ENGINEERING COUNCIL OF GHANA

GUIDELINE FOR FORENSIC INVESTIGATION

September 2023

Contents

CHAPTER 1

THE NEED FOR FORENSIC INVESTIGATION GUIDELINE

1.1 Introduction

Development of the built environment to provide decent housing, transportation, industries, health facilities, drinking water, energy, communication, educational facilities and many more compliments public expectation that built environment facilities will operate as designed.

Failure of any of the built environment facilities to function as intended, e.g., dam failure, building collapse, power outage, leaky roof, require investigation. Types of Engineering Failure like Catastrophic structural collapses with possible loss of life, e.g.; Building collapses, Dam failures and Non-structural failure of engineered facilities that fail to perform as designed, e.g. Power failure**,** Leaky roof**,** Failure of elements/components of a structure leading to the structure to perform as designed.

This document outlines the importance of forensic engineering investigations, particularly in the context of building collapses, structural failures, and related incidents. The document is developed by the Engineering Council, Ghana (EC), a regulatory authority for the engineering profession in Ghana. The main points highlighted in the text are as follows:

Purpose of Forensic Engineering Investigations: Forensic engineering investigations aim to understand the causes of failures in engineering structures and products. While the primary goal of engineering is to design and construct safe and reliable structures, failures can still occur. Forensic engineering involves identifying and analyzing the reasons behind these failures.

Roles and Responsibilities: The text emphasizes that engineering practitioners or experts involved in forensic studies play a crucial role in determining the causes of failures. Their responsibilities include collaborating with other professionals, law enforcement agencies, and stakeholders to gather and examine evidence related to the failure. This collaborative approach is vital to obtaining a comprehensive understanding of the incident.

Legal and Professional Framework: Forensic engineering investigations can have legal implications, as the findings may be used as evidence in litigation. Therefore, the text underscores the importance of conducting investigations based on sound engineering principles and practices. The open-minded approach and adherence to ethical standards are crucial when preparing forensic reports that may be used in legal proceedings.

Contribution to Prevention and Improvement: Successful forensic investigations contribute to the improvement of engineering practices. By identifying the causes of failures, engineering professionals can develop procedures and practices to prevent similar incidents in the future. This proactive approach helps in minimizing the risk of failures and enhancing the overall safety of engineering structures and products.

Importance in the Ghanaian Context: The document highlights the relevance of forensic engineering investigations in Ghana, where structural collapses have had severe consequences on human lives and the economy. The methodology developed through these investigations can help prevent future incidents and provide recommendations to mitigate risks and improve safety measures.

Guidelines for Forensic Engineering Studies: The EC provides guidelines for conducting forensic engineering studies. These guidelines set out the minimum requirements for such investigations, ensuring that they are conducted in a systematic and professional manner. The guidelines cover aspects such as evidence collection, analysis, collaboration with stakeholders, and reporting.

Collaboration and Expert Testimony: This document emphasizes the collaborative nature of forensic engineering investigations. Engineering practitioners may need to work closely with professionals from various fields, such as law enforcement, legal experts, and relevant technical experts. Additionally, this document lay emphasis on the potential need for expert testimony in legal proceedings.

Contributing to Engineering Education: The document contributes to the enhancement of the engineering profession by providing valuable resources for engineering practitioners, firms, service providers, and educational institutions. It helps in fostering a deeper understanding of failure analysis and the importance of maintaining high standards of engineering practice.

Overall, this document underscores the significance of forensic engineering investigations in improving engineering practices, enhancing safety measures, and preventing failures in the future. It also highlights the GEC's commitment to upholding engineering standards and ethics in Ghana.

1.2 **Purpose**

The outlined purpose of the document revolves around the roles and responsibilities of the Ghana Engineering Council (GEC) in the context of overseeing and regulating forensic engineering investigations within Ghana. The document serves several important purposes:

i. **Clarification of Roles and Responsibilities**: The document seeks to clearly define and explain the roles and responsibilities of the Ghana Engineering Council in relation to forensic engineering investigations. It outlines the GEC's mandate to regulate and oversee such investigations to ensure they adhere to professional standards and contribute to the safety of the built environment.

ii. **Establishment of a Legal Framework**: The document aims to establish a legal framework for conducting forensic engineering investigations. By outlining the qualifications, expertise, and standards required for forensic experts, it provides a basis for ensuring that investigations are carried out in a systematic and professional manner, with legal considerations in mind.

iii. **Promotion of Public Safety**: One of the main goals is to enhance public safety by ensuring that investigations into building collapses, structural failures, and other engineering-related incidents are conducted in a way that prevents future occurrences. By setting standards and qualifications for experts, the document helps in preventing subpar investigations that might miss crucial safety-related aspects.

iv. **Guidance for Coordinated Response**: The document provides guidance for responding to incidents such as building collapses and structural failures in a coordinated manner. It emphasizes the importance of collaboration among various stakeholders, including engineering experts, law enforcement, and other relevant professionals. This collaborative approach ensures a comprehensive and accurate understanding of the incident.

v. **Development of a Safer Built Environment**: By regulating and overseeing forensic engineering investigations, the document contributes to the development of a safer built environment. Through thorough investigations and the identification of causes, it helps in developing strategies and practices that minimize the risks of similar incidents in the future.

vi. **Structured Approach to Incident Response**: The document introduces a structured approach with five stages for incident response and investigation. These stages cover everything from prevention and emergency response to fact-finding, cause investigation, and legal responsibility determination. This framework provides a systematic way to approach and handle incidents, ensuring that each phase is addressed appropriately.

vii. **Addressing Failures and Learning from Mistakes**: The document acknowledges that failures in engineering products can lead to loss of life, property damage, and economic disruption. By providing a standardized procedure for answering the question "what happened?", the document encourages a proactive approach to addressing failures and learning from mistakes to prevent their recurrence.

Overall, the purpose of the document is to establish a comprehensive framework for forensic engineering investigations in Ghana, with the aim of enhancing public safety, promoting professional standards, and contributing to the overall improvement of the engineering industry and the built environment.

1.3 Scope

This document's scope encompasses a comprehensive overview of forensic engineering investigations, focusing on their application within the Ghanaian context. It delves into the legal framework governing building construction, safety, and environmental considerations, drawing attention to key laws, regulations, and codes that guide construction practices in Ghana. The document outlines the qualifications, responsibilities, and expertise required for a range of forensic experts, including structural engineers, fire investigators, electrical engineers, materials experts, geotechnical engineers, and other relevant professionals. Additionally, the document provides insight into the pre-investigation procedures necessary to ensure public safety, evidence preservation, and effective coordination during and after a building collapse. Finally, the document underscores the importance of site assessment, thorough documentation, and the application of lessons learned to prevent future incidents.

CHAPTER 2

LEGAL FRAMEWORK THAT NECESSITATES FORENSIC INVESTIGATION IN GHANA

2.1 Legal Framework

Some of the relevant laws, regulations, and codes governing building construction and safety in Ghana include:

2.1.1 Ghana Building Code (2018)

The Ghana Building Code provides comprehensive guidelines for building construction, design, materials, structural integrity, safety, and sustainability. It covers various aspects of building construction, including fire safety, plumbing, electrical installations, accessibility, and more.

2.1.2 Land Use and Spatial Planning Act (2016)

This law regulates land use, physical planning, and development control in Ghana. It establishes the framework for spatial planning, land zoning, and development permits.

2.1.3 Town and Country Planning Act (Act 64, 1945)

This act establishes the legal framework for urban and regional planning in Ghana. It outlines the roles and responsibilities of planning authorities, zoning regulations, and development permits.

2.1.4 Local Government Act 2016

This act governs the establishment, functions, and administration of local government authorities in Ghana. It includes provisions related to land use planning and building permits.

2.1.5 Building Regulations 2019 LI 2465

These regulations provide detailed technical standards for building construction, including structural design, fire safety, ventilation, lighting, and more.

2.1.6 Fire Precautions Act (1973)

This act addresses fire safety measures and precautions for buildings and public places.
It outlines requirements for fire exits, firefighting equipment, and fire-resistant materials.

2.1.7 Environmental Assessment Regulations (1999)

These regulations require environmental impact assessments for certain types of construction projects to ensure environmental protection.

2.1.8 Occupational Health and Safety Act (Act 651, 2003)

This act focuses on promoting occupational health and safety in workplaces, including construction sites. It covers aspects such as safety training, protective equipment, and accident reporting.

2.1.9 Electricity Regulations (2011)

These regulations provide standards for electrical installations, wiring, and safety measures in buildings.

