Editorial: First Indo–US Forensic Engineering Workshop

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Abstract: Organised jointly by members of the ASCE Technical Council on Forensic Engineering and faculties at the University of North Carolina at Charlotte and the National Institute of Technology at Trichy, the first Indo–US Forensic Engineering Workshop (INDUSFEW) was successfully completed in December 2010 at Tiruchirapalli, India. A total of 23 technical presentations were delivered by both US and Indian forensic experts including several speakers from the Structural Engineering Research Center (SERC), Chennai. The Workshop signified the international collaboration between India and the US in the area of Forensic Engineering. The specific outcomes of the INDUSFEW workshop include the publication of a proceeding and the establishment of a forensic engineering curriculum at NIT-T. This workshop offered the opportunity to study the differences between forensic engineering practice in India and USA, which is influenced by local legal systems and culture. This paper gives a concise account of the event and the curriculum.

Keywords: forensic workshop; failure case studies; forensic engineering curriculum.

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1 Introduction

With increasing concerns about the failing conditions of the built environment, forensic engineering is becoming a critical component in a modern society to assess, diagnose and quantify system and component failures. It is important to equip new engineering graduates with the knowledge of forensic engineering practices. In pursuit of this goal, the Technical Council for Forensic Engineers (TCFE) of the American Society of Civil Engineers (ASCE) has been engaged in international activities in several countries (Carper 1987, Delatte and Carper 2011 and Carper 2011).

Due to the differences in culture and legal systems, forensic engineering practices vary significantly from country to country. However, the need for professionalism and technical accuracy is universal. The intent of the first India-US Forensic Engineering Workshop (INDUSFEW) was to encourage better forensic practices and to share a common awareness of forensic engineering issues between the two countries. The workshop was held and successfully completed during 15–17 December 2010, at the National Institute of Technology at Tiruchirapalli (NIT-T), India.

The workshop was organised jointly by the TCFE, the University of North Carolina at Charlotte (UNC Charlotte), and the NIT-T and was sponsored by the National Science Foundation (NSF), the ASCE, the Indian Council of Scientific and Industrial Research (CSIR) and several local industry sponsors. The workshop included technical presentations presented by both US and Indian forensic experts. Speakers included members from TCFE, scientists from the Structural Engineering Research Center (SERC), Chennai, faculties from NIT-T and from the Indian Institute of Technology (IIT) at Madras.

The workshop signified the international collaboration between India and the US in the Forensic Engineering domain. It is important to recognise that this is not the first such effort in India. The conception of this workshop resulted from the first International Conference on Forensic Engineering (organised by the Indian Chapter of ACI) held in 2007 in Mumbai, India. Several delegates from the TCFE attended the Mumbai conference and were charged with the challenge to continue to promote forensic engineering practices to India. This dream evolved from the friendship between the late Mr. R.N. Raikar and Professor Emeritus Ken Carper of Washington State University – both pioneers in the field of Forensic Engineering: Professor Carper's book entitled "Forensic Engineering: Learning from Failures," (ASCE Pub., 1986, ISBN 0872625176, 98 pages) is a must read in Forensic Engineering and Mr. Raikar published the first forensic investigation book in India (Learning from Failures-Deficiencies in Design, Construction and Service, R & D Center Pub., 1987, ISBN 81-900037-0-4, 423 pages). Mr. Raikar passed away shortly after the conference, a great loss to the Indian engineering field (Carper, 2008). Due to his own health reason, Professor Carper was unable to deliver the INDUSFEW key note speech and Professor Norbert Delatte of Cleveland State University, a leader in Forensic Education, served as the keynote speaker and gave an overview of the history of the TCFE in US.

After the workshop, subsequent collaborative activities were conducted, including the development of the course contents for an upper-level (post-graduate) forensics course and a proposed forensic engineering curriculum. This paper reports the workshop experience and describes the important lessons learned from comparing the forensic practices in both countries.

