FOUNDATION AND GEOTECHNICAL ENGINEERING

Comparative Forensic Assessment of Building Collapse and Foundation Failure in Lagos State, Nigeria: Identifying Dominant Foundation-Related Factors through a Multi-Case Study

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Abstract

Building collapse and foundation distress remain important engineering concerns in Lagos State, where variable subsurface conditions and weaknesses in investigation, design, construction and control may interact. This study assessed foundation-related factors documented in building-collapse and foundation-failure incidents and identified recurring concerns from available forensic evidence. A qualitative–quantitative comparative case-study approach was adopted using three detailed forensic investigation reports and seven preliminary collapse reports. Evidence was extracted and classified through thematic content analysis, cross-case comparison, and frequency and percentage analysis. The detailed cases revealed concerns involving compressible peat and clay deposits, spatial variability of soil conditions, inadequate or variable pile termination depths, pile integrity defects, close pile spacing, insufficient pile capacity or pile numbers, and excessive settlement. Two of the three detailed cases (66.7%) contained clear evidence of foundation or pile-capacity inadequacy; the third also contained foundation-related concerns, although its immediate collapse mechanism was identified as flexural failure of inadequately reinforced structural vertical members. In the seven preliminary reports, absence of documented soil-investigation information and excessive loading were each recorded in three cases (42.9%), while reported or suspected foundation inadequacy occurred in two cases (28.6%). These frequencies describe only the selected reports and do not estimate prevalence across Lagos State. The preliminary reports did not provide sufficient technical evidence to confirm a specific geotechnical failure mechanism. The study concludes that foundation performance should be assessed in relation to site-specific ground conditions, verified pile capacity and founding depth, settlement response, and the loads transmitted by the superstructure. It contributes a comparative synthesis that distinguishes documented foundation concerns from unverified explanations and from the immediate structural mechanism of collapse.

Keywords: Building collapse; forensic assessment; foundation failure; geotechnical investigation; pile capacity

1 Introduction

Building collapse and foundation failure are complex engineering events that may arise from the interaction of ground conditions, foundation selection and design, structural demand, construction quality, supervision and regulatory controls. In urban environments, the consequences extend beyond damage to the building itself and may include loss of life, economic disruption, damage to neighboring properties and reduced public confidence in the construction industry. Studies of building failure in developing countries have emphasized that collapse should not automatically be

attributed to one isolated technical defect; rather, it may reflect the combined failure of several safety barriers [1, 2].

The performance of a building foundation depends on the ability of the supporting ground and the foundation system to transmit structural actions without unacceptable bearing failure, total settlement, differential settlement or other forms of distress. The design process therefore requires a defensible understanding of the subsurface profile, groundwater conditions, engineering properties of the relevant strata, the magnitude and distribution of structural loads, and the construction method adopted. A foundation that is adequate for one set of ground and loading assumptions may become inadequate if those assumptions do not represent actual site conditions or if the building configuration changes.

Lagos State presents a particularly relevant setting for examining these issues. The coastal and sedimentary environment includes variable deposits of sand, clay, peat and alluvial materials. The thickness, continuity and engineering behaviour of these deposits may vary over relatively short distances. High groundwater levels and land-subsidence processes may also affect ground response and foundation performance. Research on subsidence and building-collapse/foundation failure risk in coastal Lagos highlights the importance of understanding local ground conditions rather than relying on generalized assumptions [3].

The use of deep foundations, including bored and driven piles, does not remove the need for adequate site characterization and construction control. Pile performance depends on such factors as pile length, diameter, installation quality, integrity, soil resistance along the shaft and at the toe, group interaction, spacing, and the relationship between working loads and the available geotechnical resistance. Where weak or compressible layers extend to significant depths, terminating piles within those layers may lead to inadequate resistance or excessive movement. Likewise, a pile group may not perform as intended where the number of piles, group geometry or load distribution is inconsistent with the structural demand.

Forensic engineering provides a means of examining such events after distress or collapse has occurred. It draws on physical observations, design and construction records, investigation results, testing and professional interpretation to develop and evaluate possible failure mechanisms [4]. However, the strength of a forensic conclusion depends on the quality and completeness of the available evidence. A preliminary report based mainly on a site visit cannot be treated as equivalent to a detailed investigation supported by boreholes, cone penetration tests (CPT), laboratory testing, pile integrity testing, pile-load testing and foundation-capacity assessment.

Previous work has discussed building collapse in Nigeria, construction-stage errors, regulatory issues and the influence of ground conditions [1]–[3, 5]–[9]. Nevertheless, the usefulness of individual forensic reports for prevention is limited when findings are not compared systematically across incidents. A further difficulty is that the terms ‘foundation-related factor’, ‘contributing factor’ and ‘immediate cause of collapse’ are sometimes used interchangeably. This can lead to an inaccurate conclusion that a building collapsed solely because of its foundation when the investigation identified a different immediate structural mechanism.

