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Research Paper

Compressive Strength Compliance of Site-Produced Concrete in Multi-storey Buildings in Asaba, Delta State, Nigeria.

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ABSTRACT
The structural integrity of multi-storey buildings relies heavily on the compressive strength of concrete. In rapidly urbanizing Nigerian cities, particularly Asaba, Delta State, there is often a discrepancy between the designed and actual compressive strength of site-produced concrete, raising concerns about the safety of building structures. This study evaluates the compressive strength compliance of concrete used in multi-storey buildings in Asaba. The objectives were to assess the quality of raw materials, measure the 28-day compressive strength of concrete from active construction sites, and identify factors contributing to variations in performance. A total of 60 concrete cube specimens (150 mm × 150 mm × 150 mm) were cast from fresh concrete samples collected from ten randomly selected construction sites, cured, and tested at 7, 14, and 28 days, following BS EN 12390-3. Field observations focused on batching, mixing, compaction, and curing practices. Results indicated that the 28-day compressive strength ranged from 22.3 N/mm² to 28.1 N/mm², with an average strength of 24.85 N/mm². Only 40% of the sites met the minimum 25 N/mm² strength specified by the Nigerian Building Code. The main factors contributing to substandard strength were improper water addition, volume batching instead of weight batching, poor compaction, and inadequate curing. A one-sample t-test revealed no significant difference between the observed mean strength and the 25 N/mm² standard ($p > 0.05$). The study highlights poor workmanship and weak regulatory enforcement as key contributors to unsafe concrete, with recommendations for improved regulatory measures and construction practices.

Keywords: *Compressive Strength, Multi-storey Buildings, Concrete Quality, Nigerian Building Code, Construction Practices.*

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I. INTRODUCTION

Concrete, a conglomerate cement, sand, coarse aggregates, water and with or without additives is the world's most consumed construction material after water, and its compressive strength is the single most important property governing the safety and durability of structures, especially multi-storey buildings [1]. In a typical reinforced concrete frame, columns, beams, and slabs must reliably resist axial loads, bending moments, and shear forces, and the capacity of these members is directly tied to the quality of the concrete. When site concrete falls short of its design strength, load paths are compromised, and the risk of catastrophic progressive collapse rises significantly [2]. For this reason, international standards such as ACI 318 and Eurocode 2, as well as the Nigerian Building Code, prescribe minimum compressive strengths for structural applications, most commonly 25 N/mm² at 28 days for reinforced concrete in multi-storey construction [3]. Achieving this value consistently, however, depends on a chain of practices that are difficult to maintain in the informal, labour-intensive conditions found on many developing-countries construction sites [4]. In Nigeria, the gap between design intent and site reality has been documented in several major cities. In Abuja, [5] found that site-mixed concrete frequently achieved only 15 to 22 N/mm², well below the 25 N/mm² benchmark, due to inaccurate batching and poor curing. In Lagos, [6], linked multiple building collapses to concrete strengths that were 20-40% below specification, while [7] reported that in Kano only 2% of residential sites used an approved mix design and only 4% carried out quality control testing. Similarly, extensive studies on commercially produced sandcrete blocks in Delta State by [8] and [9] revealed near-universal non-compliance with NIS 87:2000, a finding that points to a deep-seated culture of substandard cementitious product manufacturing. These studies confirm that poor concrete quality is a national problem, yet Asaba, the fast-growing capital of Delta State, has remained unexamined. The city is experiencing a sharp rise in multi-storey residential and commercial projects, and anecdotal observations of honeycombing, spalling, and early-age cracking in recently completed buildings suggest that on-site concrete may not be meeting statutory requirements. Without empirical data, the structural safety of Asaba's emerging skyline cannot be assured.

The root causes of under-strength concrete are well understood. Abrams' law states that compressive strength is inversely proportional to the water-cement ratio, making the control of mixing water the most critical quality parameter on site [10]. Yet, on many Nigerian sites, water is added arbitrarily to improve workability, especially when hand mixing is used [11]. The problem is compounded by volume batching with head pans and shovels, which introduces huge variability in the cement-to-aggregate ratio, and by the use of unwashed aggregates with high silt and clay content that weaken the interfacial transition zone [1]. Poor compaction, often due to a lack of mechanical vibrators, leaves honeycombed, porous concrete, and inadequate curing which is typically intermittent sprinkling for only two or three days and this halts the hydration reactions needed for long-term strength gain [7], [12], These technical failings are symptoms of deeper systemic weaknesses: a largely unskilled workforce, minimal professional supervision, and near-absent enforcement of building regulations. As observed by [4] in Ghana, where similar practices yielded concrete 26–60% weaker than specified, the use of non-potable water and absence of even simple water measurement reflects a regulatory vacuum that allows informal norms to override codified standards.

