International Research Journal of Education and Technology

Peer Reviewed Journal , E- ISSN 2581-7795

Impact Factor 5.007

A CRITICAL REVIEW ON FORENSIC CIVIL ENGINEERING

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ABSTRACT

When there is a failure or damage seen in the structure, there is a need in investigation which helps in finding the reasons and causes for the failure. Forensic engineering is one of the applications in engineering sciences which gives the report of the failure by doing the forensic investigation. Forensic investigation not only comes into existence when there is a failure in civil engineering construction works. Its presence is seen when there is property damage, personal injury or death and also during the economic losses. In this paper importance of forensic engineering in civil works, some of the reasons which causes for the failure in the structure, process involved during the forensic investigation and some non-destructive tests that can be done as a part of investigation in the damaged structures are discussed.

Keywords: Forensic engineering, investigation, damaged structures, failure.

INTRODUCTION

Forensic engineering is one of the application of art and science of engineering in solving the risk problems by investigating and analyzing the performance of the structure, materials used structural design of the building and many other parameters.

Few researchers' works are Kamaluddin et al In the research, forensic engineering analysis in bridge structures and forensic engineering application in Indonesia were discussed. A study on Mahakam ll Kutai Kartanegara bridge collapse was carried out and found that because of the failure during the construction of vertical hanging cable which connects the main cable collapse was seen. Improper

maintenance, construction materials quality, errors in design process, implementation errors and improper supervision are some of the few causes for the failure which are mentioned [1].Devesha et al the main aim of the writers was to showcase the importance of forensic engineering study by the engineering students so that by investigating the failure there would be lifelong learning progress which would help the engineering's in designing the future projects in an efficient manner. The steps followed during the investigation like preliminary survey of failure; collecting the data of materials, documents, and through interviews; studying all the collected data and identifying the main reason for the failure and preparing the final report are discussed. Several empirical and theoretical methods which can be followed and conducted during the investigation were detailed [2].Shen-En Chen et al The paper recommends and suggests forensic engineering as a tool for communication base for the problem solving and must be included in the curriculum studies. Several arguments and reasons for why forensic engineering must be included in comprehensive curriculum, why it is not a mostly known field not seen the important need to include failure analysis and no demand in market are mentioned. Proposed curriculum along with different types in modes of failure is detailed [3]. Krishnamurthy et al Here the author reviews regarding the importance of forensic engineering and the qualities required becoming forensic engineer. The paper details the various numbers of failures and reasons for those. Briefing regarding the procedure to be followed during analysis, investigation and report submission is done. Reasons and causes for Hyatt Regency Walkway failure and Ronan point collapse along with Hartford Civic Center Arona Roof collapse case studies which were carried out were detailed in this research [4, 6].In this way forensic engineering plays a major role in all the civil engineering construction works when failure or damages are seen. The various types of forensic engineering investigation are fire and explosion, structural forensic, materials engineering, drone analysis and many others. The various incidents where forensic engineer presence is seen are during structural and civil failures, electrical failures, geotechnical investigations, material failures, transportation accidents, environmental disaster investigations. During all these circumstances forensic engineering importance is seen and the investigation done during this process provides the results with proof which helps the engineers in gaining more knowledge and in planning process for the future projects where performance and its efficiency would be high.

Failures:

Failures need not focus on the meaning structure collapses it might be deficiency in structure. Different types of failures occurred during construction, due to improper maintenance which was observed during investigation.

- Safety failure: during this type of failure injury, risk or death to the people might occurwhen there is collapse in formwork during concrete placement, slip, flat slab collapse, and falling on wet floor.
- Functional failure
- Ancillary failure

These failures are seen due to

- Carelessness and negligence
- Errors and mistakes during construction
- Insufficient knowledge
- Design errors and errors in structural analysis
- Mistakes in preparation and planning of work
- Errors in drawings and specifications [5]

FORENSIC INVESTIGATION

The forensic engineers who does the investigation must have formal education, experience, must be technically competent, be a detective, have good communication skills, must be ethical. During the investigation process forensic kit must be carried by engineers which contains lens, graphs, paper, pencil, pen, warning signs, camera, sample containers, safety helmets, gloves, shoes, flash light, measuring tap, data collection forms, calculators and other required items depending on the complexity of damage.

During the investigation process forensic engineering has to follow few steps:

a. Defining the failure
b. Collecting the evidences like materials, videos, photos, by interviews and through documentary
c. Analyzing the evidence
d. Finding out the root causes for the failure
e. Validating by model testing, research, through structural analysis, IS codes

f. Obtaining the conclusion regarding the root causes that resulted in the damage

g. Preparing the final report which includes all the details with the proof.[2].

