	1.01	80.40	7.75	0.00	4
3.	Proponent (owner) negligence of the importance of inspection.	4.41	0.85	88.20	12.66	0.00	1
4.	Neglecting inspection results and their recommendations in implementing corrective actions during job execution	4.29	0.91	85.80	10.86	0.00	2
	Construction inspection-related factors	4.24	0.80	84.75	11.85	0.00	

In Table 3, first and the third places were the factors of proponent (owner) negligence of the importance of inspection and lack of inspection and material testing with relative weights of 88.20% and 84.80%, respectively. The importance of inspection during construction phase agreed with [22]. Most of residential buildings' construction processes in Gaza Strip are executed without materials inspection, and no measures are taken by the owner or the contractors for inspection, which eventually leads to the use of materials nonconforming to the specifications.

On the other hand, if the inspection exists, sometimes the owners or contractors neglect the inspection results as ranked in the second place with a relative weight of 85.80% and sometimes the inspector is unqualified of the importance of inspection as ranked at last and this agreed with Assaf et al. [26] results, which consider this factor as one of the least important factors.

4.3 Construction management-related factors affecting the defects occurrence in the construction stage

Referring to Table 4, it is clear that the arithmetic mean of all factors was larger than the overall average (3). Therefore, there were significant differences in the construction management-related factors. The relative weight of the total axis reached 79.36%, the mean was 3.97 and the standard deviation was 0.5.

It is clear from Table 4 that the factor of the absence of engineer in most of the construction phases was in the first place with a relative weight of 88.80%; the absence of engineer during construction cannot make sure meeting specifications requirements and quality control standards which eventually leads to improper construction. The importance of this factor is in line with previous studies [22, 23].

Table 4 Statistical characteristics for the main construction management-related factors

No.	Construction management-related factors	Mean	SD	Relative weight %	Value of the test	*P* value	Rank
1.	Lack of QA/QC program during construction	4.15	0.91	83.00	9.77	0.00	4
2.	Poor or unqualified workmanships	3.98	0.99	79.60	7.62	0.00	9
3.	Inability to read the drawings	3.90	1.11	78.00	6.22	0.00	10
4.	Competition between companies that leads to accept the bid with low margin of profit, which affects the quality of construction	3.80	0.98	76.00	6.25	0.00	12
5.	Not complying with specification and engineer instructions	4.41	0.80	88.20	13.54	0.00	2
6.	Communication gap between contractors and design professionals	3.71	0.97	74.20	5.66	0.00	13
7.	Corruption	4.10	0.79	82.00	10.67	0.00	5
8.	Ignorance or insufficient knowledge of the methods of implementation and supporting of high slabs, drop beams and concrete walls	4.03	0.87	80.60	9.12	0.00	6
9.	Absence of engineer in most of the construction phases	4.44	0.86	88.80	12.92	0.00	1
10.	Speedy completion or poor-quality work	4.07	0.81	81.40	10.17	0.00	7
11.	Multinational construction experience	3.25	1.01	65.00	1.93	0.06	15
12.	Poor or wrong decisions	3.88	0.87	77.60	7.76	0.00	11
13.	Poor rectification processes of wrong works and failed concrete elements	4.02	0.76	80.40	10.18	0.00	8
14.	Human-side interventions and expression of opinion without knowledge	3.66	0.84	73.20	6.02	0.00	14
15.	Cumulative errors	4.16	0.64	83.20	13.67	0.00	3
	Construction management-related factors	3.97	0.56	79.36	13.18	0.00	

Not complying with specification and engineer instructions and lack of QA/QC program during construction were two important factors ranked second and fourth with relative weights of 88.20% and 83%, respectively. Working away from specifications is the most significant defect factor because the specification ensures a proper construction process without any probable defects. QA/QC programs are absent in most of the building processes in Gaza Strip, and the presence of these systems is very important to ensure the good quality of the final product and to ensure reaching the good quality through applying their approaches. The third ranked factor was a cumulative errors factor with a relative weight of 83.20%. Sometimes a small error not taken into consideration leads to a big problem by cumulating on it such as the vertical alignment, elevation errors, projection errors and columns axis errors.

Corruption and poor or unqualified workmanship factors were ranked fifth and ninth with relative weights of 82% and 79.60%, respectively. These two are main factors leading to defects occurrence during the construction stage, unqualified or corrupted workmanship affect the overall construction process either quality or safety. The importance of corruption factor was also found important by Ahzahar et al. [23] in their study, and the importance of workmanships factor was considered critical in previous studies [22, 28–30]. According to respondents' perspectives, the rest of the factors have a less effect on defect occurrence during the construction process of residential buildings in Gaza Strip. The last ranked factor in this group was multinational construction experience with a relative weight of 65%. In Gaza Strip, there are no multinational workers and the methods of construction are well known to most of the construction workers.

