



Occupational Safety and Health Risk Analysis in Chemical Anchor Installation: HIRARC Method and Fishbone Diagram

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ABSTRACT

Introduction: The implementation of Occupational Safety and Health (OSH) is an essential aspect of construction activities to prevent accidents and occupational diseases. One of the high-risk tasks in construction is the installation of chemical anchors, which involves concrete drilling, chemical adhesive injection, and rebar placement. These activities present potential hazards such as chemical exposure, noise, and physical injury from equipment use.

Objective: This study aims to identify potential hazards, assess risk levels, analyze the main causes of work accidents, and formulate appropriate risk control strategies in chemical anchor installation.

Method: This research employed a descriptive qualitative approach using Hazard Identification, Risk Assessment, and Risk Control (HIRARC) and Fishbone analysis methods. Data were collected through field observations, interviews, and documentation of work activities.

Result: The results identified seven stages of work activities with 22 potential hazards. Risk assessment showed that 71% of activities were classified as low risk and 29% as moderate risk. Human and procedural factors were the main contributors to risk, primarily due to insufficient training and non-compliance with safety procedures.

Conclusion: This study concludes that the systematic implementation of OSH through technical training, regular supervision, and the application of a hierarchical risk control system is crucial to ensure safe and efficient chemical anchor installation processes.

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INTRODUCTION

The construction industry plays a very important role in national infrastructure development, contributing significantly to economic growth, improved connectivity between regions, and the advancement of community activities. In practice, the construction process requires the application of appropriate technology and work methods so that the results achieved not only meet technical standards but also ensure safety and sustainability. One of the main challenges in construction activities is ensuring the strength of structural connections involving concrete elements, reinforced steel, and other additional components. Under certain conditions, special methods are needed to ensure the strength of the bond between old concrete and new elements to be installed. One effective solution to this challenge is the use of a chemical anchoring system. This method uses chemical adhesives to attach anchors to concrete, providing strong bonding power, quick installation, and greater flexibility compared to conventional mechanical methods. One of the leading manufacturers, Fischer, has developed superior products such as FIS EM

585S and FIS 360 S, which have high adhesive strength, resistance to various concrete conditions, and relatively short curing times (1,2).

The application of this method is highly relevant in large-scale construction projects that require high precision and time efficiency, such as the construction of gas and steam power plants. However, despite its technical advantages, chemical anchor installation also presents a number of occupational safety challenges. Some of these include fast curing times that demand worker precision, environmental conditions such as temperature and humidity that affect bond quality, limited trained labor, exposure to chemicals that are potentially hazardous to health, and mechanical risks due to the use of drilling tools and working at heights (2).

These challenges show that the success of chemical anchor installation depends not only on technical aspects, but also on the effective implementation of Occupational Safety and Health (OSH). The construction sector is one of the sectors with the highest rates of workplace accidents in the world (3), caused by a combination of high-risk environmental factors, the use of heavy equipment, and exposure to chemicals (4,5). Therefore, the application of OSH principles is a crucial aspect in every stage of work. The use of Personal Protective Equipment (PPE) such as gloves, protective goggles, respirator masks, and safety shoes must be mandatory procedures (6).

To manage risk systematically, an analytical approach is needed that can identify potential hazards, assess risk levels, and determine appropriate control measures. The HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method can be used to identify hazards, assess risk levels based on probability and consequence parameters, and formulate controls according to the mitigation hierarchy. Meanwhile, the Fishbone Diagram is used to trace the root causes of potential accidents by grouping the contributing factors into the categories of Man, Machine, Material, Method, Environment, and Management. The integration of these two methods provides a more comprehensive analytical framework that not only identifies hazards but also understands their underlying causes, resulting in more appropriate and sustainable controls.

A number of previous studies have highlighted the effectiveness of chemical anchors in technical aspects. Lahouar et al. (2018) emphasised the importance of adhesive quality on structural support (7), while Giresini et al. (2020) showed that chemical anchors have advantages in load distribution and installation efficiency compared to conventional methods (8). On the other hand, various studies related to occupational safety and health (OSH) in the construction sector show that the consistent implementation of an OSH management system can reduce the rate of workplace accidents by up to 25% through a combination of managerial (9), administrative, and technical approaches (10–12).

