Eduvest – Journal of Universal Studies
Volume 5 Number 10, October, 2025
p- ISSN 2775-3735- e-ISSN 2775-3727

Evaluation of Occupational Safety, Health, and Environmental Aspects in the Use of Geofoam on Clay Shale Soil as an Alternative Embankment Material

Suluh Damar Harbian*, Agus Triyono
Universitas Trilogi, Indonesia
Email: rangga.harbian@gmail.com*

ABSTRACT

In the Cisumdawu Toll Road Construction Package 5A, at the STA 40+125–STA 40+225 area, soil material cannot be used for embankment work because the existing soil condition is clay shale. This study aims to evaluate EPS geofoam material as a substitute for soil material because it is lighter and safer from the aspects of occupational safety, occupational health, and the environment. This study uses a qualitative research design with a descriptive method, with data collected from 13 informants ranging from staff-level employees to management among the work implementers. The data were obtained through interviews with informants and observations conducted both in the field and via related documents. The data analysis techniques applied include data collection, data reduction, data presentation, and conclusion drawing with verification. The results of this study show that unstable clay shale soil, which is not strong enough to withstand the embankment load, causes cracks and landslides; HSE risk management for handling cracks and landslides in the Cisumdawu Project Package 5A has not yet been implemented; the use of EPS geofoam can minimize the potential for work accidents, reduce the risk of occupational diseases, and lower the potential for environmental pollution. Researchers recommend using EPS geofoam because it fulfills occupational safety, occupational health, and environmental requirements.

KEYWORDS *Environment, EPS Geofoam, Evaluation, Occupational Health and Safety*

INTRODUCTION

Infrastructure construction, particularly in geotechnically challenging terrain, poses significant occupational safety and health risks globally (Baghdadi, 2024). According to the International Labour Organization (ILO, 2019), the construction sector accounts for approximately 15% of all workplace fatalities worldwide, with soil-related failures—including landslides and embankment collapses—representing a substantial portion of these incidents. Statistical data from the United States Department of Labor (2020) indicates that excavation and trenching failures cause an average of 40-50 construction worker deaths annually, with unstable soil conditions identified as a primary contributing factor. In Southeast Asia, where clay-rich and expansive soils are prevalent, the Asian Development Bank (2021) reported that soil instability-related accidents contribute to nearly 20% of construction project delays and 12% of worker injuries in infrastructure development. These global statistics underscore the critical importance of innovative geotechnical solutions that can mitigate soil-related hazards while maintaining construction productivity and worker safety (Naskar, Kumar Jha, Singh, & Aeron, 2025; Pandey, 2025).

One of the infrastructure developments is the construction of toll roads in Sumedang Regency, West Java Province, namely the Cileunyi – Sumedang – Dawuan Toll Road (Cisumdawu Toll Road). This toll road was built connecting Bandung (Cileunyi) with the Cikopo – Palimanan / Cipali (Dawuan) Toll Road. The Cisumdawu Toll Road is divided into several sections / sections. In May 2021, the construction of the Cisumdawu Toll Road Section 5A began. This 7.45 KM toll road is located in Paseh District to Conggeang District, Sumedang Regency (Adhi Karya, 2021).

Figure 1. Cileunyi – Sumedang – Dawuan Package 5A Toll Road

In one of the areas of the Cisumdawu Toll Road Construction Package 5A, namely at STA 40+125 – STA 40+225, the existing soil condition is soil with a type of clay shale. This type of soil is very unstable when directly used as the base of the pile. The geotechnical characteristics of clay shale present multiple hazards to construction workers and project integrity. According to Das (2021), clay shale soils exhibit low shear strength, high compressibility, and susceptibility to swelling when exposed to moisture, creating unstable foundation conditions that can trigger sudden slope failures. These soil conditions directly impact occupational safety and health (OSH) in several critical ways.

