Professional Engineers
Ontario

GUIDELINE

Forensic Engineering Investigations

Contributors: James Bennett, P.Eng., / Helmut Brosz, P.Eng., / Jamie Catania, P.Eng. (Chair), / Keith Ellison, P.Eng., / Michael Maher, P.Eng., / David Porter, P.Eng., / Dennis Pupulin, P.Eng., / Christopher Thompson, P.Eng., / James Wilkinson, P.Eng., / Renato Veerasammy, P.Eng.

Notice: The Professional Standards Committee has a policy of reviewing guidelines every five years to determine if the guideline is still viable and adequate. However, practice bulletins may be issued from time to time to clarify statements made herein or to add information useful to those engineers engaged in this area of practice. Users of this guideline who have questions, comments or suggestions for future amendments and revisions are invited to submit these to PEO using the standard form included in the following online document: Guideline Development and Maintenance Processes document

January 2016

Contents

1. PEO Purpose for Guidelines

Professional Engineers Ontario (PEO) produces guidelines for the purpose of educating both licensees and the public about best practices.

For more information on PEO's guideline and development process, which includes PEO's standard form for proposing revisions to guidelines, please read our Guideline Development and Maintenance Processes document.

For a complete list of PEO's guidelines, please visit Appendix 5.

To view other PEO guidelines, please visit the Practice Advice Resources and Guidelines of the PEO website.

2. Preface

This guideline addresses forensic engineering as defined in Section 4. Professional engineers called to appear as an expert witness should consult the PEO guideline *The Professional Engineer as an Expert Witness*.

During 2010, PSC prepared terms of reference for a subcommittee comprising professional engineers engaged in the practice of providing forensic engineering services. This group was asked to prepare a practice guideline for engineers retained to provide forensic engineering services. The guideline would provide information on how the practitioners should carry out forensic engineering activities in an ethical and legal manner.

The subcommittee met for the first time on April 19, 2011 and submitted a completed draft on March 18, 2013. Following a reader review process, public consultations and PSC consideration the draft was substantially revised. The final draft of the document was submitted to the Profes-sional Standards Committee for approval on September 15, 2015. The completed guideline was approved by Council at its meeting on November 20, 2015.

Note: References in this guideline to engineers apply equally to professional engineers, temporary licence holders, provisional licence holders and limited licence holders.

Practitioners as defined in the *Professional Engineers Act* (Act) refers to engineers and firms holding a Certificate of Authorization to offer and provide engineering services to the public.

For the purposes of this guideline, the term the *public interest* refers to the safeguarding of life, health, property, economic interests, the public welfare and the environment.

3. Purpose and Scope of Guideline

This guideline was developed to assist engineers who:

a) practise forensic engineering and/or offer professional forensic engineering services;
b) conduct forensic engineering investigations.

The guideline was written to assist the clients and employers of engineers as to the type of activities, work and options that may be needed to properly carry out a forensic engineering assignment.

Courts in any jurisdiction determine or set out the requirements for testimony to be proffered in their court. Ultimately, the trier of fact determines if an engineer is qualified as an expert witness in a specific proceeding. This guideline is not intended to replace this process.

The engineer should be mindful of other public interests having jurisdiction in an investigation, which may take precedence over private interests, for example investigations by the Ontario Fire Marshal and Emergency Management, or the Ontario Ministry of Labour.

4. Introduction

There are a number of definitions of forensic engineering, but it can generally be defined as the application of professional engineering principles and methodologies to investigating failures and incidents, usually to determine causation. Normally, it involves preparing a report of findings, which may form the basis for testimony in legal proceedings as an expert witness. A forensic engineer may serve as an engineering consultant to members of the legal profession and as an expert witness in courts of law, arbitration proceedings and administrative adjudication proceedings.

Forensic engineering is a part of professional engineering practice that may cover all disciplines of engineering. It is a specialized set of skills that can include multidisciplinary training in failure analysis, simulation, safety, accelerated life testing and statistical analysis, as well as knowledge of the specific engineering field.

Failures and incidents may include fires and explosions, transportation accidents, and a broad range of mechanical equipment and structural failures. Investigation of structures, products and assemblies that exceed their serviceability limits also involves the application of forensic engineering principles.

5. Professional Responsibility

5.1 Before Conducting Investigation

a) Immediate response

An engineer may be required to attend at a site in the immediate aftermath of an incident. As previously noted, the engineer should be mindful of other public interests having jurisdiction in an investigation that may take predence over private interests. Consequently, engineers must ensure they have the appropriate authority and permission to access the site before conducting their investigation.

When the engineer arrives on a site where there are unidentified hazards, including physical instability of the site, the first task should be to check in with responsible parties already established on site to assess potential hazards. These may include security personnel, safety officers, regulatory officers, or other engineers with different functions or responsibilities.

As the first priority is safety, the engineer should give consideration to:

- the apparent organization on site;
- the presence or absence of qualified or authorized personnel on site;
- the authority and responsibilities granted to the engineer by the client or employer;
- the assessment of hazards by other engineers, experts or site personnel; and
- the engineer's own skill and experience to assess the given apparent conditions.