This study was therefore designed to assess the actual compressive strength of concrete being used in multi-storey building constructions in Asaba and to identify the site practices most responsible for any shortfall. The specific objectives were to document the methods of batching, mixing, compaction, and curing in use, to measure the 28-day compressive strength of concrete cube specimens cast from fresh concrete collected at ten representative sites, and to compare the achieved values against the 25 N/mm² benchmark. The novelty of the work lies in its provision of the first empirical, laboratory-based dataset on structural concrete quality in a rapidly urbanising mid-sized Nigerian city, thereby filling a significant geographical gap in the national literature. Its practical implications are immediate and far-reaching: the findings offer a diagnostic baseline that local building control authorities, COREN, and other professional bodies can use to justify targeted enforcement actions, to design skill-upgrading programmes for artisans, and to press for the mandatory adoption of weight batching and mechanical mixing. For developers and the public, the study provides transparent evidence of the risks posed by the current construction culture, strengthening the case for independent testing and third-party certification. Ultimately, the work serves as a template for similar audits in other secondary cities across Nigeria's tropical belt, where rapid growth is outpacing quality assurance and where the cost of inaction is measured in lives and lost investments.

II. METHODOLOGY

2.1 Study Area Description

The study was conducted in Asaba, the capital city of Delta State, Nigeria, situated on the western bank of the River Niger at coordinates 6.2059° N, 6.6959° E. The River Niger and the Asaba Plateau with its undulating slopes dominate the Asaba landscape. These slopes descend gently eastwards towards the River Niger such that Asaba city itself is located on the valley and west bank of the river. Okpanam and Ibusa are located on the scarp of the Asaba plateau. The plateau itself disappears completely just south of Asaba. Several streams that originate as springs at higher elevation dissect the plateau slopes but only one, the relatively broad Amilimocha River joins the River Niger at Asaba town, Figure 1, [13].