First, instability increases the risk of catastrophic embankment collapse, potentially burying workers and heavy equipment under soil mass movements (Budhu, 2020). Second, the unpredictable nature of clay shale deformation creates hazardous working environments where conventional safety protocols may prove inadequate (Terzaghi et al., 2021). Third, continuous monitoring and remedial work in unstable zones expose workers to prolonged risk periods, increasing the probability of occupational accidents (Rahardjo et al., 2023). Fourth, the stress and uncertainty associated with working on unstable ground can contribute to psychological health impacts among construction personnel (Health and Safety Executive, 2022). These compounded risks necessitate alternative construction approaches that fundamentally eliminate or substantially reduce exposure to soil instability hazards.

The instability of this type of soil has an impact on the level of safety both from the technical aspects of the work and the aspects of Occupational Safety and Health (K3) (Saputra & Mahaputra, 2022). Because the existing soil conditions with the clay shale type are very unstable and there are avalanche basins, it is very dangerous from a technical aspect, especially from the aspect of occupational safety and health if the backfill work continues using soil materials. Research on lightweight fill materials as alternatives to conventional soil embankments has evolved significantly over the past two decades. Expanded Polystyrene (EPS) geofoam has emerged as a promising solution for geotechnically challenging construction sites.

Horvath (2020) conducted comprehensive studies on EPS geofoam applications in highway embankments, demonstrating substantial weight reduction (up to 99% compared to soil) and excellent load distribution characteristics. Similarly, Stark et al. (2021) investigated the use of geofoam in slope stabilization projects, reporting significant improvements in factor of safety values and reduced settlement rates. In the Indonesian context, Gunawan (2020, 2022, 2023) has pioneered research on geofoam applications for addressing local soil problems, documenting successful implementations in retaining wall stabilization and embankment construction. More recently, Rahardjo et al. (2023) specifically examined the application of EPS geofoam at the Cisumdawu Toll Road STA 40+200, providing technical validation for its use in overcoming landslide problems. However, existing literature primarily focuses on the geotechnical and structural performance of geofoam, with limited comprehensive evaluation of its occupational safety, health, and environmental (SHE) implications.

This research gap is particularly significant given the increasing regulatory emphasis on integrating SHE considerations into construction material selection and methodology (ISO 45001:2018). Furthermore, while international studies document geofoam applications in developed countries with advanced safety cultures, there is insufficient research examining the SHE benefits of geofoam in developing country contexts where construction safety infrastructure may be less robust. This study addresses these gaps by providing a comprehensive SHE evaluation of geofoam implementation in a real-world Indonesian construction project, contributing empirical evidence to guide future material selection decisions in geotechnically challenging environments. Therefore, in the Cisumdawu Toll Road Construction Project Package 5A, at the location of STA 40+125 – STA 40+225, the heaping work that initially used soil material was replaced with geofoam material (Rahardjo, 2022).

This study aims to comprehensively evaluate the occupational safety, health, and environmental (SHE) aspects of implementing EPS geofoam as an alternative embankment material in the Cisumdawu Toll Road Construction Package 5A, specifically at STA 40+125 – STA 40+225. The specific research objectives are: (1) to analyze the causes of cracks and landslides that increase occupational safety risk potential in clay shale soil conditions; (2) to evaluate the existing OSH risk management framework for handling cracks and landslides at the project location; (3) to assess how geofoam implementation minimizes work accident potential compared to conventional soil embankment methods; (4) to examine the occupational health benefits of geofoam use in reducing work-related disease risks among construction workers; and (5) to analyze the environmental pollution reduction potential achieved through geofoam application.

This research contributes to the growing body of knowledge on sustainable construction materials by providing empirical evidence from a real-world infrastructure project in Indonesia (Wulan, 2024). The findings offer practical insights for construction industry stakeholders, including contractors, safety managers, engineers, and policymakers, in making informed decisions about material selection that balance technical performance with worker welfare and environmental protection. Furthermore, this study supports Indonesia's commitment to improving construction safety standards and achieving Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation, and Infrastructure). By documenting the SHE advantages of innovative geotechnical solutions, this research promotes the adoption of safer, healthier, and more environmentally responsible construction practices in the Indonesian infrastructure sector and potentially in similar developing country contexts.