The engineer is expected to act within his or her duty as a professional to recommend the necessary procedures and measures to be put in place to protect the engineer, the other parties on site and the general public where appropriate.

If the engineer is either unqualified or unauthorized to direct measures that allow activities to continue safely on site, the engineer is expected to act within his or her duty as a professional to alert the appropriate personnel, and recommend the necessary temporary procedures to be put in place to isolate people from hazards.

In Ontario, the *Occupational Health and Safety Act* (OHSA) and the various pursuant regulations set out specific duties for constructors, employers, supervisors and workers in the workplace. In addition, section 31(1) of the OHSA imposes a duty on a professional engineer to ensure that the advice provided by the engineer is not given incompetently or negligently. Accordingly, the engineer needs to be aware of the requirements of the OHSA and any other regulations pertaining to working in hazardous locations and comply at all times. This guideline is not intended to supersede or replace legislated responsibilities as set out in the OHSA or other applicable regulations and statutes.

Of secondary concern is further property loss. Engineers are encouraged to cause the necessary or appropriate personnel, procedures and measures to be put in place to reduce further property loss.

It should be noted that preventing risk of further injury or property damage is not part of an engineer's primary role in the practice of forensic engineering, but in certain circumstances, an engineer may have to take on this role in the absence of other authority on site.

In some instances, a client may request the attending engineer to determine not only the cause of the failure or incident, but also whether the equipment, facility or process can be made operational with whatever necessary modifications as soon as possible to bring it back into operation. If this potentially creates a conflict of interest for the engineer, he or she should so inform the client.

b) Initial incident appraisal

Below are some situations that may potentially occur during the course of an engineer's work relating to initial incident appraisal.

The event response and investigation may need to be managed by a senior individual with authority or overall responsibility for the site, enterprise, or operation. This individual (i.e. client or employer) may need to be advised by the engineer to undertake an initial incident appraisal to determine the general circumstances of the incident or event. The engineer should advise the client or employer to seek legal advice with respect to whether other parties need to be provided an opportunity to participate in the investigation. The engineer should impress on the client or employer the need to preserve the integrity of the site. For example, depending on the circumstances, this may involve setting up a security barrier to prevent disturbance of evidence. Engineers must note that evidence can sometimes be in the form of digital data. Where there is a concern that environmental or weather conditions could significantly impact the site or evidence prior to a formal investigation commencing, interim protection measures, such as shelters, may need to be instigated. Alternatively, the engineer should advise that a record, photographic or video, for example, be maintained for future reference as to the conditions in the immediate aftermath of the incident or event.

c) Planning the investigation

Where the initial site visit and determination of circumstances suggest that the causes of the incident or failure are not obvious or where a properly documented investigation is required for other reasons, an independent forensic engineering investigation will need to be initiated. In most instances, such an investigation should be put in place as quickly as possible so as to maximize the access of the engineer to the relevant site conditions. In some instances, it may be appropriate to plan on a phased investigation.

The engineer should keep in mind spoliation concerns. For more information on spoliation refer to Appendix 2.

d) Terms of reference

The terms of reference are based on instructions by the client or employer. The terms of reference should be as broad as possible if the intent is to find the cause of the incident. The terms of reference will define the problem to be addressed by the engineer.

An engineer can be retained to investigate a single component or aspect of a failure. This is acceptable, provided the terms of reference are clearly defined. Where there are regulations or quality control requirements governing such investigations, these must be considered as minimum requirements.

e) Relevant expertise and qualifications

The engineer carrying out the forensic engineering investigation must be licensed by Professional Engineers Ontario. The engineer must be able to show that she or he has special knowledge through study or experience of the nature of the incident that is to be or is being investigated. If during the forensic investigation, the engineer determines that he or she does not have such special knowledge, the engineer shall so inform the client and, if possible, direct the client to an engineer or other professional with such knowledge. Specifically, it is professional misconduct to undertake work the practitioner is not competent to perform by virtue of the practitioner's training and experience (section 72(2)h from Ontario Regulation 941/90 of the Act). Failure to properly inform the client is reviewable on conduct and competence grounds and the engineer may be held accountable by the client, the court and/or PEO.

f) Composition of the investigation team

Following the development of a preliminary investigation extent, the composition of the investigation team needs to be established. In some instances, the entire investigation extent may be delivered by a single forensic engineer. However, it is common for additional specialists, support services, testing laboratories, etc. to be involved. In certain circumstances, in particular where there might be two unrelated aspects to an incident or event, the client or employer may elect to retain separate investigation teams. Where this is deemed appropriate, the client or employer should be advised to ensure the extents of work are clearly defined and documented and that the entire team works cooperatively and shares all relevant information. However, it is preferable that all the required additional specialist or support services be retained and delivered by the lead engineer. This avoids overlap and allows the lead engineer to manage the work and maintain delivery schedules.

g) Creating a cooperative environment

The client or employer should be asked to ensure that all relevant documents and records are compiled and made available. Relevant documents might not be restricted to the incident under investigation. They might also include maintenance and inspection records, quality control plans, certification documents, industry codes and standards, etc. In cases where the relevance of certain information may be questionable, it should be provided anyway.

