Proceedings of the 10th World Congress on Civil, Structural, and Environmental Engineering (CSEE 2025)
Barcelona, Spain - April, 2025
Paper No. ICSECT 162
DOI: 10.11159/icsect25.162

Impact of Errors and Omissions in Concrete Slab Penetrations in Construction Projects

Amani Qasrawi[1], Tulio Sulbaran[2]
[1]The University of Texas at San Antonio
One UTSA Circle, San Antonio,78249, Texas, United States
First.Author@institution.org; Second.Author@institution.org
[2]The University of Texas at San Antonio
One UTSA Circle, San Antonio,78249, Texas, United States

Abstract **-** Concrete slabs are essential elements in various building structures, acting as floors, foundations, and load-bearing components. However, Errors and omissions in slab construction can lead to serious consequences, such as safety risks, project delays, and higher costs. The problem this research paper addresses is the impact on construction sites due to the errors and omissions in concrete slab rough-in of Mechanical, Electrical, and Plumbing (MEP) systems. Thus, this paper aims to quantify the impacts of MEP System errors and omissions in concrete slabs such as incorrect dimension, wrong position, inappropriate securing of elements, and complete omissions of items. The methodology employed in this paper was quantitative descriptive. Because quantitative methodology guided the systematical collection and analysis of numerical data and descriptive methodology allowed the research team to capture a snapshot of the current state of error and omissions. The data collection instrument was an online survey, and the analysis was done through descriptive statistics. The results show that 62.5% of responses reported project delays, 93.8% experienced increased costs, and 15.4% reported a very high or high safety impact. The intellectual merit of this work is that it addresses the knowledge gap on the impact of errors and omissions in MEP rough-ins within concrete slabs

Keywords**:** Errors and omissions, Construction delays, Efficiency, MEP

1. Introduction and Background

Concrete is a commonly used construction material known for its strength, and versatility in shaping [1]. It is essential for building infrastructure and ensuring the structural integrity of various structures. However, the literature highlights several issues that can arise during construction, potentially compromising the project's quality and performance. According to Mosallam and Chen, one in every two falsework collapses was attributed to inadequate lateral bracing [2]. While cracks and other defects may seem insignificant at first, if they go undetected or unaddressed, they can develop into more severe problems that threaten the usability and safety of the structure [3]. Damage to concrete structures can lead to property and personnel losses, as well as the potential for catastrophic emergencies.

Previous studies have addressed various aspects of construction quality and error management, such as general quality control frameworks, factors affecting project delays, and strategies for minimizing construction errors. Minimizing errors and optimizing decision-making processes are crucial to achieving successful project outcomes. However, current practices are prone to errors, and they can be time-consuming and costly [4]. Errors and omissions related to MEP work during the preparation of the concrete slab can lead to significant problems, such as the need to cut into the concrete later, which may compromise the slab's integrity. A thorough understanding of the causes of rework is essential for mitigating its effects. Key contributors to these issues include insufficient supervision, lack of skilled labor, and improper subcontractor selection [5]. For instance, employing unskilled laborers can lead to frequent mistakes in construction tasks, which causes project delays and increased costs. E&O is mainly due to factors such as an unskilled workforce, non-compliance with specification requirements, inadequate supervision, and changes in the project scope [6]. Moreover, Professionals in construction and engineering are increasingly encountering challenges in learning from their mistakes, particularly regarding design errors and inconsistencies. These problems remain significant contributors to failures in building and engineering infrastructure, as well as causing delays and cost overruns in projects [7].

Errors and omissions in this stage often remain undetected until later phases, leading to costly revisions that can slow down progress and increase overall expenses [8]. Redoing tasks that were not done correctly the first time can significantly impact project completion time and lead to additional expenses. In a field survey conducted in Saudi Arabia, 73 causes of construction project delays were analyzed. The study found that common reasons for delays included change orders from owners, payment delays, inadequate planning, and rework due to errors during construction [9]. While most concrete structures have performed well, various issues have been reported. Errors and omissions in concrete slabs can arise from a variety of sources, including improper material selection, faulty design, construction flaws, and inadequate maintenance [10]. Improper quality of materials, incorrect specifications, and errors in the construction process can all contribute to the development of cracks, deterioration, and structural distress [10]. Furthermore, exposure to extreme environmental conditions can accelerate the deterioration of concrete, leading to further damage [10]. According to Baiburin, the primary cause of these critical defects is human error [11]. Different factors, including poor working conditions, lack of knowledge, and miscommunication, can contribute to errors and omissions in concrete members and associated systems. A case study indicates that correcting errors in concrete typically amounts to approximately 2.1% of the construction cost, while rework results in a waste of around 5.18% of the construction time [12].