METHOD

This study employed a qualitative research design with a descriptive approach to comprehensively evaluate the occupational safety, health, and environmental aspects of geofoam implementation in the Cisumdawu Toll Road Construction Package 5A project. The research was conducted at the Cisumdawu Toll Road Construction site, specifically at STA 40+125 – STA 40+225, located from Paseh District to Conggeang District, Sumedang Regency, West Java Province, Indonesia. Data collection took place between January 2023 and December 2023, covering the period of soil instability identification, design modification, and geofoam implementation phases. The study population comprised all personnel involved in the Package 5A project at the specified section, including project management, engineering staff, safety officers, field supervisors, and construction workers. Using purposive sampling, 13 key informants were selected based on their direct involvement in embankment work, knowledge of soil instability issues, and experience with both conventional soil and geofoam construction methods. Informant selection required a minimum of six months of project involvement and direct engagement with either soil embankment failure incidents or geofoam implementation.

Primary data were obtained through direct observation and semi-structured in-depth interviews, each lasting 45–90 minutes, conducted in Indonesian and guided by the research objectives. All interviews were audio-recorded with informed consent and transcribed verbatim for analysis. Direct field observations documented work processes, safety practices, equipment usage, environmental conditions, and worker behaviors across both conventional soil and geofoam embankment phases, totaling approximately 120 hours across 30 site visits. Secondary data, including project design documents, technical specifications, geotechnical reports, job safety analysis documents, incident and accident reports, health monitoring records, environmental management reports, photographic evidence, and relevant regulations and standards, were also collected and systematically reviewed to extract relevant information.

Data analysis followed procedures by Miles and Huberman (1984), proceeding through data collection, data reduction, data presentation, and conclusion drawing with verification. All transcripts, field notes, and documents were compiled and organized using NVivo 12 software for efficient coding and retrieval. The raw data were condensed through open, axial, and selective coding to identify themes related to soil instability, safety risks, health impacts, and environmental effects, linking causes with consequences and interventions with outcomes. Key patterns and stakeholder perspectives were presented in thematic matrices, comparative tables, and narrative descriptions, supported by visual representations, risk diagrams, and photographic evidence. Conclusions were developed through iterative analysis, triangulation across multiple data sources and informants, member checking, and peer debriefing to ensure validity.

Quality assurance was addressed through prolonged site engagement, persistent observation, triangulation, thick description, detailed documentation, and reflexive journaling throughout the research. Ethical considerations were strictly followed: informed consent was obtained from all participants, their identities were anonymized in all reporting, and research approval was secured from the project management and relevant stakeholders before data collection commenced.

RESULT AND DISCUSSION

Causes of cracks and avalanches

Based on the research conducted, the occurrence of cracks and avalanches in STA 40+125 – STA 40+225 is caused by the existing soil condition in the form of clay shale soil that is unstable and cannot accept the load of soil piles as in the initial design. As stated by one of the informants in the following interview, "The hoarding of the 40+200 sta pile work is carried out as usual per layer (per layer about 30 cm thick, according to the -red-specification), but the conditions at that time tend to rain more often, because the area (sta 40+200) is a low point (valley area / lowest point -red), so that the area becomes saturated with water. When the pile approaches the top sub grade (the limit of the pile -red), cracks occur and form a crown on the road body with the exit direction away from the Centre Line (shifted from CL: the middle area of the work -red). And the crown that occurs is also followed by a decrease in the elevation of the pile."