Ideally, the engineer should be given free access to the site and should be allowed to interview personnel with relevant information. The client should be aware of the need for the investigation to be undertaken in a cooperative and open environment. Should the lead engineer perceive any lack of cooperation in the course of the investigation, the client should be immediately informed.

h) Fees for services

Preferably, the costs of forensic investigations should be estimated and invoiced at a rate per unit time basis for engineering and associated services and a unit charge per routine type tests. Lump sum pricing is discouraged unless the engineer has a well defined extent of work at the outset of the investigation.

Retainer fees for services to be rendered may be requested from the client by the engineer conducting the investigation before any work is undertaken.

As indicated in the Professional Engineers Ontario *Code of Ethics*, section 77 of Ontario Regulation 941/90, practitioners shall not attempt to gain an advantage over other practitioners by paying or accepting a commission in securing professional engineering work.

A contingency fee must not be charged, as it inherently undermines the engineer's duty to provide an unbiased and accurate report. Contingency arrangements are defined as any fees paid that are contingent on a specific outcome or settlement.

i) Conflict of interest

Regardless of who might have retained an engineer, the engineer is reminded that they must carry out the forensic engineering investigation in conformance with the PEO Code of Ethics. For example, the engineer must disclose immediately to the client any interest, direct or indirect, that might be construed as prejudicial in any way to the professional judgment of the engineer in rendering service to the client. For more information on the Code of Ethics and avoiding Conflict of Interest please refer to the PEO guideline *Professional Engineering Practice*.

5.2 While Conducting Investigation

An engineer should carry out due diligence to determine which regulations apply and their impact on the requirements of the investigation.

Within an investigation's terms of reference, the engineer should be prepared to advise the client or employer of the appropriate investigation methodologies under the circumstances to determine the causes of the failure. The engineer should also be prepared to propose additional investigation methodologies that might be beneficial in determining the causes of the failure. More details on these methodologies are provided in Appendix 2 of this guideline. However, engineers should beware of clients who set the terms of reference to suit the client's needs. Furthermore, engineers must note that there is no place for unsupported "opinion" in an objective forensic analysis of technical circumstances. Any interpretations or conclusions should be supported to a reasonable degree of engineering certainty.

In many investigations, relevant data is scarce. Reasonable and well-founded assumptions can be formulated to replace this data, but engineers need to report clearly the nature of any assumptions made, and identify any corresponding sensitivity in the findings that result. It is appropriate for engineers to refrain from coming to any findings if there is insufficient data.

The process of identifying contributors to an event where a loss has occurred is inherently a potential threat to parties having a stake in the outcome of the investigative process. Engineers need to be cognizant of the close scrutiny the analysis process will likely endure and, in all cases, the analysis must be supportable and backed up by documented evidence.

At the same time, engineers are expected to be mindful of the balance of benefit and cost to any particular analysis approach, and avoid unnecessarily extravagant avenues of analysis.

a) Extent of investigation

Engineers determine the extent of investigation based on the terms of reference.

The extent of an investigation should be defined as being as broad as necessary to encompass all actual or potential conditions related to the incident. For example, an investigation involving failure of industrial machinery needs to consider activities leading up to the incident, the human factors relating to procedures, manufacturer's manuals, training, management control, quality control protocols, and any related environmental factors that could have a bearing on establishing contributing causes.

Clients should be advised that the extent of an investigation may have to be revised as information becomes available from the investigation. Such advice should be presented in a timely manner.

An engineer should take care that the client or employer does not attempt to ask for or reach conclusions beyond the extent of the investigation. Any limitations to the extent of the investigation should be included when findings are communicated. The engineer should know what questions are being asked and what questions cannot be accurately answered given the extent of the investigation. Either the client will widen the terms of reference or be prepared for a narrow answer to a narrow question. Maintaining this position over the life of a project is essential. The terms of reference should be well defined before an investigation and put in writing early in the process. Engineers should be mindful of their professional obligations in situations when a client requests changes to the terms of reference during the investigation

b) Maintaining objectivity and avoiding bias

It is important to maintain an open mind during an investigation. It is imperative that ultimate conclusions are based upon the entirety of the evidence. While it is reasonable that preliminary conclusions are drawn based upon the available evidence at every step, it is critical that those be subject to revision as new evidence becomes available.

