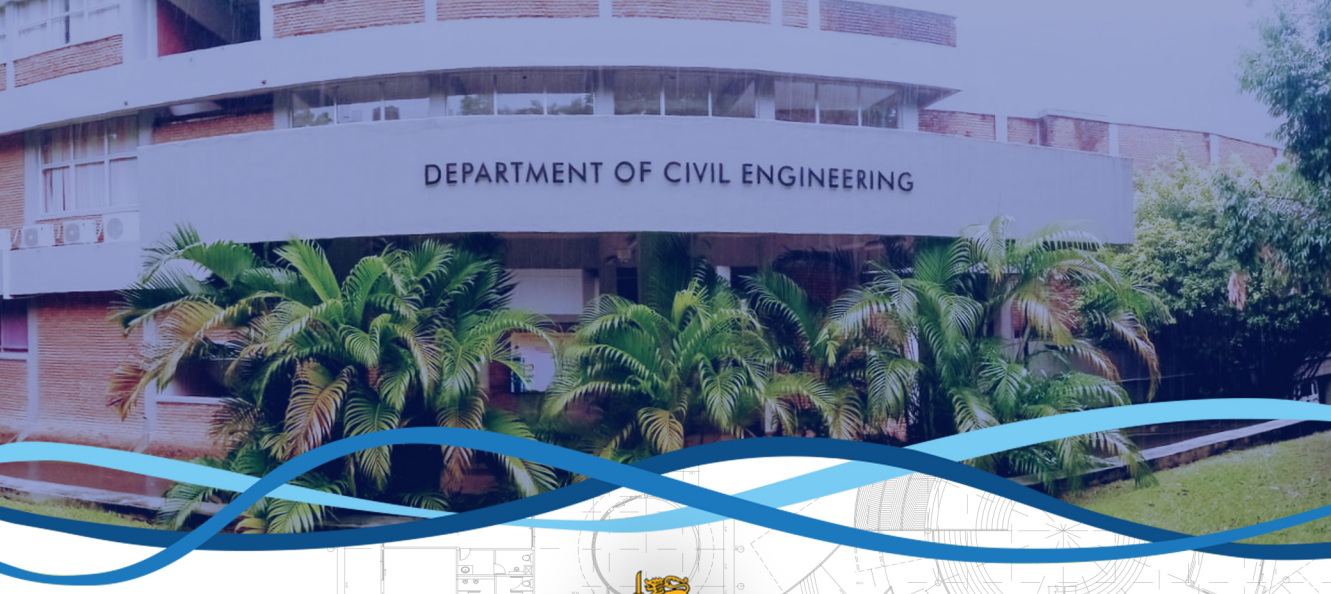

Proceedings of

CIVIL ENGINEERING RESEARCH SYMPOSIUM 2024

CERS 2024

BOOK OF ABSTRACTS

Department of Civil Engineering
University of Moratuwa
September 2024

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CIVIL ENGINEERING RESEARCH SYMPOSIUM

2024

26th September 2024

Department of Civil Engineering

University of Moratuwa

Sri Lanka

Dedicated to

Prof. Saman Bandara (retiring from University of Moratuwa on 30th September 2024)

Dr. (Mrs.) Premini Hettiarachchi (retired from University of Moratuwa on 31st May 2024)

Proceedings of the Civil Engineering Research Symposium - 2024

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Message from the Head of the Department

As the Head of the Department, I am proud to present the proceedings of the Civil Engineering Research Symposium (CERS) 2024, showcasing the research outputs of our 2019 Intake undergraduate students. This symposium is a testament to the importance of cultivating a research mindset early in the journey of a young civil engineer, for research is not just a phase in academic life but a lifelong pursuit. It is through such endeavours that engineers innovate and solve real-world challenges throughout their careers.

I am also delighted to highlight that CERS 2024 is dedicated to two of our distinguished academics, Dr. (Mrs.) Premini Hettiarachchi and Prof. Saman Bandara, whose contributions to our department and the field of civil engineering have been immeasurable. Their guidance, mentorship, and research have inspired countless students and faculty, and their legacies will continue to shape the department for years to come.

The greatest strength of our Department lies in the incredible talent of our academic staff, especially the young lecturers, whose potential is crucial for our future growth. The achievements and performances of our undergraduates reflect this talent and provide solid evidence of the growing capabilities and the future potential of the Department. I would like to extend my heartfelt thanks to our academic staff for their unwavering dedication and guidance, which made this event possible, and to our non-academic staff, whose tireless efforts behind the scenes have been invaluable.

A special appreciation goes to our sponsors, whose generous support has ensured the success of this symposium. We are especially grateful to Panacea Solutions LK, our Platinum Sponsor, and Suleco (Pvt.) Ltd., our Silver Sponsor. Their contributions enabled us to host a symposium of this calibre, fostering collaboration and innovation.

In closing, I look forward to the exchange of ideas and knowledge at this symposium, confident that the research presented here will advance civil engineering and contribute to a more sustainable and resilient future.

Prof. Jagath Manatunge
Professor/Head of the Department,
Department of Civil Engineering,
University of Moratuwa

Dedicated to -

Prof. Saman Bandara

Dr. (Mrs.) Premini Hettiarachchi

Prof. Saman Bandara

Saman Bandara is a Senior Professor in Civil Engineering & Director of The Center for Intelligent Transport Systems, University of Moratuwa. Graduated from the University of Moratuwa as a Civil Engineer and obtained a PhD in Transportation Engineering with a specialization in Airport Planning from The University of Calgary, Canada. He has over 41 years of experience in teaching and research. He has served as the Head, Department of Civil Engineering, founder Head of the Department of Transport & Logistics Management and founder Director of Undergraduate Studies, Faculty of Engineering, University of Moratuwa.

He joined the Department of Civil Engineering as an Assistant lecturer in July 1983, and proceeded to the University of Calgary for postgraduate studies. He was promoted to the post of senior lecturer in August 1991. In July 2003, he was promoted on merit as a Professor in Civil Engineering, and in July 2011, he was promoted to Senior Professor.

Prof. Bandara is a Chartered Engineer and a Fellow of the Chartered Institute of Logistics & Transport. He was a past Chairman of the Chartered Institute of Logistics & Transport, Sri Lanka, a Past President of the Sri Lanka Evaluation Association and a Past President of the Highway Engineering Society, Sri Lanka. He has also served as the President of the Engineering/ Architecture/Surveying Section of the Sri Lanka Association for the Advancement of Science.

His research interests are in the areas of Traffic Engineering, Public Transport, Transport Planning, Airport Planning & Development, Road Safety, Highway Engineering, Monitoring & Evaluation, Environmental Assessment and Logistics Management. There are over 100 national and international full paper research publications in the above areas and a joint patent for UniRoad Traffic Signal System to his credit.

Dr. (Mrs.) Premini Hettiarachchi

Dr. (Mrs.) Premini Hettiarachchi graduated from University of Moratuwa in 1982 with a First Class Honours degree in Civil Engineering having been jointly awarded the A.N.S. Kulasinghe Award for the Best Civil Engineering Graduate. On graduation she joined the academic staff of the Department of Civil Engineering, University of Moratuwa. In 1983, she proceeded to the Department of Civil Engineering of Imperial College of Science and Technology, London on an Open Commonwealth Scholarship. She successfully completed the Master's Programme in Timber Structures and Technology having obtained a Distinction level pass and then pursued further studies on the bending of plywood, which led to a PhD in 1987.

Having completed both the Masters and PhD in 4 years she returned to serve the University of Moratuwa in 1987 and has since been actively engaged in teaching structural design at undergraduate and postgraduate levels and research and consultancy in construction materials and structural design. In 1990-91 while on leave from the University, she had the privilege of working with ARUP UK, a world renowned consulting firm, on the design of the UK Pavilion for EXPO 92.

Dr. (Mrs.) Hettiarachchi is responsible for introducing the latest revisions to Codes of Practice including the Eurocode Recommendations in Timber and Steel to the Undergraduate and Postgraduate Curricula at the University of Moratuwa. While her primary research interests are in the structural use of timber and steel, she also researches into structural forms, learning from structural failures and structural engineering education. She has received awards for both teaching and research; the Senate Research Award in 2004 and the first ever Teaching Excellence Award in 2007-8, She was a joint recipient of the SD&CC Award for the best research paper in the Journal of the Institution of Engineers (IESL), Sri Lanka 1990 and more recently of the NSF Research Award 2008/2009. She was jointly awarded the Raghu Chandrakeerthy Gold Medal for the best paper at Annual Sessions of the Society of Structural Engineers (SSE), Sri Lanka on 2 different occasions in 2014 and 2019. Her research findings have been disseminated both in the written and verbal form. Since much of her research is of a Sri Lankan context, it has been published in local research proceedings and journals.

She has contributed to Continuing Professional Development of Structural Engineers by serving as a resource person on short courses organised by the University of Moratuwa and SSE Sri Lanka, and also at seminars organised by ICTAD, SSE SLSI, CCI and NCASL. She is an active member of the SSE since its inception having served on its executive committee and been a regular contributor to MODULUS. She has also served as Editor of MODULUS and the Annual Proceedings of the Society. She was appointed an Honorary Fellow of the SSE Sri Lanka 2021. She served as Editor of the Annual Proceedings of the Seminar 'Research for Industry', conducted by the Engineering Research Unit of the University of Moratuwa, during its formative years. Just prior to her retirement, she served as Director of Quality Assurance of the Engineering Faculty of the University of Moratuwa.

Symposium Agenda

07:45 – 08:15	Registration
08:15 – 08:20	Introductory Remarks
08:20 – 08:25	Lighting of the Oil Lamp
08:25 – 08:30	National Anthem
08:30 – 08:40	Opening Remarks by the Head, Department of Civil Engineering, University of Moratuwa
08:40 – 08:45	Opening Remarks by Conference Chair
08:45 – 09:40	Keynote Lecture by Prof. Saman Bandara
09:40 – 09:45	Sponsorship Video
09:45 – 10:40	Keynote Lecture by Dr. (Mrs.) Premini Hettiarachchi
10:40 – 10:45	Sponsorship Video
10:45 – 11:15	Morning Tea Break
11:15 – 12:45	Research Presentations and Panel Discussion: Technical Session 1
12:45 – 13:45	Lunch Break
13:45 – 15:15	Research Presentations and Panel Discussion: Technical Session 2
15:15 – 15:45	3-MT Challenge Video Presentation
15:45 – 16:00	Concluding Remarks and Vote of Thanks by Conference Secretary
16:00 Onwards	Afternoon Tea

Research Presentations: Technical Session 1 (11:15 – 12:45)

11:15 – 11:30	Construction quality framework for school buildings in Sri Lanka by B.R.W.M.D. Thoradeniya
11:30 – 11:45	Effect of bolt preloading and endplate imperfections in extended endplate bolted connections: investigate the moment-rotation characteristics through explainable artificial intelligence by D.A.S.T. Dharmawansha
11:45 – 12:00	Mechanical behaviour of rice husk ash and cement–stabilized peat under different curing periods by N.M.N.T. Narasinghe
12:00 – 12:15	Assess the impact of internal curing in roller compacted concrete using roof tile waste as fine aggregates by V.G.S. Dilsara
12:15 – 12:30	Numerical simulation of progressive collapse of structures under blast loads by N.T. Vandabona
12:30 – 12:45	Use of streamflow and satellite remote sensing soil moisture data for jointly calibrating the tank model by G.K. Pabasara

Research Presentations: Technical Session 2 (13:45 – 15:15)

13:45 – 14:00	Urban flood assessment targeting flood risk mitigation: A case study focusing on changing environments by J.M.P.M. Jayawardane
14:00 – 14:15	Effect of crease curvature on bending stiffness in curved crease origami by W.M.H.G.L.C.B. Weerasekara
14:15 – 14:30	Point of fixity of laterally loaded piles on layered soils by R.M.K.R. Subhasinghe
14:30 – 14:45	Evaluating the effectiveness of treatment solutions on blue stain fungi growth in pine wood plantations in Sri Lanka by L.R. Rathuge
14:45 – 15:00	Study on the effect of seawater on making and curing of unreinforced concrete applications by R.M.M.J. Kulathunga
15:00 – 15:15	Assessment of resilience of hospital buildings in Sri Lanka by M.M.G.C. Marasinghe

Contents

CONSTRUCTION QUALITY FRAMEWORK FOR SCHOOL BUILDINGS IN SRI LANKA

B.R.W.M.D. Thoradeniya [1], C. Jayasinghe [1], I.E. Ariyaratne [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

The built environment of schools plays a crucial role in shaping the educational experience, yet Sri Lanka has faced ongoing concerns regarding the quality of school construction, despite significant government investment in education. To address this issue, a comprehensive study was conducted with the primary objective of developing a construction quality framework specifically tailored for school buildings in Sri Lanka. This framework aimed to establish clear standards and guidelines for the design, construction, and maintenance of school buildings, ensuring that they meet the necessary safety, functionality, and sustainability criteria. An extensive literature review was undertaken to systematically break down the processes involved in school building construction and to conduct background research on contemporary quality standards. The breakdown included the following key phases: project initialization, design and construction, operations and maintenance, and rectification and building condition. Data collection was carried out through multiple methods, including case study reports from the National Building Research Organization (NBRO), which covered 58 buildings across 22 schools. Surveys of school stakeholders and expert interviews were also conducted. The NBRO reports included visual observations and both destructive and non-destructive testing techniques. The survey aimed to assess the efficiency of operations and maintenance processes, while expert interviews provided insights into the procurement procedures of school buildings. The collected data were analysed using statistical methods to categorize and prioritize the defects identified in the construction process. This analytical approach facilitated the identification of the most common and critical defects, along with their correlation to the overall condition of the buildings. The defects were categorized based on their location and severity, offering a clear understanding of recurring issues in school construction. The analysis revealed significant issues in design, construction, and maintenance practices, with gaps in maintenance protocols and challenges such as financial constraints and bureaucratic delays. The importance of addressing these defects proactively, particularly in critical structural elements such as slabs, columns, and beams, was emphasized to ensure the durability and safety of school buildings. The proposed framework was validated through its application to a school building construction project in the Northwestern Province, which encompassed two phases—one completed and the other ongoing. This validation demonstrated the framework's effectiveness in improving construction quality and addressing prevalent issues. The outcomes of this methodological approach provided valuable insights into the construction quality of school buildings in Sri Lanka. By identifying and prioritizing defects throughout the entire construction process, the study established a basis for minimizing or eliminating these issues in future construction projects. The insights gained from this research contribute to the formulation of targeted construction guidelines for school buildings in Sri Lanka, aligning with the evolving needs of the Sri Lankan education system.