However, most existing studies still focus on general managerial aspects such as safety culture and regulatory compliance, while studies that integrate specific technical aspects of the job, such as chemical anchor installation, with OSH risk analysis are still very limited, especially in Indonesia. In fact, this work has complex risk characteristics, including exposure to hazardous chemicals, mechanical vibrations, noise, and ergonomic factors (13–15). Based on these conditions, this study aims to fill this gap by integrating technical and occupational safety analysis in the chemical anchor installation process using the HIRARC and Fishbone methods. This study is expected to make a real contribution to improving safety performance and construction work quality, while also expanding scientific knowledge in the field of Occupational Safety and Health (OSH), particularly in the application of integrated risk analysis methods in chemical anchor technology-based installation activities.

METHOD

This study uses a qualitative descriptive approach supported by quantitative data through the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method and root cause analysis of risks using a fishbone diagram. This approach was chosen because it is able to comprehensively describe the implementation of Occupational Safety and Health (OSH) in the Fischer chemical anchor installation process and identify the main factors causing occupational risks that arise during the process.

The research was conducted in the chemical anchor installation project area, which is part of the concrete structure construction work in the Muara Tawar Gas and Steam Power Plant (PLTGU) project environment. This location was chosen based on the complexity of the work, the intensity of the use of adhesive chemicals, and the high exposure to potential occupational hazards. The research was conducted over a period of three months, starting

from the data collection stage to the final analysis of the observation results.

RESULTS

Fishbone Diagram

Fishbone diagrams are used to analyse various factors that could potentially cause workplace accidents during the chemical anchor installation process. By identifying these factors, preventive measures and solutions can be determined more effectively. In general, fishbone diagrams serve to map the causes of a problem, help uncover the root causes, analyse cause-and-effect relationships, and determine the most appropriate solution.

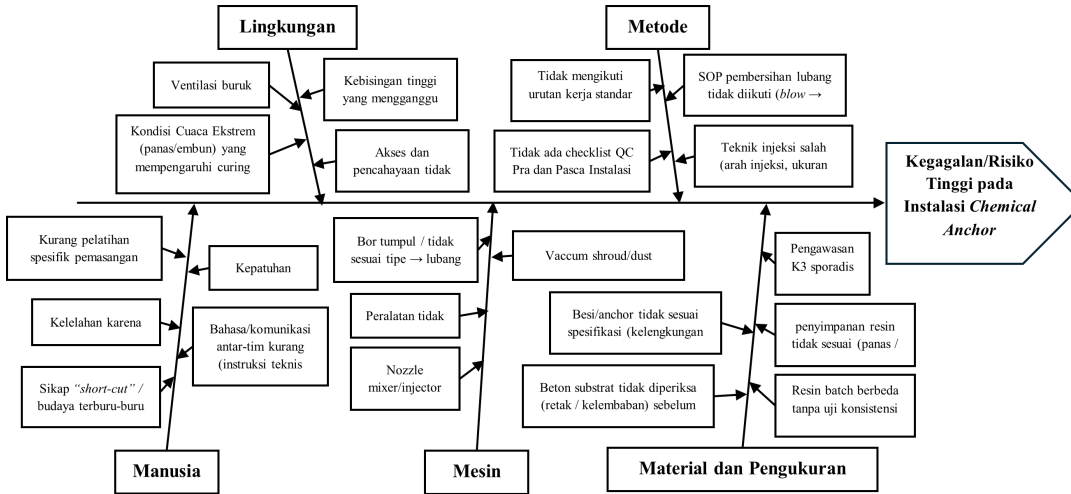


Figure 1. Fishbone Diagram

Based on the results of the fishbone diagram, various factors causing failure or high risk in the chemical anchor installation process are grouped into five main categories: human, environment, machinery, methods, and materials and measurements.