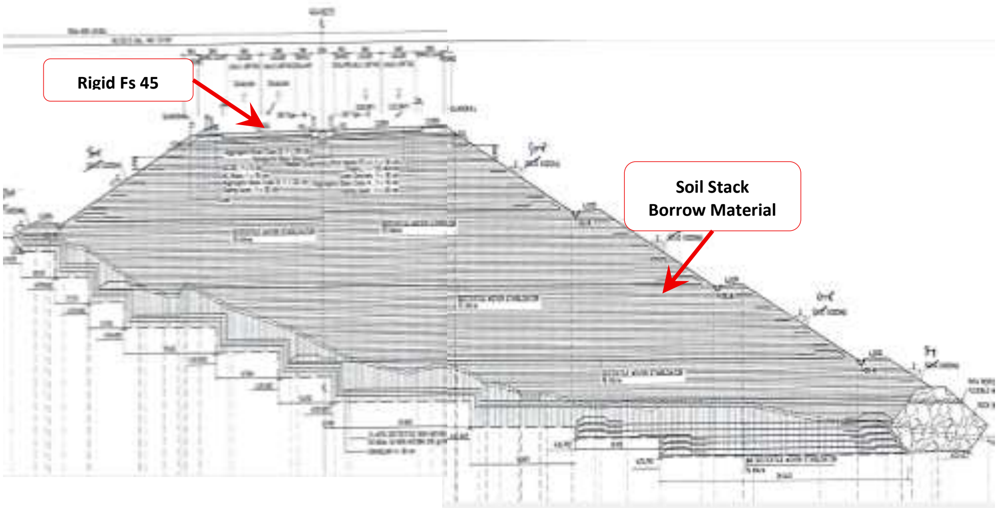

Figure 2. Initial Design Drawings of STA 40+125 – STA 40+225

This is in accordance with the opinion in the Practical Guidelines for Disaster Management, that the trigger for an avalanche can be in the form of an increase in water content in the slope, so that there is an accumulation of water that stretches the bond between soil grains which ultimately pushes the soil grains to landslide or an increase in load that exceeds the carrying capacity of the soil or the shear strength of the soil. Rahardjo (2022) said that the mechanism of slope movement is caused by the condition of the subsoil not being able to withstand the load of the heap, the granular heaps absorb water quickly. Water flow is a driver of the mass of the backpile, the condition of the weathered clayshale bedsoil can be weathered and experience a drastic decrease in shear strength.

Figure 3 Cracks in STA 40+200

From the observations and information obtained (both from interviews and other related data), compared to the literature / expert opinion (Soehatman Ramli, Paulus Rahardjo, PT. Geotechnical Engineering Consultant), the researcher argues that cracks and avalanches in STA 40+125 – STA 40+225 are caused by subsoil conditions that are unable to withstand the load of the heap. Plus the high rainfall factor which can increase the load significantly. If the hoarding work continues, it will be more dangerous from the aspect of work safety because the safety of workers is threatened and can cause even bigger landslides. In addition, the continuity of the organization/company becomes threatened because it can have an impact on the potential for greater losses and the company's image which can be bad.

K3 Risk Management Handling of Cracks and Avalanches at the Location of STA 40+125 – STA 40+225

From the research conducted, before the occurrence of cracks and avalanches in STA 40+125 – STA 40+225, there was no risk management for handling avalanches. As one of the informants said in the following interview, "Handling related cracks has not been in the initial risk management, such as in IBPRP, JSA or other documents because there is no information related to the detailed condition of the existing land at the beginning. Existing soil test data do not represent the overall condition of existing land".

This can cause losses for the company/organization because it is less prepared to face certain situations. This is in accordance with the opinion of that K3 risk management is an effort to manage K3 risks to prevent unwanted accidents in a comprehensive, planned and structured manner in a good system.

From observations and information obtained (both from interviews and other related data), compared to the literature / expert opinion (Soehatman Ramli, Fahmi, PT. Geotechnical Engineering Consultant, and also PT. Adhi Karya), the researcher argues that the risk management of avalanche handling that does not exist at the beginning of the implementation of the work is due to the absence of the necessary information and detailed data. This has been equipped with a Geofoam Job Safety Analysis, as soon as there is a new design, namely using geofoam.

