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Subsurface Mapping – The First Step in Site Preconstruction Planning For Preservation of Cultural Material and Project Risk Reduction

John Shearman[1], Ayman Hamed[2], andAli Abbass[2]
[1] Associate Director – American Research Center in Egypt (ARCE)
[2] Faculty of Petroleum and Mining Engineering, Suez University, Egypt

Abstract: *Construction activities close to cultural heritage sites are increasing in Egypt. Urban sprawl coupled with rising groundwater levels have a direct impact on cultural materials. Engineering and construction activity can be detrimental to the integrity of any site, particularly if ancient objects or structures are encountered. Damage to ancient subsurface materials is a potential possibility. On the other hand, contractors may also suffer from archaeological material encounters causing schedule delays or lower production, resulting in cost inefficiencies.*

During the design phase and preconstruction planning of any engineering project, site subsurface analysis must be included. A planning structure of avoidance or salvage can be reached within the framework of cultural preservation and economics on a construction site. Subsurface mapping is a necessary part of the production planning and risk reduction process on sites with cultural material present. Use of geophysical tools is the best method for underground mapping, however; it has never been evaluated as a preservation or economical tool in geoengineering projects. Since the primary author is experienced in geo-construction projects, the Failure Mode and Effect Analysis (FMEA) method is the best method suggested to use for analyzing the effects of archaeological encounters using geophysics to assist in the decision making process associated with design and preconstruction planning with the impact on preservation and economics on a construction site. The process can be used in project planning and highlight any adjustments that have to be made for both the contractor and the archaeologist. Geophysical mapping via several geophysical methods on a project at the KomOmboTemple in Egypt, that is rich in archaeological remains, is used in the formulation of an effective strategy and procedures that can be used in the design and preconstruction phases of other projects in Egypt. This paper will focus on the factors surrounding the subsurface encounters of archaeological remains during construction operations in and around historic sites and how its effects both the contractor's production and potential damage to historic artifacts.

Keywords: Egypt, Construction, Archaeology, Preconstruction, Geophysical, Planning, Risk, FMEA.

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I. Introduction

Construction and Archaeology have long been opposing forces in projects around cultural sites in Egypt. Construction activities focus on production and profit while Archaeology focuses on preservation and damage control of subsurface cultural material. Geophysical surveys are a necessary factor in risk management assessment associated with unexpected encounters of cultural material as well as subsurface geological conditions.

Recently, Egypt is experiencing rapid growth in construction activity and at the same time there is improved focus on preservation of subsurface cultural material encounters associated with excavating activity by the contractor.

The paper reviews both the contractor and the archaeologist issues and suggests a proven method that should be implemented in the preconstruction and planning phase of a construction project in Egypt to bridge both professions for improved production and at the same time improve preservation and damage control of unexpected encounters of subsurface cultural material.

II. Problem Definition

A study by Cohenca (1989), suggests that construction firms must adjust their planning to variable situations. Researchers may find vitally needed data, as well as suggestions for new directions of research, in studying the construction planning process.Laufer and Cohenca (1990),continued his work to state that very low percentages of design completion priorto the start of construction may result in considerable construction delays.As a result, the reduction in the overall project time that would result fromoverlapping design and construction may be significantly shorter than plannedand the financial savings expected from this overlap may in fact turn into aloss.Years later Laufer et al. (1994)added that interpretation of the planning done in mature construction companies, in the form of the four multiplicity principles introduced - hierarchy, comprehensiveness, continuity and cooperation - may be viewed as the beginning of a foundation for a theory of construction planning, which calls for profound changes in commonly practiced approaches and procedures, for the readjustment of research topics and methods and for a broader formal education and training of civil and construction engineers, encompassing multiple areas other than the traditional ones and more fields of knowledge. Kumaraswamy and Chan (1998), during their work in project complexitydeduced that the use of their developedapproach in practice to obtain a reliable measure ofproject complexity depends mainly upon how practitionersunderstand the concept of project complexity. Chan and Kumaraswamy (1997), also approved that, as a general principle, more intensive site investigations and stronger management are probably warranted in projects where delays can be crucial.Akintoye (2000) after his extensive analyses of results collected from 84 firms the author used the factor analysis technique to conclude that variables considered in the study could be grouped into seven factors with the most important being project complexity followed by technological requirements, project information, project team requirement, contract requirement, project duration and finally market requirement.Gidado (2004), mentioned that, it may be true that time and cost may be up at the first instance of implementation, but from then onwards the process would continue to improve performance and ultimately save time and cost. All experiences have shown that an investment in effective planning is always fruitful and recording of achievements offers opportunities for improvement.Assaf and Al-Hejji (2006), recommendation to minimize and control delays in construction, must minimize change orders during construction to avoid delays.

