Design and Construction Planning in High Groundwater Environments

(Technical Research Project in Civil Engineering)

Managing Risk in Structural Engineering

(Sociotechnical Research Project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Introduction

Structures play a crucial role in everyday life, and that is never clearer than when they fail. The Surfside Condominium in Florida, which claimed 98 lives when it collapsed in June 2021, served as another cautionary tale of the potential consequences and stakes of structural failures (Wolfe, 2024, para. 1). Fundamentally, a building serves as the barrier between two worlds: one in which people are vulnerable to their environments and another in which people feel safe and comfortable. Like many others throughout history, this building failed this fundamental purpose despite the structural engineering practice's critical responsibility to "protect the health, safety, and welfare of the public" (American Society of Civil Engineers, 2020, p. 2). Given the severity of these consequences, the structural engineer is entrusted with the critical responsibility of designing with sound judgment informed by logical risk mitigation methodologies.

The E.A. Fernandez Innovate, Design, and Engineer for America (IDEA) Factory makes no exception. The structure aims to foster a culture of innovation in engineering and science by providing world-class resources for research and education. In embodying such ideals, while also fulfilling its fundamental purpose, the building must remain structurally sound throughout its lifespan, ensuring the safety of its occupants and providing the space and facilities to educate future generations. This prospectus will detail some of the key constraints, objectives, and potential solutions for the design and construction planning of the E.A. Fernandez IDEA Factory, while seeking to explain and evaluate the potential ramifications of current risk assessment and mitigation practices in the industry.

Design and Construction Planning in High-Groundwater Environments

The project's objective is to respond to the University of Maryland's Request for Proposal (RFP) for the design and construction (design-build) of the E.A. Fernandez IDEA Factory located in College Park, Maryland. The 61,000-square-foot building will foster innovation in engineering and science for the University of Maryland by providing world-class facilities for research and educating the future of engineering. This structure will serve "as a signature resource within the Maryland Technology Enterprise Institute [and contribute] to the technology-driven economic development of the region and the nation" (University of Maryland, n.d., "E.A. Fernandez IDEA (Innovate, Design and Engineer for America) Factory"), fulfilling the aim of its namesake, Emilio A. Fernandez, who "realized the impact of education - it was the only asset that no one could take away" (University of Maryland, n.d., "Emilio A. Fernandez '69"). This response will culminate in a written submission of the response to the RFP and a formal presentation where the team will present on several key topics to demonstrate knowledge and qualifications in relevant fields to the unique constraints of the project.

The IDEA Factory will include many sophisticated laboratory facilities such as the Robotics Realization Laboratory, Rotorcraft Laboratory, Quantum Technology Laboratory, Microscope Suite, and ALEx Garage. The performance of the precise equipment used in these spaces may be "influenced by environmental factors," such as variations in "magnetic fields, vibrations, changes in barometric pressure, [etc.]" (Martinez-Tajeda, 2014, p. 2). Many of these adverse effects can be mitigated by constructing laboratory spaces within a basement and through careful consideration in the final design (Martinez-Tajeda, 2014, p. 3). However, one of the key constraints of constructing a basement on this site is the presence of relatively soft soils in a high groundwater environment that has historically led to water intrusion in existing, nearby basements. Given these factors, recommendations will be made for the design of the foundation, support of excavation (SOE), and subsurface drainage systems.

The design of these systems must consider the existing soil conditions, groundwater level, anticipated loading conditions, and the intended use to determine a solution best suited for the project. Potential foundation systems could include spread/strip footings, mat/raft foundations, rammed aggregate piers, driven steel piles, and/or drilled shafts/caissons. Research of potential shoring systems will include soldier piles with lagging, sheet piles, secant piles, struts, and rakers. These systems will be selected based on their capabilities to meet project specifications and their relative strengths and weaknesses considering their disruptiveness to the surrounding campus, schedule efficiency, cost, serviceability, environmental sustainability, labor efficiency, and material availability. Finally, recommendations will be made for the selection of structural materials, primarily considering a cost-benefit and schedule analysis of steel and reinforced concrete construction.

In addition to these general recommendations, preliminary design deliverables will include foundation assembly details (developed in Revit), support of excavation system selection and extent plans (developed in Revit), a construction dewatering plan (developed in Revit), permanent subsurface drainage plans (developed in Revit), a site logistics plan (developed in InfraWorks), a quality assurance/control (QA/QC) plan, and site safety plan. Finally, the team will develop a project schedule (developed in Primavera P6) and cost estimate to determine project viability and propose preliminary design recommendations to the client.

Managing Risk in Structural Engineering

If awarded the design and construction responsibilities for the IDEA Factory, the team will be responsible for assessing and mitigating associated risks, considering economic, scheduling, environmental, and safety concerns. While each of these tasks is significant, complex, and has real implications for stakeholders, the focus of the proposed sociotechnical research will consider risk assessment and mitigation strategies specifically pertaining to structural adequacy. Each of these topics is important and certainly warrants further research; however, structural failure poses the greatest immediate risk to human lives. By analyzing several case studies, examining industry risk assessment and management practices, and evaluating the broader social and societal implications of these methodologies, the proposed sociotechnical research seeks to evaluate how existing risk mitigation practices can equitably balance the conflicting interests of various stakeholders and project constraints.