This study seeks to fill a gap in the literature by focusing specifically on errors and omissions related to MEP rough-ins in concrete slabs. Therefore, the aim of this paper is to quantify the impacts of MEP System errors and omissions in concrete slabs such as incorrect dimension, wrong position, inappropriate securing of elements errors, and complete omissions of items like a-Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves). By developing a focused approach to identifying and measuring these errors, this study seeks to offer actionable insights for practitioners, ultimately enhancing quality assurance and efficiency in construction projects. A survey was conducted to measure the prevalence and severity of these errors and omissions and their impact on the project.

2. Methodology

The methodology employed in this paper was quantitative descriptive. Quantitative methodology was used because it allowed to perform a systematic investigation that involved the collection and analysis of numerical data [13]. Descriptive research was used because it is a foundational approach in quantitative research that systematically describes the characteristics of a population, situation, or phenomenon without manipulating any variables [14]. Quantitative descriptive methodology addresses "what" questions, providing a snapshot of current events or conditions through data collection methods such as surveys, observations, and case studies, but it does not establish cause-and-effect relationships [14].

Surveys are used as helpful scientific research tools to obtain information from primary sources using well-planned questionnaires accomplishing reliable specific information. The development of the online survey was as systematically organized into a five-step process, as outlined by [15] as shown in Figure 1.

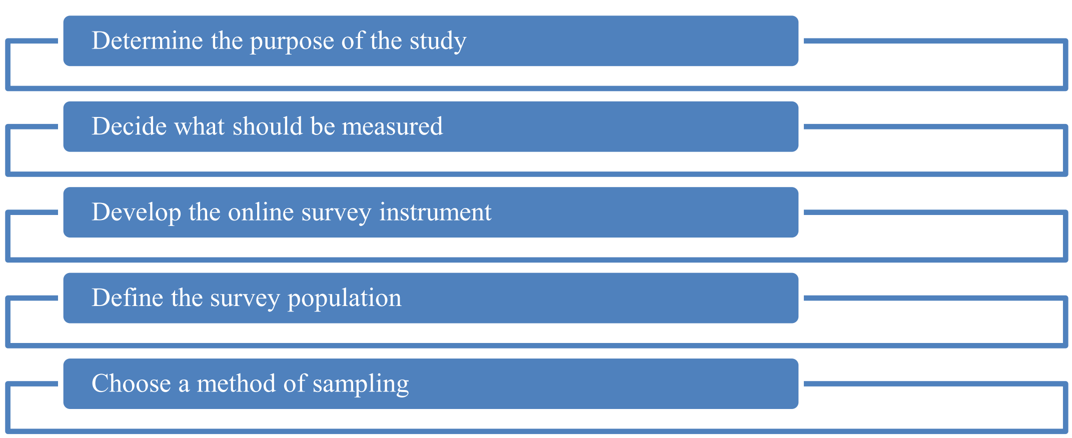

Figure 1. Online Survey Steps

The following is a brief description of each step (in Figure 1):

