Construction Defects and their Classifications in the Construction Phase of Building Projects – A Review

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DOI: https://dx.doi.org/10.47772/IJRISS.2024.802172

Received: 05 February 2024 Accepted: 23 February 2024; Published: 26 March 2024

ABSTRACT

Construction defects are a common issue faced by buildings, and they can occur at any point during the building's lifespan. The construction industry often considers construction defects as the top issue. However, accurately identifying the type of construction defects can be challenging, which makes it difficult to determine their causes and potential mitigation strategies. Several studies have been conducted to identify the various types of construction defects, and this review aims to consolidate and examine the categories of construction defects that occur mostly at the construction stage of building projects to improve the accuracy of detecting their causes and ensuring effective mitigating techniques. Based on the examination and descriptive analysis of previously published research, this review identifies several defect classifications based on; defect nature, defect occurrence time, defect functionality, and defect based on the building process. Classifying construction defects will help construction stakeholders identify potential causes of construction defects at the construction stage and offer preventive strategies during the design and construction stages, which may eventually lead to a reduction in the time and cost of major repairs during the occupancy stage.

Keywords: Construction Defects, Classification, Mitigation Strategies, Causes of Defects, Building Project, Construction Stage.

INTRODUCTION

Building is fundamental to human existence as it furnishes individuals with shelter and facilitates a variety of social, economic, religious, and recreational pursuits. Life without buildings is unthinkable in this day and age. Furthermore, to meet diverse intended needs and safeguard users, different countries have different building construction policies and procedures (Imafidon & Ogbu, 2020). Building construction entails several procedures to achieve the aforementioned goals; the construction process includes the following phases: preliminary preparation and brief concept design, design development, technical design, on-site construction, handover, and utilization (RIBA Plan of Work 2020). Every aspect of building planning and processes, from architectural designs to construction and maintenance, necessitates proper and adequate supervision and quality input from building professionals and stakeholders (Getu et al., 2021).

According to Ahmed & Stephenson (1997), construction defects frequently occur during ongoing construction activities and can be related to various construction difficulties. It is estimated that such issues account for 95% of all defect items, emphasizing the need to prevent or eliminate them to improve the overall construction process and obtain better financial outcomes (Craig, 2006). Hence, the most common error in construction is improper installation, which accounts for 24.29% of all defects (Forcada et al., 2014). This is consistent with the definition of construction defects as flaws in a project's construction, materials, or systems that are not easily visible and result in a building, structure, or components that are unfit for the intended use (Gatlin, 2013). Moreover, inappropriate installation is defined as an installation

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue II February 2024

that is inadequate for the intended functions; as a result, defects are developed during the building construction process. Furthermore, inappropriate installation refers to the improper placement of materials, elements, or items that fail to meet project specifications or lack the necessary characteristics. (Forcada et al., 2014; Ahzahar,2011).

Overview of Construction Defects

A construction defect is a prevalent issue within the construction industry that can potentially diminish a structure's value. The timely prevention of a construction defect facilitates the project's timely completion in accordance with the designated schedule (Bagdiya & Wadalkar, 2015). Hence, classifying construction defects for proper identification will enable defects to be prevented in residential buildings. Therefore, by classifying construction defects for accurate identification, it will be possible to prevent the occurrence of defects in residential buildings. Determining the source and categorizing construction defects accurately constitutes the initial measure toward their prevention (Wahab & Hamid, 2011). Consequently, it is imperative to ascertain the classification that will provide an understanding of the origins of the construction defects to devise mitigating strategies for it (Ali A. S & K. H, 2011). It is essential to categorize construction defects in order to gain a better understanding of how to prevent them. Therefore, the categorization of construction defects is important not only by type (Alomari, 2022), but also by performance indicators (Assaf et al., 1995).

Consequently, the findings of earlier research on defects make it clear that most defects during the construction phase are unquestionably technical. Likewise, a number of researchers discovered that various construction defects could be classified according to their source or impact (Alomari, 2022). However, Lee et al. (2018) classified defects into eight categories based on their causes, which are as follows: water difficulties, surface appearance, fractured objects, abrasion, separation, inappropriate fitment, missing missions, and surface cracking. Additional research identified the following types of construction defects: material, design, and geotechnical concerns. Furthermore, Ali and Wali (2019) classified defects in technological implementation, building structural components, and technology utilization, among others, into seven distinct categories. The classification of defects into distinct phases of construction is a straightforward process, as supported by previous investigations conducted by Forcada et al. (2014), Lee et al. (2018), Ali &Wali (2019), and Alomari (2022).