Assuming that instruments and testing procedures are in good condition and available to properly assess subsurface characteristics,Cummings and Kenton (2004) state that the fundamental cause of failures is human failure. In a proper investigation, naturally occurring events are known to exist, are anticipated, and are properly incorporated in the design. Site investigation is were the most serious deficiencies develop. It is important to note that nothing prevents the professional from applying a more rigorous or conservative investigation or design whenever the field conditions warrant. According to Antonakis and Day (2018), most geotechnical failures are not due to lack of knowledge but an inability to apply the available knowledge in practice or simply not recognizing critical design situations. As an example, by Cummings and Kenton (2004), anomalous test results are often discarded without assessing the reason for the anomaly.Zumrawi (2014)states that insufficient geotechnical investigation is currently the first source of projects' delays, disputes, claims and projects' cost overruns. As stated by Rathod et al.(2016), forensic investigation on the failure of piling on some bridges in India shows clear evidence that the failure had happened due to inadequate geotechnical investigation and improper pile installation.

Albatal, et al.(2014) states that several studies published over the past 30 years demonstrated that in civil engineering and building projects, the largest element of financial and technical risk usually lies in the ground. According to Brennan et. al. (2014), if a contractor encounters unknown, unanticipated, or concealed physical site conditions, the contractor will want reimbursement for its increased construction costs and/or time in dealing with such conditions. Reimbursement is subject to the project contract. When reimbursement is part of the contract language, the contractor can obtain additional project costs. As recorded by the National Audit Office (1990) in the U.K., there were eight roads where geotechnical problems resulted in extra work at a cost of £14 million.

In 2007 the author himself experienced during one of his projects in Afghanistan that no soil analysis was performed by the construction management firm for a four-story building. Soil compaction requirements were not matched with the existing soil properties causing delays in reaching specified compaction targets and massive foundations were designed on a worst case scenario causing more time and cost.

III. Objective and Methodology to Solve the Problem

The objective of the study is to review the preliminary interview data on the extent of geophysical surveys associated with unexpected encounters with subsurface archaeological remainson construction projects and determine the potential and actual impacts to construction activities. The initial focus will be on a construction project in Egypt that took place around the historic temple at KomOmbo that was completed in 2019. Observations from the project will focus on solving the problems associated with encountering archaeological remainsin the Preconstruction Phase of a project.

IV. Results and Discussion

According to Sadarangani (2019), the first step of the archaeological study was to generate a Desk Based Assessment of the history of the site and included the potential for archaeological remains. The study was conducted in parallel with the engineering design so that the design could integrate measures to minimize impacts to the historic environment (for example, routing trenches to avoid known or likely significant archaeological remains).

A Historic Environment Record[3] for the local area was created as part of the assessment so that the potential for archaeological remains (also known as heritage assets) could be assessed through comprehensive research of archaeological, documentary, and cartographic sources. This was complemented with local resident interviews, site observations, geophysical surveying and monitoring, and recording and interpretation of geotechnical investigations (boreholes and test pits). All these activities were carried out in 2014 and 2015.