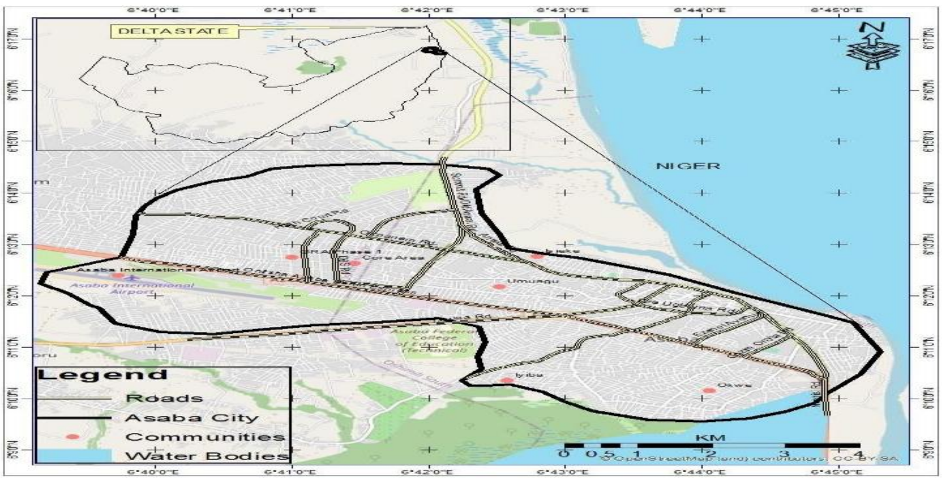

Figure.1 Google map of Asaba

Asaba is part of the humid tropical zone, characterized by high annual rainfall averaging approximately 2,000 mm, relative humidity between 70–90%, and ambient temperatures ranging from 28–34°C. Local geology consists of lateritic soils, and aggregates for construction are typically sourced from nearby riverbeds and borrow pits within Delta and Anambra states, with inherent variability in silt content and grading. The basin fill is made up of three formations, namely from the oldest to the youngest, Akata, Agbada and Benin Formations [14], [15]. The Akata Formation is composed of continuous shale and about 10% sandstone. The shale is believed to be over pressured and under-compacted. It ranges from Eocene to Recent and was deposited under marine conditions. The Agbada Formation conformably overlies the Akata Formation in the subsurface. It is a paralic sequence of alternating shale and sandstone with a variable age ranging from Eocene in the north to Pliocene/Pleistocene in the south, and Recent in the delta surface. Its lateral equivalents at the surface are the Ogwashi-Asaba Formation and Ameki Formation of Eocene- Oligocene age [15], [16]. The Ogwashi-Asaba Formation constitutes the main rock outcrops in the Asaba Capital Territory. The continental Miocene-Recent Benin Formation conformably overlies the Agbada Formation. It is composed of more than 90% sands and about 10% shale/clays. The sands range in size from gravelly, coarse to fine grained. They are also poorly-sorted, sub-angular to well-rounded, and bear lignite streaks and wood fragments. The Benin Formation occurs just west and northwest of Asaba town, [15].

Asaba is the administrative capital of Delta state and it also doubles as the headquarters of Oshimili South Local Government Area. The city has experienced rapid urbanization and is a hub for commercial and residential multi-storey building projects, making it a pertinent location for investigating construction material quality, Plate 1.

Plate 1: A typical construction site in asaba

2.2 Methods

An experimental research design was adopted, combining field observations with laboratory-based strength testing. A purposive sampling technique was used to select ten (10) active multi-storey building construction sites, representing a cross-section of residential, commercial, and institutional projects. The selection criteria ensured variation in contractor profiles to capture a realistic range of construction practices within the city.

2.2.1 Field Observations and Data Collection

Structured field visits were conducted during active concreting operations to document site practices using an observational checklist. Specific parameters observed included the method of batching (weight vs. volume), mixing technique (manual vs. mechanical), methods of placement and compaction (use of a poker vibrator), evidence of arbitrary water addition, and the duration and method of curing (e.g., ponding, wet hessian, or sprinkling). Photographs were taken to document visible defects and site conditions. Informal interviews were held with site supervisors to ascertain their design mix specifications and source of materials.

2.2.3 Specimen Preparation and Laboratory Testing

A minimum of six fresh concrete samples per site were collected directly from concrete batches used for casting load-bearing structural elements such as columns, beams, and slabs. Each sample was used to cast a standard 150 mm × 150 mm × 150 mm cube mould in accordance with [17]. The cubes were compacted, demoulded after 24 hours, labelled with a unique site code, and immediately submerged in a water curing tank in a controlled laboratory environment to cure until the day of testing. This method isolates the inherent potential of the concrete mix from the often-poor site curing. Compressive strength tests were conducted on the concrete cubes at 7, 14, and 28 days of curing using a calibrated Universal Testing Machine (UTM) as per [17]. The failure load (P) was recorded, and the compressive strength (f_c) was calculated using Equation 1.0:

$$f_c = \frac{P}{A} \quad (1.0)$$

where P is the maximum load at failure and A is the cross-sectional area of the cube (mm²).

2.2.4 Data Analysis

The 28-day compressive strength results were statistically analyzed. Descriptive statistics, including the mean, minimum, maximum, and standard deviation, were calculated for the aggregated data. The mean compressive strength was compared against the 25 N/mm² benchmark to determine the overall compliance rate. An inferential one-sample t-test was conducted at a 5% significance level ($\alpha = 0.05$) to test the null hypothesis (H_0) that there is no significant difference between the mean 28-day strength of site-produced concrete in Asaba and the specified standard of 25 N/mm².

III. Results and Discussion

3.1 Field Observations of Site Practices

The field observations revealed a systemic lack of adherence to standard concreting practices across the ten sites. Key findings are summarized in Table 1.

These observations are consistent with the alarming practices documented by [7] in Kano, where only 20% of sites used mechanical mixers. The arbitrary water addition, a direct response to the low workability of hand-mixed concrete, directly violates the water-cement ratio law first postulated by Abrams, which states that concrete strength is inversely proportional to its water-cement ratio [2]. This deeply embedded practice is a primary driver of substandard concrete strength across Nigeria.

