

Lecture Notes in Civil Engineering

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Lukas Beladi Sihombing ·
Yee Yong Lee · Harianto Hardjasaputra ·
Simone Stürwald *Editors*

Proceedings of the 9th International Conference of EURO ASIA Civil Engineering Forum – Volume 1

EACEF 2025, September 9–11, Kuching,
Malaysia

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Preface

Civil engineering has long been at the leading edge of human civilization, offering the essential infrastructure that continually strives for advances in both theoretical aspects and practical applications. To date, it experiences ever-expanding challenges that require sustainable, resilient, and future-ready solutions. In this spirit, the 9th International Conference of Euro Asia Civil Engineering Forum (EACEF 2025) was organized with the theme “Beyond Boundaries: Empowering Innovations in Civil and Environmental Engineering.” The conference illuminates the importance of interdisciplinary collaboration and cutting-edge research to meet future needs.

The event was hosted by Universiti Malaysia Sarawak (UNIMAS) in cooperation with Universitas Pembangunan Jaya (UPJ), Indonesia, at Dewan Tunku Abdul Rahman Putra (DeTAR Putra), UNIMAS, Sarawak, Malaysia, on 9–11 September 2025.

EACEF 2025 brought together researchers, academics, and practitioners from across the globe to share insights for a wide range of topics, including structural and materials engineering, geotechnical engineering, construction management, building information modeling, green and sustainable construction, geotechnical construction material innovations, water resources engineering, transportation engineering, and other developing fields within civil and environmental engineering.

This proceedings book reflects the rigorous academic readiness that was carried out for the conference. Eighty manuscripts were received. Each paper underwent a single-blind review process by at least two reviewers. Based on their recommendations and the publication committee’s evaluation, 37 papers were accepted for this book. This procedure ensures that the papers fulfill the required standards for quality and field-relevance.

We extend our heartiest gratitude to the authors for their valuable contributions, the reviewers for their critical and constructive comments, and the organizing team for their dedication in bringing this conference to fruition. We also acknowledge the institutional support from UNIMAS and UPJ, whose collaboration has enriched the success of this event.

To promote the healthy advancement of civil and environmental engineering, we hope that the research outcomes, discussions, and innovations in this proceeding will motivate future cross-disciplinary and cross-border cooperations.

November 2025

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Contents

Ultra-High-Performance Concrete in Bridge Construction: A Sustainability Perspective Through Two Case Studies	1
<i>Hui-Teng Ng, Yen Lei Voo, and Jhen Shen Tan</i>	
First Anchor Channel Qualified for Three-Dimensional Fatigue Actions in Tension and Shear	17
<i>Christoph Mahrenholtz and Thilo Fröhlich</i>	
Properties of Sustainable Foamed Concrete: Enhancing Sound and Water Absorption with Recycled Concrete Aggregate and Rice Husk Ash	30
<i>Norhaida Mohamed, Nor Azian Aziz, and Zamri Hashim</i>	
Evaluating the Compressive Strength of Artificial Aggregate Blended with Fly Ash and Rice Husk Ash	41
<i>P. Pratika Riris, Raudhah Binti Ahmadi, Rezaur Rahman, M. Abdul Mannan, M. Ardiansyah Sidiq, and Harianto Hardjasaputra</i>	
Mechanical Properties of Cellular Lightweight Concrete Incorporating Fly Ash and Polypropylene Fiber	52
<i>Reni Suryanita, Harnedi Maizir, Dewi Padila Ali, and M. G. Intan Monica</i>	
Optimization of Mechanical Properties in Lightweight Mortar Using Palm Oil Waste	65
<i>Harnedi Maizir, Randhi Saily, Puspa Ningrum, and Raihan Arditama Harnedi</i>	
Fatigue Behavior of Anchor Channels in Case of Concrete Edge Failure	77
<i>Thilo Fröhlich, Stefan Castridis, and Christoph Mahrenholtz</i>	
Analytical Study on Seismic Performance of the Andalas University Earthquake-Resistant House (RAG UNAND) Using Ferrocement Layer Reinforcement for Subsidized Housing in Indonesia	90
<i>Fauzan, Abdul Hakam, Febrin Anas Ismail, Werry Darta Taifur, Muhammad Arisman, and Julita Andrini Repadi</i>	
Effect of Location and Thickness of Cantilever Shear Walls with Boundary Element in Symmetrical and Asymmetrical Reinforced Concrete Multi-story Buildings	104
<i>Grisella Audria Gunawan, Junaedi Utomo, and Ade Lisantono</i>	