Keywords: Building condition, Construction quality, Defects, Framework, School building

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CONSTRUCTION QUALITY FRAMEWORK FOR SCHOOL BUILDINGS IN SRI LANKA

Background

- Education is crucial for human capital development, but inadequate quality in school building construction in Sri Lanka undermines learning
- This study creates a framework to ensure school buildings are safe, functional, and sustainable, thereby improving educational outcomes and student well-being

Objectives

- Assess the current construction quality standards for school buildings
- Develop a customized construction quality framework for Sri Lankan school buildings
- Assess the effectiveness and suitability of the developed framework

Research Methodology

- **Extensive Literature Review** → Systematically breakdown the process of construction
- **Data Collection and Analysis**
  - Project Initiation – Expert interviews
  - Design and Construction – Case studies provided by NBRO
  - Operations and Maintenance – Survey Questionnaire
  - Rectification and Building condition – Analysis of Case studies using IBM SPSS software
- **Framework Development** → Developed using common defects and root causes for defects
- **Validation of the Study** → Completed and ongoing school building construction project in the Northwestern Province

Summary of the Developed Quality Control Framework for School Buildings in Sri Lanka

Pre-Construction Stage

Drawbacks

- Inadequate Budget Allocation
- Lack of labour competence assessment method
- Poor quality standards maintenance and supervision
- Outdated design standards requiring updates
- Phased construction of buildings due to partial budget allocation
- Inappropriate subcontractor selection

Recommendations

- Utilize E-procurement for efficiency and transparency
- Ensure proper funding with a cushion
- Strengthen government policy documents
- Enhance stakeholder communication
- Develop maintenance manuals and monitoring mechanisms
- Introduce labourer licensing
- Develop master plans for school infrastructure

Design and Construction Stage

- Adequate site investigations (Avoiding ground settlement)
- Adequate grading and sloping of the site
- Proper compaction of the underlying soil
- Construction of proper drainage system
- Protection of structural elements against excessive moisture (Proper water proofing) and termite attacks (Proper termite treatment)

Single Storey Buildings

- Proper design of structural elements including sill and lintel beams and walls and columns on which high concentrated loads are applied from the roof

Multi-Storey Buildings

- Avoid improper construction techniques such as lack of required concrete cover and stage-by-stage construction
- Proper construction of sunshades with the required concrete cover and drainage mechanisms

Operations and Maintenance Process

- Remove mosses and vegetation grown on buildings and extensive root systems around the building
- Prevent water infiltration to the building (through roof, walls and upper floor balcony)
- Conduct systematic regular maintenance of the building
- Ensure proper funding for maintenance

Recommendations

- Adhere strictly to building regulations and industry standards
- Allocate sufficient funding and experienced professionals
- Enhance efficiency through meticulous planning and documentation
- Consider replacing concrete sunshades with metal framed Zn-Al sunshades
- Address defects promptly to prevent potential hazards

Building Condition Assessment

Building Element	Chi-Square Test		Spearman's rank correlation coefficient test	
	Fisher-Freeman-Halton Exact Test	Significance of the Relationship	Spearman's Rank Correlation Coefficient	Correlation
Slab	0.007	Significant (Only the structural elements)	0.450	Moderate Positive Correlation
Beam	0.016		0.363	
Column	0.024		0.324	

✓ Ground stability and foundation integrity are crucial for structural stability and safety

EFFECT OF PRELOADING AND ENDPLATE IMPERFECTIONS IN BOLTED CONNECTIONS: MOMENT-ROTATION CHARACTERISTICS THROUGH EXPLAINABLE ARTIFICIAL INTELLIGENCE

D.A.S.T. Dharmawansha [1], H.M.S.T. Herath [1, *]

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Stainless-steel is a popular engineering material due to its durability, high resistance to corrosion, aesthetic appeal, ease of construction and maintenance, recyclability, and ductility. It is often used in a wide range of structural engineering applications such as frames, buildings and bridges. Across these diverse applications, steel connections are a crucial component as they ensure the unified performance of the structure. This study investigated the effect of bolt preloading, endplate imperfections, and geometric parameters on the connection moment rotation response of extended endplate bolted connections.

This study employed a validated numerical model against experimental results from the structural testing laboratory of the University of Moratuwa, further validated against experimental results available in the literature. The validated numerical model was then used to investigate the impact of varying levels of bolt preloading and imperfections on rotational stiffness. The results showed that rotational stiffness increases by 134% with ultimate preloading.

Residual deformation from welding causes initial imperfections in bolted endplate connections, with V-shape, C-shape, and W-shape imperfections identified in the literature. This study examines the impact of C-shape and V-shape imperfections on rotational stiffness. The results indicate that V-shape imperfections have minimal influence if the level of imperfection is limited to the criterion of (endplate depth)/300, while C-shape imperfections significantly affect rotational stiffness, even within acceptable limits.

A novel explainable machine learning approach was utilized to investigate the influence of geometric parameters on the moment-rotation response of connections. A comprehensive numerical modelling approach (validated using related work) was used to generate data for various input features, such as endplate thickness, bolt diameter, overall section width, overall depth, web thickness, flange thickness, vertical bolt spacing, and horizontal bolt spacing. An artificial neural network (ANN), extreme gradient boosting (XGB), random forest (RF), and k-nearest neighbours (KNN) were employed alongside Shapley additive explanations (SHAP) to interpret the trained models. Analysis shows that endplate thickness strongly governs the moment-rotation behaviour of the bolted endplate connections. Moreover, SHAP explanations align with the generally accepted behaviour of steel extended endplate bolted connections according to EN 1993-1-8.

Keywords: Machine learning, Bolt preloading, Explainable AI, Endplate imperfections, Bolted connections, Rotational stiffness

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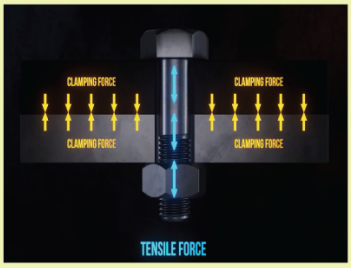
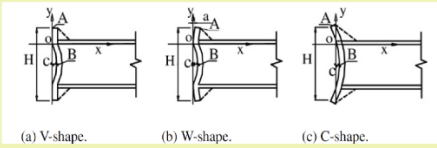
Effect of Preloading and Endplate Imperfections in Bolted Connections: Moment-Rotation Characteristics through Explainable Artificial Intelligence

D.A.S.T. Dharmawansha, H.M.S.T. Herath

BACKGROUND



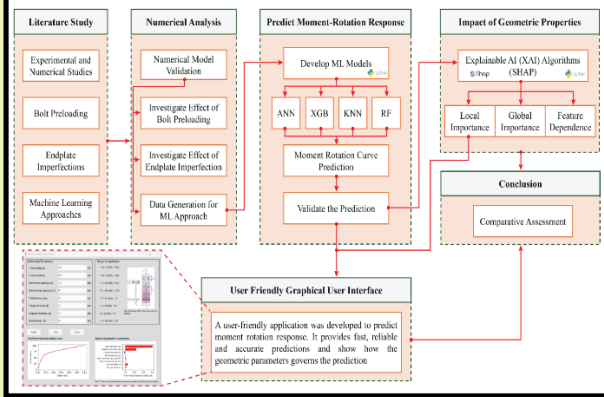
Bolt Preloading



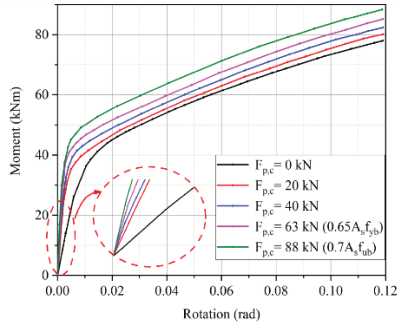
(a) V-shape. (b) W-shape. (c) C-shape.

Types of Endplate Imperfections

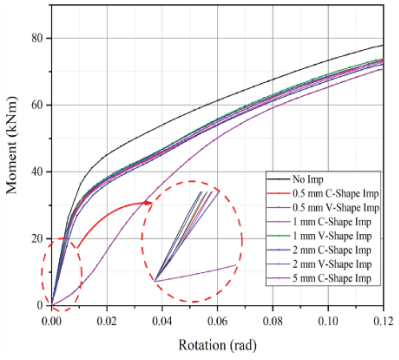
METHODOLOGY



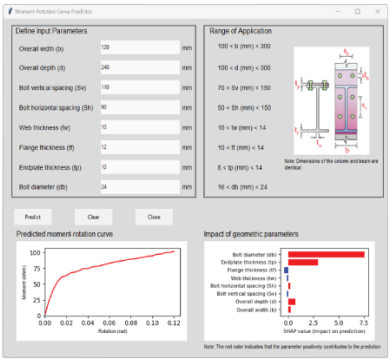
RESULTS



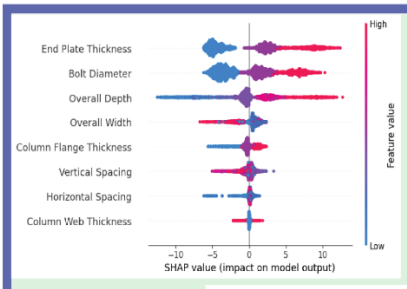
Effect of Bolt Preloading



Effect of endplate Imperfection

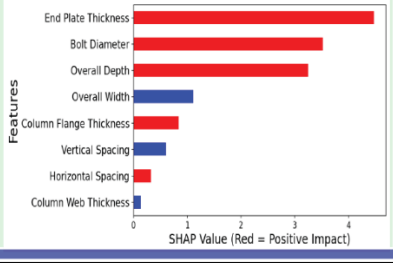


GUI: Moment-Totation Curve Predictor



SHAP Global Explanation

Average Feature Impact



MECHANICAL BEHAVIOUR OF RICE HUSK ASH AND CEMENT–STABILIZED PEAT UNDER DIFFERENT CURING PERIODS.

N.M.N.T. Narasinghe [1, *], K.H.S.M. Sampath [1]

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The problematic nature of peat due to its high organic content, substantial compressibility, and low shear strength, frequently requires stabilization to make it appropriate for construction. This research focuses on enhancing peat soil properties for construction purposes, particularly focusing on areas in Sri Lanka where peatlands present significant challenges for infrastructure development. With involvement in sustainable and cost-effective solutions, the study investigates the efficacy of using Rice Husk Ash (RHA) and cement as stabilizers for natural peatlands. In fact, this approach offers a solution for traditional stabilizers while harnessing the beneficial properties of RHA – a waste product, to enhance the peat stabilization process. This method aims not only to improve the mechanical properties of peat but also to provide an alternative to traditional stabilizers like lime or cement, which are linked to higher carbon dioxide emissions.

The suitable mix proportions of RHA and Portland composite cement (PCC) and their effects on peat's Unconfined Compressive Strength (UCS) were obtained from laboratory experiments, under different curing conditions and curing periods. The prepared samples were subjected to UCS tests to determine the stabilized peat's peak strength and stress-strain behavior. The strength and stiffness of the stabilized peat were calculated using observed test results and analyzed by comparing it with the properties of natural peat.

The findings suggest that a specific mix proportion of RHA and PCC, under a defined curing period, significantly enhances the UCS, shear strength, and stiffness of peat. The optimal curing condition was identified as submerging in water with a 1.25 kN/m^2 surcharge load and maintaining *in-situ* conditions, where stabilized samples were cured at low temperatures. It is evident from the study that different mix proportions resulted in varying strength gain variations across different curing periods, including 7 days, 28 days, 45 days, 60 days, and 80 days. In conclusion, mixing peat with 10% PCC + 10% RHA and curing for 60 days under submerged curing with a surcharge would yield optimum strength and stiffness.

After evaluating the mechanical properties, Scanning Electron Microscope (SEM) images were taken to identify the behavior of the microstructure. The microstructure reveals a hollow, perforated cellular structure, along with a minor network of fibrous elements. Voids between peat soil particles have filled with C-H-S bonds. This observation suggests that while RHA may offer certain benefits as a secondary stabilizing material, excessive reliance on it may not be conducive to achieving the desired strength properties in stabilized peat soil. However, there is a possibility of partially replacing cement with RHA which would result in the strength and stiffness gain up to anticipated levels. By demonstrating the positive impact of these materials on peat stabilization, the research contributes to the field of geotechnical engineering, offering a viable solution for construction on peatlands.

Keywords: Curing period, Peat, Portland-Composite Cement, Rice husk ash

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MECHANICAL BEHAVIOUR OF RICE HUSK ASH (RHA), CEMENT–STABILIZED PEAT UNDER DIFFERENT CURING PERIODS

Background

- Low Shear Strength
- Organic content (30-40%)
- Moisture content > 300%
- High compressibility
- High secondary consolidation settlement

Peat Soil

- Shear Failure
- Settlements of the foundation

Peat Ground Improvement Using Stabilizer

Deep mixing with traditional industrial binders (Cement, Lime, Fly ash) or non-traditional waste material (Rice husk ash) or combination of those two

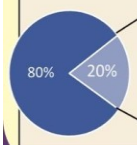
Stabilized Peat
Suitable for construction

Methodology

Selecting Mix proportion

20% of RHA and 80% of peat achieve maximum strength under submerged curing condition with surcharge load, for RHA stabilized peat.

