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Deviations and Defects of the Sub-Task's Requirements in Construction Projects

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Abstract**—**The sub-task pattern in terms of deviations and defects should be identified and understood in order to improve the quality of practices in construction projects. Therefore, sub-task susceptibility to exposure to deviations and defects has been evaluated and classified via six classifications proposed in this study. Thirty-four case studies of specific sub-tasks (from compression members in constructed concrete structures) were collected from seven construction projects in order to examine the study's proposed classifications. The study revealed that the sub-task has a high sensitivity to deviation, where 91% of the cases were recorded as deviations; however, only 19% of cases were recorded as defects. Other findings were that the actual work during the execution process is a high source of deviation for this sub-task (74%), while only 26% of the source of deviation was due to both design documentation and the actual work. These findings significantly imply that the study's proposed classifications could be used to determine the pattern of each sub-task and develop proactive actions to overcome issues of sub-task deviations and defects.

Keywords**—**Sub-tasks, deviations, defects, quality, construction projects.

I. Introduction

CONSTRUCTION management is suffering from various issues related to the quality of its practices; perhaps the most famous of these are task deviations or defects [1]. Despite notable developments in project management tools, methods and strategies that are often able to efficiently and effectively meet quality requirements, the literature clearly shows that the construction industry is still affected by construction defects and rework. This has recently became a global issue [2], and it usually increases the overrun of project costs and contributes to handover delay.

The majority of previous studies attribute task deviations and defects to three cornerstones: task characteristics, task-related factors (e.g. people, equipment, etc.) and the surrounding conditions of the task (e.g. weather, site conditions, etc.) [3]. This article will focus on the issue of deviations and defects from the point of view of task characteristics. Task characteristics are logically different from one task to another [4], [5]. A task's propensity toward deviation or defects is also based on the degree of task complexity [6]. In reality, the degree of quality of a produced task in a construction project may match the design and the building code requirements or occur with some deviation that may or may not be acceptable. Or the outputs could involve perfect work that fulfills the design and building code requirements with no deviation, acceptable work that has some acceptable amount of deviation, or defective work that has an unacceptable amount of deviation.

This study introduces some classifications in order to evaluate the degree of deviation of construction tasks. The level of quality of a practice and the degree of deviation will be determined by using project documentation and building code requirements. Case studies were conducted on a specific sub-task (i.e., steel quantity preparation) using data collected from 34 items from compression members in constructed concrete structures (columns) from seven construction project sites. The study's classifications were examined, the generated results were analyzed, and the deviations of construction sub-tasks were evaluated. The sources of the sub-task deviations were also evaluated based on the sub-task conditions. The appropriate actions that should be taken were recommended.

II. Background

Task deviations and defects have been researched in different countries, resulting in many published studies about this topic. The majority of studies concentrated on the causes and consequences of deviation, while few if any studies focused on the relationship between sub-task requirements and the issue of deviations and defects. So an anatomical study of sub-task requirements in terms of patterns of deviations and defects is demanded, in order to build a strong foundation that may help deal with quality practices in construction sub-tasks. Therefore, this section will review the literature in the areas of task characteristics (the sub-task requirements) and quality practices.

A. Task Deviation and Defect

A task deviation has been defined as "a departure from established requirements" [7], while a task defect is "a tangible occurrence that can be rectified" [8]. Therefore, deviations are often considered merely acceptable deficiencies in work or objectives, while a defect describes unsafe work that is often rejected. But both construction deviations and defects are usually considered poor quality practices that lead to a rework [6]. So to overcome construction deviations and defects that often lead to failure is a modest aim, but it should be achieved because of its contribution both to sustainability and to the safety of the constructed buildings [9].

The cost of deviations in quality were measured for nine industrial engineering projects, and the results show that total deviation costs may reach approximately 12.4% of the project

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budget [7]. The literature addressed a number of sources of deviations and defects in construction tasks. According to [6], the sources were related to different categories such as the nature of a task, human errors, tools/equipment, materials, documentation, etc. One previous study found that the nature of a task contributes 13% of the sources of deviations and defects, due to the degree of task complexity [6]. Reference [10], based on his framework, argued that the nature of a task depends on the three factors of complexity, difficulty and condition; however, it is impossible to control a task through only one factor due to the interaction of each factor with the others. Breaking down a task into meaningful sub-tasks may provide a good understanding of the nature of the task, which subsequently may help in modeling the sub-task's deviations and defects [6].