Hazard Identification

Table 1. Hazard Identification in Chemical Anchor Installations

No	Stages	Activities	Risk
1	Work area preparation	Work area preparation: inspecting the area, preparing tools and PPE	Slipped/fell; hit by material; electrocuted
2	Concrete drilling	Concrete drilling: determining the point and performing the drilling	Exposure to dust (respiratory tract infection); concrete debris; noise; short circuit
3	Drill hole cleaning	Cleaning drill holes: brushing/blowing away dust	Exposure to cement dust; eye irritation; inhaled particles
4	Injection of adhesive material (Fischer chemical anchor)	Adhesive injection (chemical resin): preparing and injecting resin	Chemical exposure (skin/eyes/breathing); spills; vapors
5	Installation of D16 steel rods	Installation of steel rods (anchor rods): insert & position the rods	Hand caught; poor ergonomic work position; resin spilled
6	Curing process (resin hardening)	Curing period: wait and protect the area	Chemical vapor exposure; slippery areas due to spills
7	Final cleaning and inspection	Final cleaning & inspection: visual inspection & tidying up the area	Anchor shifted; tripped over debris; struck by small equipment

The results of hazard identification in the chemical anchor installation process show that each stage of work has different potential risks. The work area preparation stage carries the risk of slipping, falling, or electric shock, while concrete drilling can cause exposure to dust, debris, noise, and short circuits. During the cleaning of drill holes, the main risks are eye irritation and respiratory problems due to cement dust. During resin injection, workers are potentially exposed to chemicals and toxic fumes, as well as the risk of material spillage. The steel rod installation stage poses a risk of hand entrapment and non-ergonomic work postures, while the curing process carries a risk of chemical fume exposure and slippery areas. Finally, cleaning and final inspection may potentially cause tripping or being hit by small equipment. Therefore, the implementation of safe work SOPs, the use of PPE, and strict K3 supervision are essential to prevent workplace accidents.

Risk Assessment

Table 2. Risk Analysis on Chemical Anchor Installation (Risk Matrix)

No	Stages	Activities	(L)	(S)	(LxS=R)	Risk Level
1	Work area preparation	Work area preparation: inspecting the area, preparing tools and PPE	2	3	4	Low
2	Concrete drilling	Concrete drilling: determining the point and performing the drilling	3	3	9	Moderate
3	Drill hole cleaning	Cleaning drill holes: brushing/blowing away dust	2	2	4	Low
4	Injection of adhesive material (Fischer chemical anchor)	Adhesive injection (chemical resin): preparing and injecting resin	3	3	9	Moderate
5	Installation of D16 steel rods	Installation of steel rods (anchor rods): insert & position the rods	2	2	4	Low
6	Curing process (resin hardening)	Curing period: wait and protect the area	2	2	4	Low
7	Final cleaning and inspection	Final cleaning & inspection: visual inspection & tidying up the area	2	2	4	Low

Based on the results of hazard identification, there are five low and two moderate risks, which form the basis for OSH control priorities to maintain work safety. During the work area preparation stage (R=4, Low), the risks are low, but there is still the potential for slipping, tripping, or electric shock, so a clean work area and the use of complete PPE are required.

Risk Control

The risk management stage is carried out after the risk level assessment results are obtained. The main objective of the risk control process is to prevent potential hazards, thereby reducing the possibility of workplace accidents or even avoiding them altogether in an industrial environment.

Table 3. shows the results of risk assessment and control at each stage of chemical anchor installation. Of the seven work activities, most have a low level of risk, while two activities, concrete drilling and Fischer adhesive injection, are classified as medium risk because they involve electrical equipment, noise, and exposure to chemicals. Most chemical anchor installation activities have a low level of risk, while the two main stages of concrete drilling and adhesive injection are classified as medium risk. In general, this process can be controlled well if all stages are carried out in accordance with safety procedures and the use of appropriate PPE.