- *Step 1—Determine the purpose of the study:* It was determined that the purpose was to quantify the impact of errors and omissions of MEP rough-in in concrete slabs.
- *Step 2—Decide what should be measured:* It was decided to measure errors and omissions related to installing MEP systems rough-ins in the concrete slabs. This includes identifying common issues such as incorrect dimensions, wrong position, inappropriate securing of elements, and complete omissions of items. According to the American Concrete Institute (ACI-347), critical components like a- Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves) [16], can impact project costs .
- *Step 3—Develop the Online survey instrument:* An online survey instrument was developed using Qualtrics, with mainly close-ended questions to reduce completion time. The online survey was composed of 21 questions, 16 closed-ended, and 5 open-ended questions. Only 11 of them were discussed in this paper. The 11 questions employed Likert scales and multiple-choice questions, including "other" options, to gather responses. The respondents were assured of confidentiality and anonymity in their feedback. Participation was voluntary, and respondents provided informed consent at the beginning of the survey. This study was approved by the Institutional Review Board (IRB) at the University of Texas at San Antonio (UTSA).
- *Step 4—Define the online survey population:* The online survey population consists of professionals in the construction industry, specifically those installing or overseeing MEP systems in construction projects.
- *Step 5—Choose a method of sampling the population*: the judgmental/purposive non-random sampling method was used. The population sample participants were selected based on specific characteristics that aligned with the study's objectives [17]. Those characteristics included a- Professional in the construction industry, b- knowledge about MEP systems (Familiarity with industry standards, tools, and processes), c- Field experience, d- While the survey itself was conducted online, the approach to potential participants were done in person, and e- The participant has some type of affiliation with the research team university. The first three characteristics were important because it ensure that the participants were qualified to answer the online survey. The last two characteristics were important to increase the likelihood of obtaining responses.

After completing the development of the online survey, the research team attended two Construction Career Fairs at the University and one National Association of Women in Construction meeting and asked industry professionals in attendance if they had knowledge about the topic, had field experience, and if they would be willing to participate in this study. A total of 53 industry professionals indicated that they had knowledge, had field experience, and were willing to complete the online survey. The online survey information was emailed to industry professionals within a week of our conversation. Then, a follow-up e-mail was sent to those professionals who had not responded. A final follow-up was sent in the following week. This resulted in a total of 23 responses from participants, representing a response rate of 43.4 %, which, according to the literature, is a high response. However, not all of them answered all of the questions. So, in the next section, it is indicated the number of responses used in the analysis.

3. Results and Analysis

The online survey data was analyzed using descriptive statistics implemented in Python, to provide insights into the prevalence of errors and omissions in concrete slab rough-ins for MEP systems. These insights will help identify the main factors contributing to these errors and omissions.

3.1. Demographic Information

There were 23 industry professionals who participated in the online survey. Regarding the question "Company Type" there were 23 responses. Those responses in

Figure 2 indicated that 47.8% of the participants were general contractors, 21.7% were sub-contractors/specialty contractors, 13.0% were engineering firms, 13.0% were design firms, and 4.3% were owner/owner representatives. The result indicates a diverse mix of participants from different sectors of the construction industry.

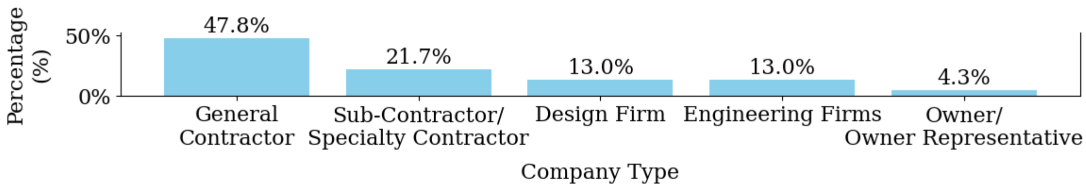

Figure 2. Distribution of Participants' Organization Types

3.2. Consequence/Impact of the error and omission

The participants were asked the question, "How often do errors and omissions of slab formwork have an impact on activities at job sites?". There was a total of 18 responses to this question shown in

Figure 3. The results indicated that 16.7% reported that 1% to 5% of projects were impacted. While, 44.4% reported that 6% to 19% of projects were impacted. Additionally, 27.8% reported that 20% to 39% of projects were impacted. Lastly, 5.6% reported that 40% to 59% of projects were impacted, and 5.6% reported that 60% to 79% of projects were impacted. The fact that no respondents reported 'no impact' shows that errors and omissions in slab formwork consistently affect project activities for all participants.

