International Journal of GEOMATE, April, 2026 Vol.30, Issue 140, pp.68-75
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2026.140.g15205
Geotechnique, Construction Materials and Environment

STUDY ON INTERACTION OF PULL-OUT TESTING BETWEEN TIN TAILING AND REINFORCEMENT FOR GEOSYNTHETIC REINFORCED SOIL ABUTMENT

Wijit Itthiwongkul[1], *Peet Homchuen[2], Suphamat Chaichana[3], Tanapon Khunin[4] and Zhen Zhang[5]

[1, 3, 4]Faculty of Engineering, Rajamangala University of Technology Lanna, Thailand; [2]Department of Mining and Petroleum Engineering, Chulalongkorn University, Thailand; [5]Department of Geotechnical Engineering, Tongji University, China.

*Corresponding Author, Received: 31 May 2025, Revised: 30 Jan. 2026, Accepted: 31 Jan. 2026

ABSTRACT: This paper presents a relevant and timely study on the use of tin tailings, which are the solid waste material extracted from tin mineral processing at tin mine in the northern region of Thailand, as an alternative backfill material in Geosynthetic Reinforced Soil (GRS) abutments. By conducting a series of physical model tests under varying normal loads, including a test with a single-layered and double-layered geosynthetic reinforcement. The study provides practical insights into the pull-out behavior and deformation characteristics of the GRS composite system. The application of tailings characterized a mixture of various particle sizes with a maximum particle size of 4.75 mm, and a friction angle of 37° which demonstrates a promising approach to sustainable construction. The tailing mainly contains Silicon (Si) and other different proportions of elements without harmful chemical components. The paper aligns well with current engineering practices and sustainability goals by integrating waste utilization within the context of GRS design.

Keywords: Waste material, Tin mine, GRS, Pull-out behavior, Deformation

1. INTRODUCTION

In recent years, the trend of green and sustainable construction materials has witnessed a notable rise in relation to environmental concerns, economics, and social aspects [1-3]. Waste material is by-products in production processes and it is alternative choices for practical applications, including road construction, geosynthetic-reinforced transport infrastructure systems, pavement, embankments, load-bearing foundations, slopes, cement production, agriculture, and backfilling in underground mining, etc. [4-8]. Recent studies published in the International Journal of GEOMATE further emphasize the importance of environmentally responsible construction materials and sustainable engineering practices in geotechnical and infrastructure applications [9-12]. Currently, the selection of materials for construction work involves more than just strength. There are other critical factors to consider, such as cost-effectiveness, which include the price of materials, transportation to the site area, operational costs, safety concerns, healthy working conditions, and the use of environmentally friendly materials. Additionally, materials that emit low levels of carbon dioxide have a long-life cycle and can be reused with considered good options [13-17]. In mineral-rich regions, particularly in Southeast Asia, the reuse of mining waste for civil and geotechnical engineering applications offers a promising pathway toward sustainable infrastructure development. Several recent GEOMATE studies have reported the feasibility of incorporating industrial by-products and waste-derived materials into geotechnical systems, highlighting both environmental benefits and acceptable mechanical performance [9]. Thus, according to previous reasons, the waste materials from the mining industry are also seen as a beneficial choice for utilization [18-21].

This study highlights the waste materials from surface mining, particularly located near urban areas. These materials are considered alternatives for utilization and development to transportation infrastructure in northern region of Thailand. There are many alternative waste materials in this region, which include various types from mining operations, such as quarries, mineral extraction, coal mining, overburden excavation, sand mining, as well as kaolin mining. Emphasizing ore processing in mining, particularly regarding the waste materials extracted from Tin ore processing. Among these, tin tailings generated from tin ore processing have accumulated in large surface stockpiles and remain largely unused, despite their favorable granular characteristics and mechanical potential. Tin tailings are solid waste materials produced during mineral beneficiation processes, typically consisting of sand-sized to fine-gravel particles with high silica content and minimal harmful chemical components. The tailings have been stockpiled over extensive surface areas and have remained unused since mining operations began as shown on Fig. 1.