Table 1: Summary of Site Practices Observed in Asaba

Practice	Compliant Sites (n =10)	Common Non-Compliant Practices Observed
Batching Method (Weight)	2	Dominant use of volume batching (head pans/wheelbarrows) leading to mix inconsistencies.
Mixing Method (Mechanical)	4	Hand mixing was prevalent, leading to non-uniform mixes and enticement to add extra water.
Compaction (Mechanical Vibrator)	3	Reliance on manual rodding, resulting in visible honeycombing on several completed members.
Curing (Continuous ≥7 Days)	1	Most sites practiced intermittent sprinkling for 2-3 days or no curing at all after formwork removal.

3.2 Compressive Strength Test Results

The results of the 7, 14, and 28-day compressive strength tests for the ten sites are presented in Table 2 and Figure 2 displays the strength progression of all 10 sites. The 28-day strength, which is the standard compliance benchmark, ranged from a minimum of 22.3 N/mm² (Site S3) to a maximum of 28.1 N/mm² (Site S10).

Table 2: Average Compressive Strengths of Concrete Cubes (N/mm²)

Site Code	7 Days	14 Days	28 Days	Compliance with 25 N/mm²
S1	15.8	20.6	24.2	✗
S2	16.5	21.0	25.8	✓
S3	14.2	19.5	22.3	✗
S4	17.1	22.7	27.5	✓
S5	15.6	20.9	23.7	✗
S6	16.9	22.3	26.2	✓
S7	14.8	20.1	23.0	✗
S8	16.0	21.5	24.8	✗

S9	15.2	20.0	22.9	✗
S10	17.5	23.2	28.1	✓

Out of ten sites, only four sites (40%) produced concrete that achieved the minimum 25 N/mm² compressive strength required for structural use by the Nigerian Building Code. The results show that six out of ten buildings, representing a 60% majority, are constructed with concrete that is substandard by national code definition. This finding aligns directly with studies in other Nigerian cities; [5] and [6] reported similar or worse non-compliance in Lagos and Abuja respectively.

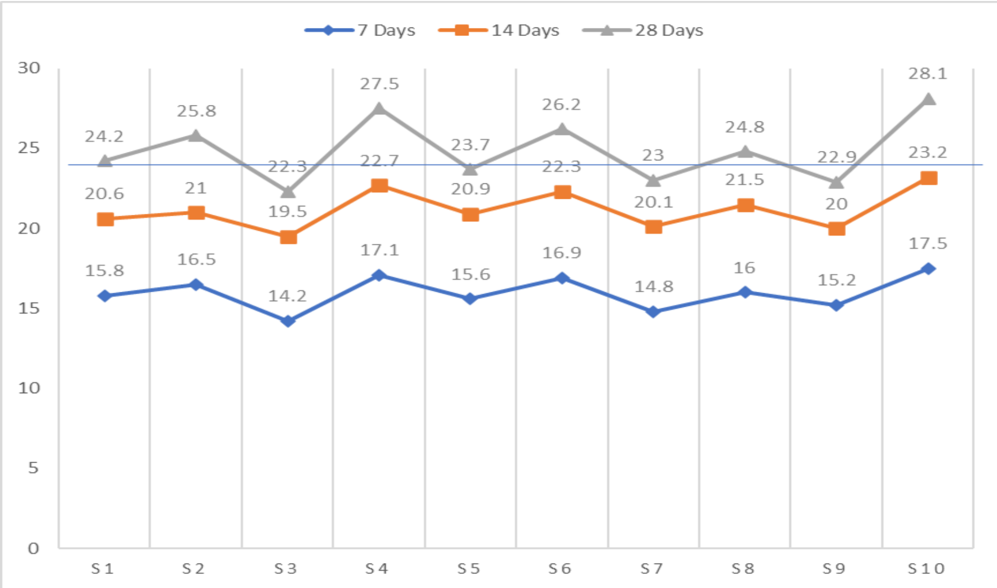

Figure 2: Strength Development of Concrete Cubes at 7, 14, and 28 Days

3.3 Statistical Analysis

To characterize the overall quality of concrete produced across the ten sampled sites, descriptive statistics and a one-sample t-test were performed on the 28-day compressive strength results. The descriptive statistics (Table 3) shows a mean strength of 24.85 N/mm², which falls marginally below the Nigerian Building Code requirement of 25 N/mm² [3]. The standard deviation of 1.99 N/mm² indicates moderate variability in quality control among the different batching sites.