Classifications of Construction Defects in Building

Any shortcomings in the design, planning, supervision, inspection, construction, or observation of construction to any new home or building that results in a construction flaw that is not reasonably workmanlike or that prevents the structure from functioning as the owner reasonably intends are commonly referred to as defects. (FindLaw, 2012). There are various techniques for classifying defects in the construction industry, such as severity, construction stage, type, cause, and others (Hood et al., 2006; Georgiou, 2010; Macarulla et al, 2013).

Classification Based on Time of Occurrence

Construction defects can be classified according to the time of their initial occurrence. Two examples are included in this classification: latent and patent.

Patent Defects

A patent defect is defined as flaws in a structure that are identifiable at or before apparent practical completion or within the defect's liability period (Barrett, 2008). Construction workers are the source of patent defects (Cama, 2004). Furthermore, patent defects are those that are easily identified and readily

visible. Cracks in the building envelope and stairways without railings are two instances of patent defects. Because of the frequent inspections that occur during construction, patent defects are handled more frequently. Even though it is typically the contractor's responsibility to find defects themselves and correct or "snag" the works as they go, the client is contractually required to inform the contractor of a client. If alerted, the contractor should correct the deficiency within a reasonable timeframe. Patent defects can be easily identified during construction inspections and the project's Defects Liability Period. Cracks in windows, water leakage, wall cracks, electrical and plumbing issues, and so on are examples of patent defects. Figure 1 depicts some patent defects commonly appearing during defects liability periods. Meanwhile, it is typically the contractor's responsibility to repair any patent defect discovered during construction activities, and they must do so within a defect liability term. (Shwan, 2011).

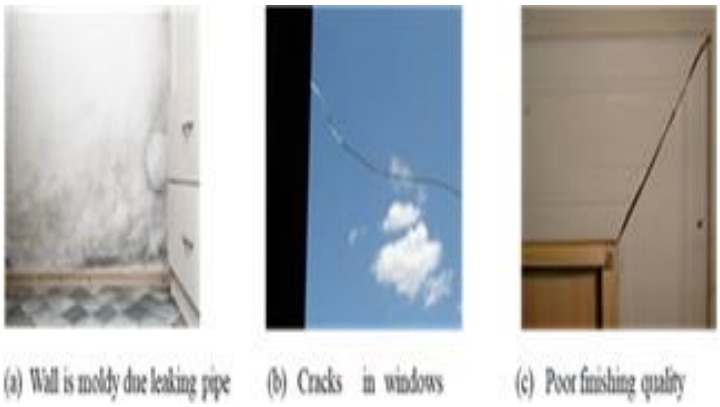

Fig. 1. Examples of Patent Defects

Latent Defects

A latent defect is concealed in the work and may go undetected for many years. This could indicate when damage has already occurred due to construction (Barrett, 2008). Similarly, latent defects are usually only discovered through research into the specific effects of the defect (Chan, 2002). Chong and Low (2005) defined latent defects as hidden defects that are not apparent until the building is used. Furthermore, the process of eliminating latent construction defects is difficult. Most latent issues become apparent only during the occupancy phase, and obtaining access to occupied buildings to collect data on these defects can be difficult. Latent defects are mostly caused by design errors, which can only be avoided by improving design (Low & Chong, 2004). The majority of these defects were seldom brought to the general public's attention unless they were of such severe nature that residents were compelled to notify the authorities. Various issues, like design errors, might cause latent defects in a residential structure. Latent defects are those that may not become apparent or easily detectable until many years after the project has been completed and the defect liability period has expired. Figure 2 shows examples of latent defects here.

Fig. 2 Examples of Latent defects

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue II February 2024

Classification-BasedNature of Occurrence

Construction defects can also be classified based on the nature of their manifestation. This group includes two types of defects: structural and non-structural defects.