Health Monitoring of Old Steel Bridges: Case Study for Tan Thuan 1 Bridge - Ho Chi Minh City – Vietnam	116
<i>Lan Nguyen, Hau Nguyen-Ngoc, Le Tan Kien, Nguyen Tien Binh, Nguyen Xuan Khoa, and Vu Ba Tu</i>	
Assessment of an Existing Steel Truss Railway Bridge with Operational Loads to Obtain Structural Performance	129
<i>Humman Abdul Hafidh, Anis Rosyidah, Jonathan Saputra, and I Ketut Sucita</i>	
Flexural Performance of Concrete Slabs Reinforced with Glass Fiber Reinforced Polymer and Steel Bars	141
<i>Rafi Ubaidillah Rachman, Anis Rosyidah, Jonathan Saputra, I Ketut Sucita, and Michael Andy</i>	
Increased Compressive Strength of Concrete with Glass Fiber Reinforced Polymer (GFRP) Mesh Jacketing	151
<i>Putranto Yusuf Hadi Wibowo, Anis Rosyidah, Jonathan Saputra, I Ketut Sucita, and Michael Andy</i>	
Effect of Heating Temperature Variations on the Mechanical Properties of GFRP Reinforcement	162
<i>Ratu Anugrah Ramadhani, Anis Rosyidah, Jonathan Saputra, I Ketut Sucita, and Michael Andy</i>	
Performance of Slab on Ground Using Glass Fiber Reinforced Polymer (GFRP) Mesh and Wiremesh	173
<i>Firda Ilma Ilahi, Anis Rosyidah, Jonathan Saputra, I Ketut Sucita, and Michael Andy</i>	
Backbone Curve Modeling for Existing Reinforced Concrete Coupling Beam Failed in Shear	183
<i>Erwin Lim and Faza Mumtaz</i>	
Comparative Study on Structural Steel Bondek II Decking for Composite Floor Connections: Design Analysis in Compliance with EN 1994-1-1: 2004	193
<i>Faisal Amsyar, Abdul Razak Abdul Karim, Norsuzailina Mohamed Sutan, Norazzlina M.Sa'don, and Siti Farhanah S.M. Johan</i>	
Assessment of a Suitable Mix Design Technique for Geopolymer Concrete	208
<i>Sunday U. Azunna, Farah N. A. Aziz, Raizal S. M. Rashid, and Ernaleza B. Mahsum</i>	

Performance of Sustainable Concrete Bricks Containing Construction and Demolition Waste as Recycled Fine Aggregate	226
<i>Steve W. M. Supit, Debby Willar, and Jeremia Kawulusan</i>	
Structural Behavior Under Construction and Effects on Surrounding Environment Control Through Instrumentation Monitoring on MRT Project Jakarta	237
<i>Hardy Willim, Wati Asriningsih Pranoto, and Amelia Yuwono</i>	
Assessing Structural Performance of High-Rise Buildings and Large-Span Structures Through Wind-Induced Vibration Intensity Levels	249
<i>Usman Hasan, Daniel Christiano, and Buntara Sthenly Gan</i>	
Evaluation of the Column Stiffness by Considering the Influence of the Beam Stiffness	263
<i>Caetano José Freitas and Yoyong Arfiadi</i>	
Effect of Biochar Incorporation on the Mechanical Strength and Thermal Behavior of Concrete	283
<i>Chunpeng Liu, Dianah Mazlan, Lulu Cheng, and Tze Liang Lau</i>	
Structural Damage and Ground Motion Characteristics of the 2015 Sabah Earthquake	294
<i>Chunpeng Liu, Jun Pin Tan, and Tze Liang Lau</i>	
Application of Energy-Based Damage Measurement on RC Beam-Column Joint Using Fractal Analysis of Crack Patterns	307
<i>Dinda Ainur Istiqomah, Stefanus Adi Kristiawan, Senot Sangadji, and Buntara Sthenly Gan</i>	
New Algorithm to Predict and Evaluate Steel Building Equipped with Gantry Crane by Using AI	321
<i>Usman Hasan, Daniel Christiano, and Buntara Sthenly Gan</i>	
A 2-D Numerical Simulation of RC Beam-Column Joints with Haunch	328
<i>Taris Zulqisthi Masulili, Erwin Lim, and Patria Kusumaningrum</i>	
The High Early Strength of Expanded Clay Structural Lightweight Concrete ...	345
<i>Jack Widjajakusuma, Ika Bali, Gino Pranata Ng, Mike Owen, and Nehemia Wijaya</i>	
Hydrated Cement Paste-Methylcellulose Composite and Its Characterization Using FTIR Spectroscopy	357
<i>Ejazulhaq Rahimi, Yuta Yamachi, Yui Ayane, and Yuma Kawasaki</i>	

Production Analysis of Bored Pile Foundation Work in Sand Layer and Rock Soil Conditions: A Study Toll Road Yogya-Bawen Section 1	367
<i>Juse Roejanto and Harianto Hardjasaputra</i>	
Impact of Post-development Slope Geometry on Landslide Hazard and Safety Factor: Field Investigation in Indrapuri Residential Area	379
<i>Merley Misriani, Muhamad Yusa, Joleha Joleha, Indra Birawaputra, and Ceni Febi Kurnia Sari</i>	
Slope Stability Analysis Along Koto XI Tarusan District Roads, South Coast of West Sumatra	392
<i>Andriani Andriani, Bambang Istijono, Zelby Rahayu, and Sirajul Fuad Zis</i>	
Landslide Analysis and Mitigation Strategies to Prevent Slope Collapse: A Case Study of Lubang Panjang Road, Berangin District, Sawahlunto City, West Sumatra	405
<i>Andriani Andriani, Bambang Istijono, Sonya Otha Laurency, and Sirajul Zis Fuad</i>	
Discrete Element Modelling (DEM) of Mine Backfill Deposition Within Narrow Wall	417
<i>Wee Kiet Ting and Alsidqi Hasan</i>	
Expansive Soils Shear Strength Reduction on Retaining Wall Structures	432
<i>Eddy Triyanto Sudjatmiko and Shilan Nazwa Alifia</i>	
Neuroseismology: A Neuro-seismic Intensity Level for Quantifying Human Emotional Responses Due to Earthquake Shaking	446
<i>Riku Suenaga, Misaki Sakai, Kaito Tanaka, and Buntara Sthenly Gan</i>	
Vibration Energy Harvesting in High-Performance Geopolymer Mortar: A Proof-of-Concept with Piezoelectric Integration	459
<i>L. Marini, M. A. Mannan, A. B. H. Kueh, A. A. Abdullah, F. Abed, K. Gunasekaran, and M. Yonis Buswig</i>	
Author Index	473