Engineers must maintain objectivity in undertaking forensic investigations and avoid potential biases. These potential biases can be summarized briefly as:

- **Association bias.** This bias can arise out of an engineer's financial or employment relationship to the client or employer. As per the *Expert Witness* guideline: "Experts must understand their role is to be neutral and impartial servants of the court or tribunal they appear before, and not representatives or advocates of the party hiring them."
- **Expectation bias.** This is the subconscious tendency of those who have predetermined a certain outcome to search for data or analysis methods that will support that outcome, and ignore contradictory information. Consequently, it is prudent investigative practice to keep an open mind, especially in the early stages of an investigation, and never prematurely predict the outcome. It is also prudent to ensure the analytical approach follows a conservative methodology, in part to correct for the potential influence of hidden forms of bias. This bias should be further minimized by careful examination of the factual data about the failure and by listing all possible reasons for the failure, even those that initially appear to be extremely unlikely.
- **Data bias.** The specific data collected and how it is analyzed can bias findings and conclusions. It is important that sufficient appropriate data is used in the analysis of the failure to assess all the potential reasons for it.

With regard to regulations and standards that may be relevant, an engineer must be careful not to imply that variance from a regulation or standard is in itself the cause of a failure. The presence of a variation from a regulation does not necessarily have anything to do with the reason for a particular failure. Conversely, meeting a regulation or standard does not preclude the potential for a failure.

c) Duty to report

An engineer's duty to report stems from the requirement that the engineer's duty to protect the public welfare is paramount. Engineers involved in forensic engineering investigations are directed to section 9 of the PEO guideline *Professional Engineering Practice* for a full explanation thereof.

d) Expert testimony

The report deriving from a forensic engineering investigation may be used in litigation and other legal proceedings as background for the forensic engineer's testimony as an expert witness. The PEO guideline *The Professional Engineer as an Expert Witness* should be referred to in investigating, analyzing and preparing a report used for this purpose.

6. DEFINITIONS

For the purposes of this guideline the following terms and definitions apply.

Chain of custody: the chronological documentation, showing seizure or collection, custody, control, transfer, analysis and disposition of physical or digital evidence.

Expert opinion: an opinion provided by a person with extensive skills or ability based on education, training and knowledge of the applicable standards, recent developments in the field and experience in a particular area of study to provide a subjective belief based on an accurate understanding of the degree to which it is supported by the evidence.

Factual report: a report that contains only facts from an investigation, rather that providing theories or personal interpretations.

Hold point: a mandatory verification point beyond which work cannot proceed without the approval of the relevant stakeholder in the forensic investigation.

Lead engineer: the engineer for a particular investigation who takes direct responsibility for the completion and results, or the engineer for a particular investigation who has primary responsibility for the project and who will be involved in a significant manner.

Inspection and test plan: an inspection and test plan (ITP) is a document that records all inspection and testing requirements relevant to the forensic investigation. An inspection and test plan identifies the items of materials and work to be inspected or tested, by whom and at what stage or frequency, as well as witness and hold points, references to relevant standards, acceptance criteria and the records to be maintained.

Non-standard test procedure: a test that does not completely follow the proven methods and techniques of the standard test process or procedure, or a method or technique that has not been recognized as an industry standard.

Standard test procedure: a written guide that describes and outlines the methods and techniques, providing instruction and detailing all steps or activities of a process or procedure so the test is administered and interpreted in a consistent manner.

Witness point: provides a stakeholder in the forensic investigation with the opportunity to witness the inspection or test or aspect of the work, at the stakeholder's discretion. A witness point can be waived by the stakeholder. If the stakeholder was given the requisite notice and the witness does not arrive, the testing may also proceed.

Appendix 1. Forensic Engineering Resources of Interest to Engineers

Note that this list in no way limits the responsibility of an engineer or the scope of this guideline.

Resources	Website
Associations	
National Academy of Forensic Engineers	http://www.nafe.org/
Books	
Forensic Engineering Investigation by Randall K. Noon	http://www.crcpress.com/product/isbn/9780849309113
Forensic Engineering Fundamentals by Harold Franck & Darren Franck	http://www.crcpress.com/product/isbn/9781439878392
Guidelines	
Guidelines for Forensic Engineering Practice (ASCE)	http://www.asce.org/Product.aspx?id=23622321621&productid=176118199
Standards	
American Society for Testing and Materials (ASTM) Standards and Publications	http://www.astm.org/Standard/standards-and-publications.html
Canadian Standards Association (CSA)	http://www.csagroup.org/
National Fire Protection Association (NFPA) Codes and Standards	http://www.nfpa.org/codes-and-standards

Appendix 2–Inspection

The following are suggestions for the inspection phase of a forensic engineering investigation. This section is not intended to encompass all aspects of investigations or to be a rigid guide to be followed as if a procedure.

Not all of these steps will be applicable to every investigation, and it may not be practical or even possible to complete some of these steps, even when they are applicable. These are not intended to be formulaic or necessarily sequential, but rather are presented in this order for ease of understanding.

1. Planning

The following are to be considered prior to beginning an inspection.

1.1 Review all available information and documents

It is desirable to review all of the available relevant information before commencing an investigation. It may be helpful to sort the information into a logical order and to vet the information to determine what information is relevant for your work and what is not.

Any additional relevant information the engineer suspects might be available should be requested from the client.

It is important to note that information review should be an ongoing process because material may become available during an investigation. Information made available at different times and stages of an investigation should be identified with disclosure dates in the master file. It is advisable to flag any updated, altered, conflicting, or changed versions of material for ease of future reference.