Structural Defects

Likewise, a structural defect is simply any flaw in a building's structural part that arises from poor construction, material, or design (Bagdiya &Wadalkar, 2015). The illustrations in Figures 3 and 3b depict customary instances of structural defects Moreover, structural defects caused the collapse of 41 residential buildings out of a total of 56 in Nigeria between 2009 and 2019. (Odeyemi et al.,2019). Structural defects occur frequently during the construction of buildings, and they can be quite hazardous. As the structural components of a structure provide support, it is vital to protect the safety of the building's occupants by preventing these faults. Consequently, it is critical to implement every conceivable precaution to avert the occurrence of structural flaws throughout the construction process due to a particular imperfection in the materials employed; a structural defect is a flaw that develops in a structural element (Ahzaha et al., 2011). The structure of a building typically includes columns, earth-retaining walls, thick slabs, and beams (Tayeh et al., 2020). Any defects in a building's structural elements cause the entire structure to fail. Over-stressing, on the other hand, causes structural faults and instability in the foundation, which can easily damage the building's other structural components. Furthermore, a structural defect is defined as any flaw in a building's structural element caused by poor construction, materials, or design (Tayeh et al., 2020). Cracks occurring in the superstructure (walls), substructure (foundations), slabs, or floors are all examples of structural defects (Robert, 2007). Moreover, insufficient soil analysis, improper site selection, and utilization of faulty materials may also contribute to the occurrence of these defects.

Furthermore, a structural defect is simply any flaw in a building's structural part that arises from poor construction, material, or design (Bagdiya &Wadalkar, 2015). The illustrations in Figure 3 depict customary instances of structural defects. Moreover, structural defects caused the collapse of 41 residential buildings out of a total of 56 in Nigeria between 2009 and 2019. (Odeyemi et al.,2019). Structural defects occur frequently during the construction of buildings, and they can be quite hazardous.

Fig. 3 Examples of Structural Defects

Non- Structural Defects

The problems with non-essential components of a building, like finishes, brickwork, and moisture, that do not jeopardize the building's structural integrity are referred to as non-structural defects (Alomari, 2022). Furthermore, a non-structural defect in a residential building refers to a faulty non-load-bearing component resulting from inadequate building work. Non-structural defects include defects in the non-structural components of the building, services like brickwork, dampness in old structures, and defects in plaster works (Bagdiya &Wadalkar, 2015). The study carried out by Bakri and Mydin (2014) discovered a variety of non-structural cracks in buildings. Some examples are peeling paint on interior surfaces due to poor surface preparation, peeling paint on external surfaces due to exposure to rain, sun, and thermal change, and

insufficient drying time for plastered or skimmed walls or ceilings before painting.

Moreover, as shown in Figure 4, non-structural defects such as honeycomb, paint peeling, dampness penetration, and vegetable growth on buildings are caused by poor maintenance, poor project management, poor quality of construction materials, poor workmanship, lack of site supervision, and poor construction practices (Borku,.2020). Additionally, Rain, condensation, flooding, service leaks, construction activities, and inappropriate building use are some of the reasons a structure may become damp. Lastly, environmental exposure during use can cause non-biological deterioration in wood. Although non-structural defects may not pose a direct threat to the structural integrity of a building, they can significantly affect the level of satisfaction derived from a residential building. This research primarily focuses on the structural defects that typically occur during the construction stage of a residential building and explores ways to prevent or minimize their occurrence.

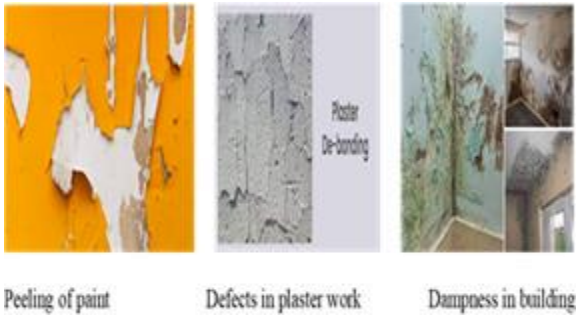

Fig 4 Examples of Non-Structural Defects

Classification-Based on the Functionality of Defects

Defects can be as critical or inconsequential depending on how well the construction performs. Serious defects are characterized by a danger of harm, including death or the possibility of significant financial loss. According to the visibility, there are apparent defects and hidden defects. Apparent defects can be detected during routine maintenance or visual inspection. Hidden defects are not detectable by routine inspection or by maintenance. Moreover, several studies rely on a different approach to viewing defects. (The Building ACT, 2006). This study focuses on looking at the construction phase and how the occurrence of defects could be prevented.