Discrete Element Modelling (DEM) of Mine Backfill Deposition Within Narrow Wall

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Abstract. Mine stope is typically backfilled with Cemented Paste Backfill (CPB). The CPB provides a regional underground stability and also a reduction of above-ground tailings accumulation. During backfilling, a phenomenon known as arching occurs and affects the stress distribution of the CPB. The change in temperature due to uncontrolled heat transfer from the surrounding rock mass and/or generation from hydration process complicates the stress distribution development of CPB. This paper presents preliminary Discrete Element Modelling (DEM) simulation of backfill material within narrow wall which validates the speculated causes observed from experimental finding which leads to stress propagation anomaly. The main finding validated the behaviour of arching from a series of modification performed on the internal and interface friction of backfill material and its adjacent wall. The said frictional properties hold the key towards the stress behaviour throughout the backfilling, consolidation, and temperature changing phase. The coupled effects are proven to behave similarly towards both the experimental finding and full-scale investigation. This opens up the potential for further optimisation of DEM simulation in this area in order to improve mine backfill design at a lower research cost.

Keywords: Arching Effects · Discrete Element Modelling · DEM · Narrow Stopes Backfill · Paste Backfill · Temperature Elevated Hydration

1 Introduction

The depletion of surface deposits from rising mineral demand has driven deeper mining operations that create narrow underground voids and generate substantial tailings, which pose challenges to stability, ore recovery and mine safety [1]. Cemented Paste Backfill (CPB) is widely used to enhance underground stability and manage mine waste by combining dewatered tailings with cement to fill mined-out voids [2]. However, its performance is influenced by multiple factors, and insufficient understanding of its behaviour may lead to structural failures, increasing safety risks and operational costs.

Full-scale studies have revealed unexpected stress propagation, with stress levels rising during rest periods contrary to predictions [3]. Arching plays a crucial role in backfill design for narrow stopes where stress distribution along the stope walls depends on the

fill material's frictional properties, while semi-confined stopes unlike fully confined conditions allow vertical deformation that alters stress-strain behaviour. The behaviour has been investigated [4] but had yet to be numerically proven.

Numerical modelling such as Discrete Element Modelling (DEM) offers a cost-effective and efficient alternative to full-scale and experimental studies for investigating mine backfill behaviour. Unlike physical models, simulations can replicate various stope conditions and material properties to provide insights on its stress distribution and mechanical behaviour. These models allow for controlled analysis of stope dimensions, material compositions, and boundary conditions, enhancing the accuracy of predictions and supporting experimental validation [5].

Numerical validation helps refine the design and optimisation of mine backfill systems, ensuring safer and more cost-effective operations. Ultimately, this approach contributes to a deeper understanding of material behaviour and allows for the development of more efficient backfilling strategies in the mining industry.

2 Methodology

2.1 Materials

This research utilises laboratory-made CPB and Uncemented Paste Backfill (UCPB) to mimic the material properties and behaviour of actual CPB. Both mixes primarily consist of silica flour and water. Sibelco (SILVERBOND® PG20) was selected as the tailing replacement material as its Particle Size Distribution (PSD) is similar to typical mine tailings [6]. In terms of chemical and physical properties, silica flour is chemically inert and shows resistance to strength retrogression at temperatures below 110 °C, making it particularly suitable for the study's conditions. Its geotechnical properties were analysed using standard testing methods, and it adheres to the specifications outlined by its manufacturer and align with previous research using silica flour. The properties of silica flour are provided in Table 1, with the PSD of silica flour and the average PSD from 9 Canadian mines illustrated in Fig. 1. As stated in the mine fill handbook [7], selected silica flour meets the requirement of at least 15% passing through 20 µm particles required for paste fill.

Table 1. The properties of silica flour.

Physical Properties	Specifications	Literature	Result
Specific gravity, Gs	2.65	2.7	2.67
Particle size distribution	–	Silt	Silt
Coefficient of uniformity, Cu	3.65	16.2–16.6	3.66
Coefficient of gradation, Cc	–	1.3	1.17
Initial water content	0.2%	–	< 0.2%
Liquid limit, LL	–	–	23.83%
Plastic limit, PL	–	–	22.22%

(continued)

Table 1. (continued)

Physical Properties	Specifications	Literature	Result
Plasticity index, PI	–	–	1.61%
Shrinkage limit, SL	–	–	5.31%
USCS Classification	–	Low plasticity silt	Low plasticity silt

*List of references of cited literature are provided in supplementary information

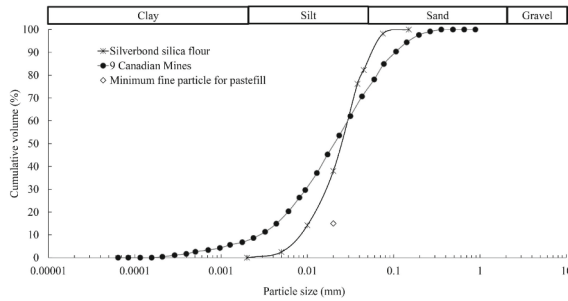


Fig. 1. The PSD of silica flour and the average PSD from 9 Canadian mines.

2.2 Sample Preparations

A fitting mix design is crucial for consistent sample behaviour. Mechanical properties like yield stress, compressive strength, and shear behaviour were assessed using slump test, unified compression test, and direct shear test with temperature control to attain strength and flowability requirements by [8]. Table 2 summarises the mix design and mechanical properties. All samples were mixed to homogeneity at the same speed before backfilling into the narrow wall model.

Table 2. The mix design of CPB and relevant mechanical properties.