Peat Vs Stabilizers



Rice Husk Ash	Cement
20%	0%
15%	5%
10%	10%
5%	15%
0%	20%

Peat RHA

Sample preparation

Peat Soil Collect from Kerawalapitiya

Moisture C. - 300%
Shear Strength - 3.65 kPa
Void Ratio - 5.3

Sample size - (h-200 mm, d-50 mm)
sample - 3 layers, 25 blows/layer
Surcharge - 1.25 kPa
Curing condition - Fully submerged

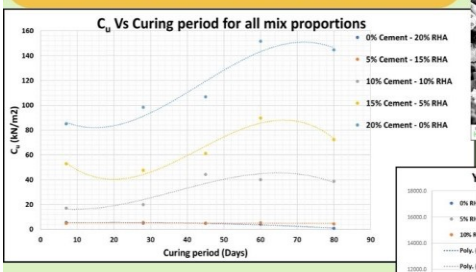
Cement - Portland Composite Cement

Rice Husk Ash -
Burning Temp.: 600-700˚C
Silicate Content: 94.8%

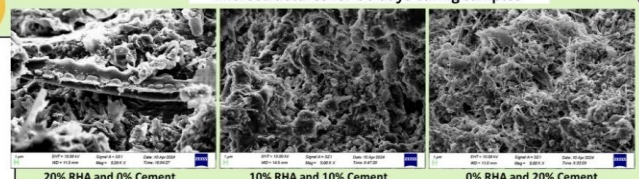
Testing & Analyzing

Stress - Strain relationships for cured samples were observed from Triaxial apparatus & calculated undrained shear strength parameters

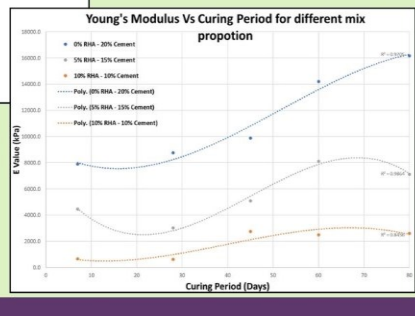
Results & Conclusion



Microstructures for 60 days curing samples



20% RHA and 0% Cement | 10% RHA and 10% Cement | 0% RHA and 20% Cement



- Shear strength & stiffness of the RHA + Cement stabilized peat soil is influenced by the curing period.
- Higher Cement percentage & lower RHA percentage can be used effectively for stabilization

Suggested mix proportion : 10% Cement + 10% RHA

Suggested curing period : 60 days in fully submerged condition

These Mix Proportions, curing periods and curing conditions are depended on initial peat properties.

ASSESS THE IMPACT OF INTERNAL CURING IN ROLLER COMPACTED CONCRETE USING ROOF TILE WASTE AS FINE AGGREGATES

V.G.S. Dilsara [1, *], W.R.A.N. Jayantha [1], W.K. Mampearachchi [1]

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The construction industry is increasingly prioritizing sustainable and eco-friendly practices, resulting in a growing interest in utilizing waste materials in concrete production. As environmental concerns continue to grow, innovative solutions are becoming essential to reduce waste and promote sustainability. One promising approach involves incorporating waste materials into concrete as internal curing agents (ICAs) to address the challenges associated with proper concrete curing. Proper curing is essential for enhancing the durability and mechanical properties of concrete, but conventional curing methods often have limitations, especially in concrete with a low water/cement ratio. This has led to a significant focus on exploring alternative methods, with internal curing gaining considerable attention. The concept of internal curing involves utilizing materials based on the ability to absorb and release water within the concrete matrix. This facilitates a more consistent and extended curing process. This research intends to address a gap in sustainable construction practices by assessing the feasibility of using roof tile waste as an internal curing aggregate (ICA) to replace fine aggregates in roller-compacted concrete (RCC). The utilization of roof tile waste not only encourages recycling and reduces landfill waste but also leverages its water absorption and desorption properties to improve the curing process.

The research involved a comprehensive series of laboratory experiments to assess the potential usage of roof tile waste as an ICA. Furthermore, the study evaluates the impact of roof tile waste on the mechanical properties of RCC, specifically focusing on compressive strength, tensile strength, and flexural strength. To achieve this, RCC samples were cast with varying percentages of roof tile aggregates (RTA) replacing fine aggregates: 5%, 10%, and 15%. Each sample was subjected to testing to assess its performance compared to externally cured conventional RCC and uncured conventional RCC.

The findings from the experiments revealed that the incorporating of roof tile waste as an ICA significantly affects the mechanical properties of RCC. The optimal performance for internal curing with RTA occurs at a 10% replacement level, balancing the benefits of internal moisture retention and the mechanical integrity of the concrete. The research emphasizes that utilizing 10% RTA replacement can lead to significantly improved early-age properties, demonstrating an 18% increase in 3-day compressive strength compared to traditionally cured RCC. This advancement is advantageous for pavement construction as it facilitates quicker access to traffic and shortens construction schedules. However, the study also identified certain constraints. Even though the early compressive strength displayed substantial enhancement, the tensile and flexural strengths of RCC samples with RTA were lower than those of conventionally cured RCC. This indicates that while roof tile waste is effective in enhancing early age compressive strength, further optimization is needed to improve its impact on tensile and flexural properties.

Keywords: Roof tile waste, Internal curing, Roller Compacted Concrete, Sustainable construction, Waste utilization

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Assess the Impact of Internal Curing in Roller Compacted Concrete Using Roof Tile Waste as Fine Aggregates.

BACKGROUND

Limitations in Conventional Curing → **Using Internal Curing Materials**

Problems in Natural Resource Depletion → **Utilizing Waste Materials**

Using Roof Tile Waste as an Internal Curing Aggregate

METHODOLOGY

Preparation of Aggregates

Aggregate Testing

1. Water absorption
2. Water desorption
3. Specific gravity

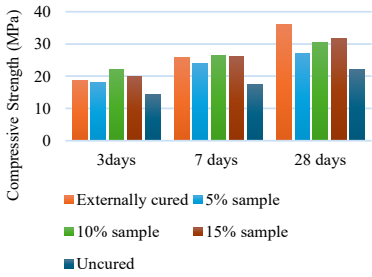
Concrete Sample Casting

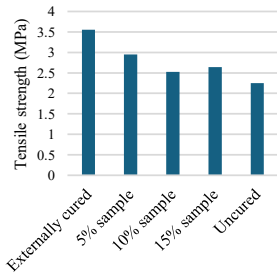
1.Externally cured conventional RCC
2.Uncured Conventional RCC
3. RCC with RTA (5%, 10%, 15% replacements)

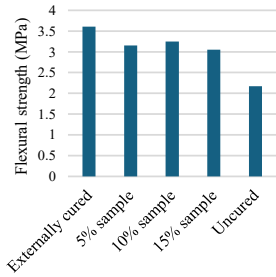
Concrete Testing

Compressive, Tensile, Flexural

FINDINGS







CTA Improves Early Strength Properties

Beneficial in pavement construction as it allows quicker access to traffic

Sample Type	Early strength gain (%)	
	3 Days	7 Days
Externally cured Sample	51.8	72.1
10% replacement	72.3	87.5

Optimal Replacement

10%

NUMERICAL SIMULATION OF PROGRESSIVE COLLAPSE OF STRUCTURES UNDER BLAST LOADS

N.T. Vandabona [1, *], P.L.N. Fernando [1]

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The growing need for blast-resistant designs in structural engineering is driven by the rising threat of terrorism, accidental explosions, and the significant risk of progressive collapse. This study presents a numerical procedure for analyzing the progressive collapse of Reinforced Concrete (RC) framed structures due to blast loads, addressing the gap in current methodologies. Traditional approaches such as the Alternate Load Path method, which are code-based and threat-independent, mainly focus on sudden column loss scenarios but do not fully capture the dynamic nature of blast-induced, threat-dependent collapses. Hence this study addresses the need for a computationally efficient and reliable method to predict and model progressive collapse under blast loading. This study employs a comprehensive numerical investigation using Finite Element Method where a seven-storeyed RC building is assessed for progressive collapse under blast loading. Progressive collapse analysis was executed using a commercially available Finite Element Analysis software, adhering to the Linear Static Procedure specified in the General Services Administration (GSA) guidelines, while blast load scenarios were examined through a nonlinear direct integration time history analysis. Different blast parameters, including charge weight and standoff distances, are varied to evaluate their impact on the structural integrity of the building. The study differentiates between threat-independent analysis, considering four column removal locations, and threat-dependent (blast-induced) scenarios with three distinct column removal positions. The scope of this study delves only into the perimeter blast scenarios neglecting the internal explosions. Demand Capacity Ratios (DCR) of columns were calculated to determine the susceptibility of the building to progressive collapse, with a DCR greater than 1 indicating failure. The numerical model was validated against the GSA baseline model. In threat-independent analysis, 30%, 60%, 22%, and 44% of the considered columns under corner, long side, short side, and interior column removal scenarios respectively exceeded the acceptable DCR criteria. In threat-dependent analysis, 100% of the considered columns under each blast induced column removal scenario exceeded the acceptable DCR criteria. This emphasizes the need for scenario-based planning in structural design to reduce collapse risks. The identification of critical columns, for threat-independent analysis as those directly above the removed column and on the topmost floor and for threat-dependent analysis as ground floor columns adjacent to the removed column, reveals potential weak points for progressive collapse initiation. The analysis of blast-induced progressive collapse reveals significantly higher DCR values than threat-independent assessments. Even the minimum percentage increases of DCRs when transitioning from threat-independent to threat-dependent analysis reaches high values up to 995%, 325%, and 981% for corner, long side, and short side column removal scenarios respectively. This specifies the importance of integrating blast resistance into the structural design of high-risk buildings. As a result, this study contributes to the understanding of structural dynamics under blast loads and offers a framework for the analysis of progressive collapse in RC buildings.

Keywords: Alternate load path method, Demand capacity ratio, Progressive collapse, Threat-dependent, Threat-independent

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NUMERICAL SIMULATION OF PROGRESSIVE COLLAPSE OF STRUCTURES UNDER BLAST LOADS

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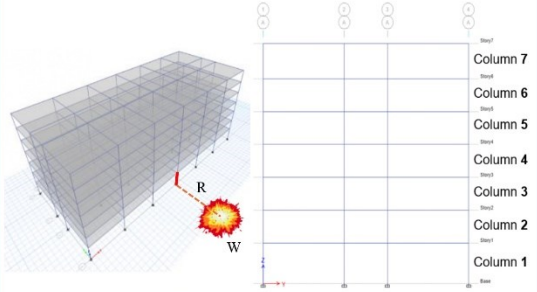
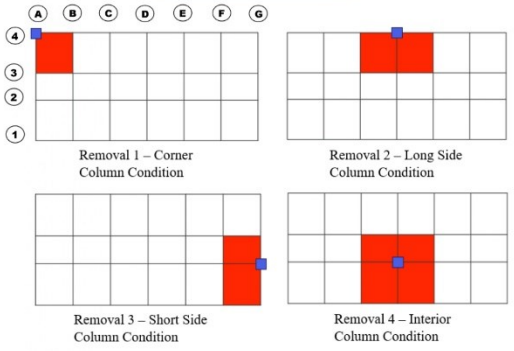
METHODOLOGY



7 storeyed RC building



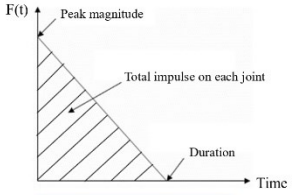
G_{LF} applied to the shaded area

G applied to the rest of the structure (unshaded area)

$$G_{LF} = \Omega_{LF} [1.2\ D + 0.5\ L] \rightarrow \Omega_{LF} = 2$$

$$G = 1.2D + 0.5L$$

Gravity load assignment after column removal

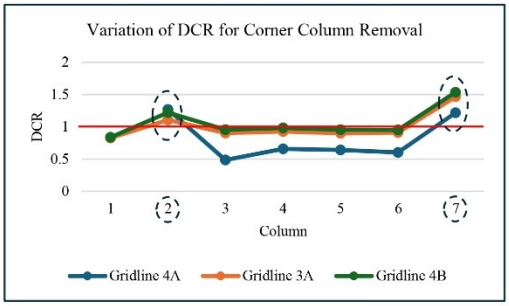


Blast loading function

RESULTS

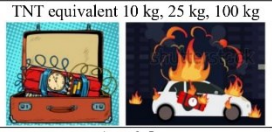
Demand Capacity Ratio (DCR)

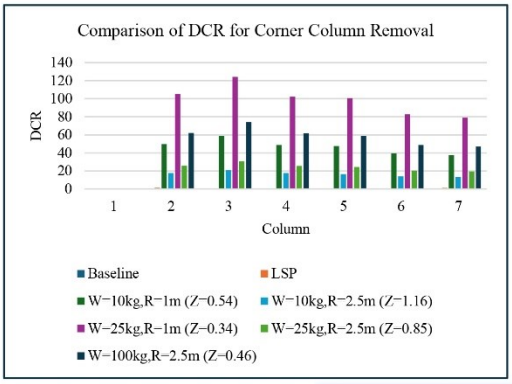
THREAT-INDEPENDENT



*for all 4 scenarios

THREAT-DEPENDENT (BLAST INDUCED)

BLAST LOAD PARAMETERS	
Type of blast	Surface blast
Explosive yield (W)	TNT equivalent 10 kg, 25 kg, 100 kg 
Standoff distance (R)	1 m, 2.5 m



*only for perimeter blasts

CONCLUSIONS

OBSERVATION	THREAT-INDEPENDENT	THREAT-DEPENDENT	CONCLUSION
DCR > 1 (Acceptance criteria)	30%, 60%, 22%, and 44% of the considered columns under corner, long side, short side, and interior column removal scenarios	100% of the considered columns	Need for scenario-based planning in structural design to reduce collapse risks
Critical columns	Directly above the removed column and on the topmost floor	Ground floor columns adjacent to the removed column	Potential weak points for progressive collapse initiation

USE OF STREAMFLOW AND SATELLITE REMOTE SENSING SOIL MOISTURE DATA FOR JOINTLY CALIBRATING THE TANK MODEL

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Hydrological modelling in arid river basins is particularly complex due to the pronounced seasonal variability in water levels fluctuating between aridity and inundation. Solely relying on a single parameter, such as streamflow data, to calibrate hydrological models in these basins can be insufficient to capture intricate interdependencies of hydrological processes. This study aimed to optimize the lumped hydrological Tank Model to accurately simulate the complex hydrological behaviour of the Maduru Oya River Basin in Sri Lanka. Further, the research investigated the use of satellite (remote sensing)-derived soil moisture data in the hydrological modelling framework, highlighting the capability of advanced technologies to enhance the reliability of hydrological predictions.