This study addresses that problem by comparing three detailed forensic cases with seven preliminary building-collapse reports in Lagos State. The analysis is deliberately restricted to foundation and geotechnical evidence while retaining relevant information about structural loading and structural failure where it affects interpretation. The study does not assume that every collapse was caused by

foundation failure, nor does it infer a specific soil failure mechanism where the reports do not provide adequate supporting data.

1.1 Aim and objectives

The aim was to carry out a comparative forensic investigation to assess foundation-related factors associated with building collapse and foundation-failure incidents in Lagos State, Nigeria, and identify the dominant factors indicated by the forensic reports examined

The objectives were to:

1. Collect and review forensic investigation reports of selected building collapse and foundation failure (buildings that collapsed or failed during construction or within five to twenty years of service).
2. Identify foundation related factors in selected cases of building collapse /foundation failure and assess the contribution of the factors to the reported failure.
3. Compare recurring factors and quantify their occurrence within the selected reports.
4. Identify and rank the dominant foundation-related factors on their occurrence and supporting evidence.
5. Recommend measures to reduce foundation failure and building collapse in Lagos state, Nigeria.

1.2 Research questions

The study was guided by four questions: What foundation and geotechnical factors were documented in the detailed cases? What foundation-related observations recurred in the preliminary reports? Which factors appeared most frequently within the selected sample? What limits should be placed on conclusions drawn from reports with incomplete technical evidence?

1.3 Scope and significance

Lagos State has recorded at least 55 per cent of all reported cases of collapsed buildings in Nigeria (Table 1), reflecting an ongoing issue of building safety and inter-jurisdictional forensic comparison.

Table 1. Share of reported building collapse cases in Nigeria.

Region	Percentage
Lagos State	55–57%
Other States	43–45%

Note: Adapted from Building Collapse Prevention Guild (BCPG, 2024).

Building Collapse Prevention Guild (BCPG, 2024). Adapted by the researcher (2026).

The study covers ten documented incidents in Lagos State: three cases supported by detailed forensic reports and seven cases represented by preliminary reports. The detailed cases comprise the Mende foundation failure, the Ikoyi building collapse, and the Maryland foundation-distress case. The seven preliminary reports concern incidents at Banana Island, Borno Way, Modupeola Street, Ishaga Road, Ikorodu (Ota-Ona), Cole Street (Yaba), and Oriwu Street (Lekki Phase 1). The analysis is not a statistical survey of all building failures in Lagos and should not be generalized as a statewide prevalence estimate. Its significance lies in organizing available evidence into a comparative framework useful for geotechnical and foundation engineering practice.

2 Research methodology

2.1 Research design

A qualitative–quantitative comparative case-study design was used. The qualitative component involved extracting statements, observations, test results and professional conclusions from the forensic reports. The quantitative component involved counting the occurrence of selected foundation-related indicators and calculating their percentages within the seven preliminary reports and the three detailed cases. This combination was appropriate because the source material contained both numerical engineering results and narrative forensic judgments.

The study used secondary data and an ex post facto approach: the incidents had already occurred, and no new physical testing was undertaken as part of the research. The reports were treated as documentary evidence. The researcher did not independently repeat the original geotechnical calculations, pile integrity tests or structural analyses. Numerical values presented in this article are therefore reported values from the source documents, not new test results generated by the present study.

2.2 Case selection and sources of data

Three detailed cases were selected purposively because their reports contained substantive information relevant to ground conditions, foundation systems, pile performance or settlement. The first case concerned a two-storey suspended-floor residential building at Mende Lagos, that experienced severe sinking and tilting. The second case is a muti storey building collapse in Ikoyi Lagos. The third concerned a proposed two-suspended-storey residential building at Maryland Lagos where foundation distress and inadequate pile performance were reported before complete building collapse.

The seven preliminary reports were included to widen the comparison beyond the three detailed cases. They contained initial observations on building condition, loading, foundation adequacy or the availability of soil-investigation documentation. Their technical depth was lower and varied between reports. The source thesis identifies the seven incidents as Banana Island; No. 333 Borno Way, Yaba; No. 4 Modupeola Street, Onipetesi Estate; Ishaga Road, Idiaraba; Ikorodu, Ota-Ona; Cole Street, Yaba; and No. 29 Oriwu Street, Lekki Phase 1. The thesis also includes a plate for Oremeta Street, Ojodu-Berger, while its seven-report enumeration does not consistently reconcile this additional plate with the seven named cases.

