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Evaluation of Concrete Work Practices in Residential Building Construction Sites in Kano Metropolis, Nigeria

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Abstract Prompted by the increasing frequency of building collapses in the region, the research assesses the processes of concrete mixing, handling, placement, and curing across 100 active construction sites. This study examines concrete work practices in residential building construction within Kano Metropolis, Nigeria, with a specific focus on compliance with Section 10.3.9.3 of the Nigerian National Building Code (NNBC). Data were collected using structured observational checklists and site photographs. The findings indicate widespread non-compliance with key standards, including batching accuracy (20% compliance), use of approved mix designs (2%), and implementation of quality control testing (2–4%). Although materials such as cement and water generally meet quality specifications, issues such as poor storage conditions, reliance on manual mixing, inadequate compaction, insufficient curing, and lack of proper documentation undermine concrete integrity. These deficiencies are largely attributed to inadequate technical expertise, limited supervision, and weak enforcement of regulatory frameworks. As a result, concrete strength is often compromised, increasing the risk of structural failure. The study emphasizes the need for targeted capacity-building initiatives, stricter regulatory enforcement, and widespread adoption of standardized practices. Key recommendations include mandatory training for site personnel, improved supervisory mechanisms, and the use of certified mix designs to enhance structural performance and safety. Overall, the study contributes to efforts aimed at improving construction quality and promoting sustainable urban development in Kano and comparable urban centres.

Keywords Concrete Work, Building Code, Construction Quality, Compliance, Nigeria, Residential Building

1. Introduction

Concrete is one of the most widely used construction materials due to its versatility, durability, and affordability [1]. It is a composite material composed primarily of cement, aggregates (such as sand, gravel, or crushed stone), and water. When mixed together, these ingredients undergo a chemical reaction called hydration, which causes the mixture to harden and gain strength over time [2]. Concrete's strength and durability make it ideal for various construction applications, from foundations and structural frameworks to roads and bridges [3]. It can also be molded into different shapes and sizes, allowing for a wide range of architectural designs. Additionally, concrete's thermal mass properties enable it to absorb and store heat, contributing to energy efficiency in buildings [4]. However, its production has significant environmental impacts, particularly due to the carbon dioxide emissions associated with cement manufacturing [5]. Efforts are being made to develop more sustainable concrete alternatives and construction practices to reduce these impacts while maintaining the material's beneficial properties [6].

Proper mixing, placement, and handling of concrete are crucial to ensuring its quality and performance [7]. The mixing process must achieve a uniform consistency, with all components evenly distributed to avoid weak spots. The water-cement ratio is particularly important, as too much water can weaken the concrete, and too little can make it difficult to work with. Once mixed, concrete must be placed promptly to avoid premature setting, which can compromise its integrity. During placement, it is essential to avoid segregation of the aggregates and ensure that the concrete fully compacts and adheres to the reinforcement and formwork. Vibrators are often used to remove air pockets and achieve a dense, uniform structure. Finally, proper curing is necessary to allow concrete to gain strength and durability. Curing involves maintaining adequate moisture and temperature conditions to facilitate the hydration process [8]. Improper handling or premature loading can lead to cracks, reduced strength, and other issues that compromise the longevity of the structure.

Concrete exhibits high durability and fire resistance, making it suitable for diverse environmental conditions [1]. It can withstand significant compressive forces, making it suitable for high-rise buildings and large infrastructure projects [3]. Over time, innovations in concrete technology have led to the development of high-performance concrete that offers enhanced strength and durability, as well as self-healing concrete that can automatically repair cracks [9]. These advancements have expanded the scope of concrete applications, enabling the construction of more resilient and long-lasting structures that can withstand harsh environments.

Building collapses in Nigeria have risen sharply in recent years. Between 2015 and 2023, the Nigerian Institute of Building reported over 200 structural failures nationwide, with Kano State accounting for at least 12 incidents—many linked to poor concrete practices in residential buildings [10]. Prior studies identified non-compliance with batching, curing, and quality control as key causes [11]. However, no recent empirical study has systematically assessed on-site concrete work compliance in Kano—a rapidly urbanizing city with a largely informal construction sector and weak regulatory enforcement. This study fills that gap by evaluating adherence to Section 10.3.9.3 of the NNBC across 100 residential sites in Kano Metropolis. The specific objectives are: (1) to assess compliance levels in concrete batching, mixing, placement, curing, and quality control; (2) to analyze the impact of current practices on structural safety; and (3) to identify priority areas for training and regulatory intervention. The research addresses three questions: (i) What is the level of compliance with established standards? (ii) How do current practices affect building safety and durability? and (iii) Which concrete work areas require urgent intervention?

The use of concrete dates back to ancient times, with the Romans being renowned for their advanced concrete structures, many of which still stand today [12]. The Pantheon in Rome, with its massive concrete dome, is a testament to the material's enduring strength and versatility. Modern advancements have continued to expand the applications of concrete, including its use in underwater structures, such as dams and tunnels [4]. The ability to construct underwater and in challenging environments showcases concrete adaptability and resilience.

Reinforced concrete, which incorporates steel reinforcement bars (rebar) to enhance tensile strength, is a critical innovation that has further extended the possibilities of concrete construction [2]. This combination of concrete and steel allows for the creation of complex architectural forms and long-span structures, such as bridges and overpasses [3]. The synergy between concrete and steel provides a robust solution for modern engineering challenges, enabling the construction of iconic and durable structures.

Furthermore, concrete's ability to be locally sourced and produced makes it a cost-effective option for many construction projects [5]. Its ability to incorporate various waste materials, such as fly ash and slag, also contributes to its sustainability [6]. By improving the formulation and production processes, the construction industry continues to push the boundaries of what concrete can achieve, striving to create structures that are not only strong and durable but also environmentally responsible [4]. As research and innovation continue, the future of concrete holds promises for even greater advancements in sustainability and performance.

The Nigerian National Building Code (NNBC) is an essential framework that sets forth comprehensive guidelines and standards for the construction industry in Nigeria, ensuring that buildings and structures are safe, durable, and sustainable. This code plays a vital role in the various stages of concrete work, particularly in mixing, handling, and placement practices. The NNBC provides standardized procedures for these processes, ensuring consistency and uniformity in construction practices. This standardization minimizes variations in concrete quality and performance, leading to more reliable and durable structures.

One of the critical aspects emphasized by the NNBC is quality control. It mandates the selection of proper materials, accurate batching, and thorough mixing to achieve the desired concrete properties. This ensures that the concrete mix meets the required strength and durability standards, reducing the risk of structural failures. Inadequate handling techniques are addressed by the code, which outlines best practices for transporting, placing, and compacting concrete. Proper handling prevents segregation of aggregates and ensures uniform distribution of the mix, leading to stronger and more durable concrete structures.