2 The INDUSFEW workshop

The goal of the workshop was to introduce forensic engineering as an engineering discipline that provides the basis to develop practices and procedures, to reduce the number of failures. The three day event included twenty-three presentations on subjects including conventional, and experimental, non-destructive testing technologies, the forensic engineering investigation process, case studies of modern and heritage structures, the role and qualifications of the expert witness, as well as, the role of law and the judiciary in resolving failure disputes. Important discussions throughout the workshop included the ethical role of the forensic engineer, the need to further develop inspection and certification practices in India, and the importance of improving the dissemination of information on past and future failures.

Presentations included representatives from NIT-T, UNC Charlotte, Cleveland State University (CSU), SERC, the Indian Institute for Technology at Madras (ITTM), as well as, several practicing engineers and scientists. Speakers included Balasubremanian, K. Muthukkumaran and C. Natarajan of NIT-T; Shen-En Chen, R. Janardhanam, Brett Tempest and David Young of UNCC; Paul Bosela and Norbert Delatte (CSU); S. Arunachalam, Balaji Rao, N.Lakshmanan, K. Muthumani, R. Nagsh Iyer, A. Rajaraman, K. Ramanjaneyulu, K. Ravisankar, and T. Srinivasan of SERC; Meharprasad and A. Menon of ITTM; Alicia Diaz de Leon and Michael Drerup (Engineers), and Ronald Anthony (Wood Scientist).

Over 150 practitioners, consultants, educators, and representatives from associated industries were in attendance at the Workshop. Figure 1 shows the organisers of the workshop, which include several students at NIT-T. The resulting proceeding is entitled "Indo-US Forensic Practices: Investigation Techniques and Technology" and is published by ASCE (Reston, VA: ASCE, 978-0-7844-1149-0, 2010, 159 pages).

Figure 1 ASCE Delegates with NITT Students during INDUSFEW (see online version for colours)

The international nature of the workshop encouraged a strong fusion of engineering practices, as well as, industrial and consultancy concerns from India and the USA. The sharing of case studies, technologies, and techniques helped our understanding of the practice differences and generated synergies in the understanding of forensic science and practice.

3 Fundamental differences between US and Indian forensic practices

3.1 US practices

Forensic engineering practices in the USA rely on professional licensure, education, and real life experiences of the engineer. A thorough understanding of engineering mechanics and principles is an absolute must. In addition to the general knowledge requirements, a forensic engineer must also have the ability to understand historic building codes, the evolution of construction and design practices, job-site inspection procedures and requirements (i.e. quality control), and legal processes and nomenclature; just to name a few (Ratay, 2007; Carper, 1989). Since engineering failure can result due to negligence; individual forensic engineers should be trained to recognise failure as a deviation from the “standard of care” (Kardon, 2005).

Due to the legalistic nature of forensic engineering practices in USA, engineers are forced to familiarise themselves with legal nomenclatures and practices, including court of law proceedings (Kardon, 2012). Most forensic engineers have experience with the deposition process via attorney interactions. However, expert witness experiences and presentations in trial settings are far less frequent. This is because arbitration is often the preferred method for resolving disputes involving partial or complete structural malfunction; cases that cannot be resolved through arbitration result in civil judicial proceedings. In the USA, the judiciary acts as the final authority in matters, both civil and criminal, including those involving partial or complete structural failure. Civil proceedings, arbitration and judicial, focus on distributing and assigning blame to the parties involved (i.e. engineers, contractors, owners, etc.) and disseminating financial responsibility accordingly.

Structural failure cases are not limited to civil lawsuit. Engineers and contractors found guilty of negligence may be prosecuted under criminal law and subject to revocation of professional license (PE), prison sentencing, or monetary fines payable to relevant government agencies, in addition to, civil liabilities. The legal system in the USA provides accountability in criminal and civil cases to promote best practices among design engineers. The revocation of professional licensure, as well as, civil and criminal accountability cases is well documented (Monheimer, 1956; Pfatteicher, 2000). Professional engineers carry liability insurance to provide financial reward to victims in failure cases for which they bear complete or partial responsibility (Lunch 1983). However, the litigious nature of the legal system in the USA has garnered the attention of engineers working in the fields of design and forensics. Concerns are based on incidences in which insurance liability providers have insisted that engineers accept settlements, at the potential cost of losing their required insurance, for failures of which they bear no responsibility (White, 1959; Horne, 1989). This has raised concern among consulting engineers regarding the potential for lawsuits on projects they have analysed and diagnosed, but for which they are not providing design services out of ethical consideration for appearing to have conflicting interests (Strand and Golden, 1997). In the US legal system, any material produced or used (i.e. personal notes, pictures, reports, etc) throughout a failure investigation may be deemed ‘evidence’ once judicial involvement is pursued. Therefore, it is essential that a failure investigation in the USA be treated as a forensic investigation from the start.