The principal documentary sources were the forensic report prepared by the Nigerian Institution of Structural Engineers Lagos chapter and a foundation consultancy company for the Mende case; the COREN Special Investigation Panel report on the Ikoyi collapse; the Damskey Engineering Construction & Consultant Ltd. report on the Maryland case; and the seven preliminary investigation reports reviewed in this study (all reports are unpublished). Published literature on forensic engineering, building collapse and Lagos ground conditions was used to frame the study [1]–[9].

2.3 Data extraction and classification

Information was extracted under the following headings: building type and condition; foundation type; available ground-investigation scope; soil profile and groundwater information; pile diameter and termination depth; pile integrity and load-test results; reported safe working load and capacity assessment; observed settlement or movement; structural loading information; and the conclusion

reached by the forensic investigator. Only information relevant to foundation or geotechnical performance was carried into the comparative analysis.

The extracted evidence was classified into four broad categories. First, direct or measured evidence included reported test results, pile depths, settlement measurements and explicit foundation-capacity assessments. Second, reported observations included statements in the reports that a foundation was inadequate or that a soil parameter had a particular value, where supporting technical records were incomplete. Third, suspected factors included possible foundation inadequacy or possible effects of loading that had not been conclusively demonstrated. Fourth, documentary deficiencies described the absence of available soil-investigation records or other technical information. The absence of a report was not interpreted as proof that no investigation had ever been carried out.

2.4 Analytical procedure

The detailed cases were first examined individually to identify the reported ground and foundation conditions and the investigator's stated conclusions. A cross-case matrix was then prepared to compare ground-investigation concerns, foundation adequacy, pile depth and founding stratum, settlement or structural failure, and load-carrying capacity. The seven preliminary reports were coded for the presence or absence of selected indicators. Frequency was calculated as the number of reports in which an indicator was recorded divided by the total number of preliminary reports, multiplied by 100:

$$\text{Percentage occurrence} = \frac{\text{Number of reports containing the indicator}}{\text{Total number of reports examined}} \times 100 \quad (1)$$

For the three detailed cases, the study calculated the proportion with clear evidence of foundation or pile-capacity concerns as two divided by three, or 66.7%. The Ikoyi case was not counted as a clear foundation-capacity failure case because the report identified flexural failure of inadequately reinforced structural vertical members as the immediate collapse mechanism, although it documented significant foundation and pile-related concerns. This classification preserves the distinction between a foundation concern and the immediate cause of collapse.

2.5 Reliability, validity and limitations of the method

Reliability was supported by using the same extraction headings and evidence categories across the reports. Validity was strengthened by comparing narrative conclusions with numerical information where available and by retaining the distinction between measured results, reported observations and suspected factors. However, the source reports were not equally detailed, and the researcher did not have the opportunity to independently verify every original field record, design drawing or test certificate. The study is therefore a documentary forensic synthesis rather than a fresh forensic investigation.

The sample is purposive and small. Three cases contain detailed forensic information, while the seven preliminary reports provide more limited evidence. The findings cannot be used to estimate the incidence of foundation-related failure across Lagos State. Some source records contain differing interpretations or incomplete descriptions, particularly for pile-test results and the enumeration of preliminary cases.

3 Results and findings

3.1 Detailed case 1: Mende foundation failure

The Mende case involved a residential development comprising two-storey reinforced-concrete suspended-floor blocks. One block experienced severe foundation movement, progressive sinking and tilting. The forensic report described sinking of approximately 2.4 m, with greater settlement towards the finished side of the building. The observed movement made this case directly relevant to the assessment of foundation performance.

The initial ground investigation comprised one borehole to approximately 35 m and two Dutch CPTs using a 2.5-tonne machine, reaching depths of approximately 16.8–21 m. The investigation identified poor-quality soil extending to about 18 m, with soft to firm clay at greater depths. Pile foundations of approximately 300–450 mm diameter and about 32 m depth were recommended for lightly loaded piles. The reported safe working load range was 80–150 kN, depending on pile condition and loading.

A trial pile was reported as 200 mm in diameter, with a stated test depth of 18 m, a working load of 250 kN, a maximum test load of 375 kN, a maximum settlement of 6.841 mm and residual settlement of 2.891 mm. The forensic report subsequently identified a discrepancy in the recorded trial-pile depth, describing the 18 m value as a typographical error. Installed pile depths were reported in the range of approximately 26.6–31.0 m, with a mean of about 28 m. The different reported values should not be treated as a single reconciled test record.

The post-failure investigation comprised two boreholes to approximately 50 m, four CPTs using a 10-tonne machine, laboratory testing and detailed geotechnical analysis. It identified substantial spatial variation in the subsurface profile. Peaty or poor-quality material extended to approximately 12 m at one borehole and 18 m at the other, while soft clay and interbedded clay/sand layers occurred at depth. Medium-dense sand was generally encountered from about 45 m.