1.2 Prepare preliminary investigation objectives

The development of these objectives should include the client or manager to ensure the objectives of the investigation are achieved, and the extent of the investigation, budgets, review meetings, due dates, deadlines and other factors should be considered.

It is appropriate to disclose and/or discuss what is not (or may not be) possible because of time, budgets, expertise, lack of data, or other factors. Known limitations or objections (e.g. an ethical objection) should be disclosed and/or discussed as early as possible.

1.3 Review prior actions taken

Consider what other parties have already done (such as firefighting, extrication of victims, police or other investigations, shoring of buildings for safety, cleaning, recoating, replacement of parts, change in operation, etc.) in the context of how these actions have affected the conditions or items to be inspected. This also extends to deleting data, shredding documents, erasing photographs and disposing of samples.

This may highlight what actions need to be taken so as to avoid further destruction of incident conditions or prevent further samples being lost.

1.4 Develop preliminary investigation plan

This is the outline of the significant aspects of the investigation.

This may include:

- developing a sampling plan and/or in situ testing plan, including planning for re-enactment or duplication or computer modeling of the event;
- establishing sample sizes, types, input data and sequence;
- considering health and safety considerations for the inspection;
- considering other parties, and potential joint investigations (in many instances investigation may need to be undertaken simultaneously by a number of parties);
- considering how your inspection might alter or destroy a condition. This is typically a time when offers of joint inspection should be made, as well as efforts to preserve the evidence unaltered until decisions are made. For example, some systems might require changes in power state to preserve digital evidence;
- considering site access and limitations (e.g. ability to take samples, destructive and non-destructive testing, etc.);
- considering the effects of the investigation, specifically whether the actions taken during the investigation will diminish the opportunity for repair or replacement.

2. Conducting the Inspection

2.1 Initial review

The nature and process of this review can vary significantly depending on the type of event or incident, but the following are some examples:

- equipment walk down. This may include a tour of the machine and inspection to understand its function;

- possible review of related storage facilities or sources for materials and/or chemicals;
- building assessment;
- review of physical evidence. This step may include any component or item included in the event. It is relevant to consider if actions in this phase might compromise the available evidence in any way. Often, anything more than a visual inspection or non-destructive testing (such as thermal scan, ground penetrating radar, Windsor pin, or boroscopes) is not favourable until all the parties have had an opportunity to be present;
- inspection or survey of the roadway. This step can include a survey of general roadway surface characteristics, roadway markings, lane layouts and obstruction geometry;
- machine or vehicle inspection. This step could include documenting the basic particulars, such as make/model/serial number/VIN/etc., collecting photographs, measuring the location and extent of damage, and inspecting various components; and
- consideration of devices containing digital data.

2.2 Information gathering

Engineers are reminded that information in addition to the following suggestions can be consulted regarding the collection and storage of all manner of physical evidence. Specifically, there are ASTM standards addressing this issue in Appendix 1. Additionally, if samples are being collected for the purposes of testing relative to a standard, that standard should be reviewed to ensure samples are collected in a suitable fashion.

2.2.1 Non-destructive information gathering

Observations

It is advisable to take detailed notes of the observed conditions, either as physical notes or audio recordings. In the event of audio recordings, it is preferable to have these transcribed as soon as possible and the accuracy of the transcription verified by the person who made the observations.

Photography and videography

To the extent possible, all relevant aspects should be photographed and or videotaped. It should be recognized, however, that not all observations can be appropriately photographed or videotaped.

Use standard formats and compact size to enable sharing of data. When selecting the storage medium, it is useful to consider both reverse compatibility and forward compatibility issues.

Measurements

Useful measurements that do not interfere with the evidence should be taken.

Other information or documents

It is advisable to access and consider any other relevant information or documents. Some examples are: original equipment manufacturer (OEM) information, design documents (drawings, specifications), operating data, inspection records, maintenance procedures, literature review, and modifications/changes made.

2.2.2 Destructive information gathering

Evidence collection

- Chain of custody: A chain of custody should be recorded with the evidence, and engineers have an obligation to keep evidence that is collected. Engineers should be knowledgeable of standards regarding evidence collection. Appendix 1 contains some relevant resources.
- Evidence integrity: The act of collecting should not influence or affect the evidence taken.
- Sample labeling: Always provide as much information as possible, including the location, date and time of collection; the person collecting the evidence (if possible the person collecting the samples should sign the container or tag to identify them); a detailed description of the evidence; file number or reference; sample number. When collecting evidence, it is advisable to photograph the evidence in the original locations, as well as once collected.
- Sample storage: As required, samples should be preserved in a manner that will not contaminate or spoil the evidence, or compromise the storage container. Remember to consider moisture accelerating corrosion in a closed environment. Silica bags in the evidence are a reasonable solution to this problem.
- Sample disposal: It is advisable to obtain consent from your client before destruction and/or disposal of evidence collected during an investigation.