Most failure and forensic investigations in the USA involve private individuals and companies. The private practice of forensic engineering is well established in the USA and many forensic companies specialise in failure investigation and legal representation. However, the federal government does establish investigation committees for high profile cases, such as the 11 September 2001 collapse of the World Trade Center in New York City, for the purpose of gaining mechanical knowledge and gaining broad dissemination of investigatory findings (NIST, 2005).

Forensic engineering has not yet been established as part of the educational curriculum in the USA (Bosela, 1993; Rendon-Herrero, 1993; Pietroforte, 1998; Rens et al., 2000; Delatte and Rens, 2002; Chen et al., 2008). Most college-educated engineers do not have knowledge of basic legal procedures and expert qualifications when they move into the workforce. Many forensic works are performed by individual practitioners who may not have the legal background to participate in dispute resolution or to testify in court (Ratay, 2007).

To enhance forensic practices, professional associations such as the Technical Council on Forensic Engineering (TCFE), founded within the American Society of Civil Engineers (ASCE), and the National Academy of Forensic Engineers (NAFE) were established to facilitate networking and the coordination of forensic engineering practices. For example, TCFE produced guidelines on the practices and procedures of failure investigations (Janney, 1979; Lewis, 2003; Kardon, 2012), while at the same time conducting conferences, such as the Forensic Engineering Congresses, with the purpose of promoting information dissemination on engineering deficiencies. NAFE is focused on establishing the standard of practice within the professional environment to allow forensic professionals to share and communicate experiences (NAFE, 2008).

3.2 Indian practices

Documentation of forensic engineering practices in India is rare, although investigations of complete and partial structural failures have been taking place for many years. The investigation process mirrors that used in the USA through similar applications of scientific methods. The most established book on the subject of failure investigation is “Learning from Failure” by R.N. Raikar (1987), which includes several case studies.

The current state of the Indian judiciary has a significant role in dispute resolution involving forensic engineering investigations. In most cases, when structural failures are reported, the investigation is initiated by the local body, state government, or central government with the formation of an investigation committee (Raikar, 1994). The investigation committee’s role is typically limited to technical fault-finding with the final judgment to be made by the court of law or the judicial branch.

The existence of forensic engineering relies on the enforcement of judicial outcomes. By definition, forensic engineering requires legal involvement in failure investigations. Therefore, without judicial ramification, i.e. enforcement of judicial rulings, failure investigations cannot become forensic (Natarajan, 2007). The Indian judiciary and law enforcement officials have a demonstrated record of detaining and blacklisting engineers and contractors found to be at fault or negligent in performing their duties. For example, in January 2010, three Chinese officials were detained in connection with the construction collapse of a chimney near Korba that killed 45 workers following a failure investigation completed at the National Institute of Technology (NIT) Raipur (Kaiser, 2010).

More recently, in September 2010, P&R Infra-projects was prevented from completing additional Indian public works projects following the well documented collapse of a footbridge being constructed for the 2010 Commonwealth Games (Magnay, 2010). However, a thorough discussion of the state of forensic engineering in India must include a discussion on the current state of the Indian judiciary as well as the apparent abundance of corruption (Wade, 2007). These topics are inextricably linked. In India, similar to the USA, arbitration is the preferred method for dispute resolution. The 1996 Arbitration and Conciliation Act is established with the intent to enhance legal practices (Kaur, 2010). However, reports that the backlog within the Indian judiciary is in excess of 30 million cases. As recently as 2006, there were approximately 13 judges per 1 million persons in India (Menon, 2008). By comparison, the ratio in Britain and the USA was 51 and 107 per 1 million people, respectively. Other than the inadequacy in judicial capability, the 1996 Act is flawed by systemic statue limitations resulting in ineffective resolutions (Ray and Sabharwal, 2006).