Fig. 2 depicts the basic flowchart of extracted Tin mineral process. In general, the process to produce Tin production can be divided into 2 parts: the mining process and the extraction process. The mining process is the process of preparing raw material, which includes planning to remove overburden and then using drilling and blast techniques to reduce the size by explosives that have high energy and create high shockwave after detonation. The drilling follows the mineral veins. The mining machines are used to dig and load raw material into the mine trucks, which are then hauled to the crusher plant that employs reduction steps. In this step, the raw material is reduced to small size and prepares for the following step. Finally, the production results in concentrated Tin production by using jig concentrators, electric, and magnetic separators. The tailings are delivered to waste stockpiles. To manage and optimize the natural resources, as well as the financial aspects and lifespan of mine. Firstly, low-grade raw materials can be blended with high-grade material using blending techniques.

Fig. 1 Location of Tin tailings, northern region of Thailand

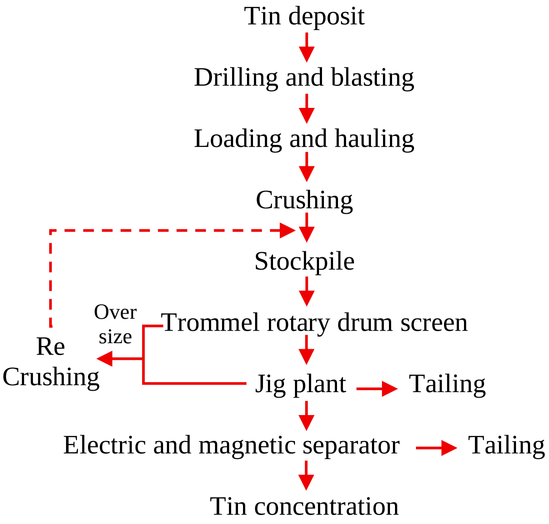


Fig. 2 Basic flowchart of extracted Tin mineral process

Regarding utilization of the tailing from Tin mining in an engineering context, the Geosynthetic Reinforced Soil (GRS) structure consists of dense multiple layers of a densely compacted fill and closely spaced geosynthetic reinforcement, and a stable facing block with either frictional or mechanical connections. The GRS structure is widely used in practice due to its advantages, such as being easier to construct, more economical, requiring less over-excavation, more ductile, more flexible, and it can be quickly built times. Moreover, GRS technology has a lower environmental impact as it uses less CO_2 emitting materials in its life cycle, and the materials can contribute to road infrastructures as they can be used as gravel for example, once their life cycle has ended. GRS technique has been adopted in many engineering contexts, including retaining walls, embankment, load-bearing structure, bridge abutment, etc. This construction consists of densely compacted backfill with closely spaced geosynthetic materials. Additionally, the space between each layer of geosynthetic sheet is usually laid less than 300 mm [17, 22-25]. Design and performance aspects of GRS structures have been extensively discussed in FHWA guidelines and supported by recent experimental investigations reported in GEOMATE, particularly regarding reinforced soil behavior under service and ultimate loading conditions [9, 10]. The calculation of bearing capacity for GRS composite is influenced by various internal factors, as shown in Eq. (1)

$$q_{ult} = (\sigma_c + 0.7^{(\frac{Sv}{6d_{max}})}\frac{T_f}{S_v})K_p + 2c\sqrt{Kp} \quad (1)$$

Where:

q_{ult}: Ultimate bearing capacity

σ_c: External confining stress due to the facing element

S_v: Vertical reinforcement spacing

d_{max}: Maximum particle size

T_f: Ultimate tensile strength of the geosynthetic reinforcement

K_p: Coefficient of passive earth pressure of the backfill

c: Cohesion of the backfill

However, according to current design guideline for GRS bridge abutments, the facing element is typically not treated as a structural component of the GRS abutment. Furthermore, the confining stress induced by the facing element is often disregarded, assuming a confining stress of 0. In addition, in this design, cohesion is also eliminated since it cannot be relied on for long-term strength as Eq. (2), Eq. (3) [23].

$$q_{ult} = (0.7^{(\frac{Sv}{6d_{max}})}\frac{Tf}{Sv})Kp \quad (2)$$

$$\sigma_c = \gamma_b d \tan\delta \quad (3)$$

Where:

γ_b : Unit weight of facing block

d : Depth of the facing block

δ : Friction angle between the geosynthetic reinforcement and facing element

The mechanical behavior of GRS structures is strongly governed by the interaction between backfill materials and geosynthetic reinforcement. Among various interaction mechanisms, pull-out resistance plays a critical role in internal stability and load transfer within reinforced soil masses. Pull-out behavior is influenced by normal stress, backfill gradation, friction angle, reinforcement surface characteristics, and reinforcement configuration. Recent GEOMATE studies have investigated geosynthetic-soil interface behavior using direct shear and related experimental approaches, demonstrating the sensitivity of interface strength to material type and loading conditions [9]. However, most of these investigations have focused on conventional granular soils or cement-treated materials, while experimental data involving mining waste backfills remain scarce.