For a 200 mm diameter driven pile, the forensic analysis estimated capacities at approximately 26.6 m ranging from about 2 kN at one borehole to 95 kN at the other. At approximately 31 m, estimated capacities were about 185–190 kN at the investigated locations. These results indicate that estimated pile resistance was sensitive to the variable ground profile. Integrity testing was carried out on ten piles, with reported residual concrete strength of approximately 15–17 N/mm^2. The forensic report also noted discrepancies between records and observed conditions, including pile depths, casing thickness, pile positions and pile numbers.

A revised as-built assessment compared the piles provided with the piles required at selected column locations. The assessment identified inadequate pile provision at most of the listed grids; only two of the twelve listed locations were classified as adequate. The forensic report consequently concluded that the pile foundations were generally inadequate in capacity and/or number, leading to excessive loading of some foundation elements. The probable sequence described in the thesis is limited initial investigation, incomplete characterization of variable weak soils, inadequate assessment of pile requirements, insufficient pile capacity or number at some locations, overloading of foundation elements, excessive movement, sinking and progressive tilting.

The Mende case therefore provides direct evidence of serious foundation movement associated with concerns about pile capacity and pile numbers in a variable profile containing peat and soft clay. It also illustrates the importance of consistency between investigation data, pile design assumptions, installation records and as-built foundation conditions [10].

3.2 Detailed case 2: Ikoyi building collapse

The second detailed case is the Ikoyi case. The building was supported on bored piles of approximately 600 mm diameter. The case examined the ground investigation, pile foundation, construction history and structural system. This study extracted the geotechnical and foundation-related findings while retaining the report's conclusion about the immediate structural collapse mechanism.

The initial site investigation was reported to comprise three Dutch CPTs using a 2.5-tonne machine and a borehole to approximately 27 m. Bored piles of about 600 mm diameter terminating at 11 m were recommended, with an initial safe working load of approximately 700 kN reported for the piles. The subsequent investigation considered the original investigation inadequate for the eventual building size and loading. It used deeper subsurface investigation, including a borehole to approximately 40 m and CPTs with heavier equipment, and led to reassessment of the foundation.

Pile integrity testing was reported for 429 piles. The results classified 329 piles as having no significant defects, 57 as having minor defects and 43 as having serious defective reflections. Of the 43 piles with serious defective reflections, 23 were associated with the collapsed building. Reported pile termination depths ranged from approximately 3.6 to 13.6 m. The thesis also reports pile spacing of approximately 2.17 times the pile diameter and identifies this as a concern in relation to pile-group behaviour and settlement.

The foundation-capacity assessment reported a combined service load of 17,647.8 kN for a pile group comprising 32 piles, with three piles treated as failed or redundant. The reported safe working capacity of the group was 16,249 kN and the ultimate bearing capacity was 40,621 kN. Thus, the reported service load exceeded the stated safe working capacity, although it remained below the computed ultimate group capacity. The report further noted that close pile spacing could increase settlement.

Following further geotechnical investigation, a revised safe working load of approximately 580 kN was reported for piles terminating at about 11–12 m. Using that revised value, the investigation reported that 103 of 231 piles exceeded the revised safe working load, eight piles within the lift-core region exceeded their ultimate capacity, and analysis of the eight critical piles produced a maximum settlement of approximately 73.4 mm. These findings establish significant foundation and pile-performance concerns in the collapsed building.

Crucially, the forensic investigation identified flexural failure of inadequately reinforced structural vertical members under combined compression and bending as the immediate collapse mechanism. The report's structural conclusion must not be replaced by a claim that foundation failure alone caused the collapse. The foundation findings indicate interacting deficiencies and capacity concerns, including limited initial ground investigation, variable pile termination depths, defective pile reflections, close pile spacing and overstressed piles in critical regions. The Ikoyi case therefore demonstrates why forensic assessment must distinguish the immediate collapse mechanism from foundation-related factors that may have contributed to the overall risk [11].

3.3 Detailed case 3: Maryland foundation distress

The third case involved a proposed residential building with two suspended storeys supported on bored piles. The building had not undergone complete collapse, but the forensic assessment identified serious deficiencies in the installed pile foundation. This case was included because

foundation failure and distress can occur without a completed superstructure collapse and can provide measurable evidence of foundation performance.

The reported soil profile comprised peaty or organic materials, clayey soils and sandy soils. More competent medium-dense to coarse sand was identified at greater depth, and groundwater was reported at approximately 1.5 m. The confirmatory investigation recommended a deep foundation system with piles terminating at approximately 24–27 m, with 27 m preferred. A 600 mm diameter pile with a theoretical safe working load of 380 kN was reported in the recommendation.

The installed piles were reported as 600 mm diameter bored piles terminating at approximately 12 m, substantially shallower than the recommended depth. At that level, the pile toe was reported to remain within organic or clayey soil rather than reaching the deeper competent sandy stratum. The initial borehole terminated at 15 m, whereas the confirmatory investigation extended to approximately 30 m. The source report questioned the adequacy of the shallower investigation for the building magnitude and loading.