Furthermore, the code highlights the significance of proper curing and maintenance. Adequate curing allows the concrete to gain the necessary strength and durability, while regular maintenance helps prolong the lifespan of the structure. By adhering to these guidelines, construction practices comply with safety regulations and standards, promoting a safer working environment for construction workers and enhancing the overall safety of the built environment.

The NNBC's role extends beyond just providing technical guidelines; it fosters a culture of accountability and professionalism within the construction industry. By ensuring that concrete practices are standardized, consistent, and of high quality, the NNBC helps build public trust in the safety and reliability of structures across Nigeria. This, in turn, supports the nation's broader goals of sustainable development and urbanization, ensuring that as cities grow, they do so in a manner that prioritizes the well-being and safety of their inhabitants.

The rapid urbanization of Kano metropolis has significantly increased the demand for residential buildings, resulting in a surge in concrete usage; however, this growth has been accompanied by several challenges that compromise the quality, safety, and longevity of structures, with an increasing rate of residential building collapses. A major contributing factor to these issues, as identified by numerous studies, is poor concrete work practice, particularly in residential construction. In response, this study aims to evaluate the current practices of concrete work in residential building construction within Kano metropolis, focusing on compliance with Section 10.3.9.3 of the Nigerian National Building Code and established industry standards. The specific objectives include assessing the level of adherence to code provisions in areas such as mixing, handling, compaction, curing, and quality control; analyzing the impact of current practices on structural safety and durability; identifying areas requiring urgent intervention or training; and providing actionable recommendations for improvement. The research seeks to answer key questions regarding the extent of compliance with standards, the implications of current practices on building safety, and priority areas for capacity building. This study holds significant value as it underscores the critical role of proper concrete work in ensuring structural integrity and promoting durable housing. By identifying gaps and offering data-driven insights, the findings will support contractors, engineers, and regulatory bodies in improving construction practices and enforcing compliance with building codes, ultimately contributing to the reduction of structural failures and building collapse incidents in Kano metropolis.

2. Study Area

The research focuses on Kano metropolis, situated in Kano State, Nigeria. This urban center consists of eight local government areas (LGAs): Dala, Fagge, Gwale, Kano Municipal, Kumbotso, Nassarawa, Tarauni, and Ungogo. Geographically, Kano metropolis is positioned between latitudes 11°59’59.57” and 12°02’39.57” North, and longitudes 8°31’19.69” and 8°33’19.69” East, with an elevation of 472 meters above sea level. The total land area covered by the metropolis spans roughly 499 square kilometers. Figure 1 illustrates: (a) a map of Nigeria highlighting Kano State and (b) Kano State indicating the study area. Kano metropolis experiences a tropical wet-and-dry climate. The dry season extends from November to April. Temperatures remain consistently high year-round, averaging highs of 33-35 ℃ and lows of 18-20 ℃. Surrounding LGAs such as Minjibir to the northeast, Gezawa to the east, Dawakin Kudu to the southeast, and Madobi and Tofa to the southwest form a continuous urban region with Kano metropolis. According to the 2006 census, Kano metropolis had a population of 2,826,307 inhabitants. Recent estimates suggest that the population has surged to about 4.3 million as of 2020, positioning it as the second-largest metropolitan area in Nigeria after Lagos. This swift urban expansion has led to challenges concerning infrastructure growth, transit systems, housing, water supply, and geotechnical issues. A map depicting Kano State with the boundaries and constituent LGAs forming Kano metropolis is shown in Figure 2.

Figure 1. Map of Nigeria showing Kano state

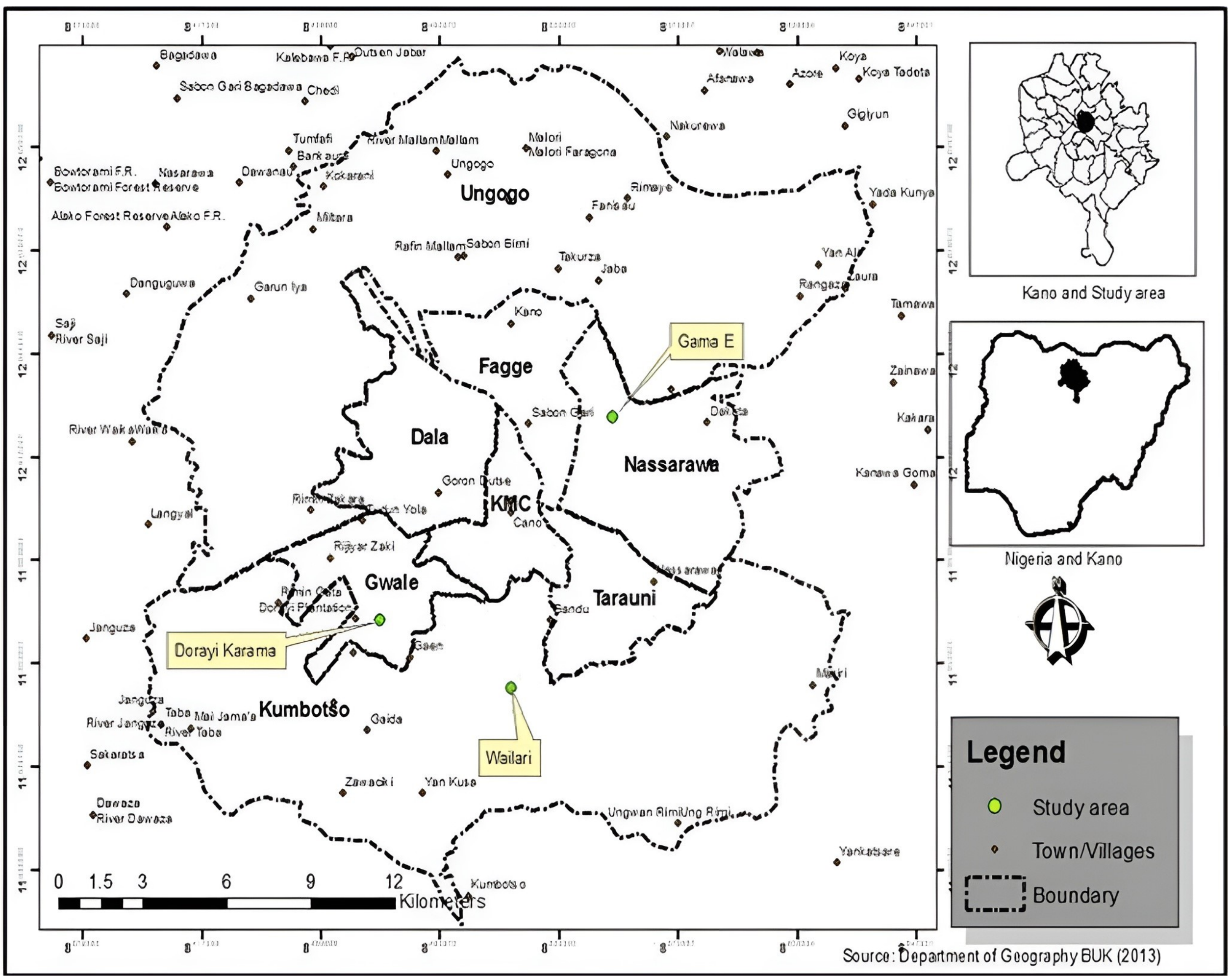

Figure 2. Map of Kano state showing study area

3. Methodology

This study employed a descriptive survey design to evaluate the practices of concrete work in residential building construction across Kano Metropolis. The chosen methodology was well-suited for observing real-time construction activities without altering site conditions, allowing for objective documentation of compliance with the Nigerian National Building Code (NNBC), particularly Section 10.3.9.3. The research was conducted across 100 active construction sites, selected purposively to ensure that each was currently engaged in concrete-related work.