The study commenced with the collection and preprocessing of climatic data, followed by the imputation of missing values using the Closest Station Patching Technique. Root zone soil moisture data derived from the Soil Moisture Active Passive Level 4 (SMAP L4) product were acquired and pre-processed using the Cumulative Distribution Function (CDF) Matching method. The primary focus of the study was the optimization of the Tank Model through a sequential joint calibration technique with the Kling-Gupta Efficiency (KGE) chosen as the optimization criterion. This process involved optimizing the model using both single-variable calibration with streamflow data and multi-variable calibration with streamflow and soil moisture data. Multi-variable optimization was conducted using a weighted approach that assigned different contributions to soil moisture (α) and streamflow (1-α) in determining model performance. This approach was implemented across 11 distinct calibration scenarios, with the parameter α varying systematically from 0 to 1 in increments of 0.1.

The results demonstrated satisfactory streamflow simulation performance under single-variable optimization, with KGE_Q values of 0.872 and 0.848 for calibration and validation, respectively. These findings underscored the Tank model's ability to accurately represent the hydrological processes within the Maduru Oya - Padiyathalawa sub-watershed. The inclusion of root zone soil moisture data (RSRZSM) significantly improved model performance, as evidenced by KGE_Q values exceeding 0.850 for all calibration scenarios except $\alpha = 1$. Multi-variable optimization techniques further reinforced the potential for enhanced overall model performance. The most accurate and reliable streamflow simulations ($KGE_Q = 0.890$) were achieved with a minimal 10% and 90% contributions from soil moisture and streamflow respectively ($\alpha = 0.1$ calibration scenario). Furthermore, the study emphasized the critical role of remote sensing data, specifically SMAP L4 retrievals, in characterizing the soil moisture intricacies of the study area, particularly in regions with limited in-situ measurements.

The study further recommends continued validation to ensure robust model predictions. Due to the short calibration and validation periods used to minimize climatic data discrepancies, long-term validation was deemed essential for assessing model performance. In addition, the study recommended investigating alternative multi-objective optimization approaches, such as Genetic Algorithms, and incorporating more satellite data for other hydrological processes.

Keywords: Maduru Oya, Multi-variable optimization, SMAP L4, Tank model

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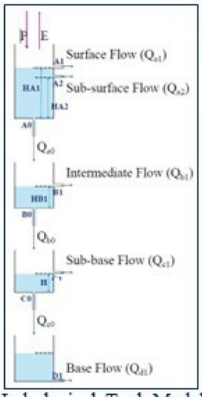
Background



Hydrological Tank Model

Uncertainties attributed to Hydrological Observations

Reliability and Accuracy of the model output

Minimization

Model Optimization

Single Variable Optimization with **Streamflow**

Inadequacy in representing catchment dynamics

Multi-Variable Optimization with **Streamflow and Soil Moisture**

Methodology

Maduru Oya – Padiyathalawa Sub-watershed

Climatic Data

Closest Station Patching Method

Remote Sensing Root Zone Soil Moisture (RSRZSM) Data

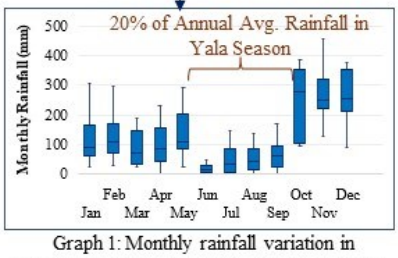
CDF Matching Method

Soil Moisture Active Passive Level 4 (SMAP L4) Product

Lack of in-situ Soil Moisture Data

Tank Model

Joint Calibration



Graph 1: Monthly rainfall variation in Welipitiya Coc. Est. rain gauge for 2009-2021.

Kling-Gupta Efficiency (KGE)

Single Variable Optimization with **Streamflow**

Multi Variable Optimization with **Streamflow and Soil Moisture**

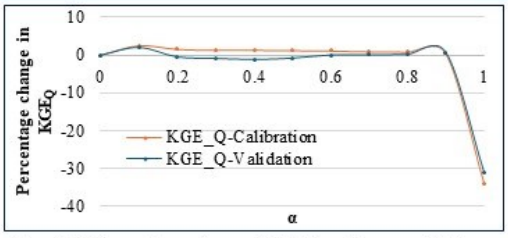
Weighted Multi-Variable Approach

$KGE_w = (1 - \alpha)KGE_Q + \alpha KGE_{SM}$

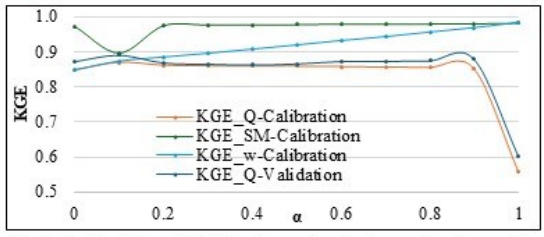
$\alpha = 0, 0.1, \ldots, 1$

Need for Water Resource Management

Results



Graph 2: Percentage change in KGE_Q with respect to the calibration scheme α = 0 (Single objective optimization with streamflow).



Graph 3: Variation of *KGE* with α value during calibration and validation using multi-objective optimization.

URBAN FLOOD ASSESSMENT TARGETING FLOOD RISK MITIGATION: A CASE STUDY FOCUSING ON CHANGING ENVIRONMENTS

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[2] School of Built Environment, Massey University, New Zealand

Among natural disasters, flooding has become a frequently significant catastrophic event causing considerable damage in urban environments in a global context. The anthropogenic changes in urban areas, along with climate change, have intensified urban floods (UFs). Metro Colombo area, Sri Lanka, is highly susceptible to UFs due to its geographical location, congested urban expansions, drainage deficiencies, lowered retention abilities, etc. Within the study, a qualitative, in-depth flood risk assessment is conducted based on a hazard assessment, vulnerability assessment, and exposure assessment for administrative units of Divisional Secretariat Divisions (DSDs). Under each assessment, six or seven influential elements were selected and assessed based on the remote sensing satellite imagery data and census data as published by the Department of Census and Statistics, Sri Lanka (DCS). Extracted data was used to develop criteria maps for influential elements, utilizing ArcGIS Pro, spatial data processing software. Utilizing the generated maps, hazard indices, vulnerability indices, and exposure indices were calculated, and by merging them, risk indices for DSDs were calculated.

In a subsequent study, the influential nature of changing land use patterns due to the effects of urbanization and changing climatic conditions was analysed for aggravating UFs. Reduced infiltration, disturbance to man-made drainage or natural runoff pathways, refilling of retention and detention areas, etc., have directly influenced the intensification of effects in urban flood events. Within this section of the study, land use changes were assessed from 2003 to 2023, using remote sensing satellite imagery, and a relationship between change in runoff coefficient and flood occurrences was generated. Subsequently, a projected climate assessment was undertaken for two (2) shared socio-economic pathways (SSP 1-2.6 and SSP 5-8.5) to execute a quantitative comparison of the exceedance probabilities of several threshold precipitation limits. A pilot study was undertaken for "Madiwela South Diversion" using HEC-RAS software to identify the inundation areas and depths for "with and without" measure scenarios.

The method successfully presented a satisfactory hazard map with four main flood hazard levels, and 11.36% of the total research area was reported as "high hazard". From the generated risk map, Colombo DSD indicated the highest risk index of 0.54, following Kesbewa, Kaduwela, and Thimbirigasyaya, with risk indices of 0.34, 0.29, and 0.28, respectively. These calculated risk index values can be utilized to reduce future flood risk by prioritizing high-risk-rated administrative divisions in executing flood mitigation measures. Through the assessment for evaluating the effect of land-use change, results revealed that standardized runoff coefficient and flood frequency are highly correlated, having an 82% correlation coefficient at a 0.90 significant level, indicating that the change in the runoff coefficient is highly related to flood occurrence. Further, Blue-Green Infrastructure (BGI) was proposed in the study as a sustainable attempt at flood mitigation.

Keywords: Flood hazard, Flood risk, Flood vulnerability, Inundation mapping

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URBAN FLOOD ASSESSMENT TARGETING FLOOD RISK MITIGATION: A CASE STUDY FOCUSING ON CHANGING ENVIRONMENTS

Aim & Objectives

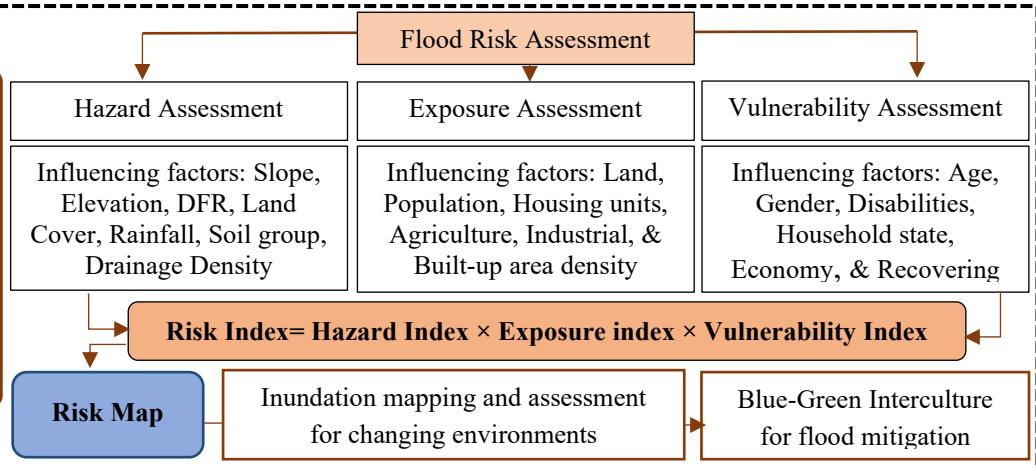
Aim

To execute a comprehensive flood risk assessment in formulating sustainable urban flood mitigation approaches ensuring the Built environment safety.

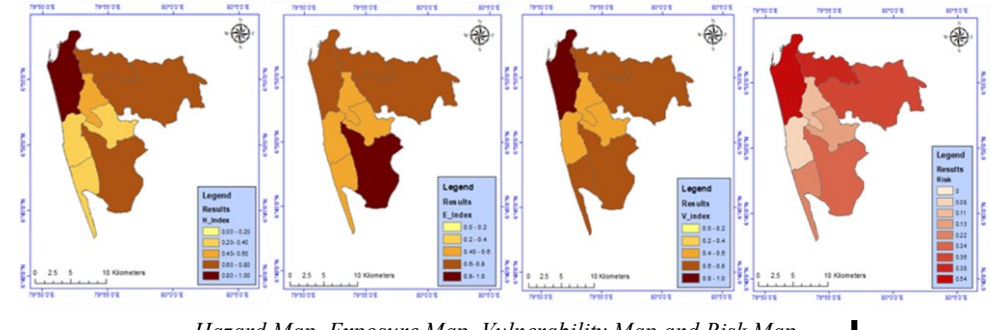
Specific Objectives

- To execute quantitative flood hazard assessment, vulnerability assessment, exposure assessment together leading to a structured risk assessment.
- To evaluate the effect of changing environment in aggravated urban flooding.
- To execute flood mapping to determine, inundation areas and inundation depths.

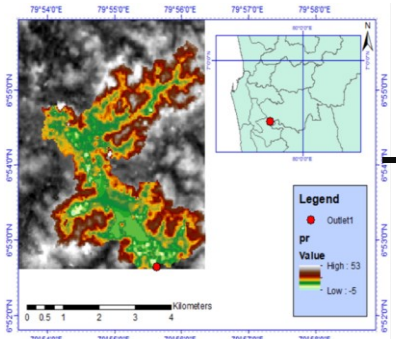
Methodology



Results



Hazard Map, Exposure Map, Vulnerability Map and Risk Map



Colombo indicated a highest risk index of 0.54.

Standardized runoff coefficient and flood frequency showed a correlation of 82%.

EFFECT OF CREASE CURVATURE ON BENDING STIFFNESS IN CURVED CREASE ORIGAMI

W.M.H.G.L.C.B. Weerasekara[11], H.M.Y.C. Mallikarachchi [1, *]

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Deployable systems play a vital role in design optimisation of spacecrafts. Limited payload capacity in launch vehicles often conflicts with the demand for large-area systems required for better performance in the operational phase. The art of origami enables the storage of a large surface structure in a compact volume by utilising plastically deformed fold lines known as creases. Origami can be categorised into two types as straight crease origami and curved crease origami based on the geometry of the crease. Straight crease origami demonstrates rigid foldability while curved crease origami facilitates smooth and efficient folding by incorporating panel bending.

The use of curved creases in deployable membranes reduces the required number of creases compared to straight creases ultimately leading to less production time and better quality deployed surface. The bending stiffness of the crease and the external force required to fold the membrane are key aspects that influence the packaging efficiency. The main objective of this research is to assess the effect of crease curvature on the bending stiffness of curved creases. The study encompassed quasi-static folding and unfolding experiments of curved-crease specimens with different crease radii made of 80 gsm printer paper to understand crease behaviour. Furthermore, numerical models were developed to simulate the crease behaviour of curved creases and validated against experiments in order to develop prediction tools for future designs.

The resistive force resulting in bending a curved crease specimen was measured experimentally for rectangular specimens with overall dimensions of 60 mm × 100 mm while varying crease radii from 35 mm to 75 mm. Additionally, the force-displacement response was recorded for flat sheets with dimensions of 50 mm × 60 mm and 100 mm × 60 mm to compare the bending stiffness of curved creases to that of a flat sheet having similar overall dimensions. The results demonstrate that the initial bending stiffness of curved-crease specimens with a low crease radius is lower but becomes higher at the maximum folded state compared to specimens with a high crease radius. Additionally, it was observed that the contribution of the unrestrained half of the specimen significantly increases the bending stiffness of a curved crease specimen during the folding motion for lower crease radius, whereas the contribution remains almost constant for higher crease radius. Numerical models of curved creases, developed in the commercial software Abaqus using a segmented curved-crease modelling approach incorporating straight crease characteristics, accurately estimate experimental reaction forces, indicating that the characteristics of straight creases can be used in modelling curved creases.