Table 3. Risk Control

No	Activities	L	S	LxS=R	Risk Level	Risk Control
1	Work area preparation	2	2	4	Low	Ensure the work area is clean and dry; Wear safety shoes and a helmet; Check the condition of electrical cables before use; Wear work gloves.
2	Concrete drilling	3	3	9	Moderate	Wear a respirator mask and protective goggles; Install a guard on the drilling machine; Use earplugs; Wear gloves and check the tool's cables.
3	Drill hole cleaning	2	2	4	Low	Wear a mask and protective eyewear; Avoid directing the blower toward your face; Ensure adequate ventilation.
4	Injection of adhesive material (Fischer chemical anchor)	3	3	9	Moderate	Wear nitrile gloves and a mask; Avoid direct contact with chemicals; Prepare a container to collect spills; Use in a well-ventilated area.
5	Installation of D16 steel rods	2	2	4	Low	Wear work gloves; Perform the installation carefully; Use an ergonomic working position.
6	Curing process (resin hardening)	2	2	4	Low	Ensure adequate ventilation; Post warning signs in the curing area; Clean up resin spills immediately.
7	Final cleaning and inspection	2	2	4	Low	Ensure that the anchor has completely hardened; Wear full PPE; Tidy up the work area after inspection.

Table 4. Risk Control Hierarchy

No	Activities	Risk Control Hierarchy
1	Work area preparation	Elimination: Remove scattered objects and sources of danger in the work area. Administrative: Create a checklist for inspecting the work area. PPE: Helmet, safety shoes, gloves.
2	Concrete drilling	Engineering: Install drill guards and dust extraction systems. Administrative: Training on drill use and work schedules to avoid fatigue. PPE: Respirator masks, goggles, gloves, and earplugs.
3	Drill hole cleaning	Engineering Controls: Use blowers with long nozzles to maintain a safe distance. Administrative Controls: Instructions not to direct blowers toward the face. Personal Protective Equipment: Masks and protective eyewear.
4	Injection of adhesive material (Fischer chemical anchor)	Substitution: Use resins with low toxicity levels whenever possible. Engineering Controls: Use automatic injection equipment and local ventilation systems. Administrative Controls: Training on chemical MSDS and spill handling. Personal Protective Equipment: Nitrile gloves, respirator masks, face shields.
5	Installation of D16 steel rods	Engineering: Use tools to ensure ergonomic working positions. Administrative: Installation guidelines and direct supervision. PPE: Work gloves, safety shoes.
6	Curing process (resin hardening)	Administrative: Post warning signs in the hardening area and restrict access. Engineering Controls: Use natural ventilation or exhaust fans when indoors. Personal Protective Equipment: Wear masks and gloves when handling resin residue.
7	Final cleaning and inspection	Elimination: Dispose of resin waste according to procedure. Administrative: Perform visual inspection according to the checklist. PPE: Helmet, gloves, safety shoes.

DISCUSSION

Fishbone Diagram

The human aspect, the dominant factor that influences this, is the lack of specific training in chemical anchor installation, so that workers do not understand the technical procedures correctly. In addition, work fatigue, rushing (short-cut behavior), and an undisciplined work culture increase the potential for errors. Ineffective communication between teams and weak delivery of technical instructions also cause miscommunication during the installation process (16,17). Environmental factors also contribute significantly to increased risk. Extreme weather conditions such as heat or dew can affect the resin curing process, while poor ventilation and high noise levels can interfere with workers' concentration. Inadequate lighting and difficult access to work areas compromise safety and accuracy in the field (18). Machines: Risks arise from the use of inappropriate equipment, such as dull or incorrectly sized drills for the type of hole, as well as poorly maintained mixer/injector nozzles. The absence of a vacuum shroud/dust collector causes dust to accumulate in the work area, which not only reduces the quality of the drilled holes but also poses health risks.