The 100 residential construction sites were selected purposively based on active concrete work and accessibility across the eight LGAs of Kano Metropolis (Dala, Fagge, Gwale, Kano Municipal, Kumbotso, Nassarawa, Tarauni, and Ungogo). The sample includes a mix of contractor types, formal firms, informal builders, and owner-supervised projects to reflect the diversity of current practice.

A structured observation checklist (summarized in Table 1 and provided in full in Appendix A) was used to assess compliance with Section 10.3.9.3 of the Nigerian National Building Code (NNBC), supported by ACI 304 and BS EN 13670. Each item was scored binary (1 = compliant, 0 = non-compliant).

Data were analyzed using descriptive statistics only (frequencies and percentages), as the study was designed to document baseline practices, not to test hypotheses or compare subgroups.

Observations were conducted with verbal permission from site supervisors. No personal data was collected, and no intervention or disruption occurred during site visits.

The study focused on a targeted population comprising civil engineers, builders, foremen, artisans, and laborers directly involved in residential construction. Data collection utilized multiple instruments, including a structured observation checklist developed from the NNBC provisions, which assessed key phases such as material selection, batching, mixing, handling, placement, compaction, and curing. Supplementary tools included photographic evidence, field notes, and brief informal interviews with site personnel to clarify non-observable practices.

Each site was visited, and activities were observed without interference. Observations were scored using a binary format (compliant or non-compliant), enabling consistent data classification. The collected data were analyzed using descriptive statistical methods such as frequency distributions, percentages, and tabulations to determine compliance levels and identify major lapses. Emphasis was placed on practical compliance indicators like the use of standard mix designs, curing durations, compaction techniques, and documentation of quality control procedures. Validation of instruments was achieved through expert reviews, pilot testing on selected sites, and alignment with international standards (ACI and BS). Ethical considerations were strictly followed, including securing consent from site authorities, ensuring participant anonymity, and avoiding disruption to site activities. This rigorous methodology ensured reliable and credible findings, forming a robust foundation for evaluating the quality and standardization of concrete work in Kano's residential construction sector.

3.1. Evaluation Criteria and Compliance Metrics

To ensure objective and standardized assessment, each concrete work practice was evaluated against explicit compliance criteria derived primarily from Section 10.3.9.3 of the Nigerian National Building Code (NNBC), supplemented by relevant provisions from ACI 304 (Guide for Measuring, Mixing, Transporting, and Placing Concrete) and BS EN 13670. Compliance was scored dichotomously (1 = compliant, 0 = non-compliant) based on direct observation or verification of documentation. The specific evaluation metrics for each category are summarized below:

- Material Quality: Cement type verified against NNBC-approved grades (NNBC 10.3.2); water tested for pH and absence of chlorides/suspended solids (NNBC 10.3.3); aggregates assessed for cleanliness and grading (BS 882); admixture usage required manufacturer dosage documentation (ACI 212.3R).
- Batching and Mixing: Compliance required the use of weight-based batching (NNBC 10.3.9.3a) and a documented mix design from a certified laboratory (ACI 211.1). Manual mixing was deemed non-compliant unless validated by slump and strength tests.
- Handling and Transportation: Concrete placement within 30 minutes of mixing (ACI 304.2R) and use of non-segregating transport methods (e.g., wheelbarrows with smooth movement). Exposure to rain or direct sun without cover constituted non-compliance.
- Placement and Compaction: Continuous placement without cold joints (NNBC 10.3.9.3d); use of mechanical vibrators for all structural elements (BS EN 13670 8.3); layered pouring thickness ≤500 mm.
- Curing Practices: Initiation within 1 hour of finishing and maintenance of moist conditions for ≥7 days (NNBC 10.3.9.3e; ACI 308.1). Acceptable methods included ponding, wet hessian, or curing compounds.
- Quality Control and Testing: On-site slump tests per batch (ACI 238.1R) and casting of at least three 150-mm cubes per 50 m^3 for 28-day compressive strength testing (NNBC 10.3.9.3f).
- Documentation: Retention of material certificates, mix design approvals, test results, and daily work logs (NNBC 10.3.9.3g).

The results of the material quality are shown in Figure 3.

Table 1. Summary of Concrete Work Practice Domains Assessed

Domain	Key Observed Practices
Material Quality	Cement type, water cleanliness, aggregate condition, admixture use, storage practices
Batching & Mixing	Use of weight batching, certified mix design, mechanical mixing, slump testing
Handling & Transport	Time from mixing to placement, protection from weather, segregation control
Placement & Compaction	Continuous pouring, layer thickness, use of vibrators, reinforcement condition
Curing Practices	Initiation time, method (e.g., wet hessian, ponding), duration (≥7 days)
Quality Control	Slump tests, cube casting, 28-day strength testing
Documentation	Availability of mix design, material certificates, test records, daily work logs

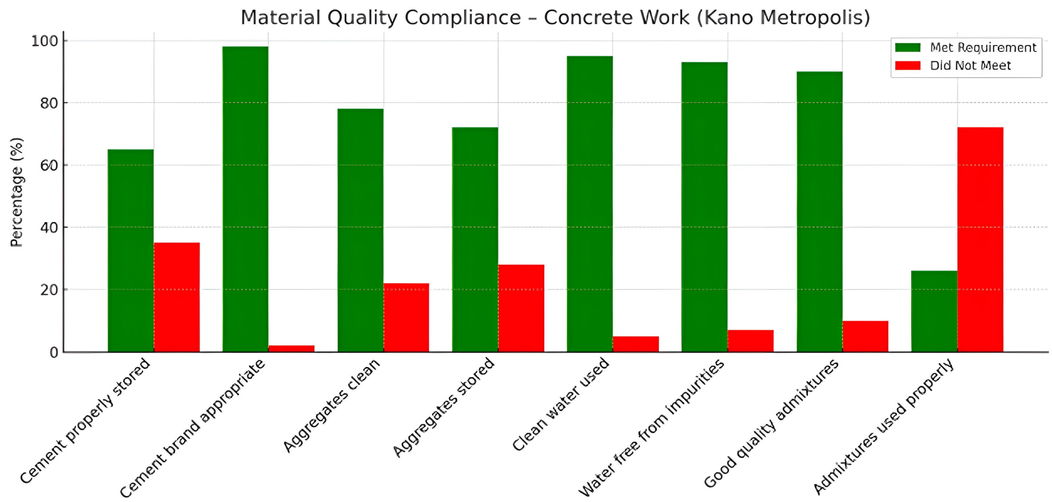

Figure 3. Material Quality

4. Results and Discussion

This section presents the key findings obtained from the analysis of the data collected from the selected residential building construction site across Kano metropolis. The section is organized based on the different parts of concrete work evaluated.