Keywords: Curved-crease origami, Crease radius, Crease stiffness

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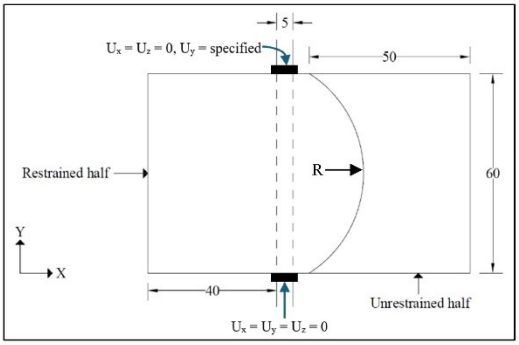
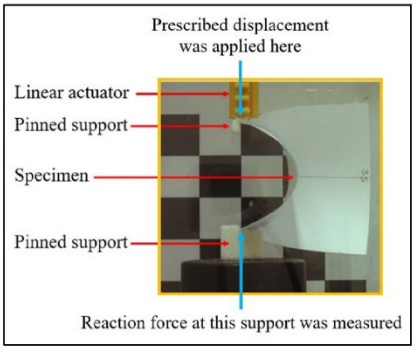
Effect of Crease Curvature on Bending Stiffness in Curved Crease Origami

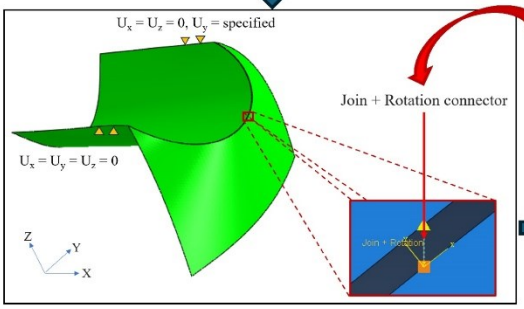
Curved beech leaf pattern inspired membrane antenna prototype



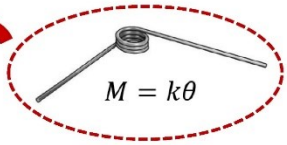
Characterisation of curved creases

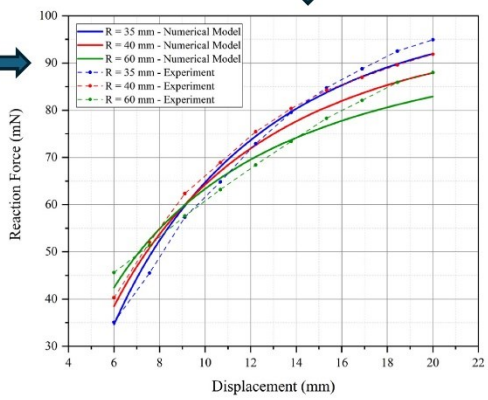


Experimental characterisation

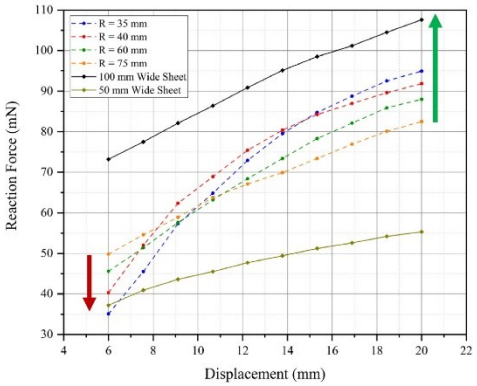


Numerical modelling





Force – displacement comparison



POINT OF FIXITY OF LATERALLY LOADED PILES ON LAYERED SOILS

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Piles are critical structural elements that often face lateral loads from various sources, including moving vehicles on bridges, wind, waves, slope movement, and seismic activities. These lateral loads can cause substantial bending moments and lateral deflections in piles, which can compromise the structural integrity of the foundation. The point of fixity is a widely used concept in the design of laterally loaded piles, providing the necessary rigidity to withstand these forces and minimize deflections. While several analytical methods have been developed to determine the point of fixity in single-layered soils, their effectiveness and applicability in multilayered soils remain less certain.

This study investigates the validity of two commonly used analytical methods, Broms method and Kocsis method for determining the point of fixity in multilayered soils. The depth of fixity was estimated using average soil properties and compared against results obtained from more advanced approaches, including finite element modelling and p-y curve analysis, which consider distinct properties of individual soil layers. A comprehensive parametric study was also conducted to examine the influence of various factors, such as soil type, soil layer thickness, pile diameter, magnitude of lateral and axial loads, and pile embedment length, on the point of fixity.

The comparison revealed significant differences between the analytical methods, particularly in the context of predominantly cohesive soils. The Broms and Kocsis methods estimated the depth of fixity to be between 1.0 and 2.0 times the pile diameter below the ground surface, while the p-y curve and FEA methods yielded slightly more conservative values, ranging from 1.0 to 1.5 times the pile diameter. In predominantly cohesionless soils, the estimated fixity depths were more consistent across all methods, varying between 1.0 and 1.5 times the pile diameter below the ground surface. These findings highlight potential limitations in the applicability of traditional analytical methods to multilayered soils and underscore the importance of refining these approaches for more accurate and reliable design.

The parametric study further revealed that for long (flexible) piles, the depth of fixity is generally not significantly affected by factors such as surrounding soil type, layer thickness, axial load, and pile length. However, pile diameter and lateral load were found to have a substantial impact on the depth of fixity, with the effects varying depending on the analytical method employed and the soil's cohesive or cohesionless nature. Interestingly, the study also found that, even in single-layered soils, the Broms and Kocsis methods could yield results that significantly deviate from those obtained via p-y curve analysis. This discrepancy underscores the necessity for further detailed studies, including experimental work with instrumented pile tests, to enhance the accuracy and reliability of these methods.

Overall, the study suggests that the point of fixity in predominantly cohesive soils ranges from 0.5 to 2.5 times the pile diameter below the ground surface, whereas in predominantly cohesionless soils, it ranges from 0.5 to 2.0 times the pile diameter.

Keywords: Broms method, Kocsis method, Maximum bending moment, Multilayered soils, p-y analysis

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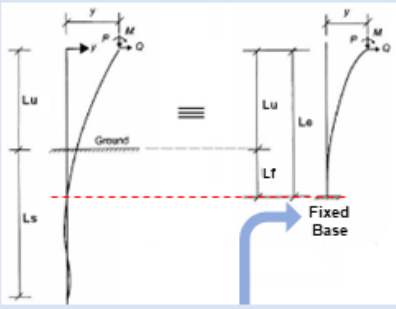
POINT OF FIXITY OF LATERALLY LOADED PILES ON LAYERED SOILS

1. Background



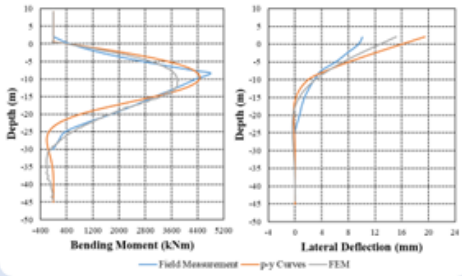
Location of the Point of Fixity

Method	Cohesive Soil	Cohesionless Soil
Broms Method	$1.5D_p + \frac{P}{9C_uD_p}$	$0.82\sqrt{\frac{P}{\gamma D_p\left(\frac{1+\sin\phi}{1-\sin\phi}\right)}}$
Kocsis Method	$0.5\sqrt[4]{\frac{E_pI_p}{k_sD_p}}$	$0.8\sqrt[5]{\frac{E_pI_p}{n_s}}$

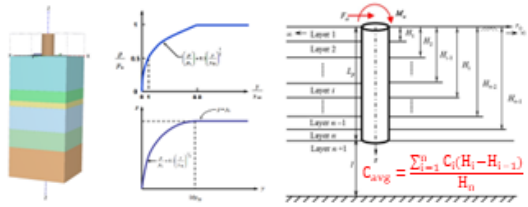
Depth of Fixity (Lf) from Analytical Methods

2. Methodology

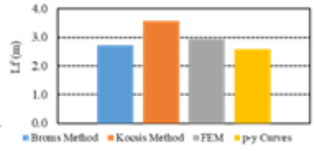
2.1. Model Validation



2.2. Estimation and Comparison of Depth of Fixity

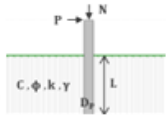


Comparison



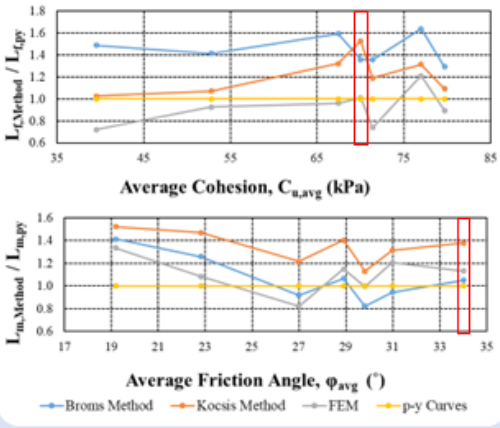
2.3. Parametric Study

Vary selected parameters while others remain unchanged

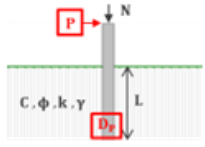


3. Results

3.1. Validity of Analytical Methods



3.2. Effect of Parameters



Significant Effect

Negligible Effect

Conclusion

- Considered analytical methods for multilayered soils have limitations
- Only lateral load and pile diameter significantly affect the point of fixity
- Point of fixity ranges: $0.5D_p$ - $2.5D_p$ depth below ground surface in cohesive soils, and $0.5D_p$ - $2.0D_p$ depth in cohesionless soils

EVALUATING THE EFFECTIVENESS OF TREATMENT SOLUTIONS ON BLUE STAIN FUNGI GROWTH IN PINE WOOD PLANTATIONS IN SRI LANKA

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The presence of blue stain fungi in pine wood plantations causes a significant challenge to the pine wood industry. Because of the visible discoloration due to the presence of fungi, it significantly reduces the market value of the wood. This study was conducted to explore the occurrence of blue stain fungi growth in pine wood plantations in Sri Lanka, with a focus on assessing the effectiveness of various wood treatment solutions. The research was conducted over six months, at a pinewood plantation in Bandarawela. The primary objective was to compare the effectiveness of different treatment solutions on the occurrence of blue stain fungi in treated versus non-treated wood samples.

27 wood samples prepared from freshly cut pine trees were used in this study. The samples were treated using four different solutions: two inorganic preservatives, Anti-blue and Anti-boron which are widely available in the market, and two innovative organic preservatives developed in Sri Lanka: Final Solution Without Mud (FSWOM) and Final Solution With Mud (FSWM). Samples were immersed in the solutions for 48 hours for the treatment, using the dipping method. To assess the impact of treatment timing, two sets of samples were prepared: one set was treated within 7 days of cutting, and another set within 7 to 14 days. To provide a baseline for comparison, a control set of non-treated samples was maintained.

The results demonstrated that all treated samples showed significantly reduced blue stain fungi growth compared to the non-treated samples. Both inorganic preservatives, Anti-blue and Anti-boron, were highly effective in mitigating the blue stain fungi growth. Remarkably, the organic preservatives were also successful. FSWM was the most effective organic solution matching the performance of the commercially available inorganic preservatives. FSWOM, while slightly less effective than FSWM, still provided good protection against blue stain fungi, indicating the potential of organic solutions in wood preservation. It revealed that adding paddy field mud significantly enhanced the antifungal properties of these organic preservatives, approaching the level of effectiveness of the inorganic preservatives.

Additionally, the study found that the timing of the treatment whether applied within 7 days or 7 to 14 days after cutting did not significantly affect the effectiveness of the treatment solutions. This implies that there is flexibility in the timing of treatment without compromising its effectiveness.

The study concludes that both organic and inorganic preservatives are effective in mitigating blue stain fungi growth in pine wood. More specifically, the organic preservative FSWM provides an effective and environmentally friendly alternative to inorganic preservatives, thereby enhancing wood preservation techniques.

Keywords: Blue stain, Fungi growth, Organic wood preservatives, Pinewood

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EVALUATING THE EFFECTIVENESS OF TREATMENT SOLUTIONS ON BLUE STAIN FUNGI GROWTH IN PINE WOOD PLANTATIONS IN SRI LANKA

Background

- Main challenge of Pine wood
  - Blue stain fungi
- Affects to the aesthetic appeal
  - Visible discoloration
- Reduce market value

Focus of the Research

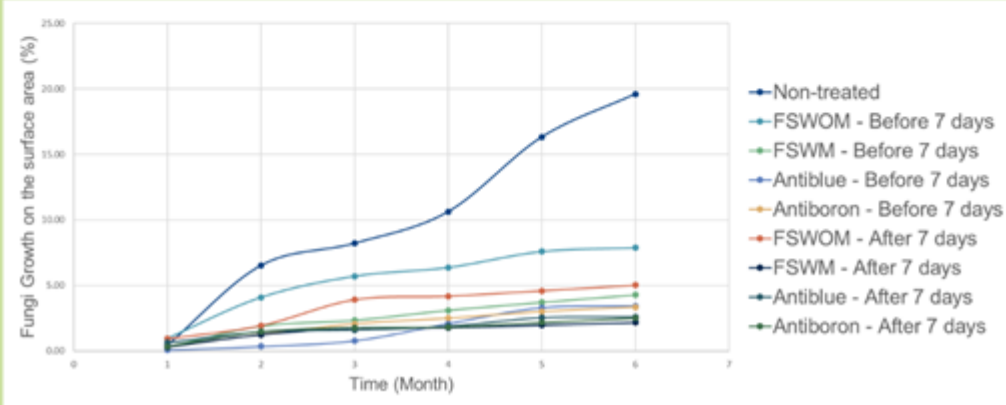
- Effectiveness of wood preservatives
- Comparing inorganic and organic treatment solutios
- Effectiveness of the timing of the treatment

Methodology

Sample Collection	Sample Preparation	Sample Treating	Data Collection	Data Analysis
				
Randomly selected Freshly Cut Trees	Sample size 2" x 2" x 18"	Anti – Blue Anti - Boron FSWOM FSWM	Monthly Photographs of all 4 sides	Grid Count Method

Results

Fungi Growth on wood samples for all treatment solutions



STUDY ON THE EFFECT OF SEAWATER ON MAKING AND CURING OF UNREINFORCED CONCRETE APPLICATIONS

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Concrete, an essential component of worldwide infrastructure, depends significantly on fresh water for its manufacturing, contributing to freshwater scarcity in many regions. As construction demands increase, transitioning to alternative water sources is important to minimize environmental impact and ensure long-term sustainability. Traditional reinforced concrete structures can experience corrosion when they come into contact with seawater, as the chloride content in seawater can lead to the deterioration of the structures. As a result, seawater is not deemed suitable for these specific applications due to the potential damage it can cause. However, it is possible to use seawater in non-reinforced concrete applications, where there is no risk of corrosion. Existing studies present conflicting results regarding the effects of seawater on concrete, with some indicating positive impacts, while others report minimal or no impact on the mechanical properties of concrete. The main objective of the study is to investigate the effect of incorporating seawater in the production and curing processes of unreinforced concrete. Specifically, the study aims to compare and analyse the properties of concrete mixed with seawater and subsequently cured with seawater, in contrast to conventional freshwater concrete.