Furthermore, in terms of methodology, many failures were caused by non-compliance with standard operating procedures (SOPs). For example, workers did not clean the boreholes properly (the blow process was not carried out), there were no pre- and post-installation QC checklists, and there were errors in the injection technique in terms of both direction and size. Sporadic K3 supervision also increased the likelihood of deviations from safe procedures. Finally, from a material and measurement perspective, sources of risk stem from material quality and specification inaccuracies. Resin is often stored at inappropriate temperatures (too hot or humid), which causes a decline in adhesion quality. In addition, the use of different resin batches without consistency testing can lead to variations in results. Errors can also arise from the use of iron or anchor rods that do not meet specifications and substrate concrete conditions that are not checked in advance, such as cracks or moisture.

Risks in chemical anchor installation are multifactorial, involving interactions between human factors, work methods, environmental conditions, equipment readiness, and material quality. Therefore, prevention must be carried out comprehensively by improving technical training, disciplined implementation of SOPs, and continuous monitoring of working conditions and materials used (16) (19).

Hazard Identification

The work area preparation stage has low risks with potential hazards such as slipping, being hit by materials, or electric shock due to damaged cables. Control is carried out by maintaining the cleanliness of the area, arranging tools neatly, checking electrical cables, and using PPE such as helmets, safety shoes, and gloves. The concrete drilling stage is classified as high risk due to exposure to silica dust, concrete debris, noise, and the potential for electrical short circuits. Controls are implemented through the use of dust collectors, equipment inspections, safety training, and the use of respirator masks, goggles, earplugs, and gloves.

The drill hole cleaning stage has a low risk, but there is still a potential hazard in the form of dust exposure and high air pressure from the blower. Control measures include the use of long nozzles, good ventilation, and PPE in the form of masks and protective goggles. The adhesive injection stage involves moderate to high risks due to the use of chemical resins that can cause skin irritation, respiratory problems, and hazardous material spills. Control measures include adequate ventilation, the use of nitrile gloves, respirator masks, face shields, and understanding of MSDS and chemical handling procedures.

During the installation of D16 steel bars, the risk is classified as low, with the potential for hand entrapment, muscle injury due to non-ergonomic working positions, or resin spills. Control measures include ergonomic work techniques, safety training, and the use of gloves and safety shoes. The curing or hardening stage of the resin is passive, but still has the potential to cause chemical vapor exposure and slipping hazards. Controls include installing warning signs, cleaning up spills, and ensuring good air ventilation. The cleaning and final inspection stages have low risks, such as tripping over leftover materials or being hit by small equipment. Control is carried out through cleaning the work area, disposing of waste, and visual inspection using PPE.

Overall, the highest risks are found in the concrete drilling and adhesive injection stages. The other stages have low risks, but still require the implementation of OSH discipline. The successful implementation of OSH in chemical anchor work is highly dependent on compliance with work procedures, the availability of PPE, and effective communication in the field. With the implementation of systematic and consistent controls, all stages of installation can be carried out safely, efficiently, and in accordance with occupational safety standards (20–22).

Risk Assessment

The concrete drilling stage (R=9, Moderate) has a high risk due to dust, noise, and electrical hazards, which are controlled by checking tools and using masks, earplugs, and gloves. Cleaning drill holes (R=4, Low) carries a risk of eye irritation and dust exposure, which is mitigated by wearing masks and eye protection. Adhesive injection (R=9, Moderate) involves hazardous chemicals, requiring nitrile gloves, masks, and good ventilation. Installation of D16 steel bars (R=4, Low) has the potential for minor injury, controlled by gloves and ergonomic work positions. The curing process (R=4, Low) requires area restrictions due to potential chemical vapours and resin spills. Final cleaning and inspection (R=4, Low) carry a risk of tripping or being struck by materials, requiring a tidy work area and visual inspection. Overall, the drilling and injection stages require stricter K3 supervision to ensure that chemical anchor installation is safe, efficient, and controlled (23,24).

Overall, of the seven stages of activities assessed, five of them have a low risk level, and the other two stages are classified as moderate, namely concrete drilling and adhesive injection. These two stages require stricter supervision, adequate K3 training, and consistent implementation of technical and administrative controls. With the implementation of appropriate risk controls at each stage of work, chemical anchor installation activities can be categorised as safe and controlled, thereby minimising the potential for workplace accidents and maintaining the efficiency and quality of the installation results.