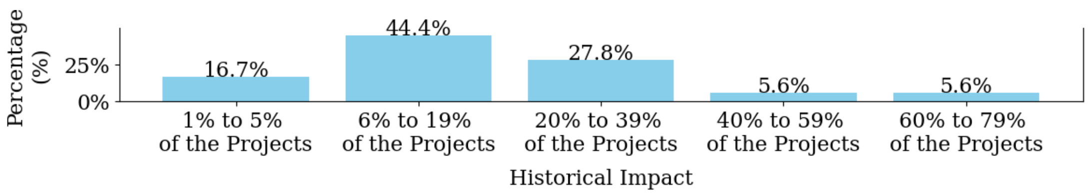

Figure 3. Historical Impact

The following two questions were asked: a - "Do errors in concrete slab penetration locations lead to project delays in your construction projects?" and b - "Do errors in concrete slab penetration locations lead to increased costs in your construction projects?". There was a total of 16 responses to these two questions, illustrated in **Error! Reference source not found.**. The results show that 62.5% responded with" Yes", indicating that errors in penetration locations do lead to delays, while 18.8% responded "No" they do not lead to delays. Additionally, 18.8% of responses are marked as "Unsure." Therefore, it appears that errors in concrete slab penetration locations are more likely to cause project delays in construction projects.

Also, errors in concrete slab penetration locations seem to lead to increased costs in construction projects. 93.8% indicated that errors in penetration locations do lead to increased cost ("Yes" responses), while 6.2% of responses suggest that they do not lead to delays ("No" responses). This indicates that errors and omissions of MEP rough-in in slab formwork have a significant impact on project delays and cost increases (62.5% and 93.8%, respectively).

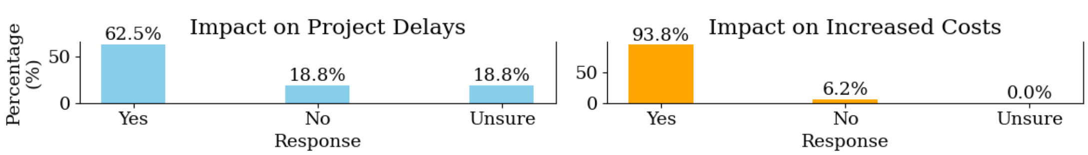

Figure 4. a-Concrete slab penetration errors and project delays (Left), and b-Concrete slab penetration errors and project increase cost (Right)

The next question presented to the participants was: "Prior to placing concrete for the slab, what are the typical project increased costs due to errors and/or omissions of Anchors, Blockouts, Bulkhead, Inserts, Embedded Items, and/or sleeves in concrete slabs?". There was a total of 15 responses to this question, shown in

Figure 55. The results indicated that 53.8% reported that 1% to 4% of projects increased cost due to both errors and omissions. Meanwhile, 23.1% reported that 5% to 8% of projects increased cost due to both errors and omissions. This

suggests that errors and omissions in critical elements like a-Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves) can impact project costs. Notably, none of the respondents reported a zero-cost impact from omission, indicating that omission always increases project cost, and only 7.7% responded with a zero-cost impact from error, indicating that most errors increase project cost.

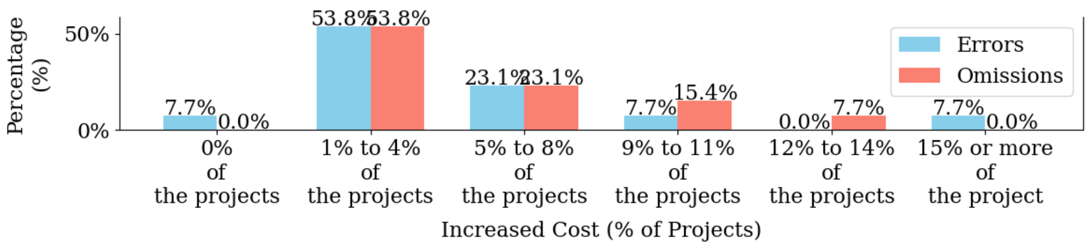

Figure 5. Quantifying Project Cost Increase Due to Errors and Omissions on MEP Rough-in Before Concrete Placement on Slabs

3.3. Cost Impacts of Errors and Omissions in Concrete Slab Elements

Regarding the question, “After placing concrete on the slab, what are the typical project increased costs due to errors and omissions of Anchors, Blockouts, Bulkhead, Inserts, Embedded Items, and/or sleeves in concrete slabs? (Error, Omission)?”. There was a total of 15 responses to this question, illustrated in

Figure 6, The results showed that 69.2% reported a cost increase of 1% to 4% of the projects due to errors, while 61.5% indicated increases due to omissions. Meanwhile, 15.4% reported a cost increase of 9% to 11% due to errors and 7.7% due to omissions. When comparing before and after placing the concrete, errors and omissions tend to cause slightly higher cost impacts. This indicates that errors and omissions become more challenging and expensive to address once the concrete has been placed.