Fresh and hardened concrete properties were evaluated for the following scenarios: concrete mixed and cured with fresh water, concrete mixed and cured with seawater, and concrete mixed with freshwater but cured with seawater. The properties of fresh concrete, specifically slump and slump loss, were evaluated, while the hardened concrete properties, including compressive strength, splitting tensile strength, and drying shrinkage, were tested at four different curing ages (3, 7, 28, and 56 days). This was done to understand the influence of seawater on the hydration process and to assess the variation in these properties over time.

The results show that the mixing of seawater has a negligible effect on the slump but leads to an increased slump loss, indicating that the workability loss is higher in seawater-mixed concrete compared to freshwater-mixed concrete. The use of seawater in curing also shows a minimal impact on the properties of hardened concrete. In addition, there is a significant difference in the mechanical performance of concrete when comparing seawater and freshwater concrete. Seawater-mixed concrete shows higher compressive strength in early ages, however, in the later stages the variation becomes less significant between the two concrete types. Early age splitting tensile strength is slightly higher in seawater-mixed concrete however at later ages it becomes considerably low compared to freshwater-mixed concrete. Seawater-mixed concrete exhibits higher drying shrinkage over time compared to freshwater-mixed concrete. Based on the findings of this research, seawater could be recommended for curing unreinforced concrete.

For further research studies, it is recommended to investigate the long-term effect of the seawater on making and curing of unreinforced concrete, focus on the effect of seawater on other properties of concrete such as setting time, permeability, electrical resistivity, etc.

Keywords: Fresh properties, Hardened properties, Seawater concrete, Seawater curing

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STUDY ON THE EFFECT OF SEAWATER ON MAKING AND CURING UNREINFORCED CONCRETE APPLICATIONS

Why is seawater needed for making and curing unreinforced concrete?

- Global threat of freshwater scarcity
- Advantageous from a sustainable perspective

Aim

Investigate the suitability of seawater for making and curing unreinforced concrete

Research Methodology

Identification of Major Parameters

- Variables
  - Concrete type
  - Curing age
- Properties
  - Slump
  - Slump Loss
  - Compressive Strength
  - Splitting Tensile Strength
  - Drying Shrinkage

Experimental Study

Concrete Mix Design → Sample Preparation → Curing → Testing

Testing

- Slump
- Compressive Strength
- Splitting Tensile Strength
- Drying Shrinkage

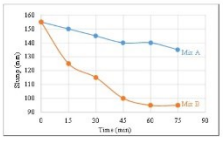
→

- BS ISO 1920-2:2016
- BS 1881-116:1983
- BS 1881-117:1983
- BS ISO 1920-8:2009

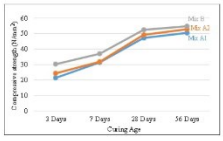
Results and Analysis

- No significant effect on the slump of concrete when using seawater as the mixing water

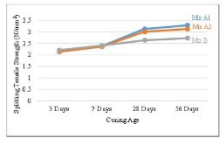
Slump Loss



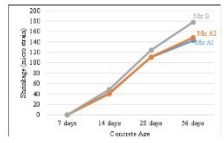
Compressive Strength



Splitting Tensile Strength



Drying Shrinkage



Mix A - Conventional freshwater mixed concrete Mix B - Seawater mixed concrete Mix A1 - Mixed with freshwater and cured with freshwater Mix A2 - Mixed with fresh water and cured with sea water

- No significant variation in the compressive strength, splitting tensile strength and drying shrinkage due to curing conditions
- Seawater-mixed concrete has a higher compressive strength in early ages, however, in the later stages the variation was less significant between the two concrete types
- Early age splitting tensile strength is slightly higher in seawater-mixed concrete however at later ages it becomes considerably low compared to freshwater concrete.
- Seawater-mixed concrete exhibits higher drying shrinkage over time compared to freshwater-mixed concrete

Recommendations

Seawater can be used for the curing of unreinforced concrete

ASSESSMENT OF DISASTER RESILIENCE IN HOSPITALS: A CASE STUDY BASED FRAMEWORK DEVELOPMENT FOR SRI LANKAN CONTEXT

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Hospitals are essential infrastructures that must maintain continuous operation during and after disasters to ensure the safety of patients and staff while providing medical services, even under surge conditions. Given the critical nature of these facilities, assessing their disaster preparedness is of utmost importance. This study addresses the limitations of the World Health Organization's Hospital Safety Index (HSI) when applied to Sri Lankan hospitals, leading to the development of the Structural Safety of Hospitals Assessment for Sri Lanka (SSH-SL). The study presents a comprehensive framework for evaluating hospital safety, divided into three primary modules: structural safety (utilizing SSH-SL), functional safety, and emergency and disaster management. Enhancements were made to the latter two modules to better align with the specific needs of the Sri Lankan context. The framework introduces a set of equations to calculate the safety index for each module, which then assigns safety levels and provides recommendations for improvement. This framework was applied to assess 15 government hospitals, revealing significant concerns across all three modules, underscoring the need for targeted interventions to enhance hospital resilience in Sri Lanka.

The results from the assessment indicate that the structural safety levels of the 15 hospitals are generally at or above average level, suggesting that these facilities can operate during disaster conditions, though steps must be taken to ensure safety of both patients and staff. In terms of functional aspects, the majority of hospitals demonstrated a safety level of average or above, with two hospitals exhibiting below-average safety levels. Regarding Emergency and Disaster Management, 11 out of the 15 hospitals displayed high safety levels, whereas two hospitals had low safety levels. Immediate actions are necessary for hospitals with below-average safety levels, with a focus on implementing both short-term and long-term remedies.

Additionally, limitations of the framework were identified during the hospital assessment process. The architectural safety submodule, under functional safety, was recognized as a critical submodule requiring modifications. Several assessment criteria specific to the Sri Lankan context were identified and subsequently incorporated into the existing submodule. Following these adjustments, a Delphi Study was conducted on the enhanced submodule, utilizing a panel of experts to gauge their consensus. Based on the survey results from the Delphi Study, weights were assigned to each assessment criterion within the submodule, leading to the derivation of a comprehensive safety score for the architectural safety of hospital buildings.

Keywords: Disaster risk reduction, Hospital safety index, Resilience, Safe hospitals

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ASSESSMENT OF DISASTER RESILIENCE IN HOSPITALS: A CASE STUDY BASED FRAMEWORK DEVELOPMENT FOR SRI LANKAN CONTEXT

Background

Aim

To assess the resilience of hospital buildings in Sri Lanka against disaster conditions and modify the global guidelines to suit the Sri Lankan context.

Methodology

Structural Safety Index (SSI)

$$SSI = \frac{SSI^{C} + \min\{SSI^{W}; SSI^{F}; SSI^{L}; SSI^{T}\}}{2}$$

Functional Safety Index (FSI)

$$FSI = \frac{\sum basic\ scores\ of\ each\ applicable\ parameter}{number\ of\ applicable\ parameters}$$

Emergency and Disaster Management Index (ESI)

$$ESI = \frac{\sum basic\ scores\ of\ each\ applicable\ parameter}{number\ of\ applicable\ parameters}$$

Safety Index		
Structural	Functional/ Emergency & Disaster Management	Safety Level
1.01 – 1.75	1.01 - 2.0	Very Low Safety (D)
1.76 – 2.66	2.01 - 3.0	Low Safety (C)
2.67 – 3.75	3.01 - 4.0	Average Safety (B)
3.76 – 5.0	4.01 - 5.0	High Safety (A)

Results

Hospital	Structural		Functional		Emergency and Disaster Management	
	Safety Index	Safety Level	Safety Index	Safety Level	Safety Index	Safety Level
Akkareipattu BH	3.71	Average	3.78	Average	4.03	High
Colombo East BH	3.42	Average	3.60	Average	3.15	Average
Dehiattakandiya BH	3.52	Average	2.93	Low	3.38	Average
Elpitiya BH	3.55	Average	3.08	Average	4.18	High
Hambantota GH	3.93	High	4.31	High	4.21	High
Kuliyapitiya TH	3.52	Average	3.51	Average	4.03	High
Mahiyanganaya BH	3.51	Average	3.30	Average	4.94	High
Marawila BH	3.38	Average	2.84	Low	3.11	Average
Nikaweratiya BH	3.61	Average	3.65	Average	2.04	Low
Nuwara Eliya DGH	3.39	Average	3.27	Average	4.54	High
Panadura BH	3.32	Average	3.57	Average	3.94	Average
Rathnapura TH	3.44	Average	3.85	Average	4.16	High
Peradeniya TH	3.52	Average	3.23	Average	4.04	High
Tangalle BH	3.49	Average	3.64	Average	4.08	High
Warakapola BH	3.71	Average	3.65	Average	4.11	High

Functional Safety Module

1) Architectural safety
2) Infrastructure protection, access and physical security
3) Critical systems
4) Equipment and supplies

Modified Architectural Safety submodule			
Attribute	Weight	Attribute	Weight
Major damage and repair of non-structural elements	0.050	Condition and safety of internal walls and partitions	0.097
Condition and safety of doors, exits and entrances	0.055	Condition and safety of false or suspended ceilings	0.108
Condition and safety of windows and shutters	0.055	Condition and safety of the elevator system	0.141
Condition and safety of other elements of the building envelope	0.047	Condition and safety of stairways and ramps	0.162
Condition and safety of roofing	0.070	Condition and safety of floor coverings	0.171
Condition and safety of railings and parapets	0.067	Level of visibility in the medical wards	0.207
Condition and safety of perimeter walls and fencing	0.053	Availability of adequate space for storage and critical operations	0.424
Condition and safety of other architectural elements	0.055	Condition of the internal ventilation/Air quality	0.284
Safe conditions for movement outside the hospital buildings	0.080	Condition and adequacy of sanitary appliances	0.736
Safe conditions for movement inside the building (e.g. corridors, stairs)	0.105		

ENHANCING STREAMFLOW PREDICTION IN SRI LANKAN RIVER BASINS USING AI MODELS: A COMPARATIVE STUDY OF WET AND DRY ZONES

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Artificial Intelligence (AI) techniques have gained significant attention in recent years for their application in various engineering domains, including hydrology. Groundwater modelling, streamflow prediction, precipitation forecasting, temperature forecasting, and time series generation for rainfall are some of the hydrological applications that have benefited from AI techniques. In Sri Lanka, water resource management is challenging due to the country's geographical characteristics, seasonal rainfall patterns, and growing water demands. Traditional methods used in water resource management have limitations and rely on complex parameters, which often result in less accurate predictions of rainfall-runoff, flood events, and drought conditions, impeding effective water resource management. To enhance water resource management practices in Sri Lankan River basins, AI methodologies were integrated into hydrological modelling.

Two river basins were chosen as representatives of the wet and dry zones in Sri Lanka: the Ellagawa sub-basin from the Kalu River basin for the wet zone, and the Thanamalwila sub-basin from Kirindi Oya basin for the dry zone, covering the period from October 1, 2000, to September 30, 2011. The pivotal recurrent neural network (RNN) architectures such as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) are highly effective for modelling time series data, especially when it comes to streamflow prediction. These models are excellent at capturing temporal dependencies, which is significant for streamflow as it depends on previous data and weather. In this study, both the physically-based semi-distributed HEC-HMS hydrological model and AI models such as RNN-LSTM and RNN-GRU were applied to evaluate their predictive capabilities in streamflow forecasting. The performance of these models was assessed using objective criteria including Nash-Sutcliffe Efficiency (NSE), Mean Ratio of Absolute Error (MRAE), and the coefficient of determination (R^2).

The observed and predicted streamflow hydrographs and flow duration curves (FDC) were generated to evaluate model goodness of fit and time series graphical comparability. The study findings indicate that the LSTM model is superior to both the GRU and HEC-HMS models in predicting streamflow, with an MRAE of 0.42 and NASH of 0.82 for the LSTM model in wet zone river basins. The LSTM algorithm used the best values of R^2, which were 0.88 and 0.87 for the testing and training phases, respectively. The proposed model may be used to develop other basins in the wet zone. However, for the Thanamalwila sub-basin, the results of both AI and physical-based models were poor, likely due to inaccurate input features and inherent mismatches between rainfall and streamflow. Better input features are essentially required to improve the model training and simulation process. Therefore, the integration of AI techniques presents an opportunity for Sri Lanka to overcome existing limitations in hydrological modelling and enhance its resilience to water-related challenges. By embracing innovative approaches and leveraging available data, Sri Lanka can strengthen its capacity for water resource management and adaptation to climate change impacts, ultimately fostering sustainable development and resilience in the face of evolving environmental conditions.

Keywords: AI techniques, GRU, Kalu river basin, Kirindi Oya basin, LSTM, RNN

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ENHANCING STREAMFLOW PREDICTION IN SRI LANKAN RIVER BASINS USING AI MODELS: A COMPARATIVE STUDY OF WET AND DRY ZONES

Aim & Objectives

Aim

To evaluate how Artificial Intelligence techniques can be applied effectively within Sri Lankan river basins to enhance water resource management.