Risk Control

Work area preparation stage: The risk level is classified as low with potential hazards such as tripping, slipping, and being hit by poorly arranged equipment. Risk control focuses on keeping the work area tidy and clean, ensuring there are no obstacles in the work path, and using PPE such as safety helmets, shoes, and gloves. This stage is an important foundation for creating a safe working environment before technical activities begin. Next, during the concrete drilling stage, the risk level increases to moderate due to the potential exposure to silica dust, concrete debris, high noise levels, and electrical hazards from the use of electric drilling tools. Control measures are implemented by installing guards on the drilling machines, implementing a dust extraction system, providing safe work training to operators, and ensuring that workers use respirator masks, earplugs, gloves, and protective eyewear. This approach emphasises the importance of technical engineering and safe work practices to minimise direct exposure to hazards.

During the borehole cleaning stage, the risk returns to the low category. Possible hazards include pressurised air bursts from misdirected blowers that could hit workers or cause dust to fly around. Control measures include the use of long nozzles to direct the air safely, ensuring good air circulation, and the use of masks and protective goggles to prevent irritation of the eyes and respiratory tract. The next stage, the injection of adhesive material (chemical anchor), has a moderate risk because it involves exposure to hazardous chemicals that can cause skin irritation, respiratory disorders, or chemical reactions if not handled properly. Control is carried out by using adhesive materials that have a low level of toxicity, applying automatic injection tools to reduce direct contact, and ensuring that local ventilation functions optimally. Workers must also understand the material safety data sheet and wear complete PPE such as nitrile gloves, respirator masks, and face shields.

The steel bar installation stage has a low risk of injury, such as being pinched, being hit by materials, or working in an ergonomically poor posture. Control measures include the use of installation tools, the application of ergonomic work guidelines, and the use of gloves and safety shoes to prevent injuries from pressure and other sharp objects. The curing stage is also classified as low risk with potential hazards in the form of exposure to resin fumes or spills of uncured adhesive materials. Control measures include installing warning signs in the work area, restricting access to unauthorised workers, maintaining good air circulation, and requiring the use of masks and gloves to prevent direct contact with chemicals. Finally, the cleaning and final inspection stages have low risk. Potential hazards mainly come from chemical residues, hazardous waste, or untidy work areas. Risk control is carried out by disposing of hazardous waste in accordance with applicable procedures, visually inspecting the work results and cleanliness of the area, and using PPE until all work is completely finished (25,26).

Overall, all stages of chemical anchor installation indicate that the implementation of engineering and administrative risk control measures is a top priority to prevent accidents. The use of PPE serves as the final layer of protection that complements control efforts at the source of the hazard and in the work environment. With the consistent implementation of occupational safety and health (OSH) systems at every stage of the work, the chemical anchor installation process can be carried out safely, efficiently, and in a controlled manner, while also reflecting the implementation of a good OSH culture in the construction work environment.

Recommendation for Future Research

Future research is recommended to explore real-time hazard monitoring technologies, assess long-term health impacts from dust, noise, and chemical exposure, and compare the effectiveness of various control measures and PPE. Studies on worker behaviour, safety culture, and differences among chemical anchor products, as well as the use of simulation-based modelling and cost-benefit analysis, can also provide deeper insights to further strengthen risk management in chemical anchor installation activities.

CONCLUSIONS

Based on the results of the risk assessment of all stages of chemical anchor installation work, it can be concluded that this activity generally has a controlled and safe level of risk. Most activities are classified as low risk, while two stages, namely concrete drilling and adhesive injection, are classified as medium risk due to potential physical and chemical hazards, such as noise, exposure to silica dust, the possibility of electrical short circuits, and exposure to chemicals that can cause skin irritation and respiratory problems. However, the implementation of a comprehensive risk control hierarchy has proven to be effective in minimising these potential hazards. Engineering controls, such as installing machine guards, implementing local ventilation, and using dust extraction systems, are complemented by administrative controls in the form of SOPs, periodic OSH training, and strict supervision of worker compliance. In addition, the use of PPE such as respirator masks, earplugs, nitrile gloves, helmets, and safety shoes serves as a final layer of protection that supports the effectiveness of comprehensive control.