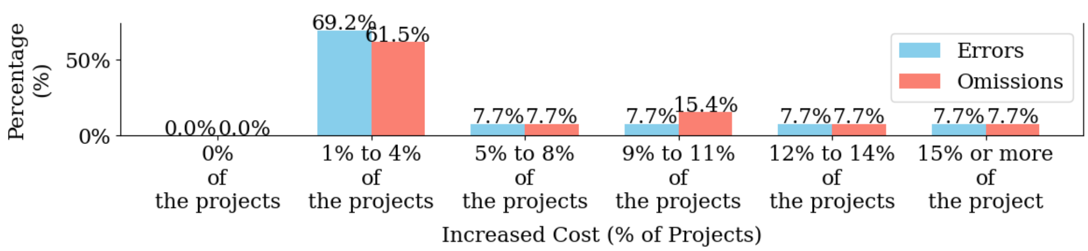

Figure 6. Quantifying Project Cost Increase Due to Errors and Omissions on MEP Rough-ins after Concrete Placement on Slabs

The participants were also asked, “What are the typical project delays due to errors and omissions of Anchors, Blockouts, Bulkhead, Inserts, Embedded Items, and/or sleeves in concrete slabs? (Error, Omission”. A total of 15 responses were received for this question, as shown in

Figure 7. In 60% of responses, a range of 1 to 4 workdays was indicated, highlighting that a significant portion of projects experience delays due to errors and omissions. The observation that longer delays and higher costs are often reported, particularly due to omissions, indicates that these omissions might be more costly and disruptive than errors.

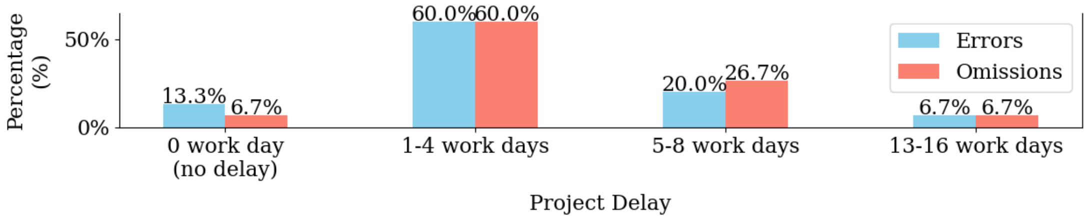

Figure 7. Quantifying Project Delays Due to Errors and Omissions on MEP Rough-in Concrete Slab

The participants were also asked the question, “How do you rate the impact of errors or omissions in concrete slab penetrations on the overall quality of your construction projects?”. There was a total of 15 responses to this question, illustrated in Figure 8. The data shows about 38.5% of such errors or omissions had a moderate quality impact, while a low-quality impact was 30.8%. Additionally, 23.1% of instances had a very low-quality impact, whereas only 7.7% had a high-quality impact. This aligns with the fact that, in construction projects, a lack of quality leads to delays, cost overruns, and unsafe structures [18].

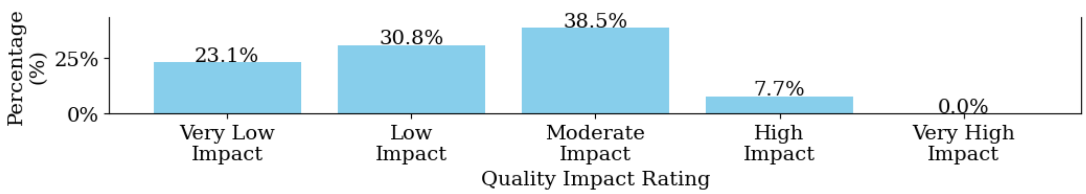

Figure 8. Concrete Slab Penetration Errors and Quality Impact

The participants were asked the question, “How do you rate the impact of errors or omissions in concrete slab penetrations on the overall safety of your construction projects?”. A total of 15 responses were received for this question, which is displayed in Figure 9. The results showed that 38.5% of participants indicated a low safety impact, and 23.1% had a moderate or very low safety impact. While 7.7% had a high or very high safety impact. Reducing errors and rework in construction projects can improve safety, as research shows that rework contributes to safety incidents [19].