4.4 Construction materials-related factors affecting the defects occurrence in the construction stage

It can be seen that the arithmetic mean of all factors was larger than the overall average (3) (Table 5). Therefore, there were significant differences between the construction materials-related factors. The relative weight of the total axis reached 85.05%, the mean 4.25 and the standard deviation 0.62.

From Table 5, it is clear that the factor of using expired cement was in the first place and the factor of using corroded steel or second-hand reinforcement steel was in the third place with relative weights of 88.20% and 87.20%. It is noticed that the quality of the construction materials (cement, steel…etc.) is the most important factor in this group due to respondents, and this agrees with Ahzahar [23] and Assaf et al. [26] results.

The second, fourth and sixth places were factors of material failure or component failure, using materials not of acceptable quality and not conforming to the specifications or design and poor storage of construction materials and exposure to weather conditions with relative weights of 87.60%, 86.80%, 84.80%, respectively. These factors are also significant during construction process; materials failure or materials of not of acceptable quality will definitely cause defects and failure of the structure. Poor storage will lead to material expiry or material failure. The importance of these factors agreed with the results of [26].

In the fifth place is the factor of using inadequate concrete mix design for structural elements with a relative weight of 86.80%. This factor is significant also in concrete elements; using inadequate concrete mix in some structural elements will weaken these elements and affect the strength of them in tolerating the applied loads and may lead to failure of these elements. Assaf et al. [26] results assured that also. The rest factors are ranked in Table 5

Table 5 Statistical characteristics for the main construction materials-related factors

No.	Construction materials-related factors	Mean	SD	Relative weight %	Value of the test	*P* value	Rank
1.	Material failure or component failure	4.38	0.90	87.60	11.74	0.00	2
2.	Poor storage of construction materials and exposure to weather conditions	4.24	0.80	84.80	11.95	0.00	6
3.	Selection of material that is unsuitable for existing climatic conditions	3.83	0.94	76.60	6.71	0.00	9
4.	Using materials not of acceptable quality and conforming to the specifications or design	4.34	0.72	86.80	14.33	0.00	4
5.	Using of expired material (cement)	4.41	0.90	88.20	11.98	0.00	1
6.	Using of corroded steel or second-hand reinforcement steel	4.36	1.02	87.20	10.16	0.00	3
7.	Erosion of mortar joint in mason works	4.07	0.88	81.40	9.30	0.00	8
8.	Lack of using sulfate resistance cement in areas exposed to sulfate attack	4.21	0.79	84.20	11.64	0.00	7
9.	Using inadequate concrete mix design for structural elements	4.34	0.75	86.80	13.45	0.00	5
	Construction materials-related factors	4.25	0.62	85.05	15.54	0.00	

according to their importance in construction process from the respondents' perspectives.

The last ranked factor in this group was the factor of selection of material that is unsuitable for existing climatic conditions with a relative weight of 76.60%. This factor had the least importance because there is not severe climate condition in Gaza Strip.

4.5 Construction equipment-related factors affecting the defects occurrence in the construction stage

Referring to Table 6, it is clear that the arithmetic mean of all factors was larger than the overall average (3). Therefore, there were significant differences between construction equipment-related factors. The relative weight of the total axis reached 83.28%, the mean was 4.16 and the standard deviation was 0.66.

It is clear from Table 6 that the first place was to the factor of lack of required equipment, the second place to the factor of inadequate performance of equipment and the third place to the factor of improper use of equipment with relative weights of 86.20%, 84%, 79.60%, respectively. The construction equipments as concrete pumps, concrete mixers, vibrator, compactor… etc., are very important factors affecting the defects occurrence; the absence of these tools will lead to improper construction process, especially during concrete casting or soil backfilling. Waziri [22] and Assaf et al. [26] results assured also the importance of construction equipment factors.

4.6 Comparison of main group factors leading to defects occurrence in the construction of residential buildings in Gaza Strip

It can be seen that the arithmetic mean of all factors was larger than the overall average (3) (Table 7). Therefore, there were significant differences between the factors. It was found that the rank of the importance of each main factor is as follows: (1) factors due to construction materials, (2) factors due to construction inspection, (3) factors due to construction equipment, (4) factors due to construction and (5) factors due to construction management.