The implementation of comprehensive and consistent risk control at every stage of work ensures that chemical anchor installation activities can be carried out efficiently, safely, and in accordance with applicable occupational health and safety standards. This shows that good risk management not only plays a role in preventing workplace accidents but also has a positive impact on productivity, time efficiency, work quality, and the strengthening of OSH culture in the construction environment. Thus, the disciplined and sustainable implementation of SMK3 is the key to creating a safe, healthy, and productive workplace.

CONFLICTS OF INTEREST

All author declare no conflict of interest

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BIBLIOGRAPHY

1. Ishimaru H, Morishige T, Takenaka T, Materials R like, Sf-mdc C, Sakairi M, et al. To the Problems of Anchoring Adhesives in High Performance Concrete. IOP Conf Ser Mater Sci Eng. 2019;
2. Haidar HH, Mussa FI, Dawood AO, Ghazi AA, Gabbar RA. Experimental Study of Post Rebar Anchor System For Structure Installed Concrete. Civ Environ Eng. 2020;16(2):308–19.
3. International Labour Organization. Exposure to hazardous chemicals at work and resulting health impacts: A global review. Encyclopedia of Human Resource Management, Second Edition. Switzerland: Geneva:ILO; 2021.
4. Fajarwati Y, Arum Dewi F, Wibowo DE. Evaluasi Risiko Likuifaksi pada Infrastruktur Vital di Kabupaten Bantul Berdasarkan Data Cone Penetration Test (CPT). J Media Konstr. 2024;9(3):199–210.
5. Azmi Y, Prasetyo YW, Purnomo DA. Penerapan Metode Monte Carlo Pada Penjadwalan Proyek Untuk Pengelolaan Risiko dan Optimasi Waktu Proyek (Studi Kasus: Renovasi Kantor Depo Mekanik Daop IX Jember). J Media Konstr. 2025;10(2):201–2014.
6. Dwiseli F, Kamilia NA, Herlambang A, Cahyani, Susilawati E, Tamimi N, et al. Kesehatan dan Keselamatan Kerja: Teori, Strategi, dan Inovasi di Era Modern. Manado: Yayasan Bina Lentera Insan; 2025. 300 p.
7. Lahouar MA, Pinoteau N, Caron JF, Foret G, Mege R. A nonlinear shear-lag model applied to chemical anchors subjected to a temperature distribution. Int J Adhes Adhes. 2018;84:438–50.
8. Giresini L, Puppio ML, Taddei F. Experimental pull-out tests and design indications for strength anchors installed in masonry walls. Mater Struct Constr [Internet]. 2020;53(4):1–16. Available from: <https://doi.org/10.1617/s11527-020-01536-2>