B. Quality Practices

Quality management is a comprehensive mechanism of monitoring and controlling activities in order to prevent deviations in requirements as well as an assurance of an optimal level of quality throughout all phases of the production process [11]. A good practice of quality management contributes to development in many organizations. However, [12] argued that the quality practices in the construction industry encounter some difficulties related to the ability of practitioners to apply quality tools and techniques in real projects. Quality assurance (QA) is often viewed merely as an administrative rule, and the costs that associated with QA; therefore, poor quality often dominates the final product in construction projects [12].

III. Aim and Assumptions

A. Study's Aim

The main objective of this study is to develop an approach to determine and evaluate patterns of quality deviation and construction defects by proposing a new classification to identify the level of practice with respect to the quality for each sub-task. Thus, it will be possible to understand and measure which sub-tasks are more prone to deviation and defects than others. Consequently, proactive measures will be more effective in avoiding unwanted results.

In order to achieve the aim of this study, two objectives should be achieved:

- Identify the design requirements for each specific sub-task from the project documentation (e.g., drawings, specifications, bills of quantity, etc.) as well as from building code requirements. Through this documentation, it is possible to extract the targeted dimensions and measurements and the range of tolerance and the maximum/minimum boundaries for each specific sub-task. Thus, the degree of deviation can be measured, the severity of the deviation can be calculated, and the appropriate decision can be taken to overcome the risk.
- Identify the source of deviation, whether it occurs in the design phase or during the execution process, by classifying the deviation of sub-tasks based on either the violated design requirements or building code requirements, or both.

B. Classification of the Sub-task Requirements

Six cases were suggested by which to test the proposed classification to achieve the study's objective, as shown in Fig. 1. Based on the design, building code requirements and the actual work at the project site, the sub-task deviations and the sources of the deviation will be classified as follows:

- **Case-1:** If the design is within the required tolerance, and the actual work matches the design, this means that there is *no deviation* in the sub-task and that the quality output will be considered *perfect work*. In this case, both the design work and the actual execution work are *valid*.
- **Case-2:** If the design is within the required tolerance, and the actual work does not match the design but is still within the required tolerance, this means that there is *some deviation* in the sub-task, and the quality output will be considered *acceptable work*. In this case, the source of the deviation is in the *execution phase,* while design is valid.
- **Case-3:** If the design is within the required tolerance, and the actual work neither matches the design nor is within the required tolerance, this means that there is a *high deviation with defect* in the sub-task, and the quality output will be considered *defective work*. In this case, the source of deviation is the *execution phase,* while the design is valid.
- **Case-4:** If the design is out of the required tolerance, and the actual work does not match the design but is still within the required tolerance, this means that there is *some deviation* in the sub-task, and the quality output will be considered *acceptable work*. In this case, the source of deviation is the *design phase,* while the execution process is valid.
- **Case-5:** If both the design and the actual work are out of the required tolerance, and the actual work matches the design, this means that there is *high deviation with defect* in the sub-task, and the quality output will be considered *defective work*. In this case, the source of deviation is the *design phase,* while the execution phase is valid.
- **Case-6:** If both the design and the actual work are out of the required tolerance, and the actual work does not match the design, this means that there is *high deviation with defect* in the sub-task, and the quality output will be considered *defective work*. In this case, the source of deviation is both the *design and the execution phases.*

For example, consider this sub-task requirement: the steel cross-section area (A_{st}) preparation for the rebar task of a column (i.e., a compression member in a constructed concrete structure) requires making the ratio of the longitudinal steel area (A_{st}) to the gross concrete cross-section (A_g) according to the requirements of both the design and the building code. This ratio of longitudinal steel, based on SBC, should be in a range from the minimum ratio (A_{st} =0.01A_g) to the maximum ratio (A_{st}=0.08A_g) [13]. The minimum ratio is essential in order to overcome bending moments and to avoid shrinkage or creep problems due to sustained compression on the concrete column. The maximum ratio is important to avoid difficulty because of crowding of the reinforcement as well as to reduce costs (economic issue).

Fig. 1 shows all six cases of the study's classifications that probably occur during implementation of the sub-task, which is the maintaining of the ratio of longitudinal steel. In case-1, for instance, the ratio of the longitudinal steel area ($A_{st} = 0.04A_g$) in the actual work at the project site matches the designed gross concrete cross-section, which means that there is no deviation (the actual work matches the design, and both are within the required tolerance), and the output is considered perfect work.

IV. Methodology

A quantitative approach is "one in which the investigator primarily uses postpositivist claims for developing knowledge" [14]. In this study, the quantitative approach was used in order to measure the deviations of the sub-task requirements. In particular, the degree of deviation is determined by calculating the difference between the required and actual dimensions. Subsequently, sub-task susceptibility to exposure to quality deviations and defects can be anticipated by determining and understanding its patterns.