Despite the growing body of research on reinforced soil systems, clear research gaps remain. Existing studies predominantly address natural aggregates or recycled construction materials as backfill, whereas experimental investigations involving mining tailings—particularly tin tailings—are limited. Furthermore, insufficient attention has been given to evaluating pull-out behavior under normal stresses representative of bridge service loads, as well as the influence of multiple reinforcement layers when unconventional backfill materials are employed. Recent GEOMATE publications have emphasized the need for experimentally validated reinforced soil behavior under realistic loading conditions to support sustainable design frameworks [9-11]. Therefore, a concept has been developed to study waste materials that impact the environment, are low in cost to manage, and can be suitably applied to local conditions by creating a physical model that simulates the real area for practical application. This paper was conducted on a series of physical models and investigates the characteristics of Tin tailings and reinforcement for geosynthetic reinforced soil abutment under vertical loading using the pull-out loading technique and focus on the above parameters.

This paper is organized as follows. Section 2 presents the research significance and highlights the novelty of the study. Section 3 describes the materials, experimental setup, and test program, including properties of tin tailings and geosynthetic reinforcement. Section 4 discusses experimental results and pull-out behavior under varying normal stresses. Finally, Section 5 summarizes the main conclusions and implications for sustainable GRS design and future research.

2. RESEARCH SIGNIFICANCE

This study presents an innovative experimental investigation into the pull-out interaction between tin tailings and the geosynthetic reinforcement for Geosynthetic Reinforced Soil (GRS) abutments. Unlike previous studies that mainly employed conventional granular backfills, this research evaluates mining waste materials under simulated bridge service loads. The originality lies in integrating tin tailings with single and double-layer geosynthetic reinforcements to assess load displacement behavior and deformation mechanisms. The findings provide new insights into the feasibility of reusing tin tailings as sustainable backfill materials, contributing to environmentally responsible infrastructure development and expanding the application of waste-derived materials in GRS design.

3. MODEL TEST

3.1 Material and Preparation

3.1.1 Tin tailings backfill soil

The Tin tailing was selected as the backfill soil for GRS applications. This tailing was used to investigate in this experiment. The first five main chemical compositions consist of Silicon (Si), Magnesium (Mg), Aluminum (Al), Calcium (Ca), and Iron (Fe) as showed in Fig. **3**. Tin tailings backfill appears in dark yellow color and contains with various particle sizes as depicted in a line graph of gradation backfill by sieve analysis (Fig. 4). The Tin tailings backfill was screened particles, which determined a maximum particle size of 4.75 mm. In addition, the uniformity and curvature coefficients are around 5.4 and 1, respectively. This waste material takes into accounts to the well-graded backfill specifications, following FHWA guidelines. The properties of the backfill were determined including specific gravity, cohesion, friction angle, min. and max. dry unit weight were depicted in Fig. **5** and Table 1.