Classification-Based on Building Process

The building processembedded three important factors they are design, materials and construction. Defects can easily be generated as a result of these three factors. Hence, researchers classified the occurrence of defects in the building process into four categories, namely: design flaws, material flaws, construction flaws, and subsurface problems (Marianne,2005; FindLaw,2012; Alomari, 2014; Georgiou, 2010; Macarulla et al., 2013). Therefore, this classification of construction defects aligns with the research's adopted definition of construction defects, which characterizes such defects as deficiencies in the design, construction, or utilization of materials that render a structure, building, or component unsuitable for its intended purpose (Gatlin, 2013).

Design Deficiency

The design phase of any construction project is critical; it specifies the specifications, plans, and parameters (Fuadie et al., 2017); the study also revealed that design faults constitute a key sort of construction defect during the construction stage of the building process. As a result, the project development and construction stages will fail. Also, design defects are deviations from the plans and standards (Ali Haghani, 2015).

Similarly, design defects are avoidable deviations from established standards of practice throughout the design of construction projects (Dosumu et al., 2017). When parties' conceptions of a design are misunderstood, it will result in design flaws, which can lower the calibre of building work. Moreover, structural failures are sometimes caused by design defects. Architects and engineers are professionals in design; they create structures and systems. Even experts do not always complete tasks exactly as instructed, frequently resulting in defects. Commonly, architectural deficiency pertains to structures that are not part of the designated building. codes. Improperly designed roofs are an example of a design defect that can result in water penetration, intrusion, poor drainage, or inadequate structural support. Similarly, Ayodele, (2017) agreed with the report that 56% of all contract modifications are made to design deficiencies. These will result in defects in the construction site, which are considered the most severe because they stem from the designer's blatant errors due to lack of training, expertise, or experience. Similarly, deficiencies in architects' designs amount to 60% of defects in construction projects based on a survey of 250 building projects (Vachara Peansupap, 2015).

Proper design during the design stage is crucial in the building construction process. Proper planning during this stage will minimize the occurrences of construction defects. Consequently, a number of studies identified design defects as one of the primary causes of construction issues. Similarly, almost 55% of building defects are related to design errors, which could have been avoided with better design (Alomari, 2022). Similarly, studies have indicated that the design of a building influences building defects, building maintenance, and building project performance (Hauashdh et al., 2020). Defects in the design stage were influenced by a lack of awareness, incomplete knowledge, wrong expectations, and ignorance (Khalid, 2019; Wali& Ali, 2019; Ali Haghani, 2015; Vashishtha et al., 2020)

Materials Deficiency

Another type of building defect that frequently arises during construction is a material deficit (Yoon. Son & Kim 2021). The materials or components (both natural and man-made) utilized to create buildings in a selected location are referred to as building materials (Bamigboye et al., 2019). According to Elkhalifa& Shaddad, construction materials comprise the largest percentage of input in the building components (2018). Various materials are utilized in the building, and all users are responsible for guaranteeing their appropriate usage. This is to prevent specific types of defects from happening on the building site. To do this, it is necessary to have solid information and understanding of building materials (Ahzahar et al., 2011).

Similarly, the majority of buildings are constructed with readily available local resources. Such building materials include timber, stone, brick and plaster. Moreover, to prevent defective materials and reduce future maintenance waste by using these local materials, it is essential to check the materials' sustainability and quality during the building construction process (Coelho &. De Brito, 2012; Kanniyapan, 2019). Furtherance to monitoring the sustainability and quality of the materials is possible by providing enough monitoring to ensure the selected materials are of satisfactory quality. Hence, to ensure that, after the building's construction is complete, their fixtures will be safe to use and fit for use in various circumstances (Asmone et al., 2019). Understanding the composition of building materials, together with proper defect identification, is crucial for the materials management of buildings. Moreover, as older people are vulnerable to certain illnesses, the same applies to buildings concerning defects. To address construction defects, architects, contractors, engineers, and those involved in building management should be familiar with common building materials and have a deeper understanding of proper materials and building preservation techniques (Ahzahar et al., 2011).

Construction Deficiency

Construction projects with poor quality of work are a worldwide phenomenon. Numerous disagreements over cases of construction defects occurred between clients, homeowners, and parties involved in the

construction process (particularly contractors). Various types of construction defects are constantly a matter of concern in the construction industry (Ali & Wen, 2011). The level of quality satisfaction in construction projects has not been attained and is a significant issue in the construction industry (Abdul Razak et al, 2010).