Dispute resolution, and the lack of legal accountability, is exacerbated through procedural and structural problems within the Indian judiciary. According to a recent report in The Hindu regarding the state of Tamil Nadu, due to lack of procedural law proficiency by judicial officers, lawyers, and police officers, about 30% of the orders by the subordinate judiciary are being set aside by the appeal courts (Special Correspondent, *The Hindu*, 2010). It has been observed that cases involving the government, either as petitioner or respondent, took an average of 15 years to be resolved. Increased funding for judicial infrastructure improvements, including regional judicial academies and court buildings, are currently being addressed by the state government with the goal of reducing government involved cases to 3 years (Special Correspondent, *The Hindu*, 2010.) While these statistics represent the judiciary as a whole, they have a profound effect on resolving disputes involving engineering failures.

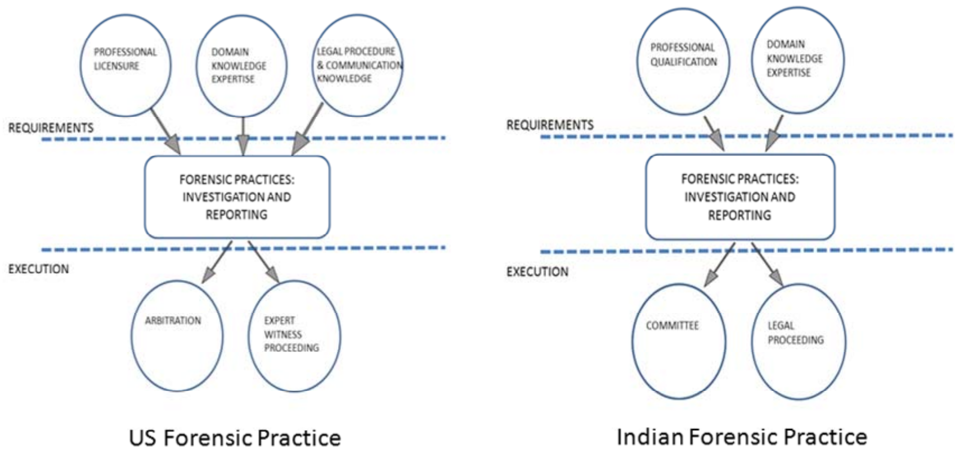
Forensic engineering is the combination of failure investigation, accountability, and legal ramification. The lack of meaningful and timely enforcement of judicial rulings, accompanied by the lack of inspection where civil law requires, can lead to an overall lack of accountability which results in poor construction quality and presents public safety hazards. It should also be noted that the lack of general regulation in engineering and construction practices can lead to significantly different levels of design and construction. Another challenging aspect of Indian construction is the mixing of traditional and conventional construction techniques. Figures 2 and 3 demonstrate mixed construction using a traditional stick frame alongside conventional masonry. Such extreme variations in publicly accessible areas, and on structures meant to serve as commercial and multi-unit living quarters, illustrate the difficulty in validating engineering design and inspection techniques.

Figure 4 summarises the fundamental differences between US and Indian forensic engineering from a practice prospective. As seen, licensure and legal knowledge are the key differences between US and Indian practices. The problems associated with each country are not viewed as a system-level deficiency. However, official approach to ensure forensic expert qualification, such as professional licensure, can be a good way to enhance best practices and prevent legal system loopholes.

Figure 2 Scaffolding constructed of bamboo, tree limbs and rope (see online version for colours)

Figure 3 Scaffolding tied together as shown in Figure 2 (see online version for colours)

Figure 4 Indian and US forensic engineering practice models (see online version for colours)