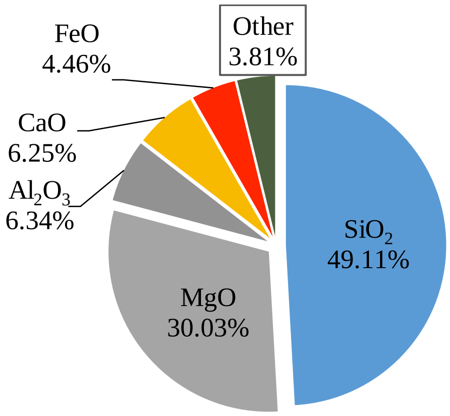


Fig. 3 Main Chemical compositions of Tin tailings

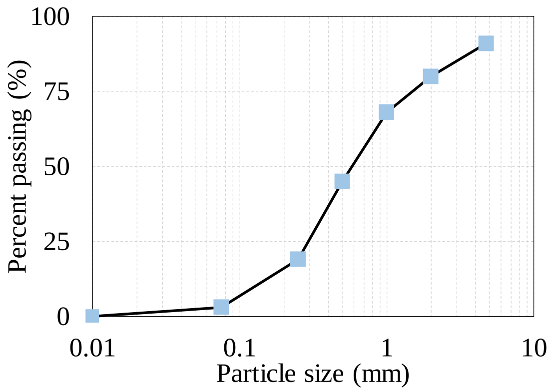


Fig. 4 Particle size gradation curve of Tin tailings

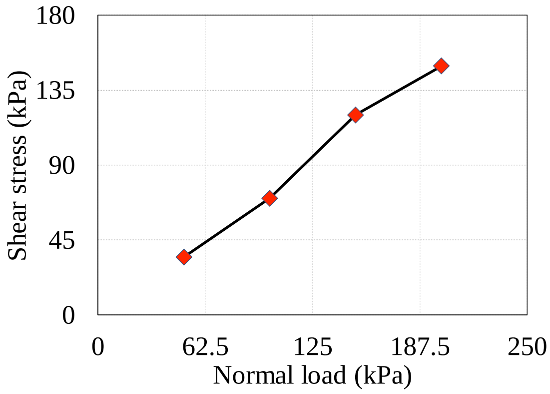


Fig. 5 The relationship between normal stress and shear stress at peak from direct shear test

Table 1 The properties of Tin backfill soil

Properties	Unit	Test Method	Tailing
Max. particle size	mm	Sieve analysis	4.75
Mean particle size	mm	Sieve analysis	0.61
Uniform coefficient	-	USCS	5.4
Curvature coefficient	-	USCS	1
Min. dry unit weight	g/cm^3	Relative Density	1.255
Max. dry unit weight	g/cm^3	Relative Density	1.600
SG	-	Water replacement	2.71
Cohesion	kPa	Direct shear test	0
Internal friction Angle	°	Direct shear test	37

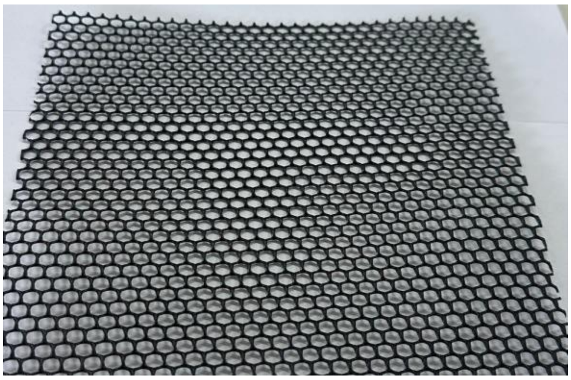


Fig. 6 Polyvinyl Chloride mesh

3.1.2 Reinforcement

Fig. 6 shows the back color of Polyvinyl Chloride mesh (PVC) was selected as geosynthetic applications in function of reinforcement for this study, with an aperture size of 5 mm, 16 holes of 100 mm, and a thickness of 2 mm for each layer. The dimensions of the PVC sheet were 300 mm in width and 420 mm in length due to the factor of GRS design, typically expressed as a base-to-height ratio (B/H) of 0.7 [23, 26].

3.2 Test Plans

There are five different experiments that applied normal load at the top of model tests ranging from 0 kPa to 400 kPa. The experiments are focused on the pull-out loading characteristics and displacement of reinforcement. To ensure consistency, a compaction level is greater than 95% of maximum dry unit weight. Tests 1 to 4 were conducted with loads of 0, 100, 200 and 400 kPa. For Test 5 was conducted in the same manner as Test 3, but an additional double sheet of geosynthetic, as detailed in Table 2.

Table 2 Test plan

Test	Normal load (kPa)	Backfill
1	0	Tin tailings
2	100	Tin tailings
3	200	Tin tailings
4	400	Tin tailings
5	200*	Tin tailings

*Note: * A double geosynthetic sheet.*

3.3 Model Test Setup

Fig. 7 shows the right-side view of the physical model, which consists of model box, backfill, geosynthetic reinforcement, digital dial gauge, hydraulic jack and load cell. The model box has the inside dimensions of 300 mm in width, 1000 mm in length, and 600 mm in height. The model was constructed with 4-side wood and 1-side transparent panel that allows us to observe the interaction between backfill and geosynthetic during testing in a rigid frame. Furthermore, the top side is open to fill the backfill through this way. The rectangular outlet gap is 300 mm in length and 20 mm in width. A narrow gap of around 5 mm was left on top-bottom sides of geosynthetic sheet to prevent the friction between outlet wood and geosynthetic sheet during pull out by horizontal hydraulic jack. The geosynthetic sheet was allowed for lateral movement, as shown in Fig. 8.