4.1. Material Quality

The results of the material quality are shown in Figure 3. The analysis of the data of material quality reveals strong compliance with cement type and water quality, which are essential for achieving the desired strength and workability of concrete. However, weak practices in the usage of admixtures and improper cement storage remain significant challenges. Admixtures play a vital role in enhancing properties like setting time and durability, but when used incorrectly, they can compromise the consistency and strength of the concrete. Additionally, inadequate storage practices, such as exposing cement to moisture, can lead to a reduction in its binding capability. These issues highlight the need for stricter adherence to storage protocols and improved understanding of material specifications to ensure long-term structural stability.

4.2. Concrete Batching and Mixing

This analysis indicates critical deficiencies in batching and mixing procedures, with minimal attention given to precise mix designs or testing, as shown in Figure 4. Proper batching is fundamental to achieving the required concrete strength and durability. Poor mixing practices result in the segregation of materials and inconsistent properties, reducing the quality of the final product. Without precise proportioning and technical supervision, the structural integrity of residential buildings is at risk. Addressing these gaps through standardized mix designs and regular testing can substantially improve the quality of construction.

4.3. Handling and Transportation

Handling and transportation practices for concrete show certain positive efforts, such as reducing the time between mixing and placement, as revealed in Figure 5. However, the lack of proper equipment and inadequate protection against environmental factors like high temperatures or rainfall pose serious risks to concrete quality. These factors can lead to premature setting or washout of the cement paste, ultimately reducing the material's workability and bonding strength. Improving logistical planning, providing adequate weather protection, and utilizing appropriate equipment are essential for maintaining the quality of transport concrete.

4.4. Handling and Transportation

Although surface finishes appear satisfactory, the data reveals poor internal placement techniques, such as insufficient compaction and improper layered pouring. These practices result in air pockets and weak bonds between layers, making the structure susceptible to cracking and other failures over time. Proper compaction techniques, such as the use of vibration tools, and better supervision during placement are necessary to ensure uniform density and enhance the structural performance of residential buildings.

4.5. Placement and Compaction

Although surface finishes appear satisfactory, the data reveals poor internal placement techniques, such as insufficient compaction and improper layered pouring, as seen in Figure 6. These practices result in air pockets and weak bonds between layers, making the structure susceptible to cracking and other failures over time. Proper compaction techniques, such as the use of vibration tools, and better supervision during placement are necessary to ensure uniform density and enhance the structural performance of residential buildings.