Sample	Binder content (%)	Solid mass content (%)	Water content by total (%)	Water content by solid (%)	Water to cement ratio (%)	Slump height (mm)	UCS (kPa)	Yield stress (Pa)
CPB	5	72	28	38.9	7.7	17	314	115
UCPB	0	72	28	38.9	–	21	–	70

2.3 Temperature-Controlled Narrow Wall Model

Figure 2 presents the schematic of the narrow wall adapted from previous studies with modifications tailored to this research. The design accounts for factors such as curing

temperature, backfill aspect ratio, confining conditions, and wall stiffness while controlling elements like filling rate, interface shear, and drainage to ensure consistency. The narrow wall model’s functionality and accuracy have been discussed in earlier studies [9].

Arching effects can be observed when the wall height exceeds twice its width. To explore these effects with temperature changes, the design minimises stress from the adjacent wall. The model has dimensions of 80 cm in height, 15 cm in width, and 5 cm in depth, constructed from aluminium plates with an elastic modulus of 70 GPa, similar to rock masses found in mining environments. These plates resist deformation under stress, facilitate heat transfer, and are easily cleaned. An impermeable film covers the top to prevent water evaporation, and a single pour with a filling rate of 150 cm³/s maximises stress generation.

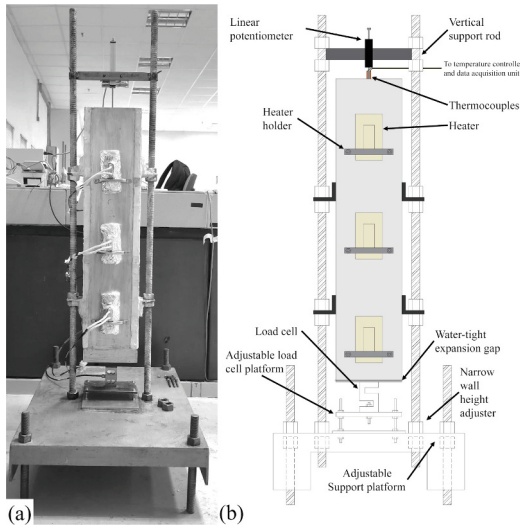


Fig. 2. Narrow wall (a) photo and (b) schematic design.

Test temperatures ranged from 30 °C to 60 °C to simulate typical in-situ conditions, where temperatures can reach up to 50 °C [3]. Both CPB and UCPB samples were heated, soaked, and cooled according to the temperature pattern in Table 3. Test 1 evaluated the effect of temperature variations on consolidated samples, with stable stress readings from the load cell indicating that temperature-induced changes occurred after this stage.

Table 3. List of tests for both CPB and UCPB.

Test	CPB and UCPB				
Step	1	2	3	4	5
Ramp	RTP-30	30–40	40–50	50–60	30–60

(continued)

Table 3. (continued)

Test	CPB and UCPB				
Step	1	2	3	4	5
Soak	30	40	50	60	60
Dwell	–	–	–	60–30	60–30

2.4 Discrete Element Modelling

In this study, Yet Another Dynamic Engine (YADE) DEM framework, developed by the SDEC group at Grenoble University is used to model the mechanical behaviour of granular materials in a semi-confined narrow wall. This simulation enables exploration on the key aspects of mine backfill behaviour, including stress distribution, self-weight consolidation, backfill expansion behaviour and the frictional interaction (arching effects) between granular material and surrounding walls. Note that only granular material is simulated in the preliminary studies where cohesion is not introduced and the particle size is scaled for simulation efficiency. Scaling effects are discussed by comparing simulation at different scale. With DEM, varying conditions without the need for full-scale experimental setups can be ideally replicated, thus offering a cost-effective and efficient method to understand material performance.

Simulation Setup and Material Configuration. The simulation model begins by defining two distinct materials: one for the granular particles (spheres) and another for the boundary walls. The material properties used in the simulation is shown in Table 4. The granular material is represented by a distribution of spherical particles, created using the `makeCloud()` function in Yade. This function generates a random distribution of spheres within a specified volume, with the PSD shown in Fig. 1. To ensure reproducibility, particles in each set of similar tests was fixed by seeding the Random Number Generator (RNG). Due to the nature of packing, an initial packing of 1.75 g/cm^3 is used in a modified direct shear test to identify an internal friction angle of 37.45° between silica flour and interface friction angle of 26.13° between silica flour and its adjacent wall material [10]. In order to mimic the expansion and contraction of particles due to temperature change, the particles were set to grow and shrink according to the linear coefficient of thermal expansion of 0.000014 every 1°C which correlated from an average finding of $0.000011/^\circ\text{C}$ based on the average strain data obtained from experimental investigation [4]. Table 5 shows the variations of the simulation.

Table 4. List of material properties used in simulation.

Material	Glass sphere	Silica flour	Aluminium wall
Density (kg/m^3)	2800	2670	2800
Poisson's ratio	0.3	0.2	-
Stiffness (MPa)	300	100	30000

Table 5. DEM simulation variations and its scaling parameters.

Particle	Glass Sphere											
Size	Radius = 1 cm											
Scale	1x				0.5x				2x			
Internal friction (°)	0	22	0	22	0	22	0	22	0	22	0	22
Interface friction (°)	0	0	24.2	24.2	0	0	24.2	24.2	0	0	24.2	24.2
Particle	Silica flour											
Size	PSD curve											
Scale	250x				500x				750x			
Internal friction (°)	0	37.5	0	37.5	0	37.5	0	37.5	0	37.5	0	37.5
Interface friction (°)	0	0	26.1	26.1	0	0	26.1	26.1	0	0	26.1	26.1

Model Geometry and Structural Design. The geometry of the narrow wall model is crucial to replicating realistic mining conditions. To recreate the narrow wall, the walls are designed using facet boxes which are flat surfaces that form the boundaries of the simulation domain. The geometry does not require thickness due to its material definition earlier, thus the facet walls are created based on the inner dimension of the narrow wall measuring 0.8m height, 0.15 m width, and 0.05 m breadth. In order to control overflowing in laboratory experiment, the fill material is filled to a height of 0.75 m only. The model includes both a lower and upper sample mould, along with additional wing structures to ensure the material remains confined during the simulation process. A funnel shape is also incorporated to guide the granular material into the confined space, further mimicking the physical backfilling process used in mining.