A Geosynthetic sheet was placed in the middle height of model, which followed the FHWA guideline for bridge abutment. Moreover, the dense layer between the backfill and geosynthetic sheet is less than 300 mm.

The strip footing is a rigid plate that is placed as the beam seat in the prototype to receive the load of an integrated superstructure. However, in the experiment, a vertically distributed load was applied from the hydraulic jack and placed on the top of model at a setback distance of 40 mm behind reinforced soil. In addition, the size of the strip footing plate is 300 mm in width and 250 mm in length.

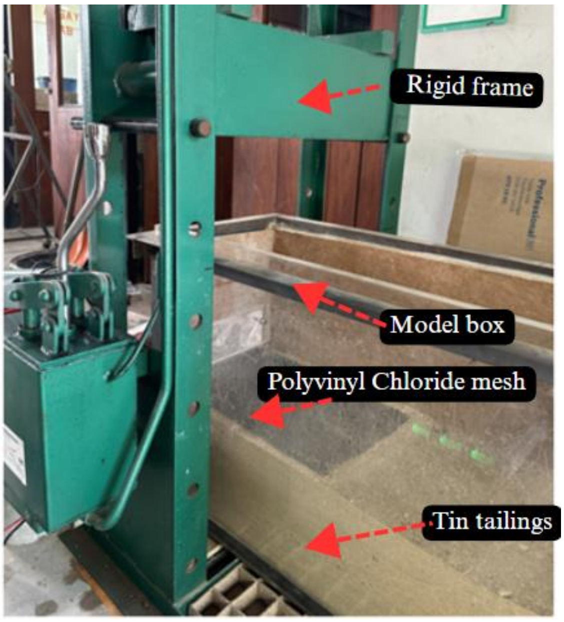


Fig. 7 Right-side view of the physical model

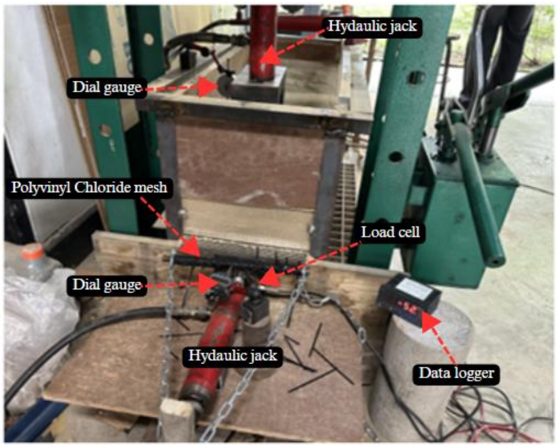


Fig. 8 A geosynthetic sheet in lateral movement

3.4 Loading Procedure

In this study, the vertical hydraulic jack was maintained and pressurized to apply normal pressure during testing. A distributed surcharge load applied to the model test, which applied an incremental pulling load of around 50 N per minute for the geosynthetic sheet until reaching maximum load. Throughout the performance test, the monitoring instruments displayed real-time data on screen, including vertical applied loading, vertical and lateral displacement and pull-out loading, as well as visual observation of the geosynthetic sheet and backfill soil through the transparent plexiglass.