It is clear that factors due to construction materials were ranked first with a relative weight of 85.05%. This result agreed with [23] study results, which is logical because the mainstay of the construction process is the materials; materials with good quality will lead to good construction process and vice versa. The absence of inspection process in most of the residential buildings' construction process in Gaza Strip makes it an important factor, which ranked second with a relative weight of 84.75%. In addition, construction equipment factors were ranked third with relative weight of 83.28%, construction equipment is associated

Table 6 Statistical characteristics for the main construction equipment-related factors

No.	Construction equipment-related factors	Mean	SD	Relative weight %	Value of the test	*P* Value	Rank
1.	Improper use of equipment (compactor, concrete pump, vibrator, concrete mixer, drill, plumb bob…etc.)	3.98	0.82	79.60	9.21	0.00	3
2.	Inadequate performance of equipment (compactor, concrete pump, vibrator, concrete mixer, drill…etc.)	4.20	0.69	84.00	13.41	0.00	2
3.	Lack of required equipment (vibrator, drill, mixer, compactor, cutting disk, plumb bob…etc.)	4.31	0.88	86.20	11.44	0.00	1
	Construction equipment-related factors	4.16	0.66	83.28	13.50	0.00	

Table 7 Statistical characteristics for group factors leading to defects occurrence in the construction of residential buildings

No.	Factors leading to defects occurrence in the construction of residential buildings	Mean	SD	Relative weight %	Value of the test	*P* value	Rank
1.	Civil construction-related factors	4.12	0.74	82.40	11.60	0.00	4
2.	Construction inspection-related factors	4.24	0.80	84.75	11.85	0.00	2
3.	Construction administration-related factors	3.97	0.56	79.36	13.18	0.00	5
4.	Construction materials-related factors	4.25	0.62	85.05	15.54	0.00	1
5.	Construction equipment-related factors	4.16	0.66	83.28	13.50	0.00	3
	Factors leading to defects occurrence in the construction of residential buildings	4.15	0.57	82.97	15.41	0.00	

to construction materials in importance. The fourth and fifth places were to civil construction factors and construction administration factors with relative weights of 82.40% and 79.36%, respectively; they were the least important factors when comparing with the other first ranked factors; however, they are very important for themselves.

5 Conclusion

The research findings identified five groups of factors derived after reviewing the literature and conducting the pilot study. These factors are ranked based on the respondents opinions' relative weights, which are: factors due to construction materials containing nine subfactors, factors due to construction inspection containing four subfactors, factors due to construction equipment containing three subfactors, factors due to construction containing 13 subfactors and factors due to construction management containing 15 subfactors, and all of them are ranked according to their importance by the respondents' opinions.

From respondents' perspective, materials and inspection are the most important factors during construction and this is logical because materials such as concrete and steel are the backbone of buildings and any defect in these materials will lead to defects in the whole building and may cause building's failure in some cases. Inspection plays also an essential role in preventing and eliminating construction defects, and it is well known that almost all the residential building projects in Gaza Strip are executed without soil and construction materials inspection due to lack of awareness and its importance by buildings owners due to their high cost. In Gaza Strip, no attention is paid by many owners to the use of ready mix concrete and concrete equipments such as concrete pumps, vibrator, concrete mixer and steel bending tool are very necessary during construction; the absence of these equipments leads to problems such as concrete segregation, bleeding, weak concrete mix and reinforcement appearance. Well construction methods, qualified and skilled labors, well-experienced management, following and monitoring are important issues during construction, and applying them will contribute to elimination of construction defects.

5.1 Recommendations

From the above conclusions, the following suggestions are recommended for the firms and regulatory authorities:

1. It is strongly recommended to apply a strict quality assurance and quality control (QA/QC) program for the designer and contractor to ensure commitment of the specifications, standards, conditions and instructions.
2. It is strongly recommended for the related authorities (engineering association and local municipalities) to activate the familiar insurances (well construction or well execution insurance and the maintenance insurance) for the informal sectors the same as in the formal sectors.
3. According to the findings of this study, the most significant cause for the building defects and failures was found to be the low quality of construction material. Therefore, it is necessary to hire a third party (consultant) who will be responsible to test and approve all the materials prior to use by the contractor.
4. For improving the productivity of residential building construction's workers, it is necessary and important to conduct building activities' training and education. Training of workers should be on a regular basis. This can be in the form of on-the-job training, workshops, seminars or conferences. Also, there is a need to increase awareness in owners toward conducting materials inspections before using them in the construction process.
5. Further awareness is needed on the risk associated with involvement of unqualified people in construction activities. The presence of more qualified and well-experienced structural engineers and civil engineers is required, without whom work quality on-site cannot be guaranteed.

5.2 Limitations and future studies

The findings of this study provide useful insights to the firms and regulatory bodies to deal with the critical factors affecting defect occurrence in the construction phase of the residential buildings. This study focuses on the Gaza Strip and has predetermined the grouping of factors. Future scholars may apply this study in other countries for further generalizability of the results. The scholars may use other statistical approaches to analyze the data, for example, factor analysis, in order to group the factors. The developed components may represent the underlying factors for defects in the study's local construction industry.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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