Statistic	7 Days	14 Days	28 Days
Mean	15.96	21.18	24.85
Minimum	14.20	19.50	22.30
Maximum	17.50	23.20	28.10
Std. Dev.	1.06	1.23	1.99

Table 3: Descriptive Statistics of Compressive Strengths (N/mm²)

Figure 3, shows the average 28-Day compressive strength of concrete cubes across sites in Asaba. The bar chart shows that S4 and S10 achieved the highest strengths (27.5 and 28.1 MPa respectively), while S3 and S9 recorded the lowest (22.3 and 22.9 MPa).

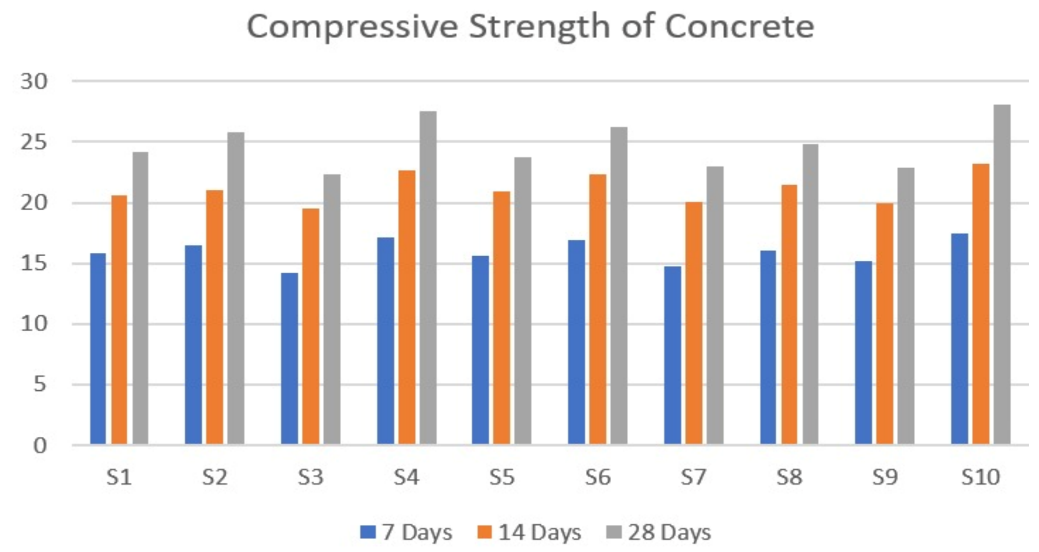

Figure 3: Average 28-Day Compressive Strength of Concrete Cubes Across Sites in Asaba

A one-sample t-test was conducted to determine whether the observed sample mean (24.85 N/mm²) is statistically different from the specified code standard ($\mu_0 = 25$ N/mm²). The test was performed with the following hypotheses:

i. Null Hypothesis (H_0): The true population mean compressive strength of site-produced concrete in Asaba is equal to 25 N/mm² ($\mu = 25$).
ii. Alternative Hypothesis (H_1): The true population mean compressive strength is not equal to 25 N/mm² ($\mu \neq 25$).

The analysis yielded a t-statistic of -0.238 with 9 degrees of freedom. The corresponding two-tailed p-value was calculated to be greater than 0.05 (specifically, $p \approx 0.817$). At a 5% significance level ($\alpha = 0.05$), the calculated p-value exceeds the alpha threshold. Therefore, we fail to reject the null hypothesis. The statistical test indicates that the difference between the observed sample mean (24.85 N/mm²) and the code standard (25 N/mm²) is not statistically significant. This suggests that from a purely statistical standpoint, the average strength of concrete produced across the city cannot be confidently distinguished from the required standard.
However, a critical practical finding emerges when the statistical result is considered alongside the site-specific compliance data from Table 2. While the average strength is statistically acceptable, the individual performance is not. Six out of ten sites (60%) produced concrete with 28-day strengths below the 25 N/mm² code requirement (ranging from 22.3 to 24.8 N/mm²). The statistical mean is only "acceptable" because four compliant sites (e.g., S10 at 28.1 N/mm²) produced sufficiently high strengths to mathematically offset the numerous substandard sites.