The report by Sadarangani et al. (2015) shows extensive geophysical studies that were performed on the site but were not assessed in an archaeological context. In 2010 the National Research Institute of Astronomy and Geophysics (NRIAG) used

Geo-Radar Field Measurements, Geo-Electric Field Measurements and Shallow Seismic Refraction Field Measurements around the site. In 2015, DC-Resistivity Sounding and multi-frequency, very low frequency-electromagnetic measurements were used as part of a multiple geophysical survey that included boreholes and test pits. The depth of the archaeological horizons were also recorded along with assessments on risk and a framework for mitigation strategies. It was clear from the data that multiple archaeological anomalies were present on the site and would be impacted by the construction work.

During the construction, the site encountered substantial and historically significant archaeological material that caused delays and work stoppages to the contractor including several incidences that necessitated the contract-specified official processes that handle substantial delays. This caused constant disputes between the archaeologist and contractor.

Sadarangani (2019), suggested several ideas on how to generally improve the coordination between the archaeologist and the contractor. These include:

- Early engagement and planning with the contractor
- Improved communication and cooperation with the Egyptian Ministry of Antiquities especially with permissions allowing key personnel on site.
- Lectures, discussions and feedback with the contractor prior to construction activities for better understanding of the archaeology work and the value of archaeological remains. This will also allow for revisions of plans.

These factors make it clear that a process is badly needed and has to be agreed upon by all parties. In order to reduce the problems, the financing entity and stakeholders must prioritize and insist on implementation of a process that focuses on these issues. A subjective process that is simple to implement is the Failure Mode and Effect Analysis (FMEA) method. FMEA is used in manufacturing to subjectively review the risk of potential failures. With multiple participants, it addresses the early engagement factor by the main stakeholders.

[3] A Historic Environment Record locates and provides information on all known heritage assets, including archaeological sites, historic sites and buildings, and historic and paleoenvironmental sites within a given area. Sadarangani (2019).

According Carlson (2012), FMEA is a method designed to:

- Identify and fully understand potential failure modes and their causes, and the effects of failure on the system or end users, for a given product or process.
- Assess the risk associated with the identified failure modes, effects, and causes, and prioritize issues for corrective action.
- Identify and carry out corrective actions to address the most serious concerns.

A FMEA is an engineering analysis done by a cross-functional team of subject matter experts that thoroughly analyzes product designs or manufacturing processes early in the product development process. Its objective is finding and correcting weaknesses before the product gets into the hands of the customer. A FMEA should be the guide to the development of a complete set of actions that will reduce risk associated with the system, subsystem, and component or manufacturing/assembly process to an acceptable level.

To modify it to fit the engineering-construction process, a multi-diversified composite of project participants and consultants is necessary. Property Owner Representative, Financier, Engineers, Construction Personnel, Archaeologists, Geologists, Government Officials, specialists and other stakeholders for a specific site would meet and assess potential problems utilizing a FMEA procedure including contractor encounters with archaeological remains. The use of the subsurface map is a crucial piece of information required for the assessment of potential encounters during construction. The data from the completed subsurface map created with the use of the appropriate geophysical assessments, is employed as a guide on what action to take dependent on the opinions of the specialists in conjunction with the FMEA factors on the spreadsheet (Example shown in Figure 1). Risk assessment can be improved, and decisions and plans can be better obtained with superior data and a multi-disciplined team. A FMEA is an agreement on what action to take. As an example, determinations and plans can be made to salvage an artifact prior to general construction activities to avoid contractor delays or damage to the archaeological remains utilizing the FMEA method.