Pile integrity testing was carried out on 42 piles, with reported lengths of approximately 9–12 m. A load test was conducted on a 600 mm diameter, 12 m deep pile with a design safe working load of 230 kN. At a test load of 115 kN, equivalent to 50% of the design safe working load, the pile recorded approximately 54.12 mm settlement after six hours. After unloading, approximately 49.74 mm cumulative settlement remained after 60 minutes. The load-test report concluded that the tested pile could not safely support the adopted 230 kN design load within the permissible settlement limit.

The subsequent foundation assessment adopted a safe working load of approximately 72 kN for the 600 mm pile based on the load-test interpretation. The column-by-column assessment listed 25 locations and classified the provided pile numbers as inadequate relative to the assessed requirements. The reported findings link inadequate pile termination depth, weak organic/clayey founding material, low interpreted pile capacity and excessive settlement to the foundation distress. The source report's different capacity figures (theoretical recommendation of 380 kN and interpreted safe working load of 72 kN after load testing) represent different assessment stages and should not be conflated.

Maryland is therefore a case of substantial foundation distress without complete building collapse. It provides evidence of a mismatch between recommended and installed pile depths, large settlement under a relatively low-test load, and inadequate pile provision for some column loads. These observations reinforce the need to verify pile length, founding stratum, load response and as-built pile-group adequacy rather than relying solely on design assumptions [12].

3.4 Summary comparison of the three detailed cases

Table 2 presents the summary comparison of the three detailed cases.

Table 2. Summary comparison of the three detailed cases.

Parameter	Mende	Ikoyi	Maryland
Incident condition	Foundation failure; severe sinking and tilting	multi-storey building collapse	Foundation distress; no complete collapse
Foundation system	Driven piles	Bored piles, about 600 mm diameter	Bored piles, about 600 mm diameter

Parameter	Mende	Ikoyi	Maryland
Ground / investigation concern	Peat, soft clay and spatially variable interbedded soils; initial 1 borehole + 2 CPTs	Original investigation scope considered inadequate for eventual building size/loading	Peaty/organic and clayey soils; deeper competent sand; initial boring to 15 m versus confirmatory investigation to about 30 m
Pile depth / performance	Installed depths reported about 26.6–31 m; capacity estimates varied markedly	PIT depths about 3.6–13.6 m; serious defective reflections among tested piles	Installed piles about 9–12 m; recommendation 24–27 m
Capacity / settlement evidence	Pile capacity and/or number inadequate at most assessed column grids	103/231 piles exceeded revised SWL; 8 lift-core piles exceeded ultimate capacity; maximum settlement reported about 73.4 mm	Load test at 115 kN recorded 54.12 mm settlement; interpreted SWL about 72 kN
Immediate / principal finding	Foundation movement associated with inadequate pile capacity and/or number	Immediate collapse mechanism: flexural failure of inadequately reinforced structural vertical members; foundation concerns also documented	Inadequate pile depth/capacity and excessive settlement causing foundation distress

Note: Extracted from the three detailed forensic reports [10]–[12].

3.5 Findings from the seven preliminary reports

The seven preliminary reports covered buildings of different heights and construction or service stages. They contained observations relating to excessive loading, construction errors, weak structural members, absent or inadequate reinforcement, supervision, regulatory compliance, foundation condition and soil-investigation documentation. The present analysis retained only the items directly or potentially relevant to ground conditions, foundation safety and investigation records.

The preliminary reports were generally based on initial site visits and preliminary evaluations. They did not consistently contain full pre-collapse ground-investigation data or detailed post-collapse work such as boreholes, CPT, standard penetration tests, laboratory testing, pile-load testing or detailed foundation-capacity calculations. Consequently, the preliminary evidence was used to identify reported indicators and documentation gaps, not to establish unreported soil profiles or specific geotechnical failure mechanisms.

Table 3 presents the foundation-related indicators extracted from the seven preliminary reports.

Table 3. Foundation-related indicators extracted from the seven preliminary reports.

Indicator extracted from preliminary reports	Frequency	Percentage	Interpretation
No documented soil-investigation report available / seen	3 of 7	42.9%	Documentation deficiency; does not prove that no investigation was ever performed.
Excessive loading reported	3 of 7	42.9%	Potentially increases foundation demand; not automatically proof of geotechnical failure.
Foundation inadequacy explicitly reported or suspected	2 of 7	28.6%	Reported or suspected concern; not necessarily confirmed by detailed capacity analysis.

Indicator extracted from preliminary reports	Frequency	Percentage	Interpretation
Confirmed bearing-capacity failure	0 of 7	0%	No preliminary report supplied sufficient detailed evidence to confirm this mechanism.
Confirmed settlement or consolidation failure	0 of 7	0%	No preliminary report supplied sufficient detailed evidence to confirm this mechanism.