4 Forensic curriculum development

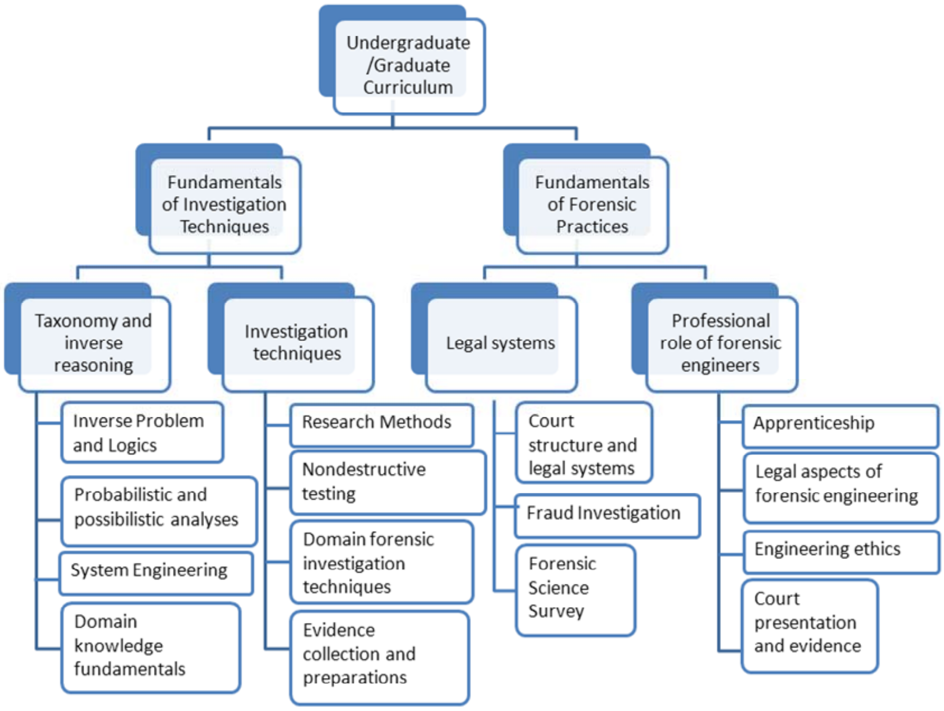
The two outcomes of the workshop were: (1) the introduction of forensic engineering practice to participants, and (2) the establishment of a potential forensic engineering curriculum. The specific objectives of the curriculum are:

- to introduce the concept of forensic engineering practices and failure investigation
- to infuse an appreciation of failure and related professional issues such as ethics and professional responsibility
- to introduce modern investigation tools and techniques.

The curriculum emphasises a clear understanding of system-level failures and new analytical tools to be introduced within a multi-disciplinary framework. The curriculum also suggests incorporating reasoning and inverse problem solutions beyond a simplistic verbal description of experiences in forensic practices. Finally, the curriculum can be completed by offering opportunities for students to conduct real-life research through apprenticeships.

Figure 5 shows the proposed curriculum, which is targeted at both undergraduate and graduate levels. The critical body of knowledge that distinguishes forensic engineering from other engineering disciplines includes fundamentals of investigation techniques and forensic practices. The fundamentals of investigation techniques are further distinguished into two categories: (1) causation taxonomy and inverse reasoning and (2) investigation techniques, which include nondestructive (nonintrusive) testing methods, and traditional domain testing methods. Research methods and evidence collection, and preparation, are aimed at preparing students for the best practices in forensic investigation. Fundamentals of forensic practices should include introduction to legal systems, court presentations, evidence preparation, ethics, and professionalism in forensic engineering.

Figure 5 Proposed forensic engineering curriculum (see online version for colours)



The complete body of knowledge for forensic engineering curriculum can be categorised into *jurisprudence*, *techniques*, and *research*:

1 *Jurisprudence* refers to an understanding of the legal system involving forensic investigations, but also associated practical considerations in juristic issues. For example, the students should learn to recognise potential fallacies in reasoning and reliability issues in evidence collection including credulity in eyewitness testimony (Engelhardt, 1999; Loftus and Palmer, 1974; Yuilie, 1988). An understanding of unethical practices and the legal and societal consequences is essential in forensic engineering education (Peterson, 1988; Roddis, 1993).