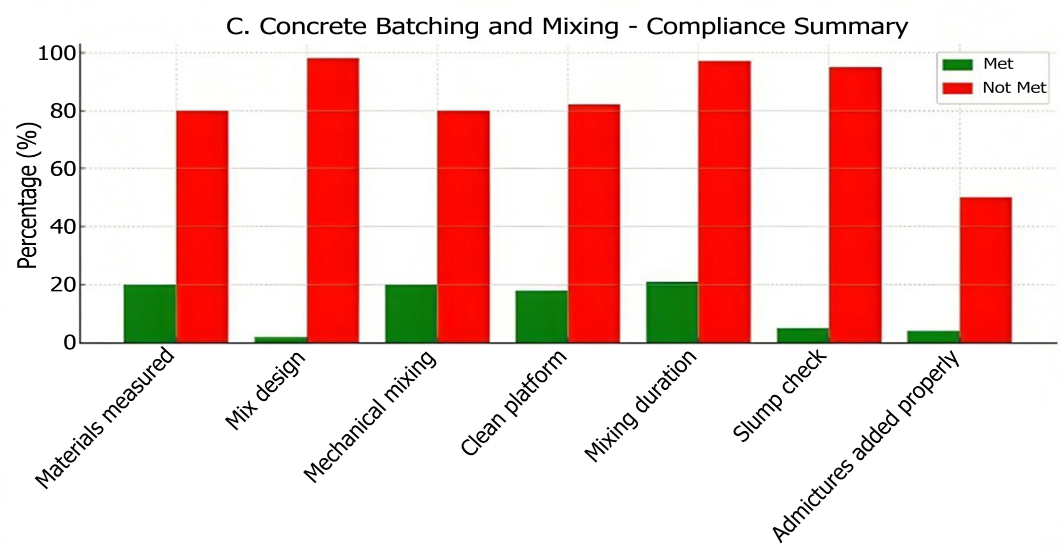

Figure 4. Batching and Mixing

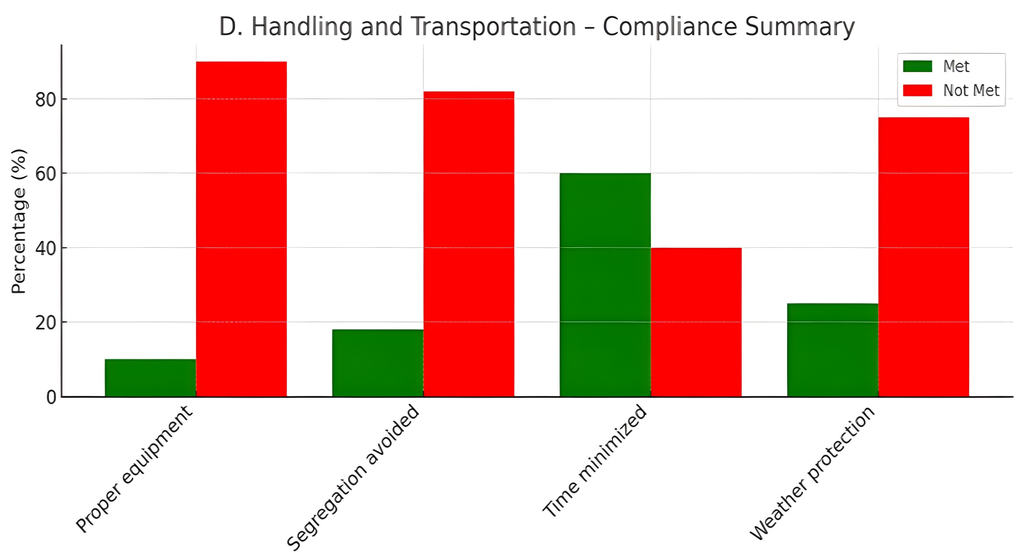

Figure 5. Handling and Transportation

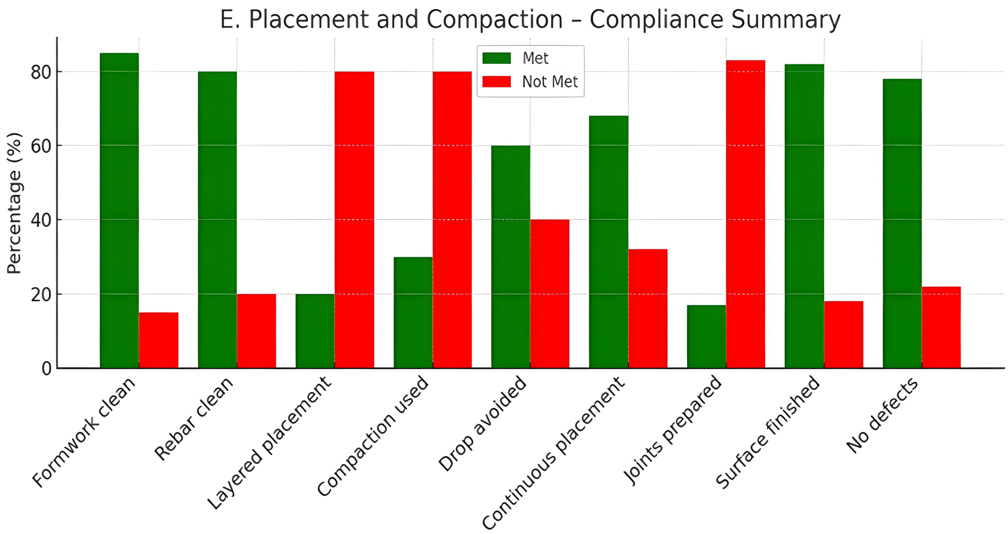

Figure 6. Placement and compaction

4.6. Curing Practices

The curing compliance is summarized in Figure 7. Curing, though initiated promptly in most cases, often falls short due to improper methods and insufficient durations. These shortcomings inhibit the concrete's ability to achieve its intended strength and durability. Adequate curing requires maintaining proper moisture and temperature levels for a specified duration to facilitate the hydration process. Neglecting these practices can lead to surface shrinkage, reduced compressive strength, and increased vulnerability to environmental stresses. Clear guidelines and consistent monitoring during curing processes are crucial for safeguarding the longevity of structures.

4.7. Quality Control and Testing

The analysis highlights a lack of routine testing and quality assurance measures across the surveyed sites. Quality control procedures, such as slump and compressive strength tests, are critical for identifying defects and ensuring compliance with design specifications. The absence of proactive testing leaves structural flaws undetected, increasing the risk of failure under operational conditions. Establishing a structured quality control framework, including regular inspections and testing, is vital to improving construction standards and reducing risks. Figure 8 gives the compliance summary for quality control and testing.

4.8. Documentation and Record-Keeping

Poor documentation practices are a recurring issue that undermines accountability and limits the ability to trace and rectify construction flaws. Documentation is essential for tracking compliance with material and procedural standards, as well as for conducting audits and maintenance in the future. The lack of recorded deviations and quality checks reduces the overall effectiveness of construction oversight. Implementing robust record-keeping systems and making it a mandatory component of the construction process will greatly enhance transparency and quality control. The compliance summary for documentation and record-keeping is highlighted in Figure 9.

4.9. Research Questions

4.9.1. Research Question 1: What Is the Level of Compliance of Concrete Work with Established Industry Standard in Residential Building Construction within Kano Metropolis

The evaluation of concrete work practices from over 100 residential construction sites reveals a mixed level of compliance with established industry standards, such as those outlined by the Nigerian Building Code, the American Concrete Institute (ACI), and the British Standards (BS EN). The findings indicate strong performance in certain areas but also expose critical lapses that warrant immediate attention.

Starting with **material quality**, compliance is relatively high. Most sites (98%) use the appropriate type and brand of cement, while 95% use clean water — both of which are fundamental to achieving durable and high-strength concrete. Clean and impurity-free aggregates were used in 78% of sites, and 72% stored them properly. Figure 10 indicates that material sourcing and preliminary handling are well understood and practiced. However, only 26% of sites used admixtures according to manufacturer recommendations, despite their potential to improve concrete workability, setting time, and long-term performance. This suggests a knowledge gap or a lack of technical guidance in admixture applications.