Note: Extracted from the seven preliminary reports by COREN, Lagos chapter.

The absence of documented soil-investigation information occurred in three reports (3/7 × 100 = 42.9%). The finding concerns the availability of records in the reports reviewed. It does not establish that the sites necessarily had poor soil or that no investigation was undertaken at any time. It does, however, indicate that the preliminary documentation did not provide a verifiable basis for assessing the ground parameters used in foundation selection and design.

Foundation inadequacy was explicitly or potentially identified in two reports (2/7 × 100 = 28.6%). One report described the foundation as inadequately exposed, while another stated that a raft foundation might not be adequate and also noted the absence of a soil-investigation report. These are preliminary observations and should not be upgraded to confirmed bearing-capacity failure without supporting test data, foundation dimensions, applied loads and capacity calculations.

Excessive loading was identified in three reports (3/7 × 100 = 42.9%). In the preliminary material, it was associated with one report's collapse explanation and with foundation concerns in two others. Increased structural load increases the demand transferred to the foundation and supporting ground. Nevertheless, excessive loading is a foundation failure mechanism only where the applied demand exceeds the available foundation resistance or causes unacceptable movement. The frequency count therefore treats loading as an interacting demand factor rather than proof of soil failure.

None of the seven preliminary reports provided sufficient detailed evidence to conclusively establish bearing-capacity failure, consolidation failure, differential-settlement failure, lateral ground movement or another specific geotechnical failure mechanism. One report cited a soil bearing capacity of approximately 280 kN/m^2 but did not provide a soil-investigation report to substantiate the value. The value was therefore treated as reported information rather than a verified geotechnical parameter.

3.6 Evidence classification

Table 4 presents the classification of evidence in the preliminary reports.

Table 4. Classification of evidence in the preliminary reports.

Evidence class	Meaning in this study	Illustration from the preliminary reports
Direct observation	A condition recorded during preliminary inspection	Foundation described as inadequately exposed
Documentary deficiency	Required technical records unavailable in the material reviewed	No soil-investigation report presented or seen
Reported condition	A technical value or condition stated but not independently substantiated	Reported soil bearing capacity of about 280 kN/m^2 without supporting report
Suspected factor	A possible deficiency identified without detailed verification	Foundation stated as possibly inadequate

Evidence class	Meaning in this study	Illustration from the preliminary reports
Not established	Available evidence insufficient to determine a specific mechanism	Bearing-capacity, consolidation or settlement failure

Note: Extracted from the seven preliminary reports by COREN, Lagos chapter.

3.7 Frequency in the detailed cases

Table 5 presents the evidence of foundation or pile-capacity concern in the detailed cases.

Table 5. Evidence of foundation or pile-capacity concern in the detailed cases.

Detailed case	Evidence of foundation/pile-capacity concern	Classification for the 66.7% calculation
Mende	Reported inadequacy in pile capacity and/or number of piles provided for assessed loads	Clear evidence: Yes
Ikoyi	Foundation and pile-related concerns reported; immediate collapse mechanism identified as structural-member flexural failure	Related concern; not counted as clear foundation-capacity failure
Maryland	Reported concerns about pile depth, pile capacity and excessive settlement	Clear evidence: Yes

Note: Extracted from the three detailed forensic reports [10]–[12].

The study's calculation classified two of the three detailed cases as having clear evidence of foundation or pile-capacity concerns: (2/3) × 100 = 66.7%. This value is a proportion of the selected detailed cases, not an estimate that 66.7% of all building collapses or foundation failures in Lagos State are caused by foundation inadequacy. The Ikoyi case remains important because it contains foundation-related concerns, but its immediate collapse mechanism was reported as structural-member flexural failure.

4 Discussion

4.1 Foundation capacity must be considered with ground variability

The Mende and Maryland cases illustrate the relationship between weak or compressible strata, pile termination depth and available pile resistance. At Mende, the forensic investigation identified peat and soft clay extending to substantial depths and significant variation between borehole locations. Estimated capacity for the same nominal pile diameter and approximate depth differed markedly between the two investigated locations. This finding indicates that a single generalized soil profile or isolated investigation point may not adequately represent the ground conditions across a building footprint where deposits are variable.

At Maryland, the reported installed pile lengths were substantially shorter than the depths recommended by the confirmatory investigation. The reported pile toes remained within organic or clayey soils, while deeper sand was considered more competent. The load test also recorded substantial settlement at 115 kN, which was only half the adopted design safe working load. The later interpretation of a safe working load of approximately 72 kN led to a finding that the piles provided were insufficient for the assessed column loads. Taken together, the cases show why foundation design requires the actual soil profile and pile founding level to be checked against the loads to be carried.