Simulation Process and Data Collection. The simulation proceeds in stages. Initially, the granular material is poured into the model, and a funnel directs the material into place. This stage simulates the self-weight consolidation of the backfill material as it is settling over time which is a critical aspect of mine backfilling operations. After the simulated particles had stabilised based on the unbalanced force reading, particle size alteration is applied to simulated both thermal expansion and shrinkage. Throughout the simulation the unbalanced force, the forces applied to the plate are monitored and recorded. These include the force on the plate (F_z), the horizontal force (F_x and F_y).

In the YADE framework, the interaction between granular materials and bounding walls is governed by discrete mechanics. The vertical (F_z) and horizontal (F_x and F_y) force components within a backfilled geometry can be expressed in analytical form as follows:

$$F_z = F_v = \gamma l^2 w^2 \frac{1 - \exp\left\{-2K \tan \delta h \frac{(l+w)}{lw}\right\}}{2K \tan \delta (l+w)} \quad (1)$$

$$F_x, \text{ or, } F_y = F_h = \gamma l^2 w^2 \frac{1 - \exp\left\{-2K \tan \delta h \frac{(l+w)}{lw}\right\}}{2 \tan \delta (l+w)} \quad (2)$$

where γ is the bulk unit weight of the fill material (kN/m^3), K is the stress ratio which factored internal friction (horizontal to vertical), z represents the height of the backfill (m), l and w are the length and width of the fill area (m), δ is the interfacial friction angle between the material and the confining wall.

In the simulation, sphere-to-wall and sphere-to-sphere interactions are implemented through an elastic-frictional contact model. This is schematically illustrated in Fig. 3 as force-displacement relationships in both the shearing and normal directions.

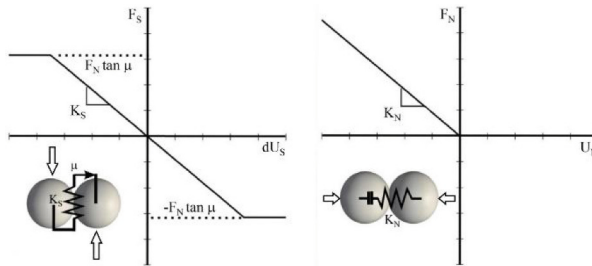


Fig. 3. Contact law based on (a) shear (tangential) and (b) normal directions.

Upon contact, the normal and tangential contact forces are calculated as:

$$F_S = K_S \sum U_S \quad (3)$$

$$F_N = K_N U_N \quad (4)$$

where F_S and F_N are the shear and normal forces at the contact point, U_S and U_N are the normal and shear relative displacements, and K_S and K_N are the contact stiffnesses in normal and tangential directions as shown below:

$$K_S = \alpha K_N \quad (5)$$

$$K_N = \frac{2E_a R_a E_b R_b}{(E_a R_a + E_b R_b)} \quad (6)$$

where, α governs the stiffness ratio between shear and normal directions, E_a , E_b , R_a , R_b are the Young's moduli and radii of the contacting particles a and b. The constant α governs the stiffness ratio between shear and normal directions.

3 Results and Discussion

3.1 DEM Simulation Results

All simulation data are discussed and compared for the understanding on the effects of variation in particle distribution, particle size, and its frictional properties towards the backfill stress propagation. After the analysis, some simulated data are then selected to

be compared with experimental data. Figure 4 below shows geometry of the wall facets along with the end results of the simulated particles at specified particle type and size. Scaling effects on the behaviour of interest is validated by simulating particles in Table 5. Note that, the simulation time for the real particle size of silica flour at such volume takes 15,625,000 times longer than the 250 times scaled simulation which took 1 day to be completed. In order to make the actual size simulation to be possible, the height and the longer span of the geometry are reduced to 0.03 cm and 0.02 cm respectively while the shorter span remained at 5 cm breadth. Figure 4 shows a 0.2 cm zoomed section from its total breadth, with consolidated height of 0.015 cm and hidden width due to 2D view.

Figure 5 shows the force-time behaviour of simulated backfill using glass spheres with varying radii and frictional properties, as well as silica flour particles with varying PSD scales and frictional properties. Glass spheres without internal and interface friction properties exhibit reduced lateral force transfer, resulting in higher force readings at the base. Since the internal and interface friction values used across simulations are based on experimentally validated data, the individual contributions of each friction parameter to overall force transfer cannot be conclusively determined from the current dataset. Nonetheless, based on the applied friction values and the fixed aspect ratio of the simulated narrow wall, it appears that internal friction contributes more significantly to force transmission than interface friction.