Some research textbooks classify a case study as one of the research strategies for collecting research data by either quantitative or qualitative methods. According to [15], "case studies can include, and even be limited to, quantitative evidence." Therefore, the data were collected by using case studies on some specific sub-task requirements from compression members in constructed concrete structures. The data set of the deviations of the sub-task requirements were created by visiting various project sites in Riyadh, the capital city of Saudi Arabia. All case studies were collected from residential building projects. A total of 34 case studies included multiple data sources such as design requirements (drawings, specifications, and bills of quantity), building code requirements (Saudi Building Code [SBC] and American Concrete Institute [ACI]), and the actual work on the project site.

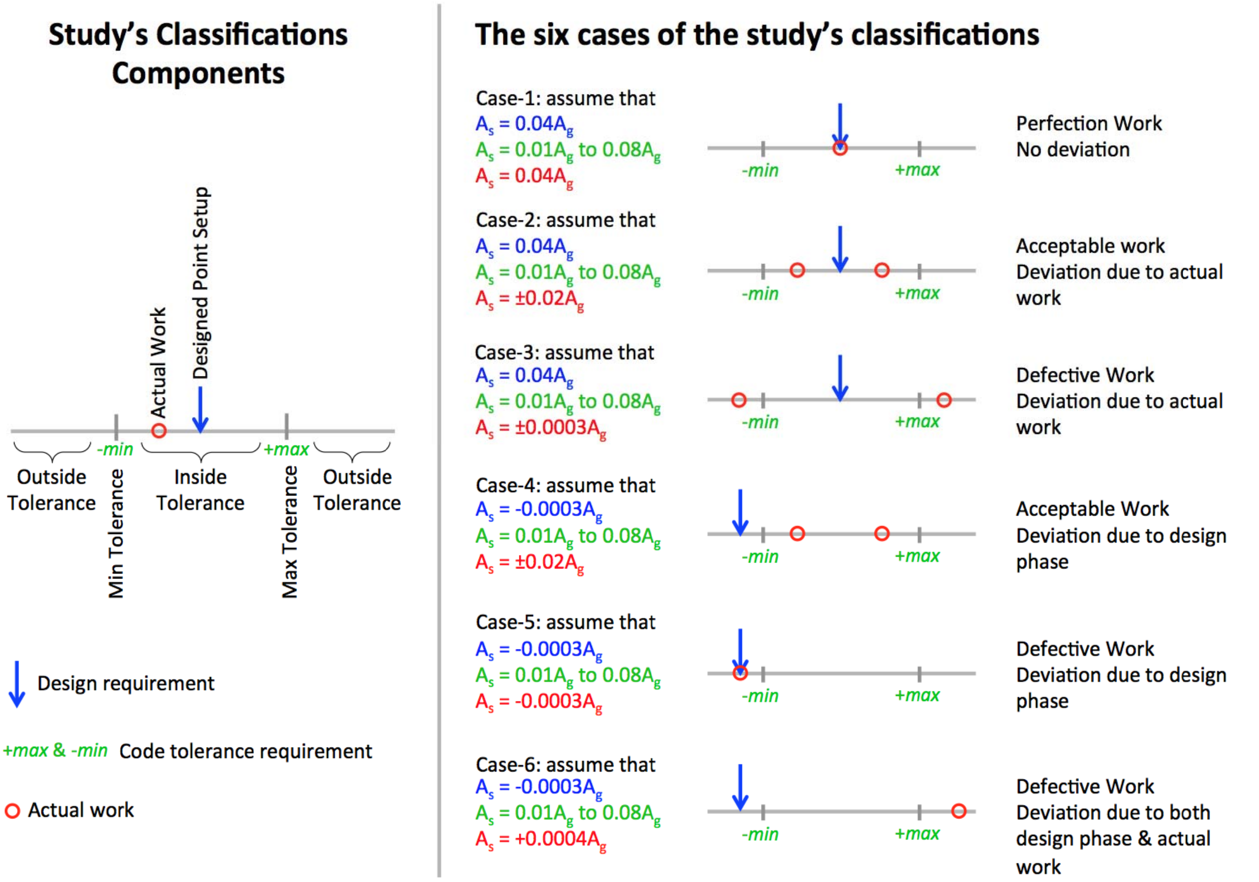

Fig. 1 Study's classifications

V. Result and Discussion

The quality deviations from the sub-task requirement (steel cross-section area (A_{st}) preparation) have been examined, and the study's classifications were conducted and evaluated for 34 samples. The study results list the sub-task deviations from the requirements of the design and the building code tolerance through to the actual work on the project site as well as the deviation condition (i.e., whether it is merely a simple deviation or is defective work). The table also shows the percent rate of each source of deviation from the sub-task requirements (see Table I).