2.1.10 Water Supply and Sanitation Act (Act 653, 2008)

This act addresses water supply, sanitation, and hygiene requirements for buildings.

2.1.11 Building and Road Research Institute (BRRI) Guidelines

The BRRI provides technical guidelines and research-based recommendations for building construction and materials.

CHAPTER 3

TECHNICAL FRAMEWORK FOR FORENSIC INVESTIGATION

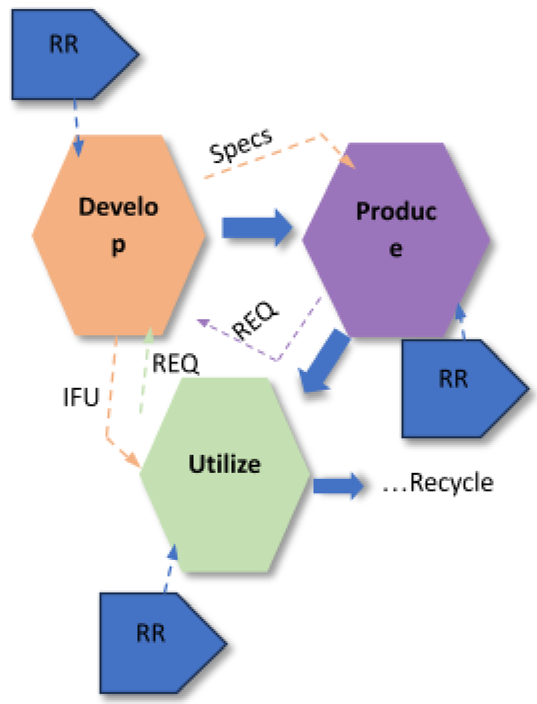
3.1 Technical System

Engineering practice is a highly technical area. This means one needs the required or relevant knowledge and skills, including the legal backing, to undertake an engineering assignment. The development of engineering products makes them a technical system. For example, buildings, bridges, roads, drainage, etc., infrastructure are technical systems. Any failure of a technical system is when such a system cannot fulfil some or any of its expected functions. In forensic engineering the cause of failure of a technical system promotes an interest in what initiated the failure including the sequence of events involved.

The technical basis for recognizing the parties responsible for or contributing to the failure of a technical system should be based on applying engineering principles.

3.2 Life Cycle of technical system

Technical systems have life cycle phases. These phases are important in dealing with technical systems should something goes wrong. The phases for the life cycle of a technical system are shown in figure 1. The life cycle is necessary to understand a technical system because to discover why failure occurs and to have prevented it, we firstly must recognize what could go wrong in a technical system and where it is coming from. Figure 2 represents a typical develop phase.



IFU – Instruction for use; RR – Rules and regulation
REQ - Requirements
Figure 1. Life cycle phases of a technical system

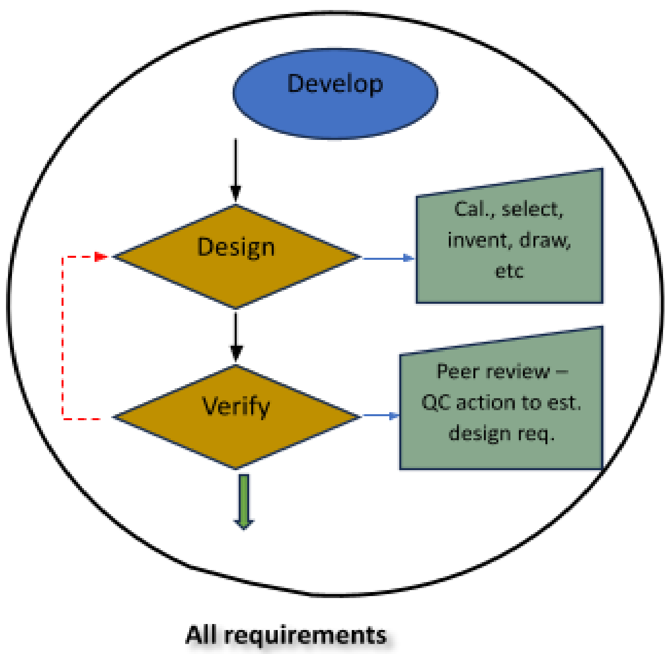


Figure 2. Typical develop phase

Initiation of the develop phase of a technical system depends on the other phases. This phase should satisfy a lot of requirements as follows:

- **Rules and Regulations** – For example, Ghana Standards, ISO, government laws, protocol agreements, etc.
- **Requirements from the Produce phase** – availability of appropriate resources or materials, economy, etc.
- **Requirements from Utilize phase** – suitability, functionality, safety, user friendly, etc.

The design activity, within the develop phase, should undergo verification using a peer review mechanism. The review process could adopt computer aided simulations, local authority checks, interviews, and ensures that all requirements have been met. The flow process is such that should there be any demanding feature or item, the design activity should undergo a review. Once all develop phase requirements are fulfilled, design drawings, technical specifications, material directories or schedules, etc., will be sent to the next phase, produce.

The Produce phase, see typical flow in figure 3, is the stage to make or produce the engineering products. This phase is expected to employ the following:

- Design drawings and schemes.
- Materials and specification details provided.
- Techniques for assembling components.
- Testing instructions.
- Etc.

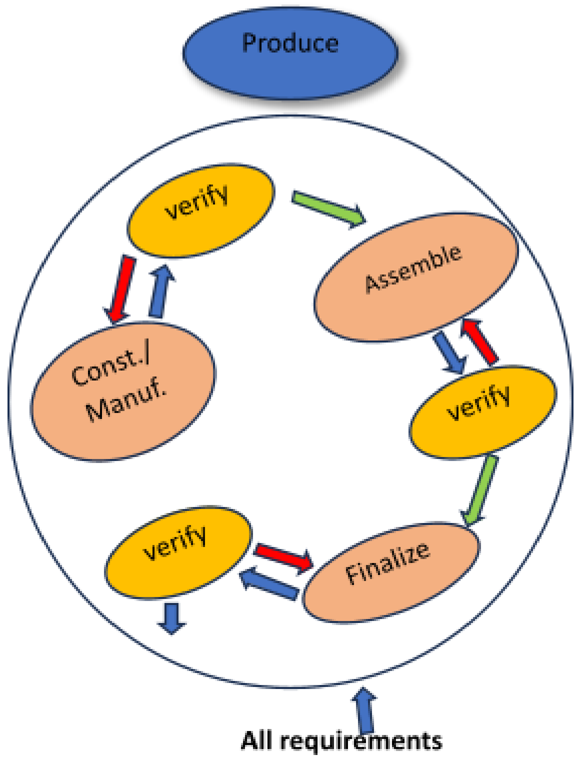


Figure 3. Typical flow for produce phase

The produce phase has the following routine activities.

- Construct or manufacture of components according to specifications and verified. For example, car parts, formwork, steel bars, etc.
- Assembling of components to form product elements and verified. For example, beams, columns, slab, car doors, windscreen, etc.
- Finalize assembling elements into finished products and verified. Once verification is complete product is ready for use. For example, verification includes final inspection of completed building, testing of finished car, removing of scaffolds, etc.

The Utilize phase of a technical system, see figure 4, is when the product is transferred to the user. This phase should also comply with requirements. For example, occupancy permit for a house. The instructions for use (IFU) are important at this stage. This can be manuals, installation instructions, safety instructions, etc. The various IFU should be provided by the Firm or licensed practitioner who develops the product. It should be noted that there could be government rules and regulations on how to use such a technical system.