2 *Technique* refers to domain knowledge as well as investigation techniques. In Figure 5, "domain knowledge fundamentals" refers to different discipline specific subjects that are required for students to enforce their domain expertise. Domain knowledge falls under taxonomy and inverse reasoning as a sub category, so that instructors are aware that the pedagogical focus should be on the recognition of the mechanics of failures, rather than design and analysis (Van Gigch, 1986). It is essential to recognise that failure analysis is fundamentally an inverse engineering problem and may require more than first order reasoning. Therefore, formal training of forward and inverse reasoning, and logic, is essential to forensic engineers. Hence, courses in logic and inverse problems should be included in the curriculum. System engineering course offers many modern techniques that will help forensic engineers

recognise failure beyond the component level.. Most recent catastrophic failures have been attributed to causes at the system-level, including critical ethics failure, which cannot be revealed through component-level investigations (Bazerman and Tenbrunsel, 2011).

3 *Research* refers to the scientific procedures that establish causality via quantitative and qualitative experimentations. However, the difference between standard scientific research and failure analysis is that statistical validation of forensic causation is rarely available; instead, engineers rely on their training, reasoning skills and unique inter-disciplinary knowledge to establish their expert opinions. This causal-comparative study is characterised by (1) collection of failure observations and (2) establishment of causality based on past experiences (a priori reasoning) (Patten, 1997). Therefore, validation of hypotheses and elimination of false hypotheses are essential.

5 Introduction to forensic engineering course

A course on failure investigation was offered during the spring of 2012 at NIT-T. Over 100 students signed up for the course. The inter-disciplinary course started with five-day condensed lectures on Forensic Engineering and Failure Analysis with a focus on Mechanics-based investigations pertinent to civil structures. Students were asked to conduct simple structural investigations on campus and do project presentations allowing them to experience public deliberation of an investigation (Figure 6). The course is then followed by an assemblage of semester long project-oriented studies by several M. Tech students. The five day lectures include the following:

Day 1: Introduction to forensic engineering and failure analysis: This lecture included brief history of the forensic engineering practices in the USA, definition of engineering failures, basic procedures of failure analysis and education in forensic engineering.

Day 2: Engineering failure and cause finding fundamentals: This lecture included basic logics and reasoning philosophies, failure quantification theories, failure classifications and failure investigation as an inverse problem.

Day 3: Investigation techniques and methodology: This lecture included the practical aspects of failure investigation process such client contact, field investigation planning, eyewitness interview, testing and documentations. This lecture also introduces some basic and advanced investigation techniques, such as damage detection using dynamic characterisation, impact echo, ultrasound, and geophysical exploration.

Day 4: Failure practices and new techniques: This lecture discusses the development of failure hypothesis and reporting of findings; also detailing the preparation of a failure investigation report. New investigation tools such as numerical simulation, LiDAR scan and GIS are also presented.

Day 5: Case studies: Several famous case studies were deliberated to demonstrate the practical aspects of forensic engineering including professional responsibilities of an engineer. Basic damage mechanics theories, such as fracture mechanics, were also introduced with association to the failure cases.

The course content is intentionally designed to allow instructors to modify the outline based on their own expertise. The course content is general enough that even students from other disciplines are encouraged to attend the course. Students taking the five-day course came from varied background including: Civil Engineering, Mechanical Engineering, Physics, Electrical Engineering and Computer Science. This indicated several disciplines are interested in Forensic Science and Engineering. A survey was conducted at the end of the five day lecture with very positive responses from the students.

Figure 6 Students delivered presentation on investigation (see online version for colours)

6 Conclusion

Due to the large number of heritage structures, and the great demands being placed on transportation, housing, and industrial infrastructure, there is a need for forensic engineers throughout India. Expanding the field of forensic engineering to large developing nations, such as India is essential and will ensure better overall engineering practice within the country, and will provide a useful set of case studies from which engineers around the world will have the opportunity to gain an increased understanding of engineering as a whole. The first Indo–US Forensic Engineering Workshop successfully served as a forum for developing the concepts, awareness, and platform for integrating forensic engineering into Indian engineering curriculum.

One of the outcomes of the workshop is the resolution created amongst the participants to create an organisation in India similar to the ASCE Technical Council of Forensic Engineering, which was established nearly 25 years ago in the USA. While the extent and purposes of the council have yet to be defined, there is a profound interest in gathering and disseminating failure information both to the public and for the purpose of improved scientific understanding.