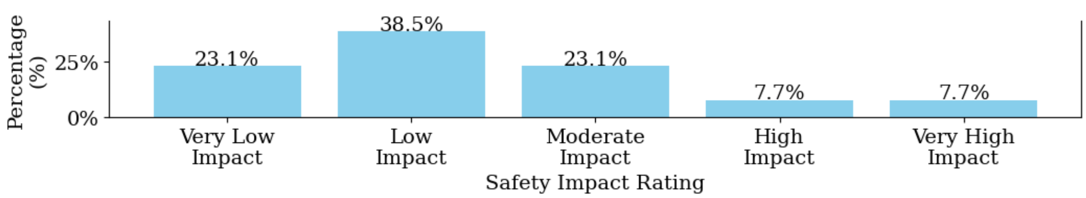

Figure 9. Concrete Slab Penetration Errors and Safety Impact

The following question was introduced to the participants for their input “What are the most common consequences of errors in penetrations?”. A total of 11 responses for this question provided a total of 43 unique consequences as shown in Figure 10, with the most common being . project delay, with 20.9% of responses, followed by increased risk for cracking and water infiltration, with 16.3% for each. These delays and structural concerns suggest that penetration errors are more than minor mistakes; they can significantly impact project timelines, structural integrity, and safety. This reinforces the importance of thorough planning, precise placement, and quality control for penetrations in slab construction.

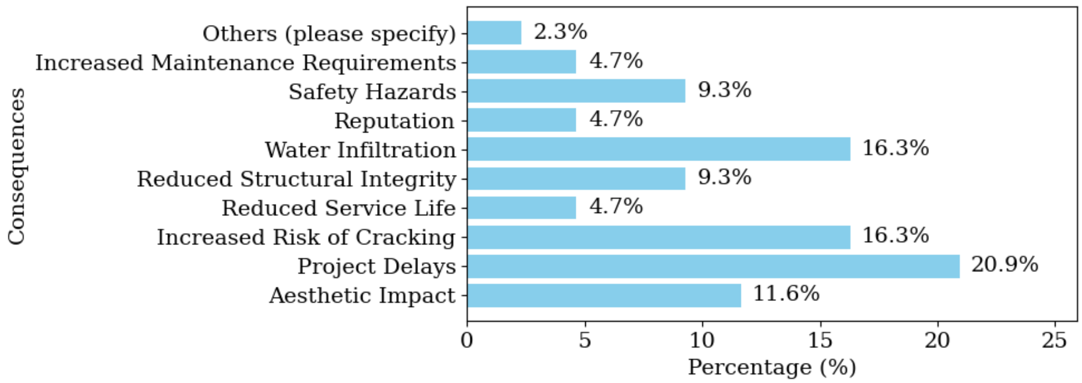

Figure 10. Common Consequences of Errors in Penetrations

They were also asked, "How can errors and omissions of concrete slab penetrations potentially jeopardize safety on construction sites?". A total of 11 responses for this question provided a total of 27 of the potential impacts as shown in Figure 10, with the most common answer being plumbing issues at 37.0%, followed by structural weakness/instability at 29.6%, and trip and fall hazards at 11.1%. These issues can create immediate hazards on the construction site, such as trip and fall risks and blocked exit paths. Additionally, they can lead to long-term risks like deterioration and structural failure. This combination of hazards highlights the critical importance of precision and quality control in the placement and construction of slab penetrations.