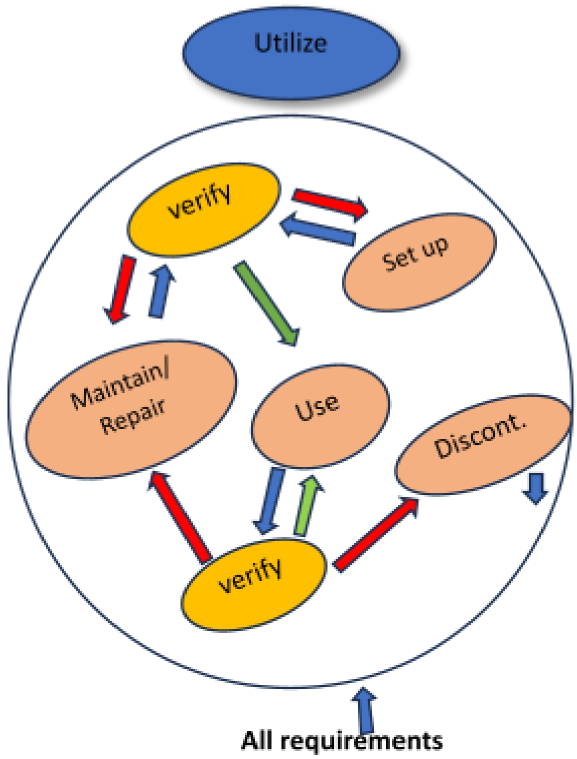


Figure 3. Typical flow for utilize phase

3.3 Potential Causes of a Technical System failure

3.2.1 General

A technical system, generally, will function well depending on the technical input or attention that addresses it. Every technical system has potential failure carriers. These carriers symbolize a cluster of potential causes leading to a failure of a technical system. The failure carriers identified are *product related*, *instruction related,* and *execution related*. Each has connecting stems and roots that must be examined during forensic engineering activity to formulate relevant casual hypotheses.

3.2.1.1 Product Related

Product-related causes of a technical system considers failures of their actual and physical nature. For example, collapse of columns, beams, slabs, engine failure, aircraft failure, pavement failure, electrical products failure, boiler failure, etc. There are, primarily, two causal stems to address product related failures. These are:

- The integrity of the product and
- The ergonomics in handling the product.

3.2.1.1.1 The Integrity

This aspect of a technical system failure should address issues related to failures in its physical reliability such as, construction aspect, electrical aspect, chemical aspect, etc., of product elements. For example, the construction of a concrete column, electrical mast, or pylon, etc. The failure of such technical systems has their root causes. The following issues, among others, can be a guide to address possible root causes.

i. **Configuration** – this is related to verification that a technical system was well set-up and complete. The forensic expert should check whether the right components were used or employed. For example, calibration certificates of any measuring devices deployed in the built up of a technical system, wrong concrete mixing set-up, electrical system failure due to inappropriate software set-up, etc.; The configuration root searches and answers questions such as:
   - "*were the column arrangements well set-up?*"
   - "*were the formwork appropriately set-up to control leaking?"*
   - "*could the malfunction of the vehicle electrical system be due to improper software set-up?"*
   - "*did the tyre of the vehicle remove because the knots or bolts were not tightened well?"*, etc.

ii. **Geometry** – geometry related issues include shape and size of parts of a technical system. For example, column shapes and sizes, seals for watertight areas, rebars sizes, bends, or dents on components, etc. Any intended deviations from design specified geometric parts could cause a failure in a technical system.

iii. **Material** – deviations from intended material employed in a technical system could cause it to fail. Chemical issues like corrosion, decomposition, neutralization, combustion, etc., could change material properties. Also, physical issues such as temperature, warmth, micro and macro structure, etc., could make materials weak, fatigue, porous, hardened, among others. For example, “could the corrosion of steel bars weaken the concrete columns?”; “could honeycombs affect the integrity of the concrete beam?”

iv. **Intactness** – this answers questions of a technical system to indicate wear, tear, fractures, erosion, etc., of components that could be consequences of failure.

v. **Purity** – this answers the question of anything that is found to be part of a technical system or its components, which ought not to be there. For example, computer virus in a system control software; overdose of a retarder admixture in concrete; cracks in the landing gear of a plane, which is covered by dust; could nail in between the lifting gears of a crane jam them?

vi. **Dependencies** – this is related to the environment or surroundings where a technical system is functioning. Issues related to disturbances resulting from the surroundings is important here. For example, “did the speed hump introduce vibrations into the building along the road?”; “does the river have sufficient water to supply the water pumping station?”; “could the foundation failure have been caused by erosion due to recent flood?”

3.2.1.1.2 Ergonomics

Ergonomics stem of a technical system relates to three important terms:

i. Usability,
ii. Accessibility, and
iii. Safeguards.

i. **Usability** – refers to how easy or clear to learn to use a technical system. It also indicates what the user should do how and when. For example, “are electrical switches labelled correctly?”; “are the steps for switching the generator or pumping machine clearly labelled?”

ii. **Accessibility** – refers to making the technical system and its components easy to be reached, heard, seen, controlled, etc., for users with broad range of disabilities and abilities. For example, “are the switches visible in the dark?”, “is the staircase within reach?”, etc.

iii. **Safeguards** – refers to how to create the proper use, clear instructions, etc., in the design of a technical system. For example, “is it safe to create balconies without railing?”; “is it safe to construct a speed hump at section with speed limit of 80km/hr?”; “what impact capacity should trigger air bag?”, etc.

3.2.1.2 Instruction Related Cases

Instruction related causes connect to any instruction that describes how a technical system should be designed, produced, utilized, or recycled. There are basically four (4) causal stems to instruction related issues that should be considered:

i. Governance requirements.
ii. Professional Disciples requirements
iii. Maker requirements
iv. Organization requirements.

i. **Governance requirements** – address instructions that cover laws, regulations, treaties, etc., in the built up of a technical system. For example, ACT 819, Company laws, Local Governance laws, Bi and Multi-Lateral agreements, other local laws, and regulations. These issuances from the governance system should be regarded in the development of a technical system. References to any such requirements should be quoted.

ii. **Professional Disciplines requirements** – relate to instructions concerning practicing standards and codes, professional norms, etc. This stem is based on agreement from professionals to cooperate on how things should be done. For example, Building Codes, Laboratory standards, ISO-standards, Manuals, etc. Reference to any such adopted documents should be quoted.

iii. **Maker requirements** – address instructions causing the production, manufacturing, creating, etc., of a technical system. Here, the requirements should focus on technical drawings, user manuals, safety instructions including maintenance directions. For example, “clear design drawings”; “clear instructions on the use of temporary structures”; clear instruction on assembling of construction components”, etc.

iv. **Organization requirements** – address instruction made internally on the use of a technical systems or products by a Firm or Company. For example, “work instructions on the use of company vehicles”; “work instructions for weld settings”; “work instructions on concrete pour during construction”, etc.

<u>A general note</u>

The root cause of failures due to instruction related are about three (3). These are:

i. Applicability,
ii. Validity, and
iii. Availability.

i. **Applicability** – relates to answer questions such as the use of correct design requirements, the necessity to follow required instructions, etc. It is important to note that not all “legal” requirements may be applicable in developing a technical system. For example, are the use of certain types of construction materials, based on treaties or others, useful taking into consideration local conditions?

ii. **Validity** – relates to establishing the quality control of design, testing, instructions, and any other rules in the build-up of a technical system. Because of the establishment of mistakes, it is important to **test** any instructions for a technical system. For example, the use of designed parameters from established codes and applied to local environments.

iii. **Availability** – relates to the convenience of accessing instructions during the overall development of a technical system or its components. For example, “were the craftsmen told how to fix the formwork or scaffold?”, “were the craftsmen told how to lift the car engine?”, etc.

3.2.1.3 Execution Related

Execution refers to how all prescribed instructions were fulfilled and implemented during the lifecycle phases of a technical system. This is where instructions are brought into practice. For example, “was the design made according to codal instructions or safety regulation prescribed by law?”, “was the concrete produced according to mix design instructions?”, etc.

There are many explanations why execution activities could go wrong. These could be placed in three (3) causal stems related to a party's behaviour in any of the lifecycle phases.

i. Knowledge stem,
ii. Rules stem
iii. Skill stem.

i. **Knowledge stem** – relates to a party's lack of knowledge about a technical system. For example, "what happens if a party does not understand the workings of asphalt and has to decide on what to do when it starts bleeding"; "what happens if a party does not understand the workings of a car engine system and has to decide on what to do when the oil light on the dashboard start blinking; what happens if a party who does not understand the physics of beams and has to decide on what to do when it starts sagging; etc.
ii. **Rules stem** – relates to a party's wrongly applying rules, design protocols, etc., in the developing processes of a technical system.
iii. **Skill stem** – relates to errors in performing an action or a routine though, the party intended to do it in the right way. For example, recording the strength of concrete test results from the compression machine and communicating it wrongly to the contractor under distractive condition; wrong dosing up a concrete mix with an admixture under distractive condition; choosing to put your fuel tank cover properly and by accident leaving it on the roof of your car because you got distracted by a friend calling you before you closed the tank, etc.