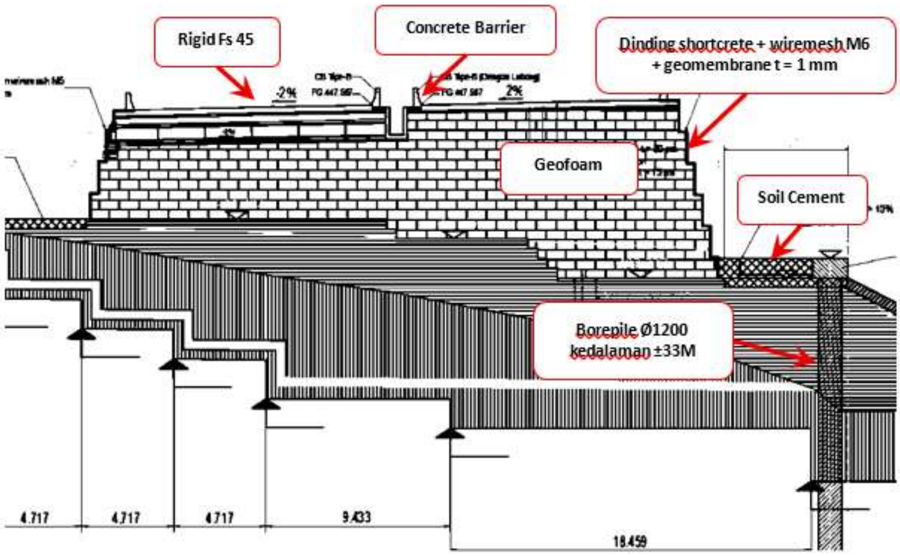

Figure 4. Handling Using Geofoam

The Use of Geofoam as an Alternative to Landfill Materials That Can Minimize the Potential for Work Accidents

Based on the research conducted, the selection of geofoam has advantages in terms of occupational safety. The use of geofoam does not require heavy equipment or dump trucks (DT). With conditions like this, the potential for work accidents is greatly reduced due to the absence of heavy equipment traffic at the work site. As stated by one of the informants in the following interview, "The initial design with conventional soil piles used a lot of heavy equipment, of course, the potential for work accidents was many as a result of human error. The final design, because this is a new method and at that time we were unfamiliar with it, there were still many uses of existing heavy equipment to be a tool and mobilize a lot of labor. This has the potential to cause many work accidents. After the work is over (in the first shipment of geofoam material), we have time to evaluate the way it works, where the use of heavy equipment is much reduced, so that the potential for work accidents can be minimized. As an illustration for the use of tools, during the implementation of earthenware work, the needs of tools at this location are:

a. Dozer D 65 = 5 units
b. Excavator PC200 = 6 units
c. Dump truck 24 ton = 22 units
d. Sheepfoot roller 8 ton = 4 units
e. Vibro smoothdrum = 2 units

Meanwhile, the needs of tools during geofoam work are:

a. Dozer D65= 3 units (road maintenance)
b. Excavator PC200 = 3 units (preparation of working land)
c. Dump truck 24 ton = 8 units (material curtains from 2 directions)
d. Mobile crane 8 ton = 1 unit (auxiliary equipment)

The mobilization of heavy equipment for the geofoam work was carried out because it was necessary to accelerate the work so that production could increase. Under normal conditions, these tools are not needed".

Figure 5. Landfill Work

Compared to traditional solid soil, geofoam is 80-90 times lighter (20 kg/m3 vs. 1600-1800 kg/m3) (Gunawan, 2024). In the field of construction, EPS geofoam has a wide range of applications, such as for road embankments as well as embankments behind bridge abutments. The use of this material is crucial in handling slopes, especially to prevent avalanches. One of the factors causing landslides is that the backlog is too heavy to be accepted by the landfill or subsoil. With its low weight, EPS geofoam can help reduce the risk of slope collapse (Andrawan, 2025).

From observations and information obtained (both from interviews and other related data), compared to the literature / expert opinions (Suma'mur, Soehatman Ramli, Anthony Gunawan, Andrawan), researchers argue that the use of geofoam can minimize the potential for work accidents. This is because the implementation of geofoam work does not require a lot of heavy equipment so that the potential for work accidents is smaller. With the potential for minor accidents, productivity increases, and potential cost and time losses can be prevented.