4. RESULT AND DISCUSSION

4.1 Pull-out Loading Characteristics

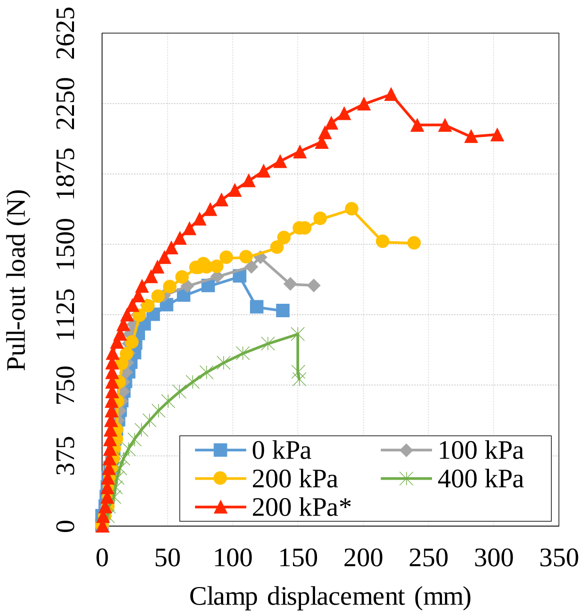
Fig. 9 shows pull-out loads and lateral displacement of model tests when the applied normal load on the strip footing ranged from 0 to 400 kPa at the top of the model. The GRS abutments are recommended to have a typical load at 200 kPa [27]. The graph demonstrates a steady line between pull-out load and displacement of geosynthetic, exhibiting elastic behavior characterized by a linear relationship according to Young's modulus. However, in the next stage, the lateral displacement rapidly increases, exceeding the maximum load and reaching frictional resistance. Finally, the pull-out load sharply drops with increasing displacement, then becomes steady, following the same trend of all five model tests. Test 1 carried out without normal stress on the top of model test, the result of this case showed the lowest pull-out load due to only frictional resistance between backfill and geosynthetic sheet. Test 4, with a normal stress of 400 kPa, experienced a significant rupture of geosynthetic sheets at front of reinforced soil composite. In terms of GRS abutments under bridge service load, the behavior of pull-out loading exhibits a higher load with longer displacement. Moreover, the use of a double geosynthetic sheet occurred a higher load capacity compared to a single sheet.

Fig. 10 shows the influence of normal stress on pull-out loads, the results indicate that the normal load increased as pull-out load increased.

Visual observations between the geosynthetic layer and backfill through the transparent plexiglass demonstrated the minimal changing due to slow movement of reinforcement.

5. CONCLUSIONS

The study compared and analyzed the results of five experimental tests, focusing on the pull-out loading and deformation behavior of the Geosynthetic Reinforced Soil (GRS) composite system. The results indicate that the pull-out resistance of the GRS composite increased with increasing normal stress applied at the top of the model. When a double layer geosynthetic reinforcement was used, the increased tensile capacity resulted in a higher pull-out load accompanied by larger displacement. Under bridge service load conditions of 200 kPa, the pull-out load capacity increased by approximately 1.2 times compared with the unloaded condition. Furthermore, the use of double layer geosynthetic reinforcement led to a significant improvement in pull-out resistance of approximately 1.7 times.



*Note: * A double geosynthetic sheet.*

Fig. 9 Pull-out loads-displacement curve of geosynthetic sheet at different normal stress

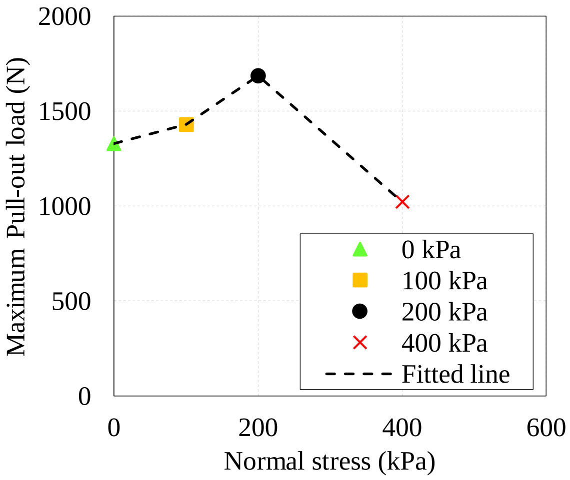


Fig. 10 Influence of normal stress on pull-out loads

All experimental cases exhibited a similar load displacement trend. After exceeding the peak frictional resistance at the interface between the backfill and the geosynthetic reinforcement, the pull-out load decreased and subsequently reached a stable residual value. Failure of geosynthetic reinforcement was characterized by a sudden rupture under excessive normal loading, with the rupture consistently occurring near the front of the GRS composite.