<u>A general note</u>

The root cause of failures carrying these execution related stems are:

i. Choice,
ii. Attempt
iii. Ability, and
iv. Awareness.

i. **Choice** – relates to decision making in getting a component or a technical system accomplished. Thus, a party doing the wrong thing, while thinking it was right. For example, was the mason fit to supervise a four-storey building; was the trainee engineer fit to design and supervise the 8-storey building; was it right to veer from a design protocol because something unexpected happened; etc.

ii. **Attempt** – relates to things going wrong because the thing the party wanted to do did not go as intended. Thus, the party tried the right thing however, not successful. For example, did the party squeeze the brakes hard enough to stop the car timely before reaching the speed hump, etc.

iii. **Ability** – relates to the involved party's capabilities to make right choices or properly perform an action in the developing process of a technical system. For example, Does the engineer have sufficient experience to be a project leader; Does the mason have sufficient understanding in concrete production; Could the customer be assumed to use the air condition without an instruction manual, etc.

iv. **Awareness** – relates to prior knowledge in the use of a technical system. For example, did the contractor know that training was necessary in the erection of props; was the car triangle on the road visible to other users at the time of the day during accident; etc.

3.3 Relating the Lifecycle and Failure Carriers

3.3.1 General

The forensic engineer should appreciate the different kinds of failure and group them based on their characteristics. This helps in performing forensic investigations in a systematic manner. In doing this, it is important to observe or note which phase of the lifecycle the failure occurred. For example, the collapse of a building during construction occurs at the *produce phase* of the lifecycle. In view of this, the forensic engineer should connect this phase to the three potential failure carriers or causes (product related, instruction related, and execution related), and delve into their stems and roots.

3.3.1.1 Failure Investigation Procedure

The convergence of forensic investigation is to look for the potential causes of failure. The connection of lifecycle phases and the failure carriers are great lead forming a failure investigation procedure defined by the flow chart below, figure 5.

The forensic engineer should think of the set of potential causes and use them to create hypothetical story line or chain of events to explain what happened. Efforts should be made to rule out wrong hypotheses. Again, time is needed to search for explanation.

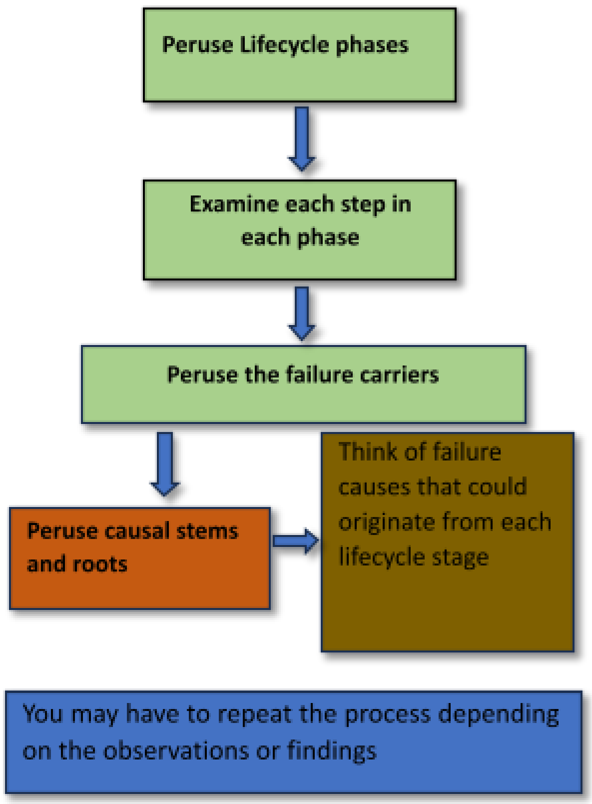


Figure 5. Typical flow for investigative procedure

Another important note is when forensic engineers stop their investigation. This may occur when probably the pre-set goal has been achieved or what caused the failure was known; based on common sense, logic, or no money to continue.

3.3.1.2 Forensic Investigation Steps

To conduct forensic investigation, there is the need to have a defined process. The submission here describes, fundamentally, six steps that should be adopted to conduct forensic investigation as presented in the flow diagram below, figure 6.

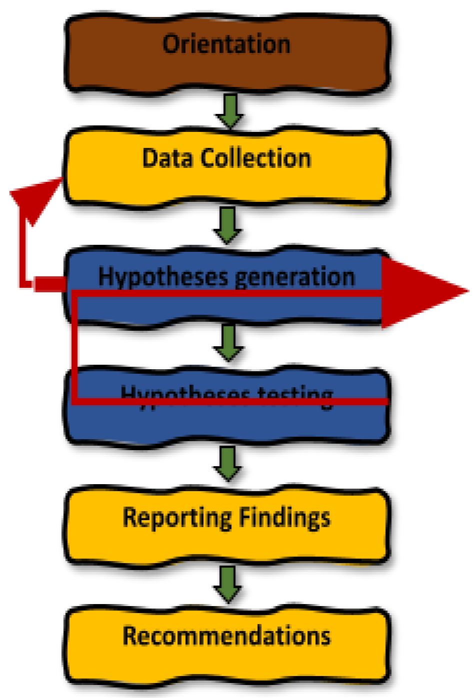


Figure 6. Typical flow for investigative steps

<u>Commentary</u>

<u>Orientation stage</u>

The following, among others, are important during this stage.

- Determine or identify the stakeholders (Client, NADMO, GNFS, GAF, Police, DVLA, MMDA's, EC, GhIE, IET, GIA, ARC, etc.)
- Determine or identify those involved. For example, pilots, masons, steel benders, engineers, architects, patients, contractor, manufacturer, etc.

- Determine or identify who wants to know what. This may determine, in part, the objectives and scope of the investigation.
- Define the main objective(s) of the assignment. For example, *the main objective of the assignment is to investigate the cause(s) of beam collapse of the second floor*.
- Define the scope of the assignment. The scope definition depends on the type of investigation.

> The objective and scope can have influence on the investigative questions!!

- Derive or propose the investigative questions.
- Determine the sequence of events or are they any questions related to the causes of failure?
- Ask the question: "is it important to focus the investigation on specific part that failed or on the whole?"; You are encouraged to tie-in the lifecycle and sequence of events.
- What should be the composition of the team for the investigation. Focus on the team (expertise) that will answer the investigative questions.
- What initial information or data is available. For example, "you may have direct access to an initial information from a person directly involved; news, online media, etc. This can help select the appropriate data collection plan.
- Define the strategy for collecting data. Depending on the incident, location, and available human resource, the data collection can start. At this stage data collection can be in the form of debriefing.

Data Collection stage

The aim of this stage is to collect relevant data on the incident in accordance with the data collection strategy and the objective of the investigation. The following should help in the data collection.

- **Desk study**: - search databases for similar events. This can give insight into regulations, production instructions, drawings, etc., which can be applicable to the investigation. Again, reading these desk study pieces helps in increasing knowledge of events and identifying possible problems.

- **Field investigation**: - visit the incident scene and record the relevant data.
    - Note the state and location of the objects that are part of the investigation.
    - Take excellent photographs.
    - Take samples as applicable in accordance with relevant procedures.
    - Any other field strategy to support the investigation.

> Always be in your PPE's during the field investigation; hand gloves are important when sampling.

Hypotheses generation stage

This stage is to signal proposals or think aloud what might be described as what happened after obtaining all relevant data. Imagine the hypotheses generation as a lineup of sequence of events, which resulted in the failure. Hypotheses should be within the framework of objectives and scope.

An important goal of hypotheses generation is to identify the possible scenarios in clear terms. **DON'T DISMISS HYPOTHESES RIGHTAWAY**.

Hypotheses testing stage

The testing of hypotheses addresses the question "does it fit the data collected or not?"; the testing stage checks whether the data collected provide a logical explanation for the observed failure. This can be done by:

- Logical reasoning
- Conduct validation calculations
- Simulation or real-life tests
- Etc.

It is important to look for additional hypotheses when the generated list of hypotheses or data collected do not provide satisfying answer to the main investigation question of objective. This creates a feedback loop. Also, the hypotheses testing phase can go on for a while until investigative questions are answered.

> Always work on a structured way and follow the investigative steps.

Report findings stage

This should contain, primarily, the following:

- All steps of the investigation. This is to ensure that the structured process has been followed.
- Address the findings (facts) and answer the main investigation questions during the orientation phase.

Recommendation stage

The recommendation should be part of the report and represents the finishing touch of the investigation. The recommendation should present what we can learn from the failure with the motive to prevent future occurrences.