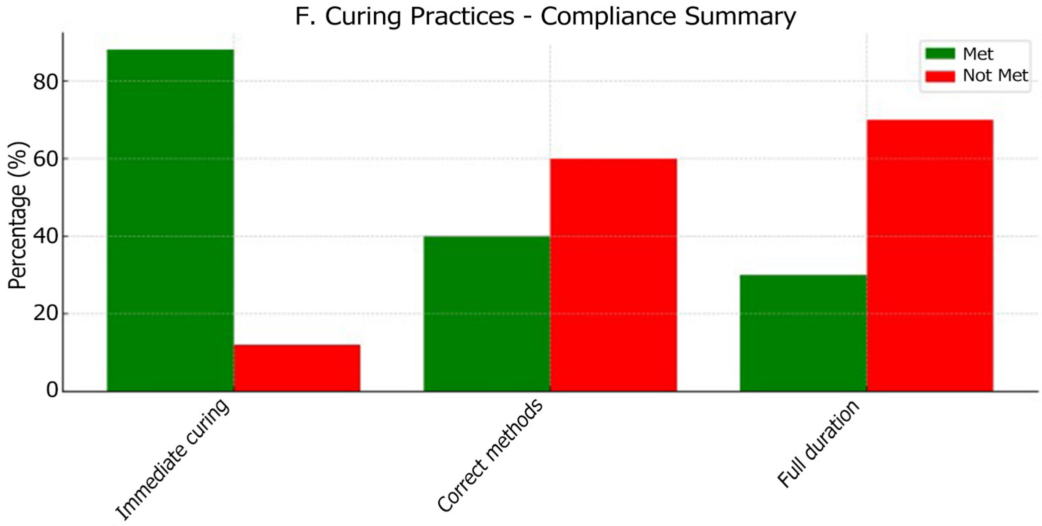

Figure 7. Curing practices

Figure 8. Quality Control and Testing

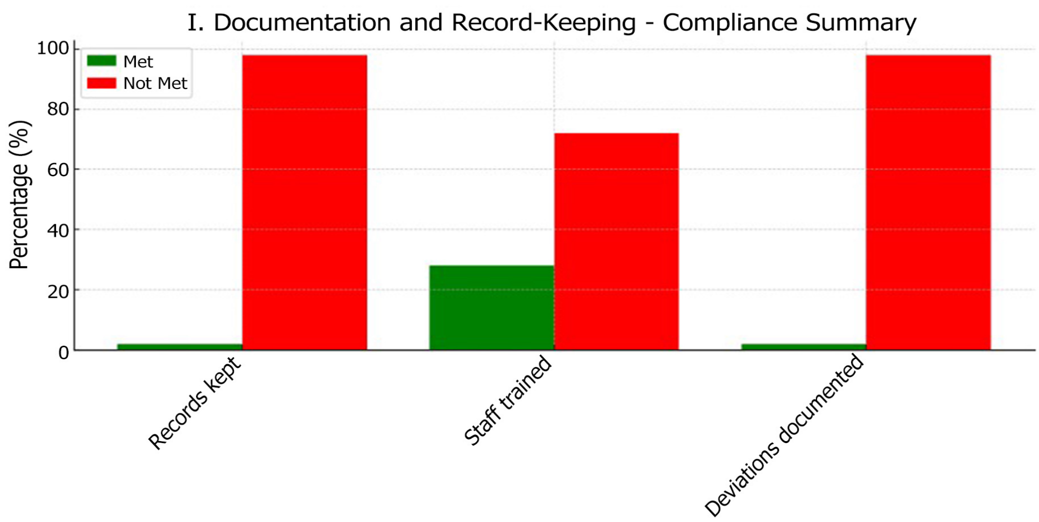

Figure 9. Documentation and Record

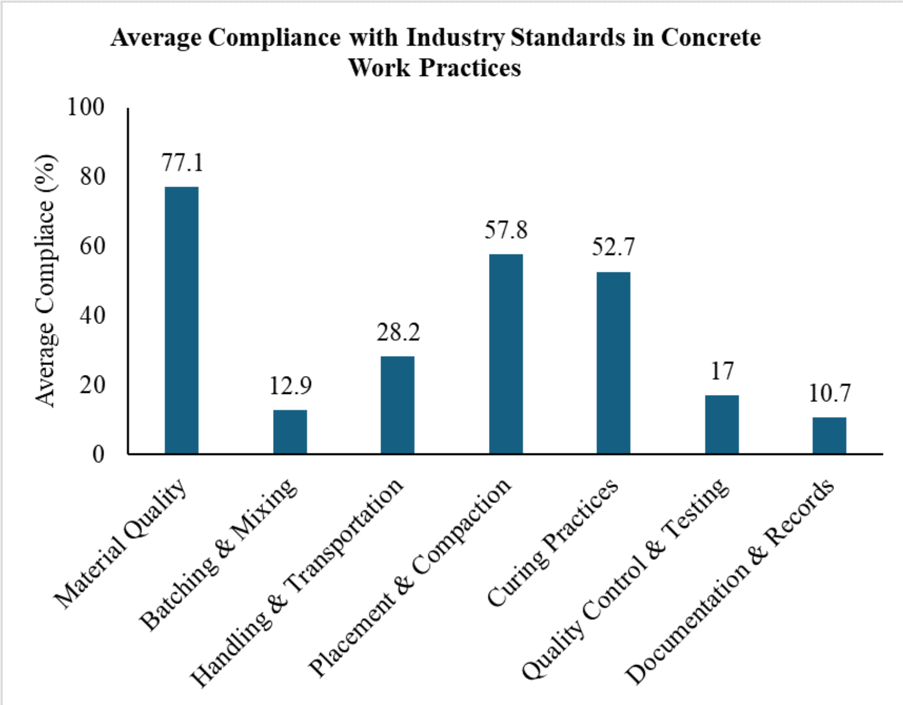

Figure 10. Average compliance level

The situation becomes more critical during the **batching and mixing** phase, which is the backbone of quality concrete production. Only 2% of the sites adhered to a proper mix design, and 20% used mechanical mixers. The remaining majority relied on manual methods, which are prone to human error and inconsistencies. Accurate batching, proper mixing, and slump testing are essential to achieve the designed concrete strength and durability. Non-compliance at this stage not only violates standard practices (such as ACI 211.1 for mix proportioning) but also directly undermines structural reliability.

Handling and transportation practices also fall short of acceptable standards. While 60% of sites minimized time between mixing and placement — an important measure to prevent premature setting — only 10% used proper equipment. Inadequate transportation practices can lead to material segregation, moisture loss, and reduced workability. Furthermore, only a quarter of the sites offered weather protection during transport, leaving concrete exposed to sun, wind, or rain, which may impair its hydration process.

Placement and compaction results show partial compliance. A commendable number of sites (85%) ensured clean and properly aligned formwork, and 80% kept reinforcement clean and supported — critical for bond development and load transfer. However, only 30% used proper compaction methods, and 17% adequately prepared construction joints. These shortcomings can result in honeycombing, reduced durability, and cracking. Proper placement techniques and compaction are emphasized in standards like BS EN 13670, which require layering, vibration, and continuous placement to avoid cold joints.

The **curing practices**, although slightly better, still reveal gaps. While 88% of sites began curing immediately, only 30–40% used appropriate methods and durations. Inadequate curing results in poor hydration, surface cracks, and compromised strength development. Industry guidelines typically recommend curing for at least 7–14 days for standard cement mixes, using techniques like ponding, wet covering, or membrane curing. One of the most concerning areas is **quality control and testing**. Only 2% of sites conducted regular quality control (QC) tests, and just 4% documented the results. This indicates a systemic absence of monitoring mechanisms. Without QC testing, issues such as incorrect water-cement ratios, material contamination, or improper curing cannot be detected or addressed. Likewise, **documentation and record-keeping** are extremely poor, with only 2% of sites maintaining material records or documenting deviations. Such documentation is essential for traceability, performance audits, and future maintenance planning.

In conclusion, while the high compliance in material quality offers a promising foundation, the overall findings highlight critical lapses in execution, supervision, and record-keeping. These lapses not only violate established standards but also pose serious risks to structural safety, lifespan, and user satisfaction. It is therefore recommended that construction stakeholders — including regulatory bodies, contractors, and professional associations — intensify efforts toward awareness, enforcement, and training. The adoption of site-specific quality assurance plans, capacity building for construction workers, and regular inspections will go a long way in bridging the compliance gap. Ultimately, adherence to best practices in concrete works is not only a technical requirement but a moral obligation to ensure safe and sustainable housing for all.

4.9.2. Research Question 2: What Is the Effect of This Current Compliance on Safety and Durability of Residential Buildings in Kano Metropolis?

The data from over 100 residential construction sites in Kano Metropolis presents a stark picture: while material quality is relatively sound, critical phases like batching, mixing, quality control, and documentation are in severe non-compliance. This raises serious red flags regarding both structural safety and long-term durability of buildings being erected across the city.

Figure 11 visually classifies the risk: green (low risk due to high compliance), orange (moderate risk), and red (high risk due to low compliance). Disturbingly, key processes — particularly *batching & mixing* (13%), *quality control & testing* (17%), and *documentation & records* (11%) fall squarely into the red zone. These are not minor oversights. In concrete work, poor batching and absence of quality control are often the root causes of premature structural failure, cracks, water ingress, and ultimately building collapse.

Furthermore, the lack of proper documentation means that even when faults are discovered, there is no clear path to trace the cause or hold responsible parties accountable. This not only affects the structural health of buildings but also undermines public confidence in the construction industry.