9. Afrian F, Mas'ud F, Muhamad LO, Arsyad N. Produktivitas Pekerja Konstruksi pada Pekerjaan Dinding Bata Ringan Berdasarkan PUPR No. 1 Tahun 2022 (Studi Kasus: Pembangunan Rumah Susun STAIN Kendari Kampus II). *J Media Konstr.* 2024;9(2):131–40.
10. Tam CM, Zeng SX, Deng ZM. Identifying elements of poor construction safety management in China. *Saf Sci* [Internet]. 2004;42(7):569–86. Available from: <https://www.sciencedirect.com/science/article/pii/S0925753503000602>
11. Toole M. Construction Site Safety Roles. *J Constr Eng Manag* [Internet]. 2002;128:203–10. Available from: <https://consensus.app/papers/construction-site-safety-roles-toole/25cc12f178d35e2dba2f13de8f243e75/>
12. Alditia AlfaReza, Susilawati Susilawati. Analisis Literatur Efektivitas Sistem Manajemen K3 di Perusahaan Kecil dan Menengah (UKM). *J Ris Ilmu Kesehat Umum dan Farm.* 2024;2(3):17–21.
13. Papazoglou I, Bellamy L, Hale A, Aneziris O, Ale B, Post J, et al. I-Risk: development of an integrated technical and management risk methodology for chemical installations. *J Loss Prev Process Ind* [Internet]. 2003;16:575–91. Available from: <https://consensus.app/papers/irisk-development-of-an-integrated-technical-and-post-hale/db76f226da1c557481823cfb81e7eec5/>
14. Kuzu A. Application of fuzzy DEMATEL approach in maritime transportation: A risk analysis of anchor loss. *Ocean Eng* [Internet]. 2023; Available from: <https://consensus.app/papers/application-of-fuzzy-dematel-approach-in-maritime-kuzu/818fe5c420345f7e942f1735cecaebfb/>
15. Wang W, Ding L, Liu X, Liu S. An interval 2-Tuple linguistic Fine-Kinney model for risk analysis based on extended ORESTE method with cumulative prospect theory. *Inf Fusion* [Internet]. 2022;78:40–56. Available from: <https://consensus.app/papers/an-interval-2tuple-linguistic-finekinney-model-for-risk-ding-liu/da1a2396416d5959846574c78eae0902/>
16. Zarei E, Yazdi M, Abbassi R, Khan F. A hybrid model for human factor analysis in process accidents: FBN-HFACS. *J Loss Prev Process Ind* [Internet]. 2019;57:142–55. Available from: <https://www.sciencedirect.com/science/article/pii/S0950423018306752>
17. Alhaidary H, Al-Tamimi AK. Importance of performance certification for post-installed anchors: An experimental assessment. *Structures* [Internet]. 2021;29:273–85. Available from: <https://www.sciencedirect.com/science/article/pii/S2352012420306457>
18. Çalışkan Ö, Aras M, Ağdağ Y. Experimental investigations the effects of dusty, humidity and temperature conditions on chemical anchors. *Rev Ia Constr.* 2023;22(3):613–31.
19. Muhammad Iqbal, A Fachrin S, Saleh LM. Hubungan Antara Pengetahuan, Sikap dan Kualitas Kerja Dengan Kinerja Perawat Dalam Penerapan Sistem Keselamatan Pasien Di RSUD Sinjai Tahun 2020. *J Aafiyah Heal Res.* 2020;1(2):44–57.
20. Jogie DJA, Rampersad DD, Bharrath-Singh DD, Joseph DS, Clarke DA, Rosa DT La. A Comprehensive Review of the Hierarchy of Controls and Barriers to its Implementation. *Int J Prev Med Heal.* 2025;5(3):32–8.
21. Babalola A, Manu P, Cheung C, Yunusa-Kaltungo A, Bartolo P. A systematic review of the application of immersive technologies for safety and health management in the construction sector. *J Safety Res* [Internet]. 2023;85:66–85. Available from: <https://www.sciencedirect.com/science/article/pii/S0022437523000075>
22. Alamskati D, Kermanshachi S, Pamidimukkala A, Loganathan K, Yin Z. A Review on Construction Safety: Hazards, Mitigation Strategies, and Impacted Sector. *Buildings.* 2024;1–18.
23. Rudakov M, Gridina E, Kretschmann J. Risk-based thinking as a basis for efficient occupational safety management in the mining industry. *Sustain.* 2021;13(2):1–14.
24. Hasle P, Uhrenholdt Madsen C, Hansen D. Integrating operations management and occupational health and safety: A necessary part of safety science! *Saf Sci.* 2021;139.
25. Rahman S, Nashek MH, Aubhi RUH, Sarmin S, Sharmin S, Rana MS, et al. Risk Assessment, Worker Training, Personal Protective Equipment, and Safety Monitoring in Occupational Safety and Health: The Case of the Construction Sector in Bangladesh. *J Posthumanism.* 2025;5(5):3943–63.
26. Benson C, Obasi IC, Akinwande DV, Ile C. The impact of interventions on health, safety and environment in the process industry. *Heliyon* [Internet]. 2024;10(1):e23604. Available from: <https://doi.org/10.1016/j.heliyon.2023.e23604>