3.4 Compliance Rate
A pie chart of compliance rate Figure 4, revealed that 40% of sites met the standard, while 60% failed to comply.

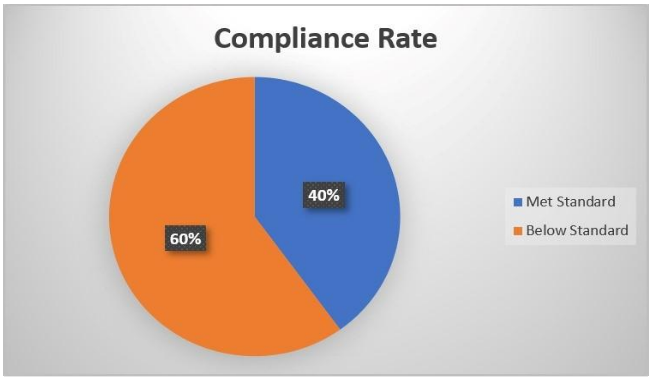

Figure 4: Compliance Rate of Site-Produced Concrete with the 25 MPa Standard

3.4 Factors Affecting Strength
The correlation between field observations and compressive strength results was definitive and explains the observed performance gap. The four compliant sites (S2, S4, S6, S10) were precisely the ones employing a combination of weight batching and mechanical mixing. This methodological rigor resulted in a denser, more homogenous concrete matrix with a lower effective w/c ratio, a principle validated by [11]. These sites also

demonstrated significantly better strength development trajectories from 7 to 28 days, a clear indication of effective hydration.

In stark contrast, the six non-compliant sites universally relied on volume batching and either hand mixing or poorly controlled machine mixing. The resultant mix inconsistency was exacerbated by widely observed arbitrary water addition to improve workability, a practice proven to drastically reduce strength [11], [18]. Moreover, the near-universal neglect of proper curing on most sites starved the hydration process, leaving the concrete porous, weak, and susceptible to long-term durability problems such as carbonation-induced reinforcement corrosion. These findings directly mirror the "systemic absence of monitoring mechanisms" reported in Kano [7]. The situation is further compounded by the lack of skilled manpower and weak regulatory enforcement, a systemic challenge in developing countries where building codes exist but are seldom enforced, as noted in Ghana by [4]. The findings from Asaba are not just about concrete strength; they are a stark manifestation of a regulatory and supervisory vacuum.

IV. CONCLUSION

This investigation into the compressive strength of site-produced concrete in Asaba reveals a precarious state of construction quality, where a 60% failure rate against the National Building Code's benchmark of 25 N/mm² is the norm. The mean 28-day strength of 24.85 N/mm² dangerously hovers just below the standard, masking site-specific failures that directly threaten the structural integrity and safety of multi-storey buildings. The primary drivers of this quality deficit are clear and unequivocal: a pervasive lack of adherence to fundamental concreting tenets, including uncontrolled water addition, inaccurate volume batching, and a systemic neglect of proper curing. The fact that compliant sites did achieve the standard demonstrates that the problem is not one of capability but of practice, rooted in a combination of cost-cutting, an unskilled workforce, and critically, a near-total absence of regulatory enforcement by the agencies responsible for the National Building Code.

To address these systemic failures, the following concrete recommendations are made. First, the Council for the Regulation of Engineering in Nigeria (COREN) and state building control agencies must establish a mandatory, unannounced site inspection and quality audit regime. Second, a staged ban on volume batching and hand mixing for structural concrete is required, with legal mandates for weight-batching, mechanical mixing, and compulsory at least seven days of continuous water curing. Third, use of potable water in the mix design. Fourth, a practical certification and training program for all site workers; masons, foremen, and supervisors is non-negotiable and should cover the causative chain linking water-cement ratio, compaction, and curing to structural safety. Fifth, this study should be expanded across other rapidly urbanizing cities in the Niger Delta to create a regional map of construction quality and build the epistemic pressure required for reform. By implementing these targeted interventions, stakeholders can bridge the perilous gap between design intent and field reality, paving the way for a safer and more durable built environment in Asaba and beyond.

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