On the other hand, the relatively high compliance in *material quality* (79%) and *curing practices* (53%) provides some assurance. However, these strengths alone cannot compensate for the weaknesses in execution and control. Concrete, after all, is not just about what goes into it, but how it is mixed, placed, monitored, and cured.

What does this mean for Kano? It means that without urgent corrective actions, many residential structures risk becoming ticking time bombs. We may not see the effects immediately, but over the next few years, these hidden flaws could lead to increased cases of structural deterioration, costly repairs, and worst of all, loss of life and property.

This situation calls for attention at all levels — from developers, contractors, and site engineers to regulatory authorities and policymakers. It is not enough to use quality materials; we must ensure quality processes. Investment in training, enforcement of standards, site supervision, and public awareness is not optional but essential.

4.9.3. Research Question 3: What Are the Concrete Work Areas Requiring Urgent Intervention or Training?

For Kano's construction industry to align with modern standards, urgent attention must be given to **training and upskilling** the workforce. The most critical areas needing intervention are those with the lowest compliance rates**:** mix design (2%), quality control testing (2%), documentation and record-keeping (2%), manual mixing practices (20%), and admixture use (26%) as shown in Figure 12.

These areas are not just low performers — they are foundational pillars of structural quality. Without training, workers are left to rely on guesswork when measuring materials or mixing concrete, leading to poor consistency and strength. When workers don't understand how to use admixtures properly, the result is reduced workability or chemical reactions that compromise the structure.

Introducing **localized training programs**, possibly in Hausa and English, using simple language, visuals, and hands-on demonstrations, can have a transformative effect. Programs should be targeted at both skilled workers (like supervisors and foremen) and unskilled laborers, with certification as an incentive for participation. When workers understand the "why" behind each step, compliance naturally improves.

4.9.4. Summary of the Findings Based on Research Questions

1. **Non-Compliance with Standard Mixing Practices**

Most construction sites in Kano Metropolis use volume batching instead of the recommended weight batching. This practice results in inconsistent concrete strength and falls short of the requirements in Section 10.3.9.3 of the Nigerian National Building Code.

2. **Inadequate Handling and Placement Techniques**

Concrete is often transported and placed manually, leading to segregation and potential cold joints. These practices compromise the uniformity and strength of the finished structure.

3. **Insufficient Compaction Methods**

Mechanical vibrators are rarely used; instead, manual compaction methods are prevalent. This results in poorly compacted concrete with voids, which reduces strength and durability.

4. **Poor Curing Practices**

Curing is generally irregular and inadequate. Many workers fail to maintain sufficient moisture for the recommended duration, weakening the concrete and increasing its susceptibility to cracks.

5. **Lack of Quality Control**

On-site quality control measures, such as cube testing and systematic inspection, are mostly absent. This absence prevents the verification of concrete strength and quality.

6. **Limited Awareness and Training**

There is a widespread lack of formal training among artisans and low awareness of the Nigerian National Building Code. Most workers learn through informal means and lack an understanding of essential concrete work standards.

7. **Weak Supervision and Regulatory Enforcement**

Supervisory practices are often informal or absent, and enforcement of building codes on-site is weak. This allows substandard practices to persist across many construction projects.