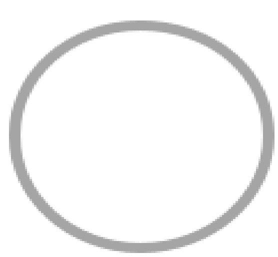
3.3.1.3 Ring of trustworthiness

The forensic engineer should bear in mind that the theatre will begin after the “beautiful report” containing all the findings. Because there is the potential for legalities, challengers may raise questions about the findings. These issues may be real because:

i. You may have ignored a lot of relevant data.
ii. You were biased during the testing of hypotheses.
iii. You hastily jumped into conclusions.

These can be harsh criticism and indicate a situation of pitfall.

The ring of trustworthiness provides relevant suggestions for a high sense of credibility for the investigation.



There are five (5) elements or items the investigation should address.

- The investigation should be **objective**. Everything must be based on fact with limited influence of the forensic engineer.
- The investigation should be **repeatable**. This means other investigators should be able to repeat all the processes or procedures or steps for the investigation without or minimal glitches. It is important the initial report provides:
    - o Provide proper description of all the steps.
    - o Description of the facts considered including accompanying pictures, figures, interviews, desk study references among others.
    - o A detailed overview of hypotheses, clear argumentation, why the hypotheses were assessed to be true or false.
    - o Description of the experiment performed.
    - o Conclusions based on the description of the report.
- The investigation should be **verifiable**. This means the investigation processes can be checked or demonstrated that all information presented in the report is true and accurate or justified. This aspect provides specificity to the reporting content.

It is important to store evidence over a period.

- The investigation should be **complete**. This means the investigation should contain everything that is necessary or appropriate. Thus, the investigation should ensure that information that is necessary to understand the context, approach, and any decision are captured clearly.
- The investigation should be **correct**. This means the investigative procedures should be free from errors. It should be in accordance with facts or truth.

The ring of trustworthiness breaks when one element is too weak or lacking. It should be incorporated at every stage of the investigation.

3.3.1.4 Measure to improve trustworthiness

The legality battle associated with forensic work requires a high sense of trustworthiness and, therefore, the investigation itself when subjected to scrutiny will help. The following, among others, are useful avenues to support the scrutiny.

i. Checking and cross-checking work done.
ii. Using various sources and approach.
iii. Provide more than the minimal information described.
iv. Peer reviews
v. External audits reviews
vi. Collaboration with relevant parties
vii. Experts' qualification and experience

3.3.1.5 Possible Pitfalls in Forensic Investigation

The forensic experts should guide against the following occurrences.

Investigative feature	Possible pitfall
Objective	Guard against already known analysis and concluding on investigation during the data collecting stage. Avoid having reference to one hypothesis. It can be risky. Avoid trying to fit this hypothesis to the available data to produce a bias outcome. Avoid the reporting of only outcomes that are beneficial to you client.
*Consequences of not being **objective** will allow a judge or the opponent to raise issues such as questions about approach, findings not reproducible or repeatable, data collected was not properly documented in the report with accompanying photos not clear, and other findings cannot be verified.*	
Hasty conclusions	Seeing an observation and jumping into immediate conclusion. Conclusions based on one observation is not very sound and verifiable, makes an incomplete report because important data is lacking. Findings may not always be correct because one can make a mistake with say a measurement leading to falsification of hypotheses.

3.3.1.6 Guide to mitigate pitfall

This guide recommends some mitigation against the pitfalls in the table below.

Investigative feature	**Possible pitfall**
Objective	Stay factual, avoid mixing facts with opinions, adopt the 4-eyes principles (or two-man rule) for your analysis and checks.
Reproduceable and verifiable	Use systematic and structures approach in the investigation. Provide reasoning and evidence for your findings.
Completeness	Use a systematic approach. Take some time off the investigation and have rest. Use this time to ask questions whether anything is not left out or missing.
Correctness	Follow the rules of logic, use validated and established test methods or approach, adopt 4-eyes principle.

3.4 Expertise and Resources

The qualifications, expertise and responsibility required for investigators, including structural engineers, fire experts, and other relevant professionals, can vary based on the specific field of investigation and the jurisdiction in which they operate. However, here are some general qualifications and expertise that are commonly sought after for these roles:

3.4.1.1 Structural Engineers (Forensic Structural Engineers)

- Bachelor's or master's degree in civil or Structural Engineering.
- Professional Engineer (PE) license or equivalent certification.
- Specialized training or coursework in forensic engineering.
- Strong understanding of structural analysis, mechanics, and materials.
- Knowledge of building codes, regulations, and standards.
- Experience in evaluating structural failures, collapses, and damage.
- Proficiency in using engineering software for analysis and modeling.

3.4.1.2 Responsibilities of Structural Engineers (Forensic Structural Engineers)

- Assess and analyze structural failures, collapses, or damage.
- Determine the cause of structural issues and recommend corrective actions.
- Evaluate compliance with building codes and standards.
- Conduct site inspections and document findings.
- Provide expert testimony in legal proceedings if required.

3.4.1.3 Fire Investigators (Fire Experts)

- Background in fire science, fire protection engineering, or a related field.
- Professional certification such as Certified Fire Investigator (CFI) or Certified Fire and Explosion Investigator (CFEI).
- Knowledge of fire behavior, fire dynamics, and ignition sources.
- Understanding of fire patterns, burn patterns, and fire spread.
- Experience in determining the cause and origin of fires.
- Familiarity with fire codes and regulations.
- Expertise in collecting and preserving evidence from fire scenes.

3.4.1.4 Responsibilities of Fire Investigators (Fire Experts):

- Determine the origin and cause of fires and explosions.
- Analyze fire patterns, burn damage, and fire spread.
- Collect and preserve evidence from fire scenes.
- Collaborate with other experts to identify contributing factors.
- Prepare detailed reports and potentially provide testimony in court.

3.4.1.5 Electrical Engineers (Forensic Electrical Engineers)

- Bachelor's or Master's degree in Electrical Engineering.
- Professional Engineer (PE) license or equivalent certification.
- Specialized training in forensic electrical engineering.
- Proficiency in electrical systems analysis and design.
- Knowledge of electrical codes and safety standards.
- Experience in investigating electrical failures, accidents, or malfunctions.
- Ability to analyze electrical circuits and systems.

3.4.1.6 Responsibilities of Electrical Engineers (Forensic Electrical Engineers)

- Investigate electrical failures, accidents, or malfunctions.
- Analyze electrical circuits, systems, and components.
- Determine the cause of electrical issues, such as short circuits or overloads.
- Assess compliance with electrical codes and safety standards.
- Provide technical expertise and consultation for legal cases.

3.4.1.8 Materials Engineers (Forensic Materials Experts)

- Degree in Materials Science, Metallurgical Engineering, or a related field.
- Specialized training or certification in forensic materials analysis.
- Knowledge of material properties, degradation, and failure modes.
- Experience in examining materials for defects, corrosion, and fatigue.
- Proficiency in laboratory testing and analysis techniques.

3.4.1.9 Responsibilities of Materials Engineers (Forensic Materials Experts)

- Examine materials for defects, degradation, and failure modes.
- Identify the root causes of material failures or deterioration.
- Perform laboratory testing and analysis on samples.
- Recommend measures to prevent future material-related issues.

- Provide expert opinions in legal disputes.

3.4.1.10 Geotechnical Engineers (Forensic Geotechnical Experts)

- Degree in Geotechnical Engineering or related field.
- Professional Engineer (PE) license or equivalent certification.
- Specialized training in geotechnical forensics.
- Understanding of soil mechanics, foundation design, and slope stability.
- Experience in investigating soil-related failures, landslides, and settlement issues.

3.4.1.11 Responsibilities of Geotechnical Engineers (Forensic Geotechnical Experts)

- Investigate soil-related failures, landslides, and foundation issues.
- Assess soil mechanics, subsurface conditions, and ground stability.
- Determine contributing factors to geotechnical failures.
- Recommend remedial measures and geotechnical engineering solutions.
- Collaborate with other experts to understand the broader context of failures.

3.4.1.12 Other Relevant Professionals (Environmental Experts, Mechanical Engineers, etc.)

- Qualifications specific to the field of expertise, such as environmental science for environmental experts or mechanical engineering for mechanical failure investigations.
- Specialized training and certification related to forensic investigations in their respective fields.
- Knowledge and experience relevant to the specific type of investigation being conducted.

3.4.1.13 Responsibilities of Other Relevant Professionals (Environmental Experts, Mechanical Engineers, etc.)

- Apply specialized knowledge to investigate specific types of incidents (e.g., environmental contamination, mechanical failures).
- Conduct thorough assessments and analyses within their field of expertise.
- Provide expert insights, opinions, and reports for legal proceedings.
- Collaborate with interdisciplinary teams to uncover contributing factors.