In addition, this study confirms that tin tailings can be effectively reused as a sustainable alternative backfill material for Geosynthetic Reinforced Soil abutments when combined with geosynthetic reinforcement. The experimental investigation of pull-out interaction under bridge service load conditions provides new evidence addressing the limitations of previous studies that primarily focused on conventional granular backfills. The comparison between single-layer and double-layer geosynthetic reinforcements demonstrate that reinforcement configuration plays a significant role in enhancing pull-out resistance and deformation performance. These findings contribute to a better understanding of soil-reinforcement interaction involving mining waste materials and support the integration of waste-derived resources into sustainable GRS design and infrastructure development.

6. ACKNOWLEDGMENTS

The authors appreciate the support provided by faculty of Engineering, Rajamangala University of Technology Lanna and department of Mining and Petroleum Engineering, Chulalongkorn University, Thailand.

7. REFERENCES

[1] Popescu C., Dissanayake H., Mansi E., and Stancu A., Eco Breakthroughs: Sustainable Materials Transforming the Future of Our Planet, Sustainability, Vol. 16, Issue 23, 2024, pp. 1-38, 10790. https://doi.org/10.3390/su162310790

[2] United Nations, Critical Milestones Towards a Coherent, Efficient, and Inclusive Follow-up and Review of the 2030 Agenda at the Global Level, 2015.

[3] Hasmori, M.F., Zin, A.F.M., Nagapan, S., Deraman, R., Abas, N., Yunus, R. and Klufallah, M., The on-site Waste Minimization Practices for Construction Waste, IOP Conference Series: Materials Science and Engineering, Vol. 713, Issue 1, 2020, pp. 1-11, 012038. https://doi.org/10.1088/1757899X/713/1/012038

[4] Guo, J., Bao, Y. and Wang, M., Steel Slag in China: Treatment, Recycling, and Management, Waste Management, Vol. 78, 2018, pp. 318-330. https://doi.org/10.1016/j.wasman.2018.04.045

[5] Zhang Q., Zhang J., Huang Y., and Ju F. Backfilling Technology and Strata Behaviors in Fully Mechanized Coal Mining Working Face. International Journal of Mining Science and

Technology, Vol. 22, Issue 2, 2012, pp. 151-157. https://doi.org/10.1016/j.ijmst.2011.08.003

[6] Turuallo G., Mallisa H., and Rupang N., Sustainable Development: Using Stone Dust to Replace a Part of Sand in Concrete Mixture, in MATEC Web of Conferences, Vol. 331, 2020, pp. 05001. https://doi.org/10.1051/matecconf/202033105001

[7] Hangen H. and Detert O., Innovative and Sustainable Geosynthetic Solutions in the Field of Bridge Abutment Construction, in Geotechnical Engineering Challenges to Meet Current and Emerging Needs of Society: CRC Press, 2024, pp. 2317-2322. https://doi.org/10.1201/9781003431749-443

[8] Ahmed I., Use of waste materials in highway construction, Joint Transportation Research Program, 1991, pp. 299. https://doi.org/10.5703/1288284313423

[9] Ranasinghe, R., Barnes, G., and Rajapakse, J., Investigation of geosynthetic-soil interface shear characteristics using a large direct shear apparatus, *International Journal of GEOMATE*, Vol. 29, No. 132, 2025, pp. 52-59. https://doi.org/10.21660/2025.132.4918

[10] Douangmixay, D., Mounnarath, P., and Eua-Apiwatch, S., Evaluation of load carrying capacity of PC I-girder and steel I-girder bridge under heavy vehicle, *International Journal of GEOMATE*, Vol. 28, No. 130, 2025, pp. 51-58. https://doi.org/10.21660/2025.130.4835

[11] Kongsung, T., Isago, N., and Tomita, T., The gathering of a dataset for tunnels and the assessment of predicted construction delay models utilizing regression and adaptive boosting techniques, *International Journal of GEOMATE*, Vol. 29, No. 135, 2025, pp. 1-15. https://doi.org/10.21660/2025.135.5065

[12] Mauludin, L. M., Susanto, A., Keryanti, and Hafizh, M., Healing efficiency of *Bacillus megaterium* for microcracks in concrete: A study of biopolymer encapsulation performance, *International Journal of GEOMATE*, Vol. 29, No. 135, 2025, pp. 16-26. https://doi.org/10.21660/2025.135.5046

[13] Iqbal M. J., Zaman B., and Budihardjo M. A., Utilization of Recycled and Waste Material in Construction - a Review, IOP Conference Series: Earth and Environmental Science, Vol. 1268, Issue 1, 2023, pp. 012046. https://doi.org/10.1088/1755-1315/1268/1/012046