The study results show only three cases (cases 1, 2 & 3) of the sub-task that could be considered deviation-free with respect to the required design and the building code, as shown in Table I. In the first case of the study's proposed classifications, roughly 9% of the total cases of this sub-task were implemented without deviation from the intended dimensions (3 out of 34 sub-task cases). Therefore, this result is considered perfect work, according to the study's classifications. The rest of the cases show that the susceptibility of this sub-task's requirements to exposure to deviations from the required design is roughly 91% (31 out of 34 sub-task cases). This clearly indicates that this sub-task's requirements (i.e., steel cross-section area (A_{st}) preparation for the longitudinal bar in a column) are susceptible to exposure to deviations and are highly sensitive to deviations in quality that allow this sub-task's requirements to be classified as either acceptable or defective work.

For the rest of the cases, according to the study classifications, the degree of deviation from the sub-task's requirements could be divided into two groups: acceptable deviation or unacceptable deviation (i.e., defective work). In the first group, case-2 and case-4 of the study's classifications, there was deviation from the required design, but it was still within the required tolerance. These cases accounted for roughly 68% (23 out of 34 sub-task cases), and these cases are considered acceptable work. This result revealed that there are few practitioners at construction sites in Saudi Arabia who have a high commitment to achieving the targeted design requirements.

TABLE I
Sub-Task Requirement Classification

Case	Design Deviation	Tolerance Deviation	Deviation Condition	Deviation Source
1	0	0	Perfection work	-
2	0	0	Perfection work	-
3	0	0	Perfection work	-
4	0.00103	0	Acceptable work	Actual
5	0.00019	0	Acceptable work	Actual
6	0.00046	0	Acceptable work	Actual
7	0.00041	0	Acceptable work	Actual
8	0.01529	0	Acceptable work	Actual
9	0.00024	0	Acceptable work	Actual
10	0.00054	0	Acceptable work	Actual
11	0.00046	0	Acceptable work	Actual
12	0.00015	0	Acceptable work	Actual
13	0.01001	0	Acceptable work	Actual
14	0.01069	0	Acceptable work	Actual
15	0.00011	0	Acceptable work	Actual
16	0.00021	0	Acceptable work	Actual
17	0.00034	0	Acceptable work	Actual
18	0.00058	0	Acceptable work	Actual
19	0.00041	0	Acceptable work	Actual
20	0.00014	0	Acceptable work	Actual
21	0.00011	0	Acceptable work	Actual
22	0.00011	0	Acceptable work	Actual
23	0.00023	0	Acceptable work	Actual
24	0.00054	0	Acceptable work	Actual
25	0.00321	0.00225	Defective work	Actual
26	0.00316	0.0022	Defective work	Actual
27	0.00089	0.00084	Defective work	Actual
28	0.0041	0.0007	Defective work	Actual
29	0.00263	0	Acceptable work	Design & Actual
30	0.00377	0	Acceptable work	Design & Actual
31	0.00077	0.00308	Defective work	Design & Actual
32	0.00077	0.00308	Defective work	Design & Actual
33	0.00035	0.00112	Defective work	Design & Actual
34	0.00829	0.00171	Defective work	Design & Actual

For the second group, case-3, case-5 and case-6 of the study classifications, the deviation from the required design was out of the required tolerance. These cases amounted to roughly 19% (8 out of 34 sub-task cases), and these cases were considered defective work. This result may indicate that the degree of susceptibility of the sub-task to exposure to defects is somewhat high, but there is also a high risk to doing unsafe work. Therefore, this could be classified as being a sub-task that is sensitive to defects.

TABLE II
Sub-Task Deviation and the Deviation Condition

Deviation Types	No. of Sub-Task	Sub-Task %	Deviation Condition
Case-1: No Deviation	3 out of 34	9%	Perfection Work
Case-2: Deviation within tolerance	23 out of 34	68%	Acceptable Work
Case-3: Deviation out of tolerance	4 out of 34	12%	Defective Work
Case-4: Deviation within tolerance	2 out of 34	6%	Acceptable Work
Case-5: Deviation out of tolerance	-	-	-
Case-6: Deviation out of tolerance	4 out of 34	12%	Defective Work