In addition to these qualifications, investigators should possess strong analytical skills, attention to detail, excellent communication skills (both written and verbal), the ability to work collaboratively in interdisciplinary teams, and a commitment to ethical conduct. It's important to note that the qualifications and requirements may vary based on local regulations and the nature of the investigation.

In general, experts are responsible for conducting thorough investigations, collecting, and analyzing relevant data and evidence, identifying the root causes of incidents, preparing detailed reports, and offering expert opinions based on their findings.

CHAPTER 4

PRE-INVESTIGATION PROCEDURES STAGE

4.1 Pre-Investigation Procedures

After a building collapse, a series of immediate and crucial steps need to be taken to ensure public safety, preserve evidence, and coordinate with relevant authorities. The following is a detailed outline of the initial steps that should be undertaken:

4.2 Emergency Response

- Immediately notify emergency services, including fire, police, and medical personnel.
- Evacuate the area to ensure the safety of nearby residents, pedestrians, and responders.

4.3 Securing the Site

- Establish a secure perimeter around the collapse site to prevent unauthorized access.
- Use caution tape, barriers, and signage to cordon off the area.
- Control access points to prevent interference with rescue and investigation efforts.

4.4 Search and Rescue

- Conduct search and rescue operations to locate and assist any survivors trapped in the debris.
- Coordinate with trained search and rescue teams, including urban search and rescue (USAR) teams.

4.5 Medical Assistance

- Provide medical care to survivors and injured individuals as quickly as possible.
- Coordinate with medical personnel to establish a triage area and facilitate patient transport.

4.6 Coordination with Relevant Authorities

- Notify and coordinate with local authorities, such as the municipal government, building department, and emergency management agency.
- Inform relevant state and national agencies as needed for support and coordination.

4.7 Establish Incident Command

- Set up an incident command structure to manage and coordinate response efforts effectively.
- Designate incident commanders, liaisons, and communication officers.

4.8 Preservation of Evidence

- Document the collapse site using photographs, videos, and sketches to capture the initial conditions.
- Collect samples of debris, materials, and components for later analysis if necessary.
- Maintain a chain of custody for all evidence collected.

4.9 Engineering Assessment

- Engage structural engineers and other relevant experts to assess the stability of any remaining structures.
- Determine whether it is safe for responders to enter the collapse site.

4.10 Communication and Public Information

- Provide accurate and timely information to the public, media, and affected individuals.
- Address concerns, share updates, and offer instructions for residents and businesses in the vicinity.

4.11 Support Services

- Arrange for support services, such as counseling and mental health resources, for survivors, witnesses, and responders.

4.12 Investigative Process

- Begin the formal investigative process to determine the cause of the collapse.
- Establish a multi-disciplinary team of experts. E.g. structural engineers, biomedical engineers, forensic specialists, and other relevant professionals.

4.13 Legal and Regulatory Compliance

- Ensure compliance with legal requirements for reporting and investigations.
- Coordinate with law enforcement if there is suspicion of criminal activity or negligence.

4.14 Recovery and Cleanup

- Plan for the recovery and removal of debris in a safe and controlled manner.
- Coordinate with debris removal contractors and waste management services.

It's essential to remember that the above steps provide a general guideline and may vary based on the specific circumstances of the collapse, the jurisdiction's procedures, and the resources available. Coordination, communication, and collaboration among all stakeholders, including government agencies, emergency services, experts, and the public, are critical to effectively manage the aftermath of a building collapse.

CHAPTER 5

SITE ASSESSMENT AND DOCUMENTATION

5.1 Site Assessment and Documentation

Conducting a thorough site assessment and documenting all relevant information, including building plans, construction history, and occupancy records, is of utmost importance in various scenarios, especially when dealing with building collapses, structural failures, or forensic investigations. Here's why it's crucial:

5.2 Safety and Rescue Operations

- During rescue and recovery operations, a detailed site assessment helps identify potential hazards, unstable structures, and areas where responders should exercise caution.
- Accurate documentation allows search and rescue teams to navigate the site more effectively and prioritize their efforts to save lives.

5.3 Investigative Process

- Detailed documentation provides a comprehensive record of the building's condition, layout, and relevant history, which is essential for conducting a thorough investigation into the cause of a collapse or failure.
- Investigators can use this information to reconstruct events leading up to the incident and analyze contributing factors.

5.4 Preservation of Evidence

- Documentation helps preserve evidence that may be critical in legal proceedings or insurance claims.
- Photographs, videos, and sketches of the site, debris, and structural components can be used as visual evidence to support findings.

5.5 Engineering Analysis

- Accurate documentation, including architectural and engineering plans, assists structural engineers in analyzing the design, load-bearing capacity, and integrity of the building.
- Comparing as-built conditions to original plans can help identify deviations and potential causes of failures.

5.6 Determining Responsibility and Liability

- Comprehensive records of construction history, permits, inspections, and maintenance activities help establish responsibility and potential liability in cases of structural failures or building collapses.
- Documentation aids in determining if construction defects, poor maintenance, or non-compliance with regulations contributed to the incident.

5.7 Regulatory Compliance

- Proper documentation ensures compliance with local building codes, regulations, and permit requirements.
- Building plans and occupancy records provide a historical record of changes and modifications made to the building over time.

5.8 Lessons Learned and Prevention

- Analyzing documented information from past incidents can lead to improvements in building design, construction practices, and safety regulations.
- Identifying patterns and trends in failures can contribute to preventing similar incidents in the future.

5.9 Collaboration and Communication

- Clear and accurate documentation facilitates effective communication and collaboration among investigators, experts, legal teams, insurers, and other stakeholders involved in the investigation or legal proceedings.

In summary, a thorough site assessment and comprehensive documentation play a crucial role in understanding the context, identifying causes, determining liability, ensuring public safety, and improving future construction and safety practices. Proper documentation helps create a factual foundation for investigations, legal actions, and decision-making processes, ultimately contributing to better outcomes and a safer built environment.

CHAPTER 6

STRUCTURAL ANALYSIS

6.1 Structural Analysis

Structural analysis to determine the cause of a collapse involves a comprehensive investigation that considers various factors such as design flaws, material defects, and construction practices. Engineers and forensic experts use a combination of methods and techniques to analyze the failures and identify contributing factors. Here are some of the key methods used in this process:

6.2 Visual Inspection

- Preliminary on-site visual assessment to identify visible signs of distress, damage, or anomalies in the collapsed structure or equipment, etc.
- Documentation of the condition of structural members, connections, and components etc.

6.3 Review of Design and Construction Documents

- Examination of architectural and engineering drawings, plans, and specifications to understand the intended design and use(s).
- Identification of any deviations from the original design during construction.

6.4 Structural Modelling and Analysis

- Creation of computerized structural models using advanced software to simulate the behavior of the collapsed structure under different loads and conditions.
- Finite element analysis (FEA) and other analytical methods to assess stresses, deformations, and failure modes.

6.5 Load Path Analysis

- Analysis of how loads, including dead loads, live loads, wind loads, and seismic forces, were transmitted through the structure and its components.
- Identification of load redistribution or overloading that could have contributed to the collapse.

6.6 Material Testing

- Laboratory testing of samples taken from the collapsed structure to determine material properties, strength, durability, and potential defects.
- Non-destructive testing methods like ultrasonic testing, radiographic testing, and magnetic particle testing to assess material integrity.

6.7 Failure Mode Analysis

- Examination of the failure patterns, fractures, and deformation of structural elements to determine the sequence of events leading to the collapse.
- Identification of specific failure modes, such as bending, buckling, or shear failure.

6.8 Construction Quality and Practices Assessment

- Evaluation of construction methods, techniques, and procedures used during the building's construction.
- Inspection of welds, connections, fasteners, and other construction details to identify workmanship issues.

6.9 Building Code and Standards Analysis

- Comparison of the actual construction with applicable building codes, regulations, and industry standards to identify potential violations or non-compliance.

6.10 Historical Records Review

- Examination of maintenance records, repair history, and alteration documentation to identify changes made to the structure over time.

6.11 Expert Testimony and Peer Review

- Collaboration with multiple experts in various fields, including structural engineering, materials science, and forensic analysis, to ensure a comprehensive assessment.
- Preparation of expert reports and, if necessary, providing expert testimony in legal proceedings.