Figure 6. Geofoam Jobs

The Use of Geofoam as an Alternative to Landfill Materials That Can Reduce the Risk of Occupational Diseases

Based on the research conducted, geofoam has advantages in the aspect of occupational health. The use of geofoam does not use heavy equipment much. The number of heavy equipment is greatly reduced because the use of geofoam affects the health level of workers. At the time of the implementation of the geofoam work, there were no complaints of illness, mainly Upper Respiratory Tract Infection (ISPA) from staff and workers who were routinely active in the area. This is due to the absence of earthworks activities. While the landfill work is still ongoing, the movement of heavy equipment, the mobility of trucks has an impact on the production of dust, both dust from soil materials and from vehicle smoke. This is in accordance with an interview with one of the informants, namely, "The resource (resource -red) of the equipment used for the STA 40 + 200 earthmound work (in the initial design before the occurrence of cracks and landslides – red) is a minimum of 20 dump trucks (DT) index (load volume -red) of 22 m3 per day. To achieve the production target, each DT must reach the target of 3 ritase per day (number of loads/transports). In the new design, the use of geofoam does not require the use of DT. Trucks as transportation are used only when mobilizing geofoam materials from the workshop to the work site. From the number of DT needs, it has been seen that the potential for work-related diseases will decrease significantly. There are no more DTs crossing from the quarry to the work site. The dust or smoke generated from DT traffic will be greatly reduced. Meanwhile, dust / smoke is the main source of the cause of ISPA."

Figure 7. Dust from Land Transport Mobility

This is in accordance with the opinion of Suma'mur, 1988, that one of the diseases caused by dust accumulation in the lungs is pneumoconioses silicosis. The disease is caused by free silica (SiO_2). This free silica is found in dust that is inhaled when breathing and is deposited in the lungs. Motor vehicle exhaust gases are made up of a variety of gases such as carbon monoxide (CO), nitrogen oxide (NO_x), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particles such as hydrocarbons, lead dioxide, and other organic compounds. These gases have the potential to cause poisoning with characteristics such as headaches, nausea, and dizziness. In severe poisoning, bleeding and respiratory failure can occur (Priyanto, 2016).

From the observations and information obtained (both from interviews and other related data), compared to the literature / expert opinion (Suma'mur, Royani – Feni Fitriani Taufik, Herry Priyanto – Faisal Yunus, Erlang Samoedro – Heidy Agustin – Fathiyah Isbaniyah), the researcher argues that the use of geofoam can minimize the potential for work-related diseases. This is because the decrease in dust and smoke production due to geofoam not using heavy equipment much.

The Use of Geofoam as an Alternative to Landfill Materials That Can Reduce the Potential for Environmental Pollution

Based on the research conducted, the use of geofoam can reduce the potential for environmental pollution. Unused materials are transported back to the workshop for recycling/reuse. As stated by one of the informants as follows, "During the rainy season, the impact of the use of soil materials in landfill work is very visible. Dust and soil materials that are scattered and exposed to water will become mud. In addition to dirtying the road, it also makes it slippery".

This is in accordance with Gunawan's opinion, 2024, that the installation of geofoam does not require compaction, unlike traditional soil heaps. Therefore, the use of geofoam instead of traditional landfills is more environmentally friendly, reducing CO_2 emissions from heavy equipment. One of the main advantages of EPS geofoam is its ability to be recycled without the need for chemical processes, making it environmentally friendly (Andrawan, 2025). EPS waste from the factory is taken to the EPS smelting site, where EPS waste is melted using a specially designed kiln, then molded into hard polystyrene in the form of chips or ingots. These polystryene chips and ingots are used as raw materials for other products, for example to be used as mobile phone cases, computer cases, and others (Properti.biz b-panel, 2010).