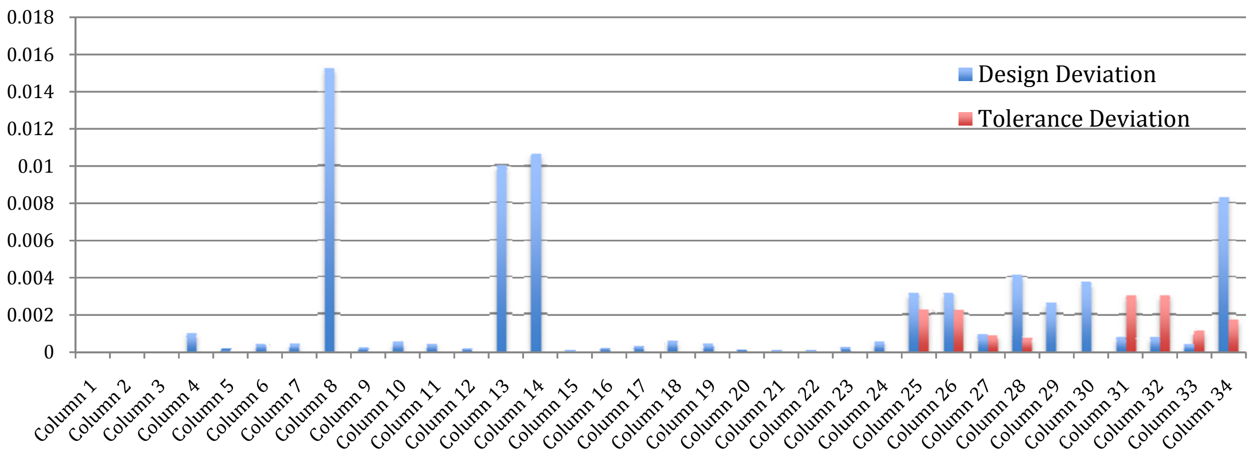

Fig. 2 Deviation source due to only the actual work

TABLE III
SUB-TASK DEVIATION SOURCES

Deviation Source		No. of Sub-Task	Sub-Task %
Design		0 out of 34	0%
Actual		25 out of 34	74%
	Acceptable Work	21 out of 25	84%
	Defective Work	4 out of 25	16%
Design & Actual		6 out of 34	26%
	Acceptable Work	2 out of 6	33%
	Defective Work	4 out of 6	67%

The results also revealed that according to the study's classifications, the deviations for this specific sub-task are often due to two sources, either the actual work only or both the design documentation with the actual work.

As shown in Table III, the first type of deviation source, which is only the design documentation, was not shown as the only source of the sub-task deviation in any of the 34 cases. This does not mean that the design documentation is always correct, but it means that the deviation usually occurs due to another common source, the actual work, given as the second type. This second type of deviation source, which includes only the actual work, accounted for 74% of the deviation sources of the sub-task (25 out of 34 sub-tasks). For this type, 84% of the cases (21 sub-tasks, as shown in Table III) were considered acceptable work that matched case-2 of the study's classifications, while 16% of the cases (4 sub-tasks, as shown in Table III) were considered defective work that matched case-3 of the study's classifications. This clearly indicates that the majority of the deviations occurred due to the reduction of, or sometimes an increase in, the steel quantities used during the execution process.

The third type of deviation source, which includes both the design documentation and the actual work, accounted for 26% of the deviation sources of the sub-task (6 out of 34 sub-tasks). In this type, 33% of the cases (only 2 sub-tasks, as shown in Table III) were considered acceptable work that matched case-4 of the study's classifications, while 67% of the cases (4 sub-tasks, as shown in Table III) were considered defective work that matched case-6 of the study's classifications.

Thus, the proposed classifications, when used to understand the patterns of this sub-task regarding its degree of susceptibility to exposure to deviations, could be used to predict and overcome this issue.

VI. CONCLUSION AND FUTURE WORK

This study aims to recognize the pattern of deviations and defects with respect to the requirements for the end products of sub-tasks in construction projects. Two main objectives were pursued: measuring the degree of deviation from a specific sub-task's requirements and determining the deviation source(s), with a view to achieving the main aim. Six classifications were proposed, based on the design and building code requirements, in order to evaluate and classify the different cases of sub-task deviations and defects.

The study's classifications have been applied to 34 cases collected from seven construction project sites, and it was found that 9% of the sub-tasks were executed perfectly and without deviations, and 91% were executed with different degrees of deviation, some of them acceptable (74%) and the others unacceptable and considered to be defects (26%). The majority of the deviation sources were found to be the actual work (74%) during the execution process, and the rest of the deviations were found to be due to both the design documentation and the actual work together (26%).

The study encountered some limitations due to insufficient data used, in terms of the variety of the sub-task requirements that were used and the number of samples that were collected for the data set. Therefore, this paper recommends using this technique for future research work in order to evaluate and identify deviations patterns for different sub-task requirements.

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