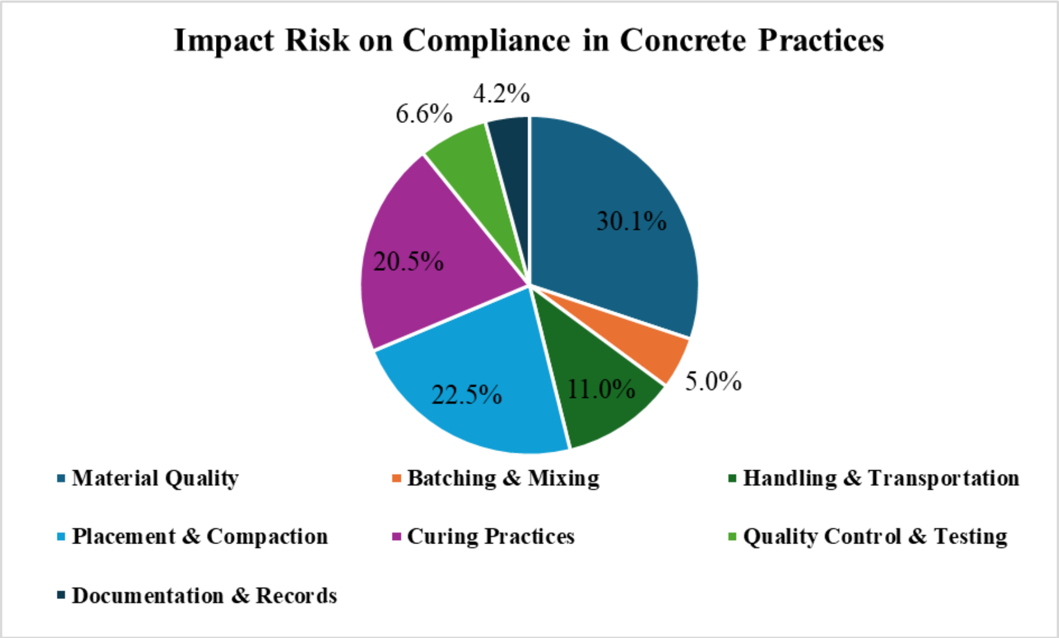

Figure 11. Areas of High risk

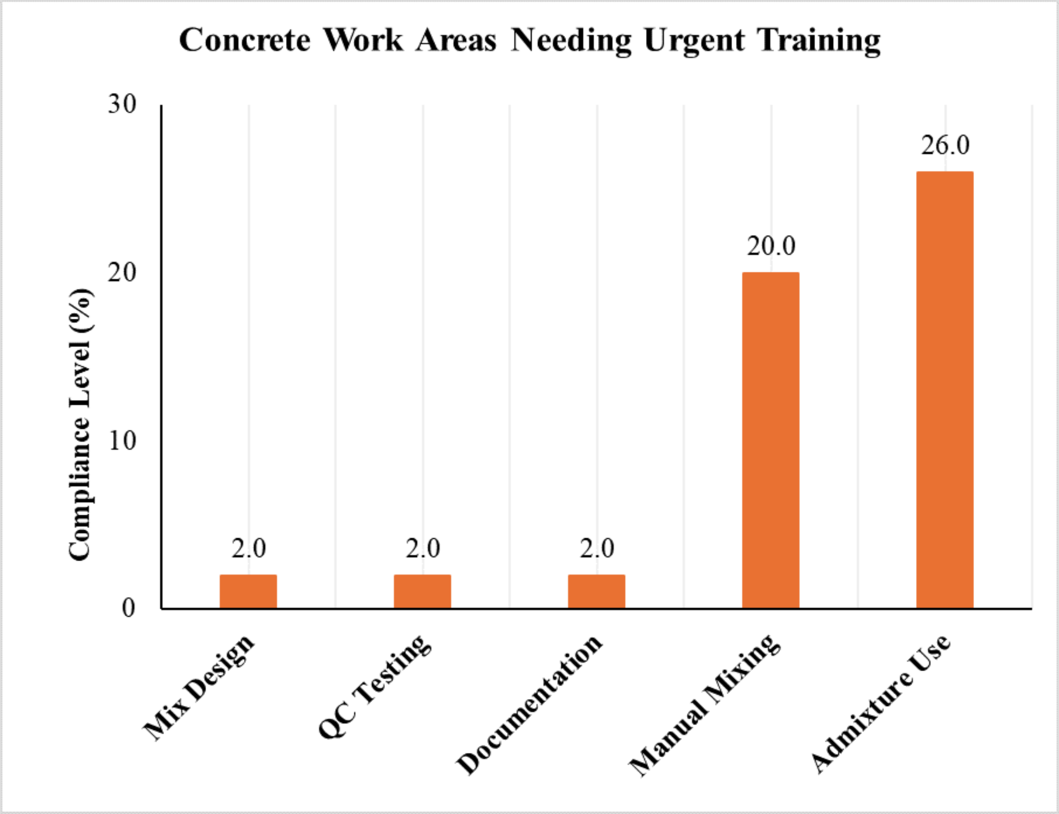

Figure 12. Concrete work areas needing urgent training

5. Conclusions

This study synthesizes the key findings from the field assessment of concrete work practices in residential construction sites across Kano Metropolis. The evaluation reveals a considerable gap between established standards outlined in Section 10.3.9.3 of the Nigerian National Building Code and on-site construction practices. While the selection of materials such as cement and clean water showed relatively high compliance, significant deficiencies were observed in critical stages of concrete work, including batching, mixing, curing, compaction, and quality control. Only a fraction of construction sites implemented proper mix designs, used mechanical mixers, or conducted basic quality tests like slump or compressive strength evaluations. Additionally, curing durations were often inadequate, and compaction was poorly executed on many sites, leading to air pockets and reduced concrete density. Documentation and record-keeping—essential for quality assurance and future maintenance—were almost absent. These shortcomings directly contribute to the structural weaknesses observed in many residential buildings within the metropolis and are strongly linked to recent incidents of building collapse.

The study concludes that while there is a baseline awareness of the importance of concrete materials, technical execution is largely informal, unsupervised, and inconsistent with national standards. The root causes identified include lack of technical knowledge among site personnel, absence of qualified supervision, minimal regulatory enforcement, and inadequate training on standard practices. These systemic gaps highlight the need for urgent interventions at both policy and operational levels to ensure safe, durable, and code-compliant buildings.

This study's findings are grounded in the specific socio-regulatory and operational context of Kano Metropolis, Nigeria—a rapidly urbanizing city with unique construction practices, workforce dynamics, and enforcement challenges. While this contextual focus enhances the depth and applicability of our insights for similar settings in Northern Nigeria and other low-resource urban centers in West Africa, it inherently limits direct extrapolation to regions with stronger regulatory frameworks, different climatic conditions, or more formalized construction sectors. Future studies could build on this work by conducting comparative analyses across diverse geographies to identify both context-specific and universally applicable barriers to code compliance in concrete construction.

6. Recommendation

The study recommends a multi-pronged approach. First, training programs should be instituted for artisans, laborers, and site supervisors to enhance their understanding of proper concrete practices. Second, routine on-site quality control should be mandated, including compulsory slump testing, material documentation, and strength testing during and after placement. Third, regulatory bodies must strengthen their inspection frameworks and enforce compliance with building codes more strictly, particularly during critical stages such as batching and curing. Finally, public and private construction stakeholders should invest in awareness campaigns and professional certification schemes to promote a culture of safety, durability, and accountability within the residential construction sector.

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Appendix

Appendix A. Structured Observation Checklist for Concrete Work Compliance

Category	Observation Item	Compliance Criterion	Standard Reference
Material Quality	1. Cement type matches NNBC-approved grade	Use of Portland cement (CEM I 32.5R or higher)	NNBC
	2. Water is clean, free of oil/chlorides	pH 6–8; no visible impurities	NNBC
	3. Aggregates clean and properly graded	Free from clay, organic matter; within BS 882 limits	BS 882
	4. Admixtures used per manufacturer dosage	Documentation of type, dosage, and purpose	ACI 212.3R
	5. Cement stored in dry, covered area	No exposure to moisture or direct ground contact	NNBC
Batching & Mixing	6. Batching by weight (not volume)	All materials measured by mass	NNBC
	7. Certified mix design used	Approved lab-issued mix design on site	ACI 211.1
	8. Mechanical mixer used	Mixer capacity $\geq$0.2 m^3; uniform mixing	ACI 304R
	9. Slump test performed per batch	Test conducted; result recorded	ACI 238.1R
Handling & Transport	10. Time from mixing to placement $\leq$30 min	No delay causing stiffening	ACI 304.2R
	11. Concrete protected from sun/rain during transport	Covered with tarpaulin or similar	BS EN 13670
	12. No segregation observed during transport	Homogeneous mix on arrival	NNBC
Placement & Compaction	13. Continuous placement (no cold joints)	Pouring without interruption >30 min	NNBC
	14. Layer thickness $\leq$500 mm	Measured or visually verified	BS EN 13670
	15. Mechanical vibration used	Vibrator operated during placement	BS EN 13670
	16. Reinforcement clean and properly supported	No rust, mud, or oil; chairs/spacers used	NNBC
Curing Practices	17. Curing started within 1 hour of finishing	Moisture applied promptly	NNBC
	18. Moist curing maintained $\geq$7 days	Daily wetting, ponding, or wet hessian	ACI 308.1
	19. Curing method appropriate for weather	Membrane or shading in hot/dry conditions	BS EN 13670
Quality Control	20. Slump test documented per batch	Record includes date, mix ID, result	ACI 238.1R
	21. Cube samples cast ($\geq$3 per 50 m^3)	Properly labeled, stored in water	NNBC
	22. 28-day compressive test planned	Samples sent to lab or stored for testing	NNBC
Documentation	23. Mix design available on site	Signed and stamped by certified lab	NNBC
	24. Cement/aggregate test certificates present	Supplier or lab reports available	NNBC
	25. Daily worklog maintained	Includes date, crew, materials, issues	NNBC
	26. Test results recorded	Slump, cube tests documented	NNBC
General Compliance	27. Site supervised by qualified personnel	Civil engineer or certified foreman present	NNBC
	28. No addition of water on-site after mixing	No water added during transport/placement	ACI 304R
	29. Formwork clean, rigid, and leak-proof	No bulging or leakage observed	BS EN 13670
	30. Construction joints properly prepared	Roughened, cleaned, and bonded	BS EN 13670
	31. Concrete placed at $\leq$2 m height to avoid segregation	Chutes or tremie used if needed	ACI 304R
	32. Waste materials not reused in structural concrete	No retempered or leftover concrete used	NNBC

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