The combination of these methods allows investigators to develop a comprehensive understanding of the factors that contributed to the collapse, whether they involve design flaws, material defects, construction practices, or a combination of these elements. The goal is to determine the root causes and lessons learned to prevent similar incidents in the future.

CHAPTER 7

FIRE OUTBREAK INVESTIGATION

7.1 Fire Outbreak Investigations

Investigating fire outbreaks that could potentially lead to building and other equipment collapses/failures requires a systematic and thorough approach. Here are guidelines for conducting such investigations, including fire pattern analysis and identification of potential accelerants:

7.2 Scene Assessment and Safety

- Secure the fire scene to ensure the safety of investigators and prevent tampering with evidence.
- Establish an incident command structure and coordinate with relevant authorities.

7.3 Document the Fire Scene

- Document the fire scene using photographs, videos, and sketches to capture the initial conditions, fire spread, and damage.
- Note the location and extent of fire patterns, burn damage, and areas of intense heat.

7.4 Fire Pattern Analysis

- Analyze fire patterns, such as V-patterns, point of origin, and direction of fire spread, to determine the origin of the fire.
- Identify irregularities or anomalies in fire patterns that could indicate potential accelerants or ignition sources.

7.5 Point of Origin Determination

- Use fire pattern analysis, witness statements, and other evidence to pinpoint the area where the fire likely started.
- Investigate potential ignition sources, such as electrical equipment or heating systems.

7.6 Accelerant Detection and Analysis

- Collect samples of debris, residues, and materials from areas of interest for analysis.
- Conduct laboratory tests, including gas chromatography-mass spectrometry (GC-MS), to detect and identify potential accelerants.

7.7 Fire Dynamics Analysis

- Utilize fire science principles to analyze fire behavior, heat release rates, and fire dynamics.
- Determine how the fire affected structural elements and potential weakening of building components.

7.8 Structural Damage Assessment

- Engage structural engineers to assess the impact of the fire on the building's structural integrity.
- Evaluate damage to load-bearing elements, framing, and connections.

7.9 Material and Component Analysis

- Analyze fire-damaged materials for changes in strength, deformation, and structural integrity.
- Assess how materials' properties were altered due to exposure to high temperatures.

7.10 Electrical and Mechanical Systems Analysis

- Investigate electrical systems and equipment to determine if electrical issues contributed to the fire.
- Analyze mechanical systems and appliances for potential malfunction or failure.

7.11 Witness Interviews

Interview occupants, witnesses, and emergency responders to gather information about the fire's origin, spread, and behavior. - Obtain statements regarding any unusual activities or events leading up to the fire.

7.12 Compliance with Fire Codes and Standards

Evaluate the building's compliance with fire codes, regulations, and safety standards. - Determine if fire protection systems, alarms, and exits were properly functioning.

7.13 Expert Collaboration

Collaborate with fire investigators, structural engineers, materials experts, and forensic analysts to ensure a multidisciplinary approach. - Peer review and expert consultations contribute to a comprehensive analysis.

7.14 Report Preparation and Expert Testimony

Compile findings, analyses, and conclusions in a detailed report. - If required, provide expert testimony in legal proceedings.

By following these guidelines and employing a combination of scientific analysis and forensic techniques, investigators can determine the cause and origin of the fire outbreak, assess its impact on the building's structural integrity, and identify any contributing factors that could potentially lead to a building collapse.

CHAPTER 8

MATERIAL TESTING

8.1 Material Testing

Material testing is a critical component of investigating engineering failures, as it provides essential insights into the quality, integrity, and behavior of construction materials etc. By conducting thorough material testing, investigators can uncover valuable information that contributes to understanding the causes of the collapse/failure.

8.2 Assessing Material Properties

- Material testing helps determine the physical and mechanical properties of construction materials, such as concrete, steel, wood, and masonry.
- It provides information about factors like strength, durability, elasticity, and thermal properties.

8.3 Identifying Defects and Anomalies

- Testing can reveal material defects, manufacturing flaws, or irregularities that might have contributed to the collapse.
- Detecting cracks, voids, corrosion, or other weaknesses is vital to understanding structural vulnerabilities.

8.4 Analysing Fire Damage

- Fire-damaged materials can undergo changes in composition, strength, and structural behavior.
- Material testing helps assess how high temperatures and exposure to fire affected the integrity of building components.

8.5 Validating Design Assumptions

- Material testing helps verify whether construction materials meet design specifications and assumptions.
- It ensures that materials were used correctly and as intended during the building process.

8.6 Evaluating Load-Bearing Capacity

- Testing materials under various loads and conditions helps determine their load-bearing capacity and performance.

- This information is essential for assessing the structure's ability to withstand applied forces.

8.7 Comparing Expected vs. Actual Performance

- By comparing tested material properties with expected values, investigators can identify discrepancies that might have contributed to the collapse.
- Deviations from design standards or specifications can indicate potential areas of concern.

8.8 Understanding Material Degradation

- Over time, construction materials can degrade/biodegrade due to environmental factors. Eg. Fatigue, wear and tear.
- Material testing helps assess the level of degradation and its impact on the structural integrity.

8.9 Formulating Evidence-Based Conclusions

- Material testing provides empirical data that supports evidence-based conclusions about the causes of the collapse.
- It enhances the credibility and reliability of investigative findings.

8.10 Informing Future Design and Construction

- Insights gained from material testing inform best practices for future design, construction, and maintenance.
- Lessons learned contribute to improving building safety and preventing similar incidents.

In summary, material testing is essential for unraveling the complexities behind a building collapse. It helps investigators piece together the puzzle of how construction materials performed under different conditions, shedding light on potential weaknesses, defects, or anomalies. By systematically evaluating material properties, investigators can contribute to a comprehensive understanding of the collapse's root causes, thereby facilitating improved building practices and safety standards moving forward.

CHAPTER 9

HUMAN FACTORS

9.1 Human Factors

When investigating a building collapse, it's important to consider human factors such as maintenance practices, building usage, and potential negligence during construction or operation. These factors can significantly influence the collapse and provide valuable insights into the root causes. Here's how these human factors play a role in the investigation:

9.2 Maintenance Practices

- Neglected or inadequate maintenance can lead to the deterioration of building components over time.
- Investigate whether routine maintenance, inspections, and repairs were performed as required.
- Assess whether improper or delayed maintenance contributed to the weakening of structural elements.

9.3 Building Usage and Occupancy

- Analyze how the building was used and occupied before the collapse.
- Determine if changes in occupancy, alterations, or renovations affected the building's load distribution and structural integrity.

9.4 Human Error and Negligence During Construction

- Investigate construction practices to identify potential instances of negligence, poor workmanship, or shortcuts taken during construction.
- Assess whether design changes were properly communicated and implemented.

9.5 Compliance with Regulations and Codes

- Evaluate whether the construction, alterations, and usage of the building followed building codes, regulations, and safety standards.
- Identify any instances of non-compliance that could have contributed to the collapse.

9.6 Training and Knowledge

- Consider the qualifications, training, and expertise of individuals involved in design, construction, maintenance, and operation.
- Assess whether the responsible parties had the necessary knowledge to ensure the building's safety.

9.7 Inspection and Oversight

- Evaluate the effectiveness of oversight, inspection, and quality control mechanisms during construction and ongoing operation.
- Determine if there were gaps in oversight that could have contributed to the collapse.

9.8 Communication and Coordination

- Investigate the communication and coordination among various stakeholders, including architects, engineers, contractors, and regulatory authorities.
- Determine if miscommunication or lack of coordination played a role in the collapse.

9.9 Record-Keeping and Documentation

- Review records and documentation related to construction, alterations, inspections, and maintenance.
- Identify any discrepancies, missing records, or incomplete documentation that could have implications for the collapse.

9.10 Legal and Ethical Considerations

- Assess whether legal or ethical violations, such as fraudulent practices or deliberate disregard for safety, were factors in the collapse.
- Investigate any potential conflicts of interest that could have influenced decision-making.

9.11 Lessons Learned and Prevention

Analyse the findings related to human factors to identify lessons that can prevent similar incidents in the future. - Recommendations for improved practices, regulations, and oversight can enhance building safety.

Incorporating an analysis of these human factors alongside technical investigations allows investigators to develop a holistic understanding of the collapse. By considering the interplay between human actions, decisions, and negligence, investigators can uncover the full scope of factors that contributed to the collapse and develop actionable recommendations to prevent such incidents in the future.