Objectives

To gather data, conduct a detailed investigation of the characteristics of Sri Lankan River basins, and develop a traditional or AI-based model for predicting missing data

To develop AI-based models for streamflow prediction in two river basins, covering both dry and wet zones

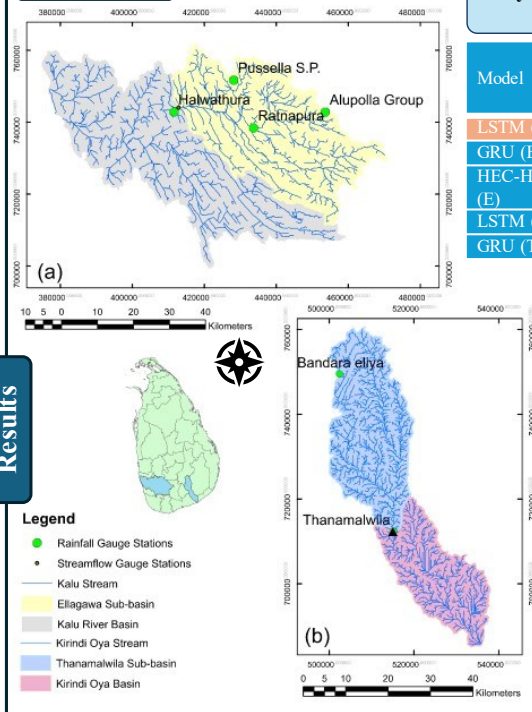
To compare the performance of AI models with traditional hydrological models to verify the results gathered from AI models

Methodology

Two River basins from Wet and Dry zone → Streamflow, Precipitation & Temperature Data → Training (2000-2008) / Testing (2008-2011) → HEC-HMS / RNN-LSTM / RNN-GRU → Streamflow Simulation

Results

Study Area

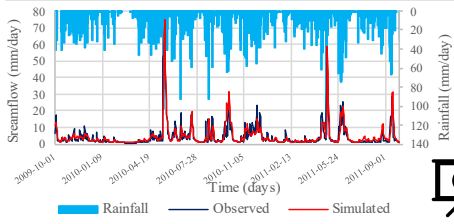


(a) Ellagawa sub-basin in wet zone (1,414 km ^{2})
(b) Thanamalwila sub-basin in dry zone (675 km^2)

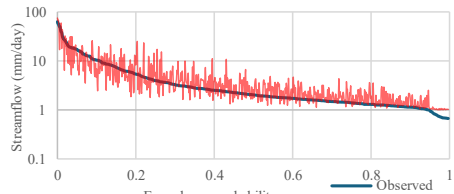
Hydrological Model Performance in Ellagawa & Thanamalwila

Model	Training Period			Testing Period		
	NSE	MRAE	R^2	NSE	MRAE	R^2
LSTM (E)	0.76	0.39	0.87	0.82	0.42	0.88
GRU (E)	0.63	0.22	0.83	0.81	0.32	0.87
HEC-HMS (E)	0.73	0.37	0.86	0.80	0.40	0.86
LSTM (T)	0.63	2.47	0.81	0.42	2.24	0.56
GRU (T)	0.34	0.79	0.62	0.30	1.42	0.45

Unsatisfactory results in Kirindi Oya basin



Hydrograph forEllagawa sub-basin (LSTM model)- Testing



FDC curve Ellagawa sub-basin (LSTM model)- Testing

DESIGN-INFORMED OPTIMIZATION OF 2D SKELETAL STRUCTURES USING CONVOLUTIONAL NEURAL NETWORKS

J.A.N.N. Jayaweera [1], H.M.S.T. Herath [1, *]

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Structural optimization aims to find the most efficient material distribution within a design domain by minimizing material usage, self-weight, and strain energy, while maximizing strength. Optimization approaches often use compliance as the objective function and volume as a constraint, which can result in designs that may not fully meet the practical requirements of civil and structural engineering due to potential inadequacies in structural integrity. To address this issue, design-informed optimization integrates structural optimization with design codes such as EN 1993-1-1, ensuring that optimized designs comply with structural integrity requirements and real-world applicability. Existing design-informed optimization algorithms typically rely on iterative schemes, which are computationally intensive and require specialized expertise. To overcome these challenges, this study introduces a novel computer vision-based framework that predicts design-informed optimized frames and accurately identifies member sizes using image processing techniques coupled with probabilistic section classifiers. This framework utilizes input parameters such as span, height, and load to predict the topology, size, and layout of optimized frames that satisfy structural adequacy criteria. It is particularly beneficial for assembly-based manufacturing, where precise member section prediction is crucial for construction efficiency and material optimization. The framework consists of three stages. In Stage 1, the CNN64 model generates a low-resolution layout of the optimized frame using input parameters such as span, height of the design domain, and load. In Stage 2, the CNN512 model refines this layout to produce a high-resolution image of the optimized frame, where section sizes are assigned. These models are trained on varying parameters including fixity, design domain, and load conditions. Stage 3 involves a member section identification algorithm that classifies the optimal structural section sizes through image processing techniques.

The efficacy of the framework was validated using simply supported and cantilever beam datasets, achieving pixel accuracies of 94.6% and 91.8%, respectively. Post-calibration, the section identification algorithm, which accounts for unavoidable errors such as generator residuals and section identification errors, achieved near 100% accuracy, demonstrating the robustness of the probabilistic section classifier. Compared to alternative architectures, the CNN64+CNN512 framework consistently outperformed others in metrics such as pixel accuracy, true positive rate, and binary cross-entropy in both datasets. It also demonstrated a significant reduction in computational loss, further confirming its computational efficiency. Overall, the analysis reveals that the CNN64+CNN512 model not only provides superior performance in prediction accuracy but also strikes an effective balance between computational efficiency and model complexity.

Keywords: Convolutional neural networks, Data-driven optimisation, Section identification, structural optimisation

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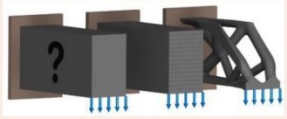
Design-Informed Optimization of 2D Skeletal Structures Using Convolutional Neural Networks

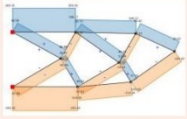
Background

Structural optimization



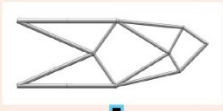
Finding the best material distribution

Integrity Check



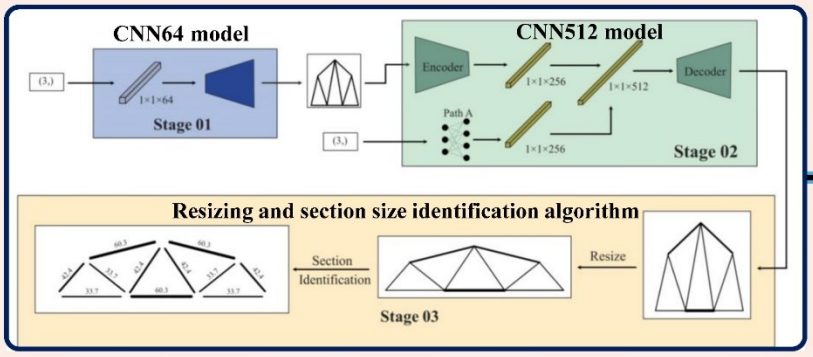
design-code-based structural evaluation

Design-informed optimization



A computationally expensive iterative algorithm

Proposed computer vision-based framework to reduce computational cost



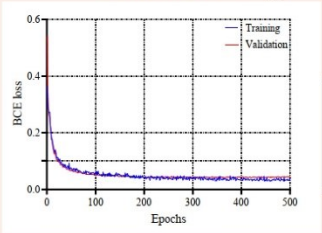
Stage 1 – Generates layout of the optimized frame

Stage 2 – Generates images of optimized frames in 512x512 resolution

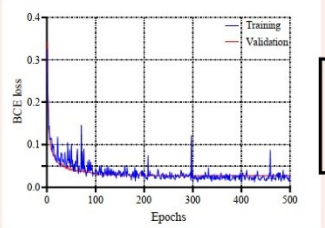
Stage 3 – Identification of section sizes

Results

Model Training



CNN64 with simply supported dataset



CNN512 with cantilever dataset

Evaluation of Stage 1 and Stage 2 models

Metric	Simply supported dataset	Cantilever dataset
Mean BCE	0.410	0.310
Pixel accuracy	0.946	0.918
True positive rate	0.874	0.807
True negative rate	0.967	0.948

Stage 3 as a classification

Identified thickness → Tolerance interval of equivalent thickness → Standard CHS

EFFECT OF TIE BEAMS ON THE BEHAVIOR OF ISOLATED FOUNDATION SYSTEMS

L.T.D. Gunathilaka [1], L.I.N. De Silva [1, *]

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The stability of isolated foundation systems is crucial to the structural integrity and safety of buildings, especially in regions with varying load conditions. Tie beams, widely used to connect isolated footings, play an integral role in this process. However, their impact on bearing capacity and settlement characteristics is often overlooked in standard analyses. This research primarily aimed to explore the influence of tie beams on the settlement characteristics and overall performance of isolated foundation systems. A comprehensive methodology combining both model experiments and finite element analysis (FEA) was employed to achieve these objectives.

Initially, two model experiments were conducted using small-scale prototype structures: one with a single isolated footing and another with two footings connected by a tie beam. These experiments aimed to validate the FEA results by comparing the experimental settlement data with the simulated outcomes.

Two distinct models of the foundation system were developed, each based on a typical three-story building with 16 isolated footings. This setup was designed to simulate a realistic structural scenario and evaluate the impact of tie beams under varying loading conditions. The footings were loaded with varied loadings in the range of 350 kN to 1300 kN to simulate real-world scenarios. One model included tie beams connecting the footings, while the other omitted them, allowing for a comparative analysis of their effects on settlement and structural integrity.

The findings reveal that incorporating tie beams significantly reduces the maximum individual settlement, with a decrease of up to 22 mm (43%). Furthermore, the inclusion of tie beams narrowed the variation in settlement across individual footings, resulting in a more uniform distribution of settlements. Differential settlements were notably reduced, with all values staying under 2 mm, reflecting a 92% reduction compared to the model without tie beams.

In conclusion, the inclusion of tie beams significantly reduces both settlements and differential settlements, contributing to a more uniform distribution of loads across isolated foundation systems. While positioning tie beams at the footing level may further reduce settlements, it also increases the forces acting on the tie beams, necessitating higher reinforcement and potentially leading to increased construction costs. The research recommends maintaining tie beams at ground level in general construction practices, except in scenarios where minimizing settlements is critically important. This study underscores the significance of tie beams in enhancing the performance and stability of isolated foundation systems, highlighting their essential role in mitigating settlement-related issues.

Keywords: Pad footings, Finite element analysis, Shallow foundations, Differential settlement, Model experiment

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EFFECT OF TIE BEAMS ON THE BEHAVIOR OF ISOLATED FOUNDATION SYSTEMS

Model Experiment

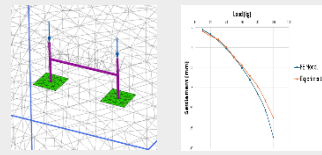
Apparatus

Two prototype footings

Experiment Procedure

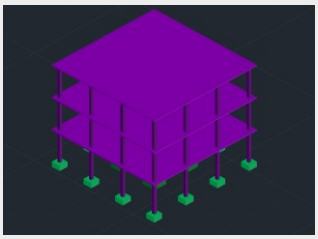
The experimental setup was loaded, and settlements were measured

FEM Validation

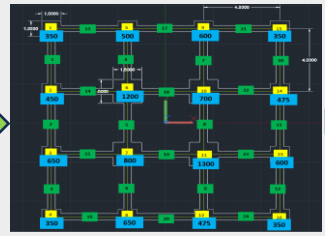


Experiment modeled with FE Software for both setups, and results were compared

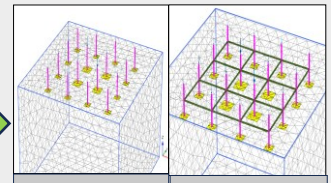
Finite Element Model



Considered building with isolated foundation system



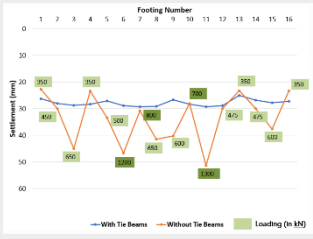
Foundation system with varying loadings (350 kN - 1500 kN)



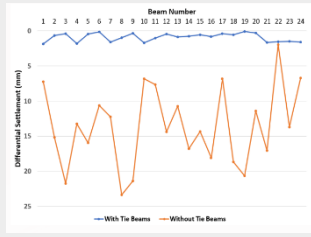
Without Tie Beams | **With** Tie Beams

FEM for two foundation systems

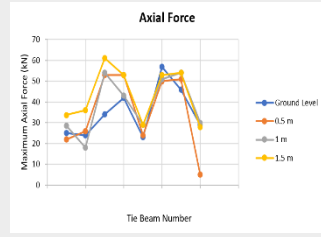
Results and Conclusion



Variation of verticle settlement



Variation of differential settlement between adjacent footings



Variation of axial load with tie beam location

- Incorporating tie beams significantly reduces the maximum individual settlement, with a decrease of up to 22 mm (43%)
- Differential settlements were notably reduced, with all values staying under 2 mm, reflecting a 92% reduction compared to the model without tie beams
- Positioning tie beams at the footing level may further reduce settlements, it also increases the forces acting on the tie beams

TSUNAMI HAZARDS: ASSESSMENT OF EXPOSURE OF SRI LANKA – CASE STUDY IN POTUVIL, KALMUNAI AND NILAVELI

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[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Tsunamis, caused by impulsive disturbances such as undersea earthquakes, volcanic eruptions, and landslides, pose significant risks to coastal regions worldwide. This research focuses on assessing the tsunami exposure levels of Sri Lanka, specifically from potential future events generated in the Sunda Trench, using numerical modelling techniques. The study highlights the importance of understanding the varying degrees of risk along the coastline to enhance disaster preparedness and mitigate impacts. The Indian Ocean Tsunami of December 26, 2004, demonstrated the devastating effects of such events, particularly in Sri Lanka, where extensive loss of life and property occurred. Subsequent tsunami alerts underscored the need for accurate risk assessments, as damage levels varied significantly across different coastal areas. Sri Lanka's geographical location, in proximity to earthquake-prone zones like the Sunda Trench and the Makran Fault, exposes it to far-field tsunamis, providing a crucial time window for early warnings and evacuations.