From observations and information obtained (both from interviews and other related data), compared to the literature / expert opinion (Anthony Gunawan, Andrawan – Aniek Prihatiningsih – James. W – Albert Johan, Herry Priyanto – Faisal Yunus, Suma'mur), researchers argue that the use of geofoam can minimize the potential for environmental pollution. This is because geofoam material produces little residual pieces. In addition, the use of heavy equipment can be minimized so that dust and smoke that pollute the environment can be drastically reduced.

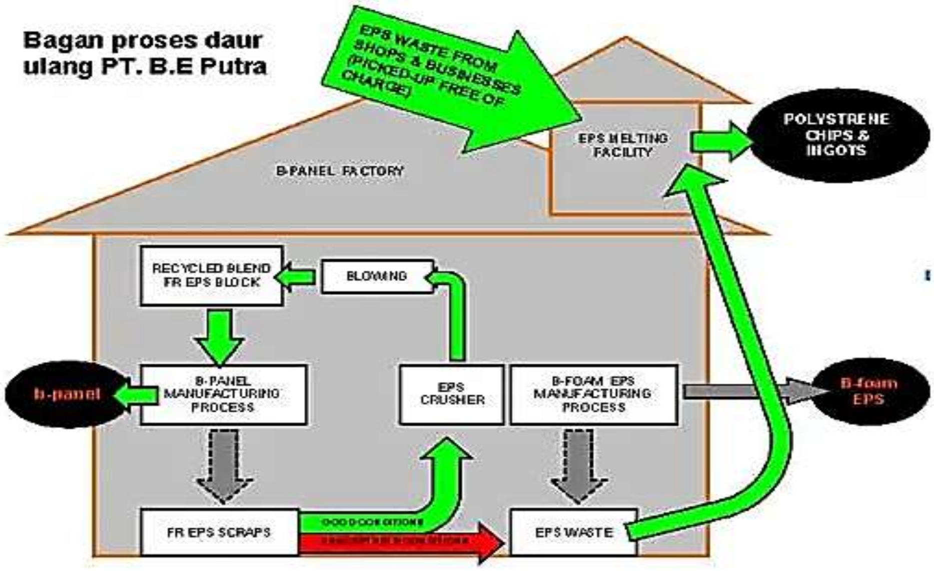

Figure 8. EPS Material Recycling Process Drawing

CONCLUSION

The study concluded that unstable clay shale conditions and high rainfall at STA 40+125 to STA 40+225 increased the likelihood of cracks, landslides, and occupational safety risks in the Cisumdawu Package 5A Project. Strengthening *K3* risk management is essential due to inadequate baseline data and limited reporting on previous incidents. The use of geofoam was found to significantly minimize work accidents by reducing dependence on heavy equipment, thereby lowering emissions, dust, and noise exposure that contribute to occupational diseases. Additionally, geofoam decreased environmental pollution and land disturbance, supporting sustainable construction practices. Nevertheless, attention should be given to geofoam's susceptibility to organic solvents and flammable liquids. Future research should focus on developing safety guidelines and material protection protocols for geofoam use in high-risk and varying environmental conditions to enhance long-term performance and worker safety.

REFERENCES

Adhi Tol Cisumdawu 5A. (2021). *Buku pedoman pelaksanaan proyek pekerjaan pembangunan Jalan Tol Cisumdawu Paket 5A*. Sumedang: Adhi Tol Cisumdawu 5A.

Adhi Tol Cisumdawu 5A. (2021, Juni). *Pre-construction meeting: Pekerjaan pembangunan Jalan Tol Cisumdawu Paket 5A*. Sumedang, Jawa Barat, Indonesia: Adhi Tol Cisumdawu 5A.

Adhi Tol Cisumdawu 5A. (2023). *Gambar kerja pekerjaan timbunan tanah: Pekerjaan pembangunan Jalan Tol Cisumdawu Paket 5A*. Sumedang, Jawa Barat, Indonesia: Adhi Tol Cisumdawu 5A.

Andrawan, Prihatiningsih, A., W, J., & Johan, A. (2025). Analisis kinerja expanded polystyrene (EPS) geofoam sebagai material timbunan. *Jurnal Mitra Teknik Sipil, 8*, 405–414.