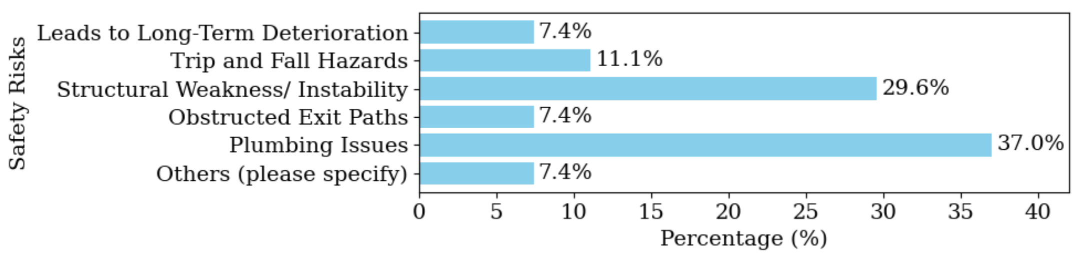

Figure 11. Impact of Concrete Slab Penetration Errors on Construction Site Safety

4. Discussion and Practical Implications

The results from this research have critical implications for construction project management and highlight some of the impacts of errors and omissions in MEP system rough-ins in concrete slabs. With 62.5% and 93.8% of participants reporting that errors and omissions in concrete slab penetrations lead to project delays and increased costs, respectively, it is evident that these errors are prevalent and financially impactful. The consistent reporting of cost impacts, in different ranges due to errors and omissions before and after concrete placement indicates that project budgets are considerably affected by slab-related issues.

Delays due to errors and omissions in concrete slab penetrations have a measurable impact on schedules, with 60% reporting delays of 1 to 4 workdays. This could delay timelines and create bottlenecks, leading to further schedule impacts across different phases of the project. Additionally, errors in slab penetrations can lead to significant consequences, such as project delays, water infiltration, and diminished structural integrity. These errors and omissions not only result in immediate problems but also have long-term effects on the quality and lifespan of a building. This highlights the importance of early intervention and thorough quality control processes. Moreover, the data highlights significant safety impacts linked to errors and omissions in concrete slab penetrations, especially regarding MEP Systems and structural stability. The online survey results highlight that errors and omissions in concrete slab penetrations are common and have significant consequences for project costs, timelines, quality, and safety.

5. Conclusion

The findings of this paper contribute to the construction field by emphasizing the importance of addressing the impact of errors and omissions in concrete slab penetrations, specifically regarding a-Embedded items (anchors or inserts), b- Slab space created with form (block-outs or bulkheads), and c- Trade place tube (Sleeves). The findings reveal that common risks, such as MEP system issues and structural instability, can lead to both immediate and long-term consequences, including trip hazards, water infiltration, and compromised structural integrity. Additionally, the analysis highlights the frequent occurrence of project delays and cost overruns associated with these errors, indicating a substantial opportunity for improvement in construction practices.

To address these challenges, it's crucial to identify ways to enhance the quality control process at job sites. This improvement could be achieved by establishing strategies to enhance personnel skills through training or utilizing advanced technologies. By adopting these strategies, the construction industry can reduce safety risks, manage costs effectively, and improve project timelines. Additionally, establishing standardized guidelines for MEP penetrations and encouraging collaboration among design, engineering, and construction teams can help minimize errors, leading to a more reliable and efficient building process.

While this study provides valuable insights, it's important to acknowledge the limitations that may impact the generalizability and applicability of the results. One key limitation is that the data were collected through surveys, reflecting only the opinions of the participants. To enhance the robustness of future research, alternative data collection methods should be considered, such as examining project accounting to assess cost impacts or analyzing project schedules to identify delays. However, accessing data from companies can be challenging, as such information is often highly protected. Additionally, the sample size was limited to 23 participants, highlighting the need for future studies to include a larger sample for more comprehensive findings. Furthermore, conducting comparative case studies using various inspection tools, along with feedback from field personnel, could help identify best practices and refine inspection processes.

References

[1] Autodesk, "The 5 Most Common Construction Materials," Digital Builder. Accessed: Nov. 07, 2024. [Online]. Available: https://www.autodesk.com/blogs/construction/common-construction-materials/

[2] K. Mosallam and W.-F. Chen, "Design considerations for formwork in multistorey concrete buildings," *Engineering Structures*, vol. 12, no. 3, pp. 163–172, Jul. 1990, doi: 10.1016/0141-0296(90)90003-B.

[3] K. Cui, J. Chang, L. Feo, C. L. Chow, and D. Lau, "Developments and Applications of Carbon Nanotube Reinforced Cement-Based Composites as Functional Building Materials," *Front. Mater.*, vol. 9, p. 861646, Mar. 2022, doi: 10.3389/fmats.2022.861646.