CHAPTER 10

ANALYSIS AND REPORTING

10.1 Analysis and Reporting

Analyzing collected data and generating a comprehensive investigation report is a crucial step in understanding the causes of the Engineering failures. The report serves as a culmination of the investigative process and provides a clear, objective, and evidence-based account of the failure factors.

10.2 Data Analysis and Review

- Review all collected data, including documentation, photographs, laboratory results, witness statements, material testing data, equipment, structural analyses, and fire pattern assessments.
- Identify patterns, correlations, discrepancies, and anomalies within the data.

10.3 Restoration of the failed structure or equipment

- Piece together a timeline of events leading up to the collapse, considering design, construction, maintenance, occupancy, and any other relevant factors.
- Analyze how individual components, actions, and decisions contributed to the collapse.

10.4 Cause-and-Effect Analysis

- Establish cause-and-effect relationships between various factors, such as design flaws, material defects, construction practices, maintenance issues, and fire-related incidents.

- Determine which factors played a primary or contributory role in the collapse.

10.5 Evidence-Based Conclusions

- Formulate conclusions based solely on the available evidence and data, avoiding speculation, assumptions, or biases.
- Clearly articulate the reasoning behind each conclusion, citing specific data and analyses that support it.

10.6 Identification of Root Causes

- Identify the root causes of the collapse by tracing back the contributing factors to their origins.
- Highlight the primary factors that directly led to the collapse and secondary factors that exacerbated the situation.

10.7 Recommendations and Lessons Learned

- Provide actionable recommendations to prevent similar incidents in the future. These recommendations may involve changes in design practices, construction methods, maintenance protocols, fire safety measures, or regulatory oversight.
- Emphasize lessons learned from the investigation and highlight areas where improvements are needed.

10.8 Clarity and Transparency

- Present the findings, analyses, and conclusions in a clear and concise manner, using language that is easily understandable by both technical and non-technical audiences.
- Avoid jargon, technical terms, or complex language that might obscure the report's meaning.

10.9 Review and Peer Validation

- Subject the investigation report to a thorough review by experts from various relevant fields. This helps ensure accuracy, objectivity, and completeness.
- Incorporate feedback and address any concerns raised during the review process.

10.10 Importance of Clear and Objective Conclusions

- Credibility: Clear and objective conclusions enhance the credibility of the investigation report, making it more likely to be accepted by stakeholders, legal proceedings, and relevant authorities.
- Accountability: Objective conclusions ensure that accountability is appropriately assigned based on evidence, minimizing the potential for bias or subjectivity.
- Informed Decision-Making: Stakeholders can make informed decisions about future actions, policy changes, and improvements when conclusions are based on solid evidence.
- Preventing Future Incidents: Objective conclusions guide the formulation of effective recommendations for preventing similar incidents in the future, leading to enhanced building safety and standards.

In summary, the process of analyzing data and generating a comprehensive investigation report involves thorough data analysis, evidence-based conclusions, clear articulation of findings, and actionable recommendations. By prioritizing objectivity and transparency, investigators ensure that their conclusions are credible, reliable, and informative, ultimately contributing to the prevention of future building collapses.

CHAPTER 11

LEGAL RESPONSIBILITY PHASE

11.1 The Legal Responsibility Phase

1. Who bears legal responsibility for the Engineering Project?
2. And what are the Legal liabilities and Sanctions awaiting a person found to be responsible for the Engineering failure?
    - Key Actors in Engineering Projects
    - Legal Liabilities and Sanctions

11.2 Persons Who May Bear Legal Responsibility When there is an Engineering failure.

- Property Owner

- Project Manager
- Project Design Team
- Project Supervisor
- Builder
- The Occupier/User
- Local Authority

11.3 Legal Liabilities

A person who is found to have contributed to or responsible for the Engineering Failure may be liable for:

- Civil Liabilities and
- Criminal Liabilities

The liability may be out of:

11.3.1 Misrepresentation

That is making a false statement of fact to another person which induces that person to act on it and the person suffers loss or injury or damage. It may be made negligent or fraudulent.

11.3.2 Negligence

Simply means the failure to exercise the care towards another which a reasonable or prudent person would do in the same or similar circumstances. Is a breach of a duty of care to another person which has resulted in damage or injury.

11.4 Offences

11.4.1. Criminal Negligence

Section 12 of Criminal Offences Act 1960 (Act 29) states "A person causes an event negligently if, without intending to cause the event, he causes it by voluntary act, done without such skill and care as are reasonably necessary under the circumstances."

11.4.2. Defrauding by False Pretense

Section 131 of Act 29 states whoever defrauds any person by any false pretense shall be guilty of a second-degree felony.

11.4.3. Causing Loss, Damage, or Injury to Property

Section 179A (3) any person through whose willful, malicious, or fraudulent action or omission— (a) the State incurs a financial loss; or

(b) the security of the State is endangered, commits an offence.

11.4.4. Manslaughter

Section 51 of Act 29 states whoever causes the death of another person by any unlawful harm shall be guilty of manslaughter. Provided that if the harm causing death is caused by negligence, he shall not be guilty of manslaughter unless the negligence amounts to a reckless disregard for human life.

11.5 PROFESSIONAL BODIES REGISTRATION ACT 1973, NRCD 143

11.5.1 Offences

Section 20 of Professional Bodies Registration Act 1973 provides that A person who.

(a) not being registered under section 17 as a member of a registered professional body poses as so registered, or

(b) not having the qualification for admission to or enrolment in or for being accepted as a member of a registered professional body poses as having that qualification, or

(c) otherwise contravenes a provision of this Act

11.5.2 Offences by Bodies of Persons

Section 20 of Act 1973 (NRCD 143) states where an offence under this Act is committed by a body of persons then every president, vice-president, chairman, vice-chairman, director or partner and every officer of that body commits that offence where that person is proved to have directly or indirectly by an act or omission, permitted to be done the act or omission which constitutes the offence commits an offence and is liable on summary conviction to a term of imprisonment not exceeding five years or to a fine not exceeding one thousand penalty units (1000 p.u.) or to both the fine and the imprisonment; and where the offence is of a continuing nature the offender is liable to a further fine not exceeding twenty-five penalty units in respect of each day during which the offence continues.

11.6 FOR ARCHITECTS

11.6.1 Striking off and Cancellation of Registration

The section 13 states subject to section 14 of Architects Act 1969, NLCD 357 the Governing Board (Council) may strike off the register the name of an architect if satisfied that the architect is unfit to practice the profession of architecture by reason of having been found guilty of professional misconduct.

11.7 FOR ENGINEERS

11.7.1 Suspension or cancellation of registration

Section 17(1) of Engineering Council Act 2011 (Act 819) states The Board may suspend or cancel the certificate of registration of an engineering practitioner where an enquiry conducted by the Board confirms that the registered engineering practitioner.

11.8 Laws which may be breached

You may be charged of the following offences:

1. Criminal negligence (s. 12 of Act 29)
2. Defrauding by false pretense (s. 131 of Act 29)
3. Causing damage to property (s 179A of Act 29)
4. Manslaughter (s. 51 of Act 29)
5. Section 17(1) of Engineering Council Act 2011 (Act 819)
6. The section 13 states subject to section 14 of Architects Act 1969, NLCD 357
7. Section 20 of Professional Bodies Registration Act 1973 (NRCD 143)

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APPENDIXES

APPENDIX 1

Legislations of interest/ Normative references

The following local legislation are of interest to Engineering Practitioners.

Legislation	Issues of Concerns
Engineering Council Act, 2011 (ACT 819)	
Engineering Council Regulations LI 2410	
Ghana Building Code (2018)	
Building Regulations 2019 LI 2465	
Ghana Procurement Act, ACT 914	
Land Use and Spatial Planning Act (2016)	
Town and Country Planning Act (Act 64, 1945)	
Local Government Act 2016	
Fire Precautions Act (1973)	
Environmental Assessment Regulations (1999)	
Occupational Health and Safety Act (Act 651, 2003)	
Electricity Regulations (2011)	
Water Supply and Sanitation Act (Act 653, 2008)	
Building and Road Research Institute (BRRI) Guidelines	
Criminal negligence (s. 12 of Act 29)	
Legislation	Issues of Concerns
Defrauding by false pretence (s. 131 of Act 29)	
Causing damage to property (s 179A of Act 29)	
Manslaughter (s. 51 of Act 29)	
Section 17(1) of Engineering Council Act 2011 (Act 819)	
The section 13 states subject to section 14 of Architects Act 1969, NLCD 357	
Section 20 of Professional Bodies Registration Act 1973 (NRCD 143)	

Occupiers' liability	