Table No. 1 – Example of a FMEA analysis spreadsheet with action plan

FAILURE MODE AND EFFECTS ANALYSIS

Process:
Product:
Core Team:

Responsibility:
Prepared by:

Page:
Number:
Created:
Modified:

Process Function	Potential Failure Mode	Potential Failure Effect	Severity Rating	Potential Failure Cause	Occurance Rating	Preventive Action	Detection Action	Detection Rating	RPN	Recommended Actions	Responsible & Deadline	Actions Taken
The planned constuction process (example: trenching)	In what ways can the process go wrong?	What is the impact on the owner if the failure mode is not prevented or corrected?	How severe is the effect on the customer?	What causes the step to go wrong (i.e., how could the failure mode occur)?	How frequently is the cause likely to occur?	What are the existing controls that prevent the failure mode from occuring?	What are the existing controls that detect the potential failure mode?	How probable is detection of the failure mode or its cause?	Risk Priority Number calculated	What are the actions for reducing the occurrence of the cause or for improving its detection? Provide actions on all high RPN's and on severity ratings of 9 or 10	Lead individual responsible and the date for assuring corrective measures	What were the actual actions taken?

SEVERITY: Severity of impact of failure event. It is scored on a scale of 1 to 10. A high score is assigned to high impact events while a low score is assigned to low impact events.

OCCURRENCE: Frequency of occurrence of failure event. It is scored on a scale of 1 to 10. A high score is assigned to frequently occuring events while events with low occurrence are assigned a low score.

DETECTION: Ability of process control to detect the occurrence of failure events. It is scored on a scale of 1 to 10. A failure event that can be easily detected by the process control is assigned a low score while a high score is assigned to a not easily seen or not immediately obvious event.

RISK PRIORITY NUMBER: The overall risk score of an event. It is calculated by multiplying the scores for severity, occurrence and detection. An event with a high RPN demands immediate attention while events with lower RPN's are less risky.

Egypt is known for its antiquities and much of it remains buried. It is clear that unexpected encounters during construction projects on historic sites can lead to archaeological remains delaying contractor production and possibly causing damage to the artifact. Subsurface mapping utilizing correct geophysical instruments is one of the essential planning tools that should be used for proactive actions in preconstruction activities on historic sites. This coupled with a simple process like FMEA where multiple experts assess information and risks that are identified and can be dealt with in the preconstruction phase rather than reacting during archaeological remain encounters. It is highly probable that preconstruction salvage costs of much of the archaeological remains is a more efficient way of reducing overall construction costs and disputes. FMEA is a proven way to formulate a plan for decision making and implementation of any preconstruction action based upon the severity and occurrence of archaeological remain encounters. Subsurface mapping and testing utilizing the most effective geophysical testing instruments for the specific site is the necessary and superior method for preconstruction decision making and subsequent activities that could reduce damage to archaeological remains and reduce contractor delays from unexpected archaeological encounters.

V. Summary

This case shows that the correct use of geophysical surveys will reveal archaeological anomalies prior to project subsurface excavations. The case also shows the division between the archaeologist and the contractor when performing their professional duties. Ultimately, the contractors saw any archaeological mitigation as an unnecessary hindrance to their workand failed to adjust their plans or use the available knowledge in reference to the subsurface obstacles. The archaeologist also may not understand that the value of the archaeological remains is subjective and may not totally recognize the contractors need for production.

It is clear that a procedure to reduce contractor delays and work stoppage with emphasis on archaeological preservation is needed.

VI. Conclusion and Recommendations

Literatureand site investigations shows a strong connection between geophysical testing and the impact on contractor production. The geophysical studies have the ability to reveal archaeological remains as well as profile strata, geological formations and other attributes of subsurface data that is valuable information for the contractor.In regards to archaeology, geophysical testing has several advantages in preserving archaeological remains from damage and/or destruction by providing essential information so decisions can be made prior to encountering during construction activities. Salvage archaeology or excavating anomalies prior to construction implementation can eliminate or reduce project construction delays and contractor claims. Utilizing a proven, uncomplicated, systematic preconstruction planning method such as FMEA can bridge the gap between construction, archaeology and other stakeholders.

DECLARATION OF INTEREST: NONE

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