Structural engineering plays a crucial role in shaping human experience, with significant economic and social implications. Each of these world-shaping structures demands substantial communal collaboration of competencies and financial commitments. With such considerable investment, a design, along with its implications, is cemented into place for long structural lifespans. A key historical example of these persistent implications is Robert Moses' restrictive design of bridges in New York from the 1920s to the 1970s (Winner, 1980). Decisions made during the design restricted access across social groups who relied on mass transit, perpetuating a "systematic social inequality" (Winner, 1980, p. 127). While the intentions may differ, decisions on structural risk mitigation are similarly inscribed into a design that continues to influence society over long structural lifespans.

As such, every design decision is a "social [choice] of profound significance" (Winner, 1980, p. 127). Interpretive flexibility, the idea that these decisions constituting the design process could result in any number of outcomes, necessitates the negotiation of risk tolerances amongst all stakeholders to equitably design a solution that appropriately distributes risk consequences

(Klein & Kleinman, 2002). As the engineer responsible for the closure and stabilization of the design, it is also their responsibility to ensure they understand and address concerns across all the relevant social groups, especially those who are not typically included in the design process.

There is significant guidance on maximum risk tolerances, such as codified standards based on technological limitations produced from organizations such as the American Concrete Institute (ACI), the American Institute for Steel Construction (AISC), and the American Association of State Highway and Transportation Officials (AASHTO). Throughout history, the engineering understanding has developed, often following tragic failures from the past. To better understand these interactions, Latour's (1992) actor-network theory, a methodology that recognizes that technology is an actor whose competencies are leveraged to play some role within a network of human and non-human actors, can be applied (pp. 157-158). In this scenario, the structure is leveraged to accomplish its original purpose. When it fails, the actors within the network must renegotiate; code writers, engineers, and the failed or nearly failed structure negotiate the existing social paradigm to prevent future catastrophe. It is through these dynamic interactions of past failures that standards of practice evolve, and by which the proposed research aims to discern the evolution of risk tolerances across social networks.

Successful implementation of risk mitigation metrics, like those included in codified design standards, is paramount to the just propagation of risk across varying social groups. They attempt to describe the world objectively, using numbers, models, and equations to help narrow a nearly infinite range of potential solutions. In practice, structural engineers often operate "within a paradigm of tradeoff between safety and expense" and often serve "competing criteria" (Gainsburg, 2007, pp. 483, 496). The most obvious method for making these decisions is to implement some form of modeling technique that attempts to quantify structural mechanics and probabilistic service conditions. However, in Porter's (1995) book, *Trust in Numbers*, he demonstrates that numerical solutions are a medium towards objectivity but not necessarily inherently objective.

The structural engineer must recognize that models are simplified representations or numerical perceptions mediated by socially constructed numerical devices (Verbeek, 2008). In some cases, the probability of failure based on these models may be low enough that the engineer, and therefore society, finds the level of risk acceptable. In a quantitative metric evaluating preventative measures versus the risk of terrorist attacks, Stewart (2021) demonstrates that structural measures to withstand terrorist attacks are unreasonable based on the event's probability and exorbitant costs across every building. While a decision for risk management might be made solely based on these numerical devices, it is more often the case that these metrics will be "simultaneously essential and inadequate" (Gainsburg, 2007, p. 498).

To bridge this gap, engineers employ engineering judgment, described by Gainsburg (2007) as "the integration of theory and practicality" (p. 487). This need for engineering judgment offers "degrees of freedom" that allow the engineer to "tailor unique solutions to unique problems" (Shapiro, 1997, p. 293), but also exposes the practice to both technical subjectivity and an inherent "malleability of risk perception" (Clarke & Short, 1993, p.5). These deficiencies in objectivity could be dangerous as consequences may be disproportionately distributed amongst marginalized groups (Tierney, 1999), but they also provide an opportunity to exercise this freedom to address sociological concerns. Rather than limiting risk analyses to technological studies, engineering judgment can extend towards the justification of the social dimensions that describe how risk actually affects people (Short, 1984). With these considerations, a successful risk mitigation strategy must incorporate numerical approaches, the tailored, experienced knowledge of the engineer, and the relevant social considerations.

The evaluation of risk in this project, and many others in the industry, involves more than technical analysis. It requires considering societal needs, past failures, and future uncertainties. The proposed research will consider these complex factors as they apply to practical case studies and develop key takeaways that can help inform responsible engineering decision-making. The decisions made by engineers today constitute profound implications for the communities that rely on them now and in the future. Understanding the lessons from past failures and balancing practicality with precaution can guide the design and construction of safer, more resilient structures.

Conclusion

In completion of the response to the RFP for the University of Maryland's E.A. Fernandez IDEA Factory, the team aims to tailor designs towards a fit-to-purpose solution that successfully negotiates risk tolerances between stakeholders, employing a reasonable and responsible approach that prioritizes occupancy safety, while addressing the unique project constraints. Informed by the lessons of the past, the moral obligation of engineering, and modern design standards, many risks can be effectively mitigated, but the likelihood of an extenuating circumstance can never be negated completely. With this knowledge and practicing sound engineering judgment, the team can effectively weigh the potential consequences with the likelihood of these events and make difficult, sometimes contradictory decisions that characterize the priorities of safety and financial accessibility while fulfilling the University's goals.

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