This research employs the Community Model Interface for Tsunami (ComMIT) to simulate various tsunami scenarios and analyse nearshore wave characteristics. The study focuses on Potuvil, Kalmunai, and Nilaveli, areas significantly impacted by the 2004 tsunami and characterized by high population density and growing tourism, increasing their vulnerability to coastal hazards. ComMIT, based on the Method of Splitting Tsunamis (MOST), is used for the numerical simulations, incorporating predefined earthquake sources and detailed bathymetric data. The simulations cover potential tsunami events from earthquakes of magnitudes 7.5 to 9.2 in four segments of the Sunda Trench. The results provide insights into the maximum wave amplitudes and arrival times at selected coastal locations.

The findings reveal that the coastal areas of Potuvil, Kalmunai, and Nilaveli are highly exposed to tsunamis generated in the Sunda Trench, especially from high-magnitude earthquakes. Nilaveli and Potuvil show severe exposure to events with magnitudes 9.0 and 9.2, while Kalmunai faces substantial exposure to magnitude 9.2 earthquakes. These results are critical for enhancing disaster preparedness and risk mitigation in Sri Lanka's coastal regions. By identifying areas with high exposure, authorities can prioritize the development and implementation of early warning systems, evacuation plans, and infrastructure improvements. This research contributes to the broader goal of increasing resilience to natural disasters through informed decision-making at both local and national levels.

Future research should continue to refine tsunami hazard assessments with updated data and advanced modelling techniques to ensure accurate predictions. Additionally, efforts to enhance public awareness and community preparedness are essential to foster a culture of resilience and proactive response to tsunami threats. Leveraging scientific research and collaborative efforts, Sri Lanka can effectively mitigate tsunami impacts, safeguarding lives, and livelihoods in its coastal communities.

Keywords: ComMIT, Early warning, Numerical modelling, Tsunami height

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TSUNAMI HAZARDS: ASSESSMENT OF EXPOSURE OF SRI LANKA – CASE STUDY IN POTUVIL, KALMUNAI AND NILAVELI

Study Area

Nilaveli

Kalmunai

Potuvil

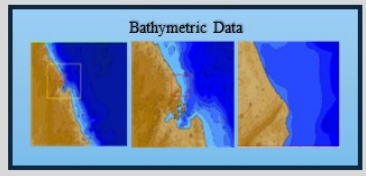
Details of the Locations

Location	Latitude	Longitude	Depth (m)
Potuvil	6.84764	81.94170	50
Kalmunai	7.41187	81.95249	50
Nilaveli	8.7112	81.24723	50

Earthquake Magnitudes

7.5	8.0	8.2	8.4
8.6	8.8	9.0	9.2

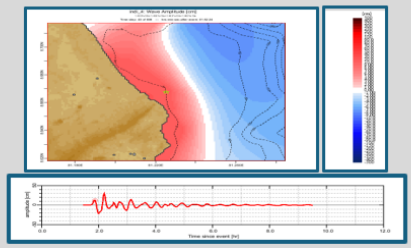
Input Data for ComMIT



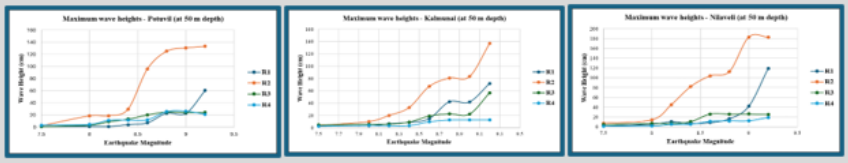
Fault parameter calculation

Forming unit source combinations

Output Data from ComMIT

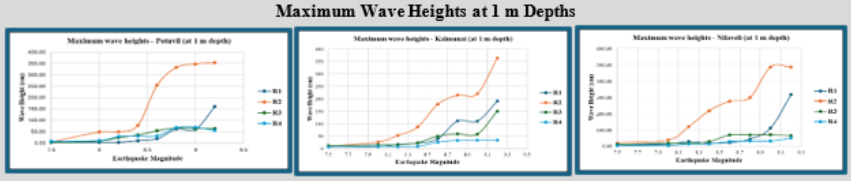


Maximum Wave Heights at 50 m Depths



Wave Transformation

Maximum Wave Heights at 1 m Depths



Exposure Assessment

Maximum wave height at 1 m depth	Level of exposure
0 – 0.5	Low(L)
0.5 – 2	Medium(M)
>2	High(H)

M_w	Potuvil				Kalmunai				Nilaveli			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
7.5	L	L	L	L	L	L	L	L	L	L	L	L
8.0	L	L	L	L	L	L	L	L	L	L	L	L
8.2	L	L	L	L	L	M	L	L	L	M	L	L
8.4	L	M	L	L	L	M	L	L	L	H	L	L
8.6	L	H	M	L	L	M	M	L	L	H	M	L
8.8	M	H	M	M	M	H	M	L	L	H	M	L
9.0	M	H	M	M	M	H	M	L	M	H	M	L
9.2	M	H	M	M	M	H	M	L	H	H	M	M

IMPACT OF PARTICLE MORPHOLOGY ON THE SHEAR BEHAVIOR OF QUARRY DUST/SEA SAND - CONCRETE INTERFACE IN GEOTECHNICAL STRUCTURES

K.A.M.M. Deshan [1], K.H.S.M. Sampath [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Soil-structure interaction is a fundamental consideration in geotechnical and structural engineering, influencing various applications such as pile systems, retaining walls, and other foundational structures. In recent years, the use of alternative materials like quarry dust and sea sand as complete replacements for traditional materials in ground improvement projects has gained attention due to their potential to enhance soil properties and overall geotechnical performance. This study focuses on the shear strength of the soil-concrete interface, particularly when utilizing quarry dust, river sand, and sea sand. The primary objective is to evaluate the influence of particle morphology on the shear behavior of these materials through a series of direct shear tests.

Quarry dust, river sand, and sea sand samples were collected from different regions in Sri Lanka and subjected to thorough testing, including sieve analysis and direct shear tests, to investigate their gradation and interface shear behavior. The samples were tested in fully dry conditions, with particle sizes ranging from 0.075 mm to 2.36 mm. Additionally, particle morphology parameters such as angularity, roughness, roundness, and sphericity were quantified using image analysis techniques. These parameters were then correlated with the shear strength characteristics of the soil-concrete interface.

Experimental results indicate that angular-shaped quarry dust particles exhibit an enhanced friction angle and interface friction angle by 10.8% and 12.4%, respectively, with an increase in angularity from 1.091 to 1.122, compared to spherical or rounded particles. Additionally, with an increase in regularity from 0.76 to 0.81, the interface friction angle decreased from 27.4^0 to 24.8^0, and the friction angle decreased from 32.4^0 to 28.9^0, marking percentage decreases of 9.7% and 11.0%, respectively. When comparing the coefficient of uniformity (C_u) values of the quarry dust, river sand, and sea sand samples, it was identified that higher C_u values correspond to higher friction angles and interface friction angles. The friction angle has increased by 4.7% and 15.6%, respectively, at the soil interface and the soil-concrete interface when the C_u value rises. Additionally, an increase in particle sizes increases the shear strength of samples. For instance, for a normal stress of 150 kPa, when the particle size increases from 0.075 mm to 2.36 mm, the shear strength increases by 21.2%.

The study concludes that quarry dust, with its angular and irregular particles, can enhance the shear strength of soil-concrete interfaces, making it a suitable material for geotechnical applications. However, the developed correlations are valid only within the analyzed particle size range, and further studies are recommended to extend the applicable range and include the effects of moisture content on interface shear strength.

Keywords: Interface shear behaviour, Particle size, Gradation, Particle morphology, Image analysis

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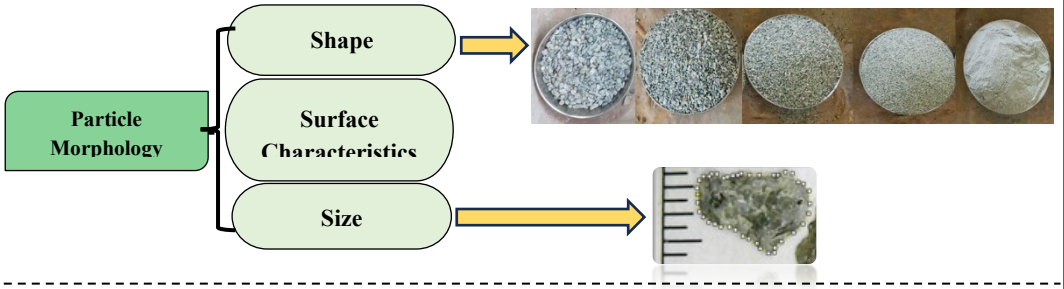
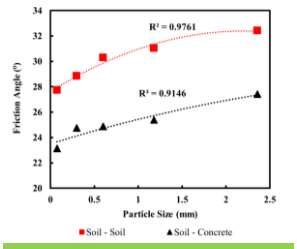
Impact of Particle Morphology on the Shear Behavior of Quarry Dust/Sea Sand - Concrete Interface in Geotechnical Structures

1. Background & Methodology

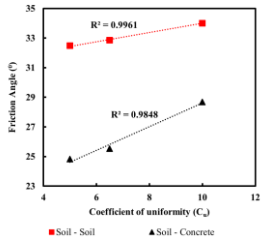


2. Results



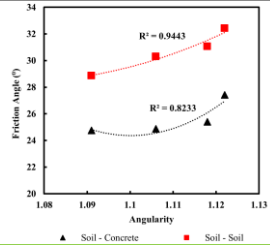
$\emptyset = -0.98PS^2 + 4.34PS + 27.61$

$\delta = -0.22PS^2 + 2.15PS + 23.5$



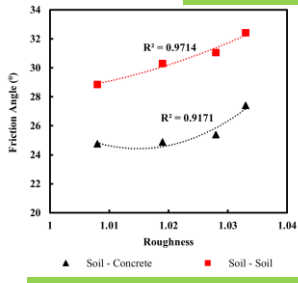
$\emptyset = 0.31C_u + 31$

$\delta = 0.8C_u + 20.6$



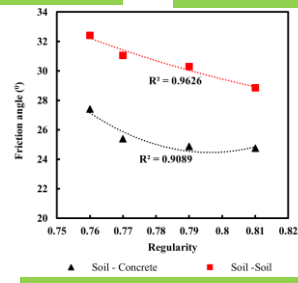
$\emptyset = 1568.6A_n^2 - 3367.8A_n + 1836$

$\delta = 5410.7A_n^2 - 11905A_n + 6573$



$\emptyset = 1963.6R_n^2 - 3874R_n + 1938.7$

$\delta = 8393.3R_n^2 - 17037R_n + 8670$



$\emptyset = 338.7RE_n^2 - 597.6RE_n + 290.8$

$\delta = 2037.2RE_n^2 - 3244.5RE_n + 1316.3$

3. Conclusions

Shear strength of the quarry dust-concrete interface increases significantly with larger particle sizes and higher coefficients of uniformity (C_u).

DEVELOPMENT OF BOND STRESS-SLIP MODELS FOR CFRP/CONCRETE BOND EXPOSED TO MILD ACIDIC EXPOSURE

A.K.S. Ravidu [1], E.R.K. Chandrathilaka [1], J.C.P.H. Gamage [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Sri Lanka

Carbon Fiber Reinforced Polymer (CFRP) is widely used in various industries due to its excellent mechanical properties, including a high tensile strength-to-weight ratio and resistance to corrosion. However, the bond performance of CFRP with concrete can be adversely affected by exposure to mild acidic environments, which can originate from sources such as acidic rains, soil, sewage, and industrial activities. This study focuses on developing an understanding of the bond stress-slip behaviour of CFRP/concrete joints exposed to acidic conditions, specifically examining the impact of different bond curing temperatures and exposure periods in a mildly acidic environment.

The experimental results, obtained from a previous study, involved CFRP/concrete single-lap shear specimens exposed to a sulphuric acid solution with a pH value of 2 for 15, 30, and 90 days. Those specimens were cured at ambient temperature (28 °C), 65 °C, and 75 °C to investigate the effects of curing conditions on bond performance. The experimental results from that study provided data on load-displacement behaviour and failure modes under those varying conditions. Complementing the experimental work, a finite element model (FEM) was developed using a commercially available finite element software to simulate the bond behaviour of CFRP/concrete joints. A modified version of Simplified concrete damage plasticity model was used as the material model for concrete, while a linear elastic model was employed for the CFRP, and the adhesive was modelled using a damage evolution model to account for potential degradation. The numerical model was validated against the experimental data, showing a strong correlation in predicting the load-displacement behaviour of the joints under different curing and exposure conditions.

The results of the study indicated that curing temperature significantly influenced the bond strength of CFRP/concrete joints. Specimens cured at 65 °C exhibited the highest failure loads, suggesting that elevated temperature curing enhanced the bonding mechanism. However, curing at temperatures beyond the glass transition temperature (T_g) of the epoxy resin resulted in a reduction of bond strength. Furthermore, prolonged exposure to acidic environments degraded the bond strength, with noticeable reductions observed after 90 days of exposure. This degradation is due to chemical reactions with the acid that weaken the bond interface.

Parametric studies were also conducted to assess the effects of adhesive layer thickness and different types of CFRP on bond performance. An adhesive thickness of approximately 1 mm was found to be optimal for maximising bond strength. Additionally, the use of CFRP with a higher modulus showed marginal improvements in joint strength but did not significantly alter the overall failure behaviour when exposed to a mildly acid environment.

Keywords: CFRP / Concrete joints, Finite element modelling, Bond-slip variation, Mild acidic exposure

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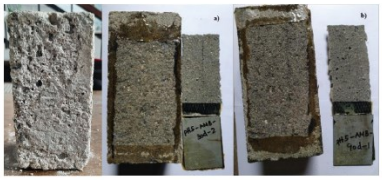
Development of Bond Stress-Slip Models for CFRP/Concrete Bond Exposed to Mild Acidic Exposure

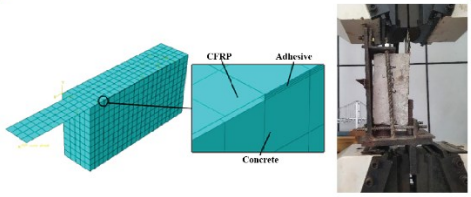
Environmental Impact on CFRP/Conrete Bonds