[4] J. Yang, M.-W. Park, P. A. Vela, and M. Golparvar-Fard, "Construction performance monitoring via still images, time-lapse photos, and video streams: Now, tomorrow, and the future," *Advanced Engineering Informatics*, vol. 29, no. 2, pp. 211–224, Apr. 2015, doi: 10.1016/j.aei.2015.01.011.

[5] M. Wasfy, "Severity and impact of rework, a case study of a residential commercial tower project in the Eastern Province-KSA," KING FAHD UNIVERSITY OF PETROLEUM & MINERALS, DHAHRAN, SAUDI ARABIA, 2010.

[6] S. M. Arifullah, D. C. K. Jagarapu, and S. H. Jeelani, "Redoing of work on waste material in building construction projects," *AIP Conference Proceedings*, vol. 2759, no. 1, p. 060010, May 2023, doi: 10.1063/5.0144436.

[7] R. M. Choudhry, H. F. Gabriel, M. K. Khan, and S. Azhar, "Causes of Discrepancies between Design and Construction in the Pakistan Construction Industry," *JCDC*, vol. 22, no. 2, pp. 1–18, 2018, doi: 10.21315/jcdc2017.22.2.1.

[8] C. Eden, T. Williams, F. Ackermann, and S. Howick, "The role of feedback dynamics in disruption and delay on the nature of disruption and delay (D&D) in major projects," *Journal of the Operational Research Society*, vol. 51, no. 3, pp. 291–300, Mar. 2000, doi: 10.1057/palgrave.jors.2600919.

[9] S. A. Assaf and S. Al-Hejji, "Causes of delay in large construction projects," *International Journal of Project Management*, vol. 24, no. 4, pp. 349–357, May 2006, doi: 10.1016/j.ijproman.2005.11.010.

[10] A. A. Shash, "Repair of concrete beams – a case study," *Construction and Building Materials*, vol. 19, no. 1, pp. 75–79, Feb. 2005, doi: 10.1016/j.conbuildmat.2004.04.024.

[11] A. Kh. Baiburin, "Errors, Defects and Safety Control at Construction Stage," *Procedia Engineering*, vol. 206, pp. 807–813, 2017, doi: 10.1016/j.proeng.2017.10.555.

[12] S. Meshksar, “Cost and Time Impacts of Reworks in Building a Reinforced Concrete Structure,” Thesis, Eastern Mediterranean University (EMU), 2012. Accessed: Apr. 16, 2024. [Online]. Available: http://i-rep.emu.edu.tr:8080/xmlui/handle/11129/290
[13] R. B. Johnson and L. Christensen, Educational Research: Quantitative, Qualitative, and Mixed Approaches. SAGE Publications, 2020.
[14] L. Cao, M. F. Shamsudin, and A. A. Hassim, “Understanding the Key Types of Quantitative Research and Their Impact,” Journal of Postgraduate Current Business Research, vol. 9, no. 1, Art. no. 1, Sep. 2024.
[15] C. W. Irwin and E. T. Stafford, “Survey Methods for Educators: Collaborative Survey Development (Part 1 of 3). REL 2016-163,” Regional Educational Laboratory Northeast & Islands, Aug. 2016. Accessed: Jan. 16, 2025. [Online]. Available: https://eric.ed.gov/?id=ED567751
[16] American Concrete Institute, “Guide to Formwork for Concrete: An ACI Standard,” American Concrete Institute, 2004. Accessed: Jan. 08, 2025. [Online]. Available: https://www.concrete.org/store/productdetail.aspx?ItemID=347U14&Format=PROTECTED_PDF&Language=English&Units=US_AND_METRIC
[17] I. Etikan, “Sampling and Sampling Methods,” BBIJ, vol. 5, no. 6, May 2017, doi: 10.15406/bbij.2017.05.00149.
[18] FIDIC, Quality of construction. 2019.
[19] Love, P. E. D., Teo, P., Ackermann, F., Smith, J., Alexander, J., Palaneeswaran, E., & Morrison, J. (2018). Reduce rework, improve safety: an empirical inquiry into the precursors to error in construction. Production Planning & Control, 29(5), 353–366. https://doi-org.libweb.lib.utsa.edu/10.1080/09537287.2018.1424961