4.2 Investigation adequacy and documentation

The preliminary reports recorded absence of documented soil-investigation information in three of seven cases. The detailed Mende and Ikoyi cases also raised concerns about the scope or adequacy of the original investigations relative to the complexity and eventual demands of the buildings. These observations do not prove that every undocumented case lacked a site investigation, nor do they demonstrate that investigation scope alone caused a collapse. They show that a lack of accessible, site-specific records weakens the ability of designers, reviewers and forensic investigators to verify the assumptions used for foundation design.

An adequate investigation should be proportionate to the building scale, structural loading, site variability and anticipated foundation type. The number and depth of boreholes or CPT soundings should be selected to characterize the relevant strata and identify weak layers that may control settlement or pile performance. Where a deep foundation is proposed, investigation depth should be sufficient to assess the layers that influence shaft resistance, toe resistance and the expected pile termination zone. The present study does not prescribe a universal number or depth of tests; these must be established from project-specific conditions and applicable standards.

4.3 Pile installation, integrity and group effects

The Ikoyi case highlights the relevance of pile integrity, termination depth and group behaviour. The report recorded serious defective reflections in 43 of 429 tested piles, with 23 of those serious reflections associated with the collapsed building. It also reported variable termination depths and close pile spacing. These observations indicate that design capacity cannot be assumed to have been achieved unless pile installation and quality are verified. Integrity testing, however, should be interpreted within its limitations: a low-strain integrity test identifies changes in pile impedance and possible anomalies; it does not by itself provide a complete direct measurement of geotechnical bearing capacity.

The Maryland case reinforces the importance of confirming actual pile length and performance. The reported difference between recommended and installed pile depths was substantial, and the load test showed a response inconsistent with the adopted design safe working load. At Mende, discrepancies between construction records and observed pile information were also identified. Across the three detailed cases, the evidence supports a practical need for traceable pile installation records, verification of pile dimensions and depth, appropriate integrity testing, and load testing where required by the design and project conditions.

4.4 Loading as an interacting factor

Excessive loading was recorded in three of the seven preliminary reports. The detailed Ikoyi investigation also considered the relationship between building loading and pile-group capacity. An increase in the number of floors or change in building use can alter the magnitude and distribution of loads transmitted to the foundation. However, load increase should not be labelled a geotechnical failure by itself. Its significance depends on whether the foundation and supporting ground have adequate resistance and acceptable settlement performance under the revised demand.

The findings support the need for formal engineering review before any material change in building configuration or loading. Where a proposed change increases the design actions, the structural system and foundation should be reassessed together. This is particularly important where the original foundation was designed using assumptions that may no longer apply.

4.5 Immediate collapse mechanism versus foundation contribution

The Ikoyi case is central to the interpretation of the study. The forensic panel identified flexural failure of inadequately reinforced structural vertical members under combined compression and bending as the immediate collapse mechanism. At the same time, the investigation documented pile integrity, pile-capacity and settlement concerns. It would therefore be inaccurate to state that the building collapsed solely because of foundation failure. A more defensible conclusion is that the report identified significant foundation-related deficiencies alongside the structural failure mechanism.

This distinction also explains why the study uses the term 'foundation-related factors' rather than attributing all ten incidents to geotechnical failure. In the preliminary reports, several concerns were only reported or suspected, and none contained sufficient technical evidence to confirm a specific soil bearing-capacity or settlement mechanism. The evidence hierarchy adopted in this study prevents the frequency analysis from overstating the certainty of the source reports.

4.6 Interpretation of dominant factors

Within the three detailed cases, inadequate foundation or pile capacity was classified as a clear concern in two cases (66.7%). The underlying factors differed: Mende involved weak and variable ground conditions and inadequate pile capacity and/or numbers; Maryland involved pile termination above the recommended founding depth, low interpreted pile capacity and excessive settlement. Ikoyi involved foundation-related concerns but was classified separately because the immediate collapse mechanism was structural-member failure.

Within the seven preliminary reports, absence of documented soil-investigation information and excessive loading each occurred in three cases (42.9%). Reported or suspected foundation inadequacy occurred in two cases (28.6%). These are the dominant recorded indicators in the preliminary material. They should not be combined with the 66.7% detailed-case figure because the denominators, evidence quality and definitions differ. The results are descriptive counts of the selected reports, not statistically comparable estimates of statewide risk.

4.7 Implications for engineering practice

The combined findings suggest that preventive practice should focus on the complete chain from ground investigation to design, construction and verification. Site investigation results should be sufficiently detailed to characterize variability and weak strata; design parameters should be traceable to the investigation; foundation selection should reflect the actual soil and structural demand; pile installation should be monitored and documented; and test results should be evaluated against serviceability as well as ultimate resistance requirements. Any alteration to the approved building configuration should trigger a coordinated review of the structural and foundation systems.