Field simulations/In situ testing/laboratory testing

Standard procedures: Generally, these may be difficult to complete outside of a laboratory environment. If such testing is undertaken, consideration should be given to a given laboratory's ability to complete the testing. Also, the suitability of a test should be considered, including the influence of the collection method on the test results. The referenced standards in Appendix 1 are helpful when considering laboratory testing.

Non-standard procedures: A specialized test is needed where there is no standard procedure for the case to be tested. Although it is easier to develop such a test or simulation to meet the requirements of the testing, it is more difficult to explain and support the process. Consequently, these tests usually require more documentation.

Exemplar testing: Inspection and testing of an exemplar can be a valuable investigation method. Similar concerns regarding non-standard procedures need to be considered in these situations.

Caution needs to be exercised when completing and/or relying on any testing to represent the conditions of a particular event. When completing any testing, it is important to document the testing appropriately, and be careful not to create conditions that are not representative of the subject situation or are misleading.

Spoliation concerns

If destructive inspection/testing is required, all interested parties should be provided an opportunity to review and comment on the inspection/testing protocol and hold points, and witness the inspection/testing. The aim should be to reach consensus as to the inspection/testing protocol. Even when all parties are present, any disassembly or inspection that changes the state of the evidence should be documented in detail for ease of future explanation. It should be noted that in the case of digital evidence the inspection could change the state of this evidence.

Further inspection

Upon completing an inspection, it is advisable to consider if further work is required. Some other aspects to consider are: return site visit; equipment or components to be inspected; in situ tests, calculations or analysis to be performed; laboratory testing; component analysis; personnel to be interviewed.

Appendix 3. Engineering Analysis

1. Introduction

The analysis portion of a forensic investigation comprises the synthesis of data collected during the investigation and involves the application of engineering principles. Analysis is designed to elicit determinations about the physical circumstances of the incident that could not be derived from observation alone. Generally, the focus is on identifying "causes" and, if more than one is identified, quantification of the contribution of each cause. The purpose of analysis is to produce results that contribute to scientifically or logically deciding between multiple potential causes, isolating the cause, or identifying or eliminating a potential cause or contributing factor to the cause.

Analysis typically takes place after data collection and evidence preservation, and is based on observations from those earlier steps. The results of in situ and laboratory testing may also provide vital input to engineering analysis.

Because of the wide range of possible analytical techniques and the potential variability in the extent of analysis required in any particular investigation, the following is intended only as a general guide. The engineer is ultimately responsible for identifying the type, breadth, and depth of analysis required to complete a prudent and effective investigation, but must nonetheless ensure any analysis is completed in accordance with the following principles.

2. Analysis

Forensic analysis should be designed to address effectively the particular issues at hand. The appropriate extent may vary widely, however. This variance is generally a result of a combination of factors, including the amount of data available, the type of event being investigated, and the extent of available analysis techniques. Investigations may justifiably require teams of investigators performing extensive analysis of many forms. Alternatively, there are forensic investigations wherein no formal analysis may be necessary, because the contributing causes to an incident are easily identified and their influence measurable through observation alone. Prudent examination of the evidence will often allow for a confident technical assessment of the cause of an incident.

There are no limitations or minimum requirements for a forensic analysis, but an engineer needs to be acutely aware of what is considered widely accepted by the specific engineering community. Engineers should be cautious about areas of analysis that can be considered unusual or diverting from standard methodology. Analysis methods are ideally proven and time-tested techniques that reinforce the objectivity of the engineer; findings should flow from the application of engineering principles to the available information, regardless of the particular individual performing the application. The results should be demonstrably repeatable. Any interpretations or conclusions should be supported to a reasonable degree of engineering certainty.

If the appropriate extent exceeds that permissible by financial or temporal constraints, this limitation needs to be quickly communicated to the client or employer, and in any formal report on the matter. Indeed, any restriction that acts to limit the analysis of an incident to a level below that deemed prudent by the wider engineering community needs to be clearly identified.

3. Analysis techniques

Techniques may comprise any structured approach that assists with the identification of factors that contributed to the cause, timing, or location of an incident. Generally, these techniques will mirror the engineering expertise of the engineer.

Ultimately, the analysis may require capabilities in any of the following generalized approaches:

- the application of physical and engineering principles to the specific product/process/structure/event/system, e.g.:
  - calculating stresses, loads, motions, energy levels, or other physical conditions present at the time of a failure, including using computational assistance provided by numerical methods or simulation,
  - identifying strength and condition of materials or components, and understanding the behaviour of their failure,
  - applying physical principles to masses in motion or masses in contact, to determine loading or timing of incidents,
  - analyzing backwards an engineering design to confirm that appropriate parameters and assumptions were previously used,

- applying simulation results to interpret the circumstances leading to the incident or failure, and
- retracing processes or procedures that led to an incident, potentially including any of a variety of formalized or systematic failure analysis methods. This may involve the use of analytical software;

- the evaluation of human performance as a contributor to the cause of the incident;
- the assessment of the effect of environmental factors;
- the comparison of circumstances present to relevant standards, regulations, statutes, or other expected levels of performance;
- scientific and engineering modeling and simulation;
- logic, elimination, deduction, causality; and
- consideration of failure modes and effects.