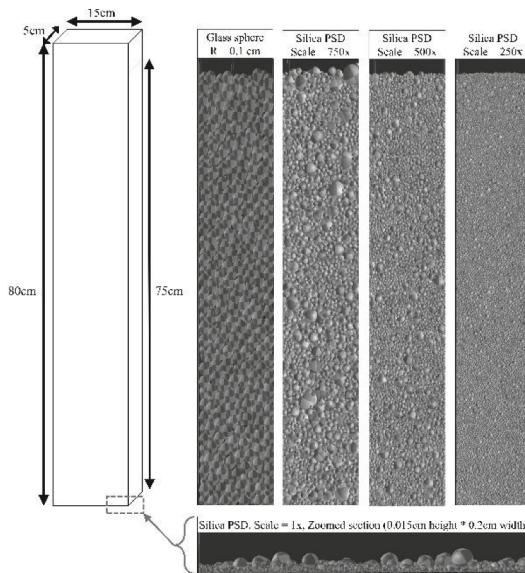


Fig. 4. Simulated wall geometry and its corresponding simulation across specified particles variations.

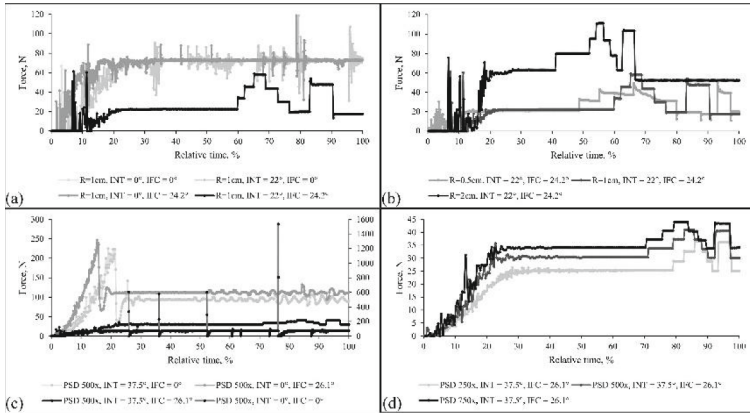


Fig. 5. Force-time behaviour of glass sphere (a) by varying frictional properties, (b) by varying size, and silica flour (c) by varying frictional properties, and (d) by varying size.

During the temperature variation phase, glass spheres without frictional properties undergo expansion and contraction, leading to cyclic increases and decreases in recorded forces. Due to the lack of friction, these particles are able to reposition themselves within the semi-confined space, allowing stress relief and preventing excessive force buildup. In contrast, simulations incorporating both internal and interface friction show the development of arching, as frictional resistance partially restricts particle expansion. This restriction leads to elevated force readings. As expansion stabilises, some force concentrations are relieved as particles settle.

By maintaining the realistic frictional properties, it is observed that the three-dimensional increase in the size of glass sphere exponentially alters the total number of particles simulated to be filled into the same volume, where larger particles reduce the force transfer towards the side wall. The magnitude of force propagation during the thermal phase correlates with the magnitude observed at full consolidation, highlighting the influence of particle size on stress transmission under temperature fluctuations.

The effect of mono-sized particle over particles with a wide PSD can be compared via Fig. 5. Despite having similar density, the magnitude of force generated differs significantly between the two cases. Simulations using PSD-based particles typically result in more efficient packing, with fewer voids than mono-sized particles. This denser packing leads to greater force generation due to the increased number of particle contacts within the same volume. The size variation within the PSD simulations does not produce substantial differences in force magnitudes as Fig. 4 indicates all PSD configurations are well-packed. However, a consistent trend is observed where smaller PSD particles generate lower force levels, similar to the effect seen with smaller glass spheres. As with the glass sphere simulations, the frictional properties of PSD particles play a significant role in determining the peak force after backfilling, the consolidated stress level, and the magnitude of force variation during thermal cycling. It is worth noting that one dataset is plotted on the secondary y-axis due to excessive force generation during temperature increase, where its particles are not restricted by any friction. However, this force spike quickly dissipates as there is no arching effect to retain the thermal stress.

To validate the vertical force transfer mechanisms, selected simulation datasets were plotted alongside their corresponding horizontal forces as shown in Fig. 6. For particles lacking both internal and interface friction, the vertical and horizontal forces peaked simultaneously, whereas simulations with full frictional properties exhibited a longer time to reach equilibrium. The time for vertical and horizontal force to stabilised appears to be different when presented in the graph. Based on the unbalance force, it confirms that the vertical force had yet to stabilise. Due to pronounce arching effects, changes in vertical force are apparent though not visually significant when compared to other datasets. Upon consolidation, the changes in vertical and horizontal forces during temperature variation follow a consistent behavioural pattern regardless of particle size or frictional conditions.

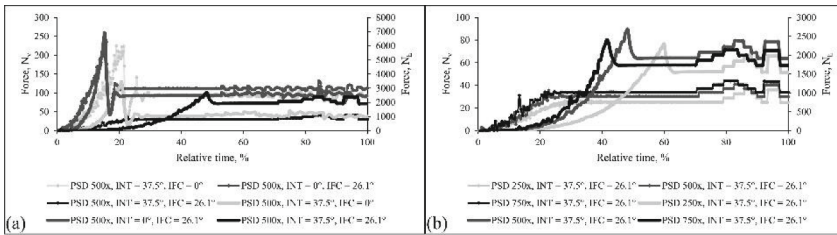


Fig. 6. Vertical and horizontal force-time behaviour of silica flour (a) by varying frictional properties and (b) by varying size.

3.2 Experimental Results

According to Table 3, the backfilling experiment consists of deposition, consolidation, thermal ramping, soaking, and dwelling. Each of these phases was examined to assess how temperature variations influence the mechanical response of CPB and UCPB. Figure 7 shows the stress-strain-temperature monitoring of both CPB and UCPB backfilling test. Individual analysis according to each phase will be discussed concurrently with DEM results later.