The study also indicates the value of improving access to forensic findings for engineering learning. Preliminary reports are useful for rapid identification of issues, but where possible they should be followed by detailed investigation that records the ground profile, foundation geometry, load history, test methods, results and reasoning supporting the final mechanism. Clear documentation would improve the ability of future researchers and practitioners to distinguish confirmed causes from initial hypotheses.

5 Conclusion and recommendations

5.1 Conclusion

This study assessed foundation-related factors associated with building collapse and foundation-failure incidents in Lagos State through three detailed forensic reports and seven preliminary collapse reports. The detailed cases identified recurring concerns involving weak and compressible soils, spatial variability of subsurface conditions, inadequate or variable pile termination depths, pile integrity defects, close pile spacing, insufficient pile capacity or pile numbers, and excessive settlement. The nature and strength of the evidence differed between cases.

Two of the three detailed cases (66.7%) were classified as containing clear evidence of foundation or pile-capacity concerns. The Ikoyi case also contained foundation-related concerns, but the immediate collapse mechanism was identified as flexural failure of inadequately reinforced structural vertical members. This confirms the importance of distinguishing the contribution of foundation-related deficiencies from the mechanism that immediately precipitated collapse.

Among the seven preliminary reports, absence of documented soil-investigation information and excessive loading were each recorded in three cases (42.9%), while reported or suspected foundation inadequacy occurred in two cases (28.6%). None of the seven preliminary reports provided sufficient evidence to confirm a specific bearing-capacity or settlement failure mechanism. Accordingly, the dominant factors indicated by the selected evidence are inadequate or undocumented geotechnical investigation, inadequate foundation/pile capacity or provision in the detailed cases, and loading increases that may raise foundation demand. These findings apply only to the reports examined.

5.2 Recommendations

Based on the evidence reviewed, the following recommendations are proposed:

1. Site-specific geotechnical investigation should be completed and documented before foundation construction begins. The investigation scope should be appropriate to the building size, loading, foundation type and anticipated variability of the ground. The relevant approval and building-control processes should require the investigation report to be available for technical review.
2. Foundation design should be based on verified ground parameters and the actual structural load combinations. For pile foundations, the design should consider pile capacity, group effects, settlement, pile spacing, founding depth and the properties of the strata through which the piles are installed.
3. Pile construction should be subject to effective quality assurance. Records should capture pile location, diameter, depth, installation method, concrete or grout information, reinforcement details and any deviations from the design. Integrity testing and pile-load testing should be undertaken where required by the design, specifications and applicable standards, and their results should be reviewed by competent professionals.
4. Any proposed increase in the number of floors, change in use or other material change in structural loading should be reviewed and approved by the relevant design professionals before implementation. The review should assess both the superstructure and the foundation rather than considering the additional load in isolation. It will be best if strict regulation decides no review of the number of floors if construction has commenced.
5. Construction supervision and professional responsibility should be strengthened. This study proposes a formal process through which engineers accepting responsibility for a project, and those

disengaging from it, notify the relevant professional regulator. This is presented as a recommendation for consideration, not as a statement that such a portal-based process is already an established regulatory requirement.

6. Professional bodies and relevant public agencies should improve the availability of forensic investigation reports or publish suitably redacted technical summaries, subject to legal, privacy and confidentiality requirements. Access to reliable technical findings would support professional learning, research and preventive engineering practice.

5.3 Contribution to knowledge

The study contributes a comparative synthesis of three detailed forensic cases and seven preliminary reports, with a specific focus on foundation and geotechnical evidence. It brings together observations on soil variability, pile depth, pile capacity, pile integrity, settlement, investigation documentation and loading demand within a common analytical framework. A further contribution is the explicit separation of confirmed or measured evidence, reported conditions, suspected factors and mechanisms that could not be established from the available reports. The Ikoyi case demonstrates the importance of retaining the distinction between foundation-related concerns and the immediate structural mechanism of collapse. The frequency results provide a transparent description of the indicators recurring in the selected reports without presenting them as statewide prevalence estimates.

5.4 Limitations and further research

The study was limited by the availability and completeness of forensic reports. The three detailed cases all involved pile foundations, while the preliminary reports did not provide enough technical data to establish specific geotechnical mechanisms. The sample was purposively selected and was not designed to represent all incidents in Lagos State.

Further research should include a larger number of cases and a wider range of foundation systems, including shallow foundations, raft foundations, driven piles and bored piles. Future studies should seek access to complete investigation reports, design drawings, pile installation records, laboratory results and load-test data. A larger and more consistently documented dataset would allow more robust comparison of foundation types, ground conditions and failure mechanisms. Where appropriate, future research could also examine the relationship between measured ground parameters, foundation design assumptions and observed building performance.

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