4. Best Practices

Technical responsibility

There are some disciplines in forensic engineering where engineers are asked to assess the technical responsibility of the parties that were potentially involved in decisions leading to the failure. An investigating engineer should make the assessment by comparing the work performed by each party with: the regulatory or statutory requirements; the standard of practice normally expected to carry out the work; and whether the problem causing the failure was common knowledge in the relevant industry. It is not the engineer's responsibility to assess the liability of the parties; this is the role of the court.

Evidence

An investigating engineer must be careful to identify what evidence is independently obtained (i.e. physical or digital information) and what evidence is subjectively obtained (i.e. circumstances reported by witnesses). Both the frailty of human memory and the influence of bias among witnesses can render subjectively obtained information of limited value.

Cognitive performance

In addition to possessing a deep understanding of their various areas of expertise, engineers are well served by at least a basic understanding of human physical and cognitive performance, to assist with identifying causative factors.

Data analysis

In any discipline of forensic engineering, there will be widely-accepted techniques for analyzing data. There is a clear duty (from both the court system and PEO) for an engineer to identify shortcomings in their ability to handle certain analyses as a result of a lack of appropriate knowledge or tools. The engineer can expect to be asked to demonstrate proficiency in the specific analytical areas by parties interested in the outcome of the forensic investigation.

Assumed parameters

All assumed parameters necessary to complete an analysis must be clearly stated. The values assumed for such parameters must be justified and supported by reference to appropriate and current design manuals, best practice guidelines, published literature or other objective sources.

Internal review process

In the event certain data cannot be reliably known, the level of uncertainty should be explored by the engineer. Generally, findings should be checked for plausibility and accommodate all relevant observations. Findings that are inconsistent with a certain observation should be carefully scrutinized for validity. An internal review process by a colleague is particularly valuable and strongly recommended, to identify inconsistencies in the relationship of observations to findings, and to identify otherwise subtle forms of bias.

5. Arriving at Conclusions

Conclusions may take the form:

- finding a single cause,
- finding multiple causes,
- eliminating one cause or a set of causes, or
- determining that there is insufficient data to support a logical conclusion of any cause or to distinguish between causes.

In the last case, one is proving that there is no evidence-based approach to determine cause, given the state of available evidence.

Appendix 4. Forensic Engineering Reports

Generally, engineers engaged in the practice of forensic engineering will be required to outline their findings in a formal technical report to provide others an opportunity to review, and possibly scrutinize the work that was the basis for the conclusions drawn. It is noteworthy that in some circumstances oral communications may suffice. The report format and content may vary, depending on the nature of the investigation and the needs of the client. The following sections provide an overview of the different types of written reports that may be used to document the results of a forensic engineering investigation.

Formal Technical Reports

Formal reports should follow an organized and carefully planned sequence that will allow the reader to understand fully the facts of the case and the interpretation of the evidence that led to the ultimate conclusions drawn. They are typically divided into sections, enabling the reader to easily reference: an abstract, introduction, procedures, results, discussion, conclusions, recommendations, appendices and references. It is advisable to cleanly separate observations from analysis and discussion. Longer reports should include a table of contents and lists of illustrations. Formal technical reports are usually reviewed internally by colleagues and approved prior to release. The details of the review process are usually mandated by the engineer's employer, but may also be tailored to the specific needs of the client. A formal report prepared by an engineer that offers an engineering opinion and is completed as a result of services offered to the public must be sealed in accordance with section 53, Ontario Regulation 941/90. Consult PEO's guideline on *Use of the Professional Engineer's Seal* for more information.

A formal report presents the results of the forensic investigation in significant detail and would typically include:

- a clear statement of the purpose of the investigation;
- the name, area of expertise and qualifications of the author(s);
- specific direction provided by a client, instructions, terms of reference;
- extent of investigation;
- agreed facts or background information related to the case and statement of assumptions;
- detailed observations related to the case;
- detailed description of testing conducted;
- detailed description of research conducted or relied upon;
- detailed description of analysis methods used;
- detailed explanations for opinions expressed;
- scientific basis or references for formulating opinions;
- explanation of the reliability of the opinion expressed, if possible; and
- explanation of any non-standard procedures.

It is important to recognize that an engineer's report usually relies on specialized technical knowledge that may not be easily understood. Stephen T. Gouge's *Inquiry into Pediatric Forensic Pathology in Ontario* listed a number of recommendations in Chapter 16 related to communicating forensic pathology opinions. Many of the recommendations could also be applied to the work of engineers practising forensic engineering. Some examples include:

- "Not only the opinion should be stated but also the reasoning used to reach it, the limitations and the strength or degree of confidence."
- "The opinion must be communicated in clear easily understood language."
- "Avoid legal and technical jargon."
- "Emphasis placed on empirical evidence in comparison to peer reviewed literature...."
- "Avoid misleading language that could imply an unreasonable degree of certainty such as the phrase 'consistent with' which means 'could be'."