Furthermore, construction is a complicated stage of a building's life cycle, as Alomari (2022) established, because it involves a lot of interconnected tasks that require efficient operation to manage within the necessary parameters without compromising the quality of the structure and its components. Consequently, when different covering to some sections of work is carried out incorrectly, the structure is exposed to several defects that inadvertently affect other tasks like painting and plastering. In addition, construction defects usually result from incorrect assessment of designs and standards. Construction defects become prominent at the construction stage once there is non-performance of this construction indicator: damaged formwork, excavation tools close to the building, painting in an unsuitable condition 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, lack of communication.

Meanwhile, according to Alomari (2022), the construction phase of a building's life cycle is complex because it entails a number of interrelated tasks that must be managed effectively within the required constraints without sacrificing the structure's and its components' quality. Consequently, when different covering to some sections of work is carried out incorrectly, the structure is exposed to several defects that inadvertently affect other tasks like painting and plastering. In addition, construction defects usually result from incorrect assessment of designs and standards. Construction defects become prominent at the construction stage once there is non-performance of these construction indicators, e.g damaged formwork, excavation tools in close proximity to the structure, unsuitable painting conditions or surfaces, insufficient drainage and waterproofing, inadequate reinforcement concrete cover, loss of adhesion between materials at cold joints, premature removal of formwork, inadequate curing and soil compaction, and a lack of communication.

Moreover, it was revealed that the most prevalent defects in residential buildings are primarily the result of poor workmanship quality (Ali & Wen, 2011). The study further discovered that lack of experience and competency was considered the most important factor that contributes to poor workmanship, which gives rise to occurrences of construction defects. In furtherance, a worker will not be able to work in accordance with standards and specifications if such a worker lacks knowledge and expertise in a particular field. Hence, the expertise of a construction worker is a major factor in the quality of work done on a construction site.

METHODOLOGY

This review employed a methodology that involved an examination of several published articles pertaining to the classification of construction defects. The classifications from the review literature were extracted and displayed in a table (Table 1). The table took into account the following indicators to draw up the findings and conclusion:

Column 1: demonstrates the methodology used to classify construction defects. The rationale behind the classification is disclosed in this column.

Column 2 reveals the group name for the classification of construction defects. This serves to identify one classification from another.

Column 3 displays examples of construction defects in that group's classifications. This allows us to

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue II February 2024

identify the specific defects of a given class.

Column 4 shows the stage in the construction process at which the defects occur. This will improve information on when certain defects occur in the building, either during construction or during occupancy. It aids in determining the root causes and how best to mitigate them.

Column 5 shows the stage at which the defects in the building become visible. This will also improve understanding of the defects' causes, whether they appear during the construction or occupancy stages.

Table 1. Classification of Construction Defects in the Construction Stage.

S/N	Classification of Construction Defects and Basis.	Name of Classifications	Examples of D Defec Construction Defects.	Occurrence of Construction Defects		Appearance of Construction Defects		
				Cons.	Occupy	Cons.	Occupy	. Author.
1	Classification Based on Time of Occurrence	Patents Defects	Cracks in Window	✓		✓	✓	
			Water leakages	✓			✓	
			Electrical and Plumbing issues	✓	✓		✓	Shwan, (2011)
			Poor Finishing Wall	✓				
			Moldy Water	✓			✓	
		Latent Defects	Plaster Cracks	✓			✓	Barrett, (2008).
			Leak in the Roof				✓	Chan, (2002).
			Water Seepage				✓	Chong &Low (2004
			Tiles Delamination				✓	Chong & Low (2006)
			Loose Panel				✓	
2	Classification Based on the Nature of Defects	Structural Defects						
			Cracks in Column & Beams	✓			✓	Bakri &Mydin (2014
			Cracks in Slab	✓			✓	Bagdiya &Wadalkar, (2015).
			Cracks in Foundation	✓			✓	Borku,.(2020
		Non-Structural Defects						