The process followed during forensic investigation is shown graphically in Fig.1

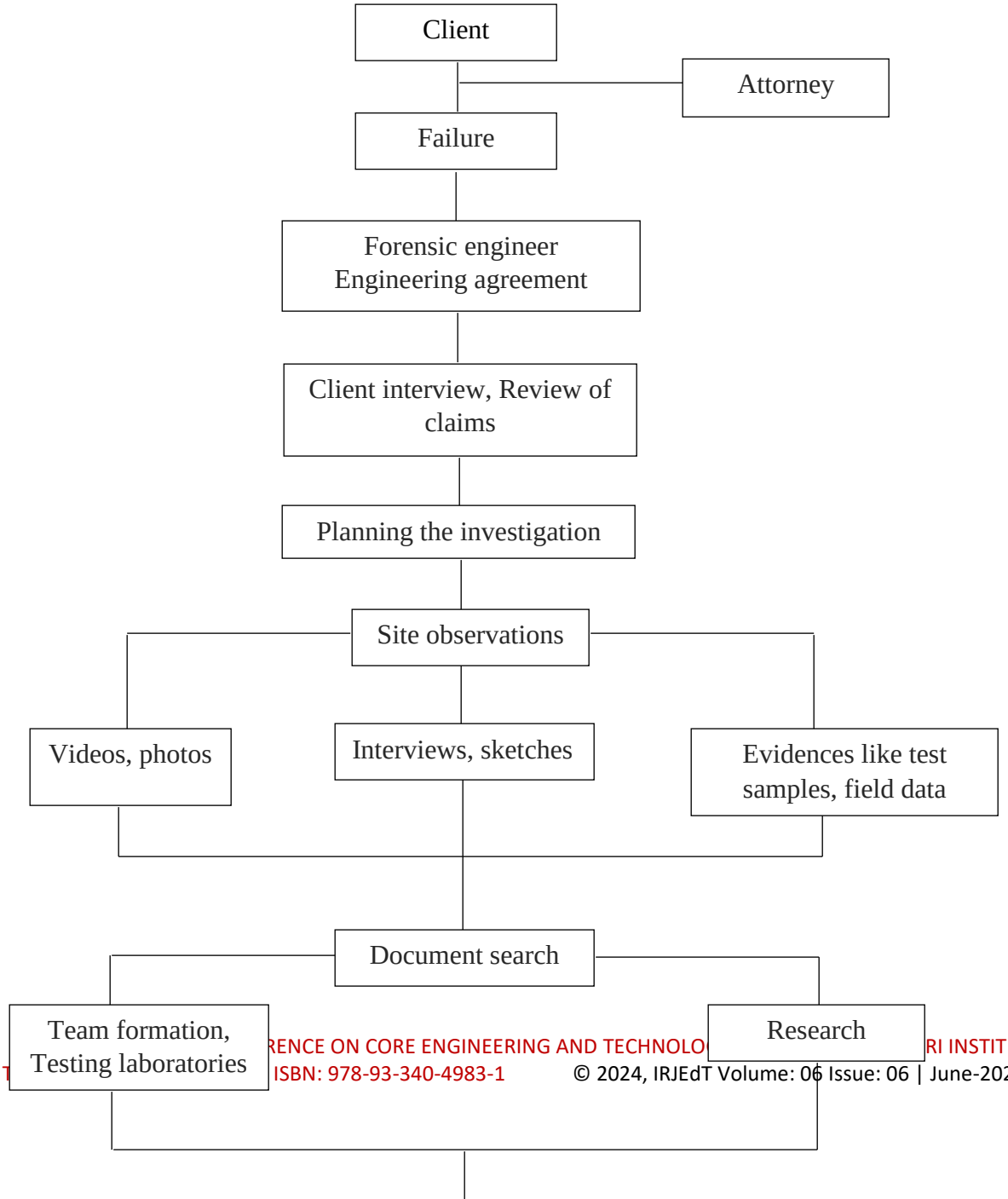

Fig.1 Process followed during the forensic investigation [5]

The framework stages of forensic includes

- Preliminary stage; where the required information related to the damaged building is collected and the review of documents is carried out.
- Evidence collection stage; where site visits, visual inspection, eye witness information, and sample collection process is carried.
- Failure hypothesis and analysis stage; where testing methods, interviews are done.
- Conclusion stage. [5]

TESTS PERFORMED DURING THE INVESTIGATION PROCESS

During the forensic engineering investigation to determine the strength and durability of hardened concrete several tests are performed [7-18]. It's highly needed to evaluate the entire structure or construction. Role of Non-destructive testing in evaluation of failure starting from cracks to heavy damages is predominant.