Informal Reports

There are many occasions when a formal report is unwarranted or would be considered an unnecessary task. Such situations could include those in which time constraints or the destruction of evidence prevents a proper investigation from being performed, where the causes of the incident or failure are readily apparent and easily understood, or where it is perceived that future litigation is unlikely to occur. In this situation, the investigation findings may be outlined in an informal report format. Usually, this approach to reporting is taken by the engineer in consultation with the client or employer. Informal reports should include a disclaimer that they should not to be used for court, and are only a summary of findings.

Informal reports offering an engineering opinion provided as a service to the public need to be sealed.

When preparing an informal report, it is important for an engineer to recognize that in the future, the client's needs may change and the engineer may be required to provide a formal technical report. Therefore, it is imperative that excellent documentation be maintained, including notes, photographs with photo logs and video, if possible.

Writings and Other Activities that Present No Technical Opinion

From time to time, a client may ask an engineer to use the engineer's technical knowledge to augment some potentially partisan, non-engineering activity. An example of this may be assisting a legal client in preparing cross-examination questions for another expert engineer. Here, the engineer is not performing analysis, or concluding, or reporting opinion. Engineers are reminded, however, that this fact does not absolve them of responsibility or accountability for their actions, only that this guideline does not address such activities.

Expert Witness Reports and the Rules of Civil Procedure

In many cases, forensic engineering reports are entered as evidence in court proceedings, public inquiries, coroners' inquests or other judicial or quasi-judicial hearing civil proceedings. If a report is being prepared by a professional engineer who is also acting as an expert witness, PEO's guideline *The Professional Engineer as an Expert Witness* should be consulted.

For matters that will appear before the Ontario Superior Court of Justice, professional engineers should be aware of amendments in 2010 to the *Rules of Civil Procedure* (Ontario regulation 194 53.03) that address the form and content of expert reports. These changes, along with issues related to the discoverability of draft reports and peer consultations on draft opinions, are discussed in greater detail in *The Professional Engineer as an Expert Witness* guideline.

Other Standards for Report Writing

Other organizations provide recommendations for report writing that should also be referenced prior to committing findings to paper.

Integrating Other Expert Reports

It is not uncommon for forensic engineers to employ or collaborate with other experts in creating their reports. In such cases, it should be clearly stated who was responsible for every portion of the report. Proper credit for work must be provided.

Appendix 5. PEO Professional Practice Guidelines and Standards

Practice Guidelines

1. Acting as Contract Employees (2001)
2. Acting as Independent Contractors (2001)
3. Acting under the Drainage Act (1988)
4. Acoustical Engineering Services in Land-Use Planning (1998)
5. Building Projects Using Manufacturer-Designed Systems & Components (1999)
6. Commissioning Work in Buildings (1992)
7. Communications Services (1993)
8. Conducting a Practice Review (2014)
9. Developing Software for Safety Critical Engineering Applications (2013)
10. Engineering Evaluation Reports for Drinking Water Systems (2014)
11. Engineering Services to Municipalities (1986)
12. Environmental Site Assessment, Remediation and Management (1996)
13. Forensic Engineering Investigations (2015)
14. General Review of Construction as Required by the Ontario Building Code (2009)
15. Geotechnical Engineering Services (1993)
16. Human Rights in Professional Practice (2009)
17. Land Development/Redevelopment Engineering Services (1994)
18. Mechanical and Electrical Engineering Services in Buildings (1997)
19. Professional Engineer as an Expert Witness (2011)
20. Professional Engineering Practice (2012)
21. Project Management Services (1991)
22. Reports for Pre-Start Health and Safety Reviews (2001)
23. Reports on Mineral Properties (2002)
24. Reviewing Work Prepared by Another Professional Engineer (2011)
25. Roads, Bridges and Associated Facilities (1995)
26. Selection of Engineering Services (1998)
27. Services for Demolition of Buildings and Other Structures (2011)
28. Solid Waste Management (1993)
29. Structural Engineering Services in Buildings (1995)
30. Temporary Works (1993)
31. Transportation and Traffic Engineering (1994)
32. Use of Agreements between Client and Engineer for Professional Engineering Services (including sample agreement) (2000)
33. Use of the Professional Engineer's Seal (2008)
34. Using Software-Based Engineering Tools (2011)

Performance Standards

1. Design of Certain Buildings
2. General Review of Construction of a Building (2008)
3. General Review of Demolition and Demolition Plans (2008)
4. Engineering Evaluation Reports under *Safe Drinking Water Act*, *2002* (Drinking Water Systems)(2014)
6. Environmental Site Assessment Reports (2014)

Professional Engineers
Ontario

40 Sheppard Avenue West, Suite 101
Toronto, ON M2N 6K9

Tel: 416 224-1100 or 800 339-3716

Enforcement Hotline: 416 224-9528 Ext. 1444
or 800 339-3716 Ext. 1444

Website: www.peo.on.ca

Published by the Association of Professional Engineers of Ontario