Baghdadi, A. (2024). Navigating occupational safety and health challenges in sustainable infrastructure projects: A comprehensive review. *Frontiers in Built Environment, 10*, 1414366.

Geotechnical Engineering Consultant. (2023). *Desain rehabilitasi longsoran Jalan Tol Cisumdawu STA 40+200*. Bandung: Geotechnical Engineering Consultant.

Geotechnical Engineering Consultant. (2023). *Laporan inception redesain lereng timbunan STA 40+200 proyek Jalan Tol Cisumdawu Paket 5A Sumedang*. Bandung: Geotechnical Engineering Consultant.

Geotechnical Engineering Consultant. (2023). *Laporan interim redesain lereng timbunan STA 40+200 proyek Jalan Tol Cisumdawu Paket 5A Sumedang*. Bandung: Geotechnical Engineering Consultant.

Gunawan, A. (2020). Geofoam: A potential for Indonesia's soil problem. *IOP Conference Series: Earth and Environmental Science, 426*.

Gunawan, A. (2022). Geofoam: A potential for Indonesia's soil problem III – Stabilizing retaining wall. *IOP Conference Series: Earth and Environmental Science, 998*.

Gunawan, A. (2023). Geofoam: A potential for Indonesia's soil problem IV – Update on geofoam application. *IOP Conference Series: Earth and Environmental Science, 1324*.

Naskar, J., Kumar Jha, A., Singh, T. N., & Aeron, S. (2025). Climate change and soil resilience: A critical appraisal on innovative techniques for sustainable ground improvement and ecosystem protection. *Journal of Hazardous, Toxic, and Radioactive Waste, 29*(4), 3125002.

Pandey, T. (2025). *Introduction to soil mechanics*. Educohack Press.

Priyanto, H., & Yunus, F. (2016). Pengaruh gas buang kendaraan bermotor terhadap faal paru. Dalam A. D. Susanto, F. Yunus, M. Ikhsan, & F. Fitriani (Eds.), *Penyakit paru kerja & lingkungan* (hlm. 114–126). Jakarta: Penerbit Universitas Indonesia (UI-Press).

Rahardjo, P. P. (2023). *Kajian stabilitas Jalan Tol Cisumdawu STA 40+200*. Sumedang.

Rahardjo, P. P., Anggoro, B., M, W., & DP, S. (2023). EPS–Geofoam as lightweight material for replacement of embankment fill to overcome landslide problems at STA 40+200 of Cisumdawu Toll Road, West Java. *IOP Conference Series: Earth and Environmental Science, 1249*.

Ramli, S. (2018). *Sistem manajemen keselamatan & kesehatan kerja OHSAS 18001*. Jakarta: Dian Rakyat.

Royani, & Taufik, F. F. (2016). Efek debu karbon terhadap kesehatan paru. Dalam A. D. Susanto, F. Yunus, M. Ikhsan, & F. Fitriani (Eds.), *Penyakit paru kerja dan lingkungan* (hlm. 85–98). Jakarta: Penerbit Universitas Indonesia (UI-Press).

Samoedro, E., Agustin, H., & Isbaniyah, F. (2016). TB paru di tempat kerja. Dalam A. D. Susanto, F. Yunus, M. Ikhsan, & F. Fitriani (Eds.), *Penyakit paru kerja & lingkungan* (hlm. 225–233). Jakarta: Penerbit Universitas Indonesia (UI-Press).

Suma'mur. (1988). *Higiene perusahaan dan kesehatan kerja*. Jakarta: CV Haji Masagung.

Suma'mur. (1989). *Keselamatan kerja & pencegahan kecelakaan*. Jakarta: CV Haji Masagung.

Saputra, F., & Mahaputra, M. R. (2022). Building occupational safety and health (K3): Analysis of the work environment and work discipline. *Journal of Law, Politic and Humanities, 2*(3), 105–114.

Wulan, K. T. (2024). Innovation in sustainable construction materials in green infrastructure development. *Research of Scientia Naturalis, 1*(3), 144–153.