For all of the experimental backfilling test, the vertical stress recorded from the initiation of backfilling until the end of backfilling at a fixed rate which takes around 1 min to complete, showed near linear increase that corresponds to the theoretical geostatic mass of backfill that is the product of backfill density and its current height of backfill. Slurry when flowing behaves as a continuum with low frictional properties but its frictional properties evolve when it's filled into position. The non-Newtonian paste establishes its internal and interface frictional properties which led to the establishment of a phenomena called arching effects which transfer a portion of stress exerted by the mass towards its horizontal plane. Thus, proven by the reduction of vertical stress recorded for all samples with the differences being the rate to attain a stable stress distribution between UCPB and CPB due to the presence of cementation in CPB that hasten the process.

Upon reaching a stable stress reading, all sample experienced a near linear gain in stress over the temperature applied during ramping. Upon reaching the targeted temperature, the sample is soaked at the targeted temperature until its behaviour stabilised. Note that, UCPB sample experience reduction in stress while CPB experience less reduction,

and the reduction is further minimised as it cures. Such behaviour is speculated to be due to the relaxation of concentrated thermal stress that is initially restricted by arching effects. The cycles repeat for each of the targeted temperature and the samples are the cooled back to the initial temperature which indicates further reduction in stress. While CPB shows a great reduction in stress during dwelling, UCPB shows less reduction in stress in comparison. This validated the explanation of UCPB earlier on the stress relaxation which reduces the total stress concentration at elevated temperature, while CPB retains more thermal stress at elevated temperature due to its elastic behaviour from curing process. Finally, the behaviour is proven to be similar when temperature is shifted at a greater magnitude. In depth analysis of this experimental finding and its comparison to other forms of testing conditions are previously discussed in [4].

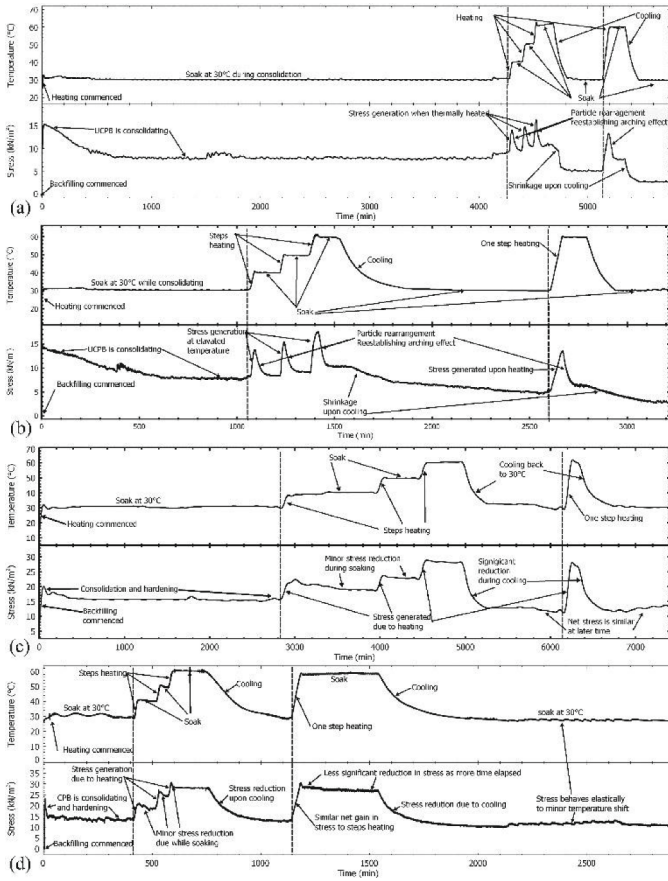


Fig. 7. Stress-temperature behaviour of (a) UCPB1, (b) UCPB2, (c) CPB1 and (d) CPB2.

3.3 DEM Simulation Validation with Experimental Findings

The selected variations of findings are extracted based on the region of interest to be compared between simulation and experimental. To compare their behaviour effectively,

all results are plotted against relative time and the vertical stress from experimental finding are converted to force.

Backfilling Phase. Backfilling phase indicated the commencement of backfilling until the last particle came into contact with the particles medium. Figure 8 shows the comparison across UCPB, CPB, glass sphere and silica flour on their force increment during backfilling. As dry granular particles simulated in DEM settles quickly under gravity, most force are transferred during the backfilling which resulted in low gain in vertical force over the backfilling period. By comparing the forces relatively, the characteristic is similar to both continuum samples.

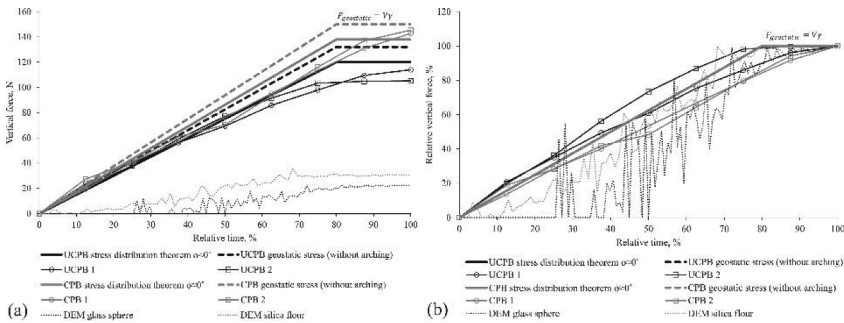


Fig. 8. Experimental and simulated samples' behaviour via (a) vertical force and (b) relative vertical force over backfilling phase.