The need to include forensic investigations in the engineering curriculum, and to provide increased accountability in the design, construction, and rehabilitation of Indian structures, was a common theme throughout many of the Indian presentations at the workshop. The idea that "forensic engineering is coming, due to increased accountability" was a common theme among the Indian participants. The proposed forensic curriculum addressed such a need.

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References

Bazerman, M.H. and Tenbrunsel, A.E. (2011) 'Ethical breakdowns', *Harvard Business Review*, pp.59–65.

Bosela, P. (1993) 'Failure of engineered facilities: academia responds to the challenge', *ASCE Journal of Constructed Facilities*, Vol. 7, No. 2, pp.140–14.

Carper, K.L. (1989) *Forensic Engineering*, Elsevier Science, New York, NY.

Carper, K.L. (Ed.) (1986) *Forensic Engineering: Learning from Failures*, ASCE, New York, NY.

Carper, K.L. (1987) 'Failure information: dissemination strategies', *ASCE Journal of Performance of Constructed Facilities*, Vol. 1, No. 1, pp.1–10.

Carper, K.L. (2008) 'Editor's Note', *ASCE Journal of Performance of Constructed Facilities*, Vol. 22, No. 4, pp.193–194.

Carper, K.L. (2011) 'Editor's Note', *ASCE Journal of Performance of Constructed Facilities*, Vol. 25, No. 3, pp.147–148.

Chen, S.E., Janardhanam, R., Natarajan, C. and Schmidt, R. (2010) 'Indo-US Forensic Practices – Investigation Techniques and Technology', *Proceedings of the First Indo-US Forensic Engineering Workshop*, ASCE, Reston, VA, ASCE, ISBN 978-0-7844-1149-0, 159 pp.

Chen, S.E., Young, D., Hutchins, M., Anthony, R., Cohen, J.M. and Mlakar, P. (2008) 'Students' recommendations for the guidelines for failure investigation', *J. Performance of Constructed Facilities*, ASCE, Vol. 22, No. 6, pp.353–355.

Delatte, N.J. and Rens, K.L. (2002) 'Forensic and case studies in civil engineering education: state of the art', *ASCE Journal of Performance of Constructed Facilities*, Vol. 16, No. 3, pp.98–109.

Delatte, N. and Carper, K.L. (2011) 'US and International Developments in Forensic Engineering and Education', *Indo-US Forensic Practices – Investigation Techniques and Technology – Proceedings of the First Indo-US Forensic Engineering Workshop*, 2011, pp.1–9.

Engelhardt, L. (1999) 'The problem with eyewitness testimony', *Stanford Journal of Legal Studies*, Vol. 1, No. 1, pp.25–30.

Horne, R.M. (1989) 'Understanding Terra RRG Professional Liability Insurance', *ASCE Journal of Performance of Constructed Facilities*, Vol. 116, No. 3, pp.239–249.

Janney, J.R. (1979) *Guide to Investigation of Structural Failures – with editorial revisions incorporated*, ASCE, New York, NY, 1979.

Kaiser, E. (2010) '3 Chinese Techies Held for Balco Mishap', *The Hindustan Times*, 11 January 2010.

Kardon, J.B. (2012) *Guidelines for Forensic Engineering Practices*, 2nd ed., ASCE, Reston, VA, ISBN: 9780784412466.

Kardon, J.B. (2005) 'Concept of "Care" in Engineering', *ASCE Journal of Performance of Constructed Facilities*, Vol. 19, No. 3, pp.256–260.

Kaur, H. (2010) '1996 Arbitration and Conciliation Act: A Step Towards Improving Arbitration in India', *Hastings Business Law Journals*, Vol. 6, p.261.

Lewis, G.L. (2003) *Guidelines for Forensic Engineering Practices*, ASCE, Reston.

Loftus, E.F. and Palmer, J.C. (1974) 'Reconstruction of automobile destruction: an example of the interaction between language and memory', *Journal of Verbal Learning and Verbal Behavior*, Vol. 13, pp.585–589.

Lunch, M.F. (1983) 'New Construction Methods and New Roles for Engineers', *Law and Contemporary Problems*, Vol. 46, No. 1, pp.83–94.