			Peeling paint		✓		✓	Bakri & Mydin (2014)
			Condensation		✓		✓	
			Skimmed Wall		✓		✓	Bagdiya &Wadalkar, (2015).
			Dampness in Building		✓		✓	
			Growth in building		✓		✓	(Borku,.2020
3	Classification Based on Functionality.	Serious Relevance Defects	Cracks in Slab	✓		✓		
		Irrelevant Defects	Broken Tiles		✓		✓	The Building Act (2006)
		Visible Defects	Unsightly Wall Surface		✓		✓	
		Hidden Defects	Reduced Structural Strength	✓			✓	
4	Classification of Construction Defects Based on Building Process.							
		Design Deficiency Defects						
			Leaking of Roof based on bad Design	✓		✓	✓	Vashishtha et al., (2020).
			Unsightly Surface based on Design not relating to material selection to climate	✓			✓	Ali Haghani; (2015)
			Reduced Structural Strength due to Design Inadequate provision for expansion.	✓		✓	✓	Wali& Ali, (2019) Khalid, (2019
		Materials Deficiency						
			Roof leakages due to Inferior asphalt roofing shingles	✓		✓	✓	Bamigboye et al., (2019

			Unsightly wall surface due to the use of expired materials	✓			✓	Yoon. Son & Kim - 2021
			Reduce strength due to Concrete aggregates not to standard.	✓		✓	✓✓	Ahzahar et al., (2011). Asmone et al., (2019
		Construction Deficiency Defects	Wrong fixing of door frame due to Incompetency of worker	✓		✓	✓	Ali & Wen, (2011) Alomari (2022 Abdul Razak et al, (2010)
			Wrong positioning of Wall due to Misinterpretation of drawing Faulty Foundation	✓		✓	✓	
			Lack of Supervision	✓		✓	✓	

FINDINGS AND DISCUSSION

Table 1 examines the various classifications of construction defect occurrence in a residential structure. The table shows that building defects can be divided into four categories. This supported the findings of Georgiou (2010) and Macarulla et al. (2013), who proposed that construction defects in the building industry can be classified based on factors such as severity, construction stage, types, cause, and more.

The Table also shows the stage at which construction defects appear in the building. This should shed some light on the underlying cause of the building's construction defects. Finding the precise moment when a defect occurs and manifests itself increases the likelihood that its causes will be known, and if that cause is identified, mitigating the problem will be a simple effort. This matched the findings of Nabihah et al. (2016) and Tayeh et al (2021).

Additionally, Table 1 shows that the majority of problems occur more frequently during the building process' construction stage than during the occupancy stage, suggesting that further research is needed to determine methods to prevent construction defects during this period. By doing this, the consequences of issues arising when the building is occupied will be significantly decreased. This is consistent with the findings of Chong & Low (2006).

The prevalence of defects during the occupancy phase as shown in Table 1, on the other hand, emphasizes the importance of defect classification based on the building process. Throughout the building process, special attention must be paid to the materials, design, and construction used (FindLaw, 2012). Construction materials must meet the required standards. This increases their durability within the building structure and protects against premature defects caused by external factors (Chong & Low, 2006).

CONCLUSION AND RECOMMENDATION

According to this review, construction defects are classified into four major categories. The results showed

that there are four major categories of defects: those based on defect nature, those based on defect occurrence time, those based on defect functionality, and those based on building process. These results may be used for the following purposes: Finding the specific flaws shared by different defect classification categories will help determine the root causes of construction defects and the most effective ways to mitigate them. It will also provide better information about when specific building defects occur during construction or the occupancy stage. Construction stakeholders and the government should collaborate to ensure that the information provided in this review is used to mitigate the problem of construction defects in the building construction process in Nigeria. Future research could look into how a framework could be developed to reduce construction defects in the building industry as well as time and cost waste during the occupancy stage.

Recommendation

Stakeholders in the construction industry should pay attention to ways to stop defects from occurring when a structure is being constructed.

It is imperative for professionals to exercise diligent oversight during the design and construction phases to avert incurring additional costs and time required to rectify defects during the occupancy phase.

To mitigate the risk of construction defects in the building, the contractor must ensure high-quality supervision, utilize standardized materials, and guarantee effective workmanship throughout the construction phase.

Furthermore, the building owner is responsible for ensuring that standard and appropriate materials for the building's construction are procured through a representative present on the construction site. In the long run, the owner bears the financial and temporal or permanent consequences.

The government is responsible for enforcing building regulations by ensuring that construction processes and materials adhere to the established standard.

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