Consolidation Phase. Figure 9 shows the force-time propagation of UCPB, CPB, glass sphere and silica flour throughout its consolidation. Based on Eq. 1 and 2, arching effects are mainly affected by backfill density, internal, interface friction angle, and backfilling geometry which did not consider the effects of viscoelasticity, cohesion, and the evolving nature of hydrating sample. Non-viscous particles reach stability faster than material such as UCPB and CPB, which justifies the use of relative time in comparing their behaviour. Though there is slight reduction in vertical force during consolidation for both simulated materials, the magnitude of reduction is insignificant compared to both CPB and UCPB samples. The instability is justified from the high unbalance force where the simulated particles are still rapidly settles.

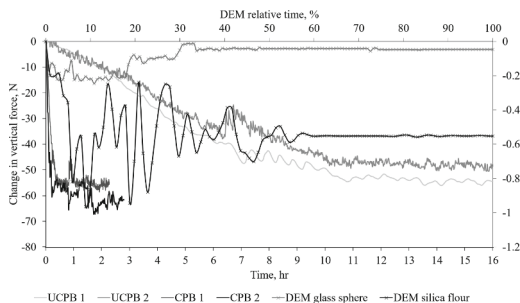


Fig. 9. Experimental and simulated force propagation over the consolidation phase.

Temperature Alteration Phase. Figure 10 shows the force-time propagation of UCPB, CPB, glass sphere and silica flour over temperature ramping, soaking and dwelling. All test gives the same behaviour where temperature increase led to force increase, and vice versa. The only differences is the magnitude of force gained and loss over the temperature changing period. Both glass sphere and silica flour shown possess of both frictional properties, with the only possibility of particle size and distribution differences that leads to great differences in force magnitude. The relative force change of silica flour simulation corresponds similarly to CPB with consideration of force relief. As time elapsed, each material behaves in a pseudo-elastic behaviour where limited force relief on the thermal stress concentrated during heating is possible. This highlights the importance to consider force relaxation in studying backfill material within semi-confined space.

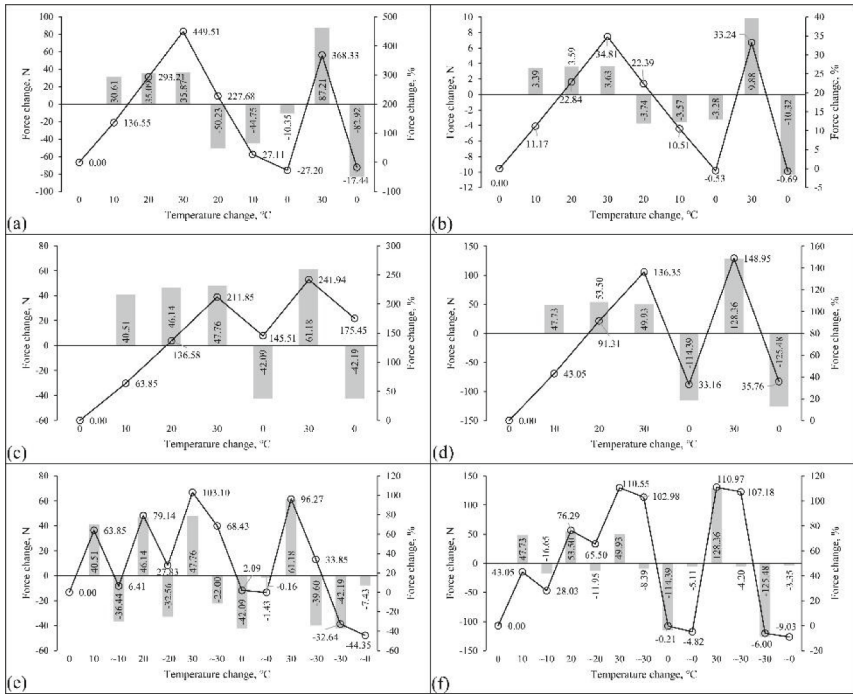


Fig. 10. Force-temperature behaviour of (a) glass sphere, (b) silica flour simulation, (c) UCPB, (d) CPB without considering, and (e) UCPB, and (f) CPB considering force relief during soak.

4 Conclusion

This study employed Discrete Element Modelling (DEM) to investigate the behaviour of backfilling within a narrow wall geometry. By comparing the simulation results with experimental observations, the following conclusions were drawn:

- Abnormal stress propagation that differs from expected geostatic stress is primarily attributed to the arching effect within the backfill material.
- The stress reduction after backfilling is negligible in backfill materials lacking frictional properties. Conversely, excessively high friction hinders particle rearrangement during each phase.
- Mono-sized particle systems consolidate more efficiently than those with a wide particle size distribution. However, no significant differences were observed in other behaviours.
- At fixed volume, larger particle size regardless of particle type gives lesser reduction in stress which is hypothesised to be the lack of freedom in particle rearrangement during consolidation. However, thermal stress generation, relief, and reduction remain similar across sizes.
- During temperature change, backfills with both wall and inter-particle friction shows sensible increment, relief, and reduction in their stress pattern.
- The overall stress propagation patterns in the simulations closely resemble those observed in both UCPB and CPB experiments, with differences primarily in magnitude rather than behaviour across deposition, consolidation, and thermal phases.

Future work may improve the realism of simulations by incorporating more advanced mechanics, such as cohesion, viscosity, and coupling with fluid dynamics which are proven to be individually possible in recent literature. Such coupled integration might result in a more realistic simulation in comparison to experimental data. Additionally, dedicated physical experiments aligned with the parameter variations used in this study would further validate the simulated behaviours.

This preliminary investigation demonstrates the potential of DEM in simulating various backfilling scenarios with reasonable accuracy. The ability to model particle-level interactions makes DEM a cost-effective and safe alternative to extensive physical testing, supporting its application in optimising mine backfill design.

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