Magnay, J. (2010) 'Commonwealth Games 2010: British Parts in Collapsed Bridge Under Scrutiny', *The Telegraph*, 22 September 2010.

Menon, N.R.M. (2008) 'Law and Justice: A Look at the Role and Performance of Indian Judiciary', *Berkeley Seminar Series on law and Democracy*, University of California, September 2008.

Monheimer, M.H. (1956) 'Administrative Law: Professional and Occupational Licensing: Standard of Conduct for Administrative License Revocation', *California Law Review*, Vol. 47, No. 2, pp.403–408.

NAFE (2008) *Forensic Engineering Curriculum - Forensic Engineering Curriculum Committee Summary Report*, National Academy of Forensic Engineers, Hawthorne, NY.

Natarajan, K. (2007) 'Forensic engineering in structural design and construction', *Proceedings, Structural Engineering World Congress*, 2–7 November 2007, Bangalore, India.

NIST (2005) *Final Report on the Collapse of the World Trade Center Towers, Federal Building and Fire Safety Investigation of the World Trade Center Disaster*, National Institute of Standards and Technology, Report # NCSTAR 1.

Patten, M.L. (1997) *Understanding Research Methods- An Overview of the Essentials*, Pyrczak Pub., Los Angeles, CA.

Peterson, J.L. (1988) 'Teaching ethics in a forensic science curriculum', *Journal of Forensic Sciences*, Vol. 33, No. 4, pp.1081–1085.

Pfatteicher, S.K.A. (2000) 'The Hyatt Horror: Failure and Responsibility in American Engineering', *ASCE Journal of Performance of Constructed Facilities*, Vol. 14, No. 2, pp.62–66.

Pietroforte, R. (1998) 'Civil engineering education through case studies of failures', *Journal of Performance of Constructed Facilities*, No. 2, pp.51–55.

Raikar, R.N. (1987) *Learning from Failuires – Deficiencies in Design Construction and Service*, R&D Center Pub.

Raikar, R.N. (1994) *Diagnosis and Treatment of Structures in Distress*, R&D Center, Structwel Designers and Consultants, ISBN 9788190003759.

Ratay, R. (2007) 'Professional Practice of Forensic Structural Engineering', *Structural Engineering International*, May Issue, pp.50–53.

Ratay, R.T. (2007) 'Forensic Structural Engineering-Focus on the United States', *Structural Engineering International*, Vol. 17, No. 2, pp.114–118.

Ray, A. and Sabharwal, D. (2006) 'Indian Arbitration at a Crossroads', *Global Arbitration Review*, Vol. 1, No. 6.

Rendon-Herrero, O. (1993) 'Too Many Failures: What can Educators do?', *ASCE Journal of Constructed Facilities*, Vol. 7, No. 2, pp.133–139.

Rens, K.L., Rendon-Herrero, O. and Clark, M.J. (2000) 'Failure of Constructed Facilities in Civil Engineering Curricula', *ASCE Journal of Performance of Constructed Facilities*, Vol. 14, No. 1, pp.27–37.

Roddis, W.M.K. (1993) 'Structural Failures and Engineering Ethics', *ASCE Journal of Structural Engineering*, Vol. 119, No. 5, pp.1539–1555.

Special Correspondent (2010) 'More Funds for Infrastructure needs of Judiciary Sought', *The Hindu*, 18 December 2010.

Strand, M.N. and Golden, K.C. (1997) 'Consulting Scientist and Engineer Liability: A Survey of Relevant Law', *Science and Engineering Ethics*, Vol. 3, No. 4, pp.357–394.

Van Gigch, J.P. (1986) 'Modeling, metamodeling, and taxonomy of system failures', *IEEE Transactions on Reliability R-35*, No. 2, pp.131–136.

Wade, R. (2007) 'The System of Administrative and Political Corruption: Canal Irrigation in South India', *Journal of Development Studies*, Vol. 18, No. 3, pp.287–328.

White, G.M. (1959) 'Architects' and Engineers' Third Party Negligence Liability – The Fall of the House of Privity', *Western Reserve Legal Review*, No. 563.

Yuilie, J.C. (Ed.) (1988) *Credibility Assessment*, Kluwer Academic Publishers, Boston.