- Non-destructive testing methods like Surface hardness test, Rebound test, Ultrasonic pulse velocity method, Ultrasonic pulse echo method, Dynamic tests, Radioactive, Magnetic, nuclear, electrical methods andresonant frequency method.
- Semi-destructive testing methods like Penetration techniques, Pull out and pull off tests, Chloride content test, Carbonation and pH value test.

1. Rebound hammer test (Fig.2) many researchers prefer Rebound hammer test due to its simple handling and unique features [19-21]. It comprises of a helix control hammer that slides on a plunger within a tabular housing. When the plunger is hard-pressed against the concrete surface,

the mass rebound from the plunger. If the average rebound number is >40 the quality of concrete is said to be very good hard surface, if the rebound number is <20 then the surface is poor concrete.

Fig.2 Rebound hammer apparatus and the graph showing compressive strength for the rebound number [2].

2. Ultrasonic pulse velocity method (UPV) (Fig.3) It consists of measuring the time of travel of an ultrasonic pulse passing through the concrete to be tested. Pulse velocity of concrete can be measured in three techniques namely; direct transmission, indirect transmission, surface transmission. Many researchers prefer UPV due to its technical benefits and they have used this various civil engineering applications [22,23]

Fig.3 Ultrasonic pulse velocity measuring instrument and different techniques of pulse transmission .

3. Carbonation test (Fig.4)This test is performed using phenolphthalein indicator. The test is conducted by drilling a hole on the surface of concrete to different depths and the indicator is sprayed. The change in color is observed. Carbonated concrete exhibits no change in the color and the surface which is not carbonated exhibits pink color. The depth of carbonation is calculated based on the change in color profile.

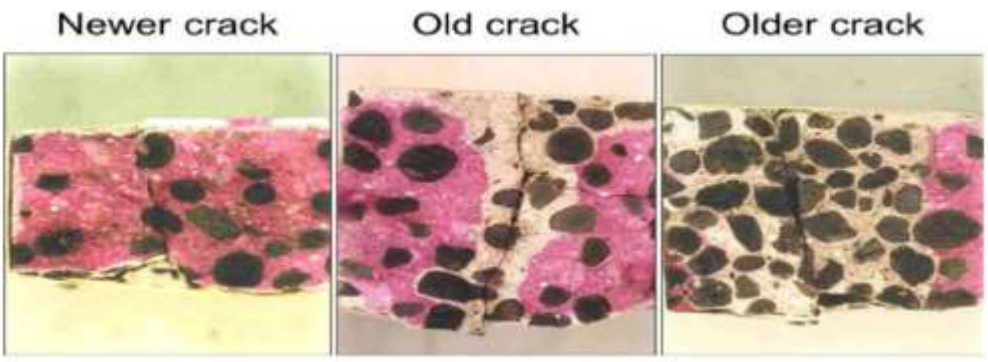

Fig.4 Carbonation test performed on the concrete surface [24].

SUMMARY

Forensic investigation in civil engineering pays way to detail investigation of damages in all fields using advance equipments [25, 26]. Awareness on structural health monitoring should be done. Periodic monitoring may protect the buildings from heavy damages and modern technology such as internet of things is employed in structural health monitoring [27]. Condition assessment of structures plays a vital role is damage assessment, the investigation on entire structure, part of structure example parts of bridge, building and components are the important factor should be considered during investigation [28-30]. Forensic investigation gives better idea about defect, damage, causes and solution for different failures of structures. The process of forensic engineering for investigation of various damages caused by fire, cracks, etc has been performed by many researchers [31-40].

CONCLUSION

In recent days forensic engineering is gaining recognition as a field of professional engineering practice in many parts of the world. The forensic engineering study must be included in the engineering curriculum so that the engineers will get in touch with the investigation of damage structures and understands the importance of forensic investigation. Forensic engineering investigation helps a lot in the civil structure failure works to find out the main reasons and causes for the damaged occurred. Low quality construction materials, improper maintenance, errors in design and its detailing, poor communication management, lack of team work are some of the few causes observed for the failure of any structure. In view of all this, forensic investigation helps in improving the efficiency and performance of the structure.

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