[14] Raja J., Dixon N., Fowmes G., Frost M., and Assinder P., Obtaining Reliable Embodied Carbon Values for Geosynthetics, Geosynthetics International, Vol. 22, Issue 5, 2015, pp. 393-401. https://doi.org/10.1680/jgein.15.00020

[15] Moncada A., Olivella S., Damians I. and Bathurst R. J., Impact of Transport Distance in Life Cycle Assessments of Geosynthetic Reinforced Soil Walls, in Geotechnical Engineering Challenges to Meet Current and Emerging Needs of Society: CRC Press, 2024, pp. 3149-3152. https://doi.org/10.1201/9781003431749

[16] Ferreira F., Pereira P. V., Ribeiro P. B., Vieira C. S., Lopes P., and de Lurdes Lopes M., Recycled Construction and Demolition Aggregates as Alternative Fill Materials for Geosynthetic Reinforced Systems, in Proceedings of the Technical Workshop on Reinforcement and Drainage in Soil Structures, Vol. 662, 2025, pp. 1-5, 05001. https://doi.org/10.1051/e3sconf/202566205001

[17] Bizjak K. F. and Lenart S., Life Cycle Assessment of a Geosynthetic-Reinforced Soil Bridge System-A Case Study, Geotextiles and Geomembranes, Vol. 46, Issue 5, 2018, pp. 543-558. https://doi.org/10.1016/j.geotexmem.2018.04.012

[18] Zetola V., Keith BF., Lam EJ., Montofré ÍL., Rojas RJ., Marín J., and Becerra M., From Mine Waste to Construction Materials: A Bibliometric Analysis of Mining Waste Recovery and Tailing Utilization in Construction, Sustainability, Vol. 16, Issue 23, 2024, pp. 1-28, 10314. https://doi.org/10.3390/su162310314

[19] Satapathy S., Mishra M., and Das M. R., Sustainable Waste Management Practices for the Mining Sector Through Recycling of Mining Waste. Springer Nature Switzerland, 2024. https://doi.org/10.1007/978-3-031-67932-2

[20] Makhathini T. P., Bwapwa J. K., and Mtsweni S., Various Options for Mining and Metallurgical Waste in the Circular Economy: A Review, Sustainability, Vol. 15, Issue 3, 2023, pp. 2518. https://doi.org/10.3390/su15032518

[21] Gairola S. U., Khanduri A. K. and Bhuvaneswari V., Sustainable Mining: Reducing Waste and Enhancing Resource Efficiency, Discover Civil Engineering, Vol. 2, Issue 1, 2025, pp. 75. https://doi.org/10.1007/s44290-025-00233-9

[22] Wu J. T. H., Pham T. Q. and Adams M. T., Composite Behavior of Geosynthetic Reinforced Soil Mass, Federal Highway Administration, McLean, VA, Report No. FHWA-HRT-10-077, 2013.

[23] Adams M. and Nicks J., Design and Construction Guidelines for Geosynthetic Reinforced Soil Abutments and Integrated Bridge Systems, United States. Federal Highway Administration, McLean, VA, Report No. FHWA-HRT-17-080, 2018.

[24] Saghebfar M., Abu-Farsakh M., Ardah A., Chen Q., and Fernande B. A. Z, Performance Monitoring of Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) in Louisiana, Geotextiles and Geomembranes, Vol. 45, Issue 2, 2017, pp. 34-47. http://dx.doi.org/10.1016/j.geotexmem.2016.11.004

[25] Wu J., Adams M., Pham T., Lee S., and Ma C., A generic Soil-Geosynthetic Composite Test, International Journal of Geotechnical Engineering, Vol. 6, Issue 1, 2012, pp. 103-116. http://dx.doi.org/10.3328/IJGE.2012.06.01.103-116

[26] Adams M., Nicks J., Stabile T., Wu J., Schlatter W., and Hartmann J., Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide, Federal Highway Administration, McLean, VA, Report No. FHWA-HRT-11-026, 2012.

[27] Nicks J. E., Esmaili D., and Adams M. T., Deformations of Geosynthetic Reinforced Soil under Bridge Service Loads, Geotextiles and Geomembranes, 44(4), 2016, pp. 641-653. https://doi.org/0.1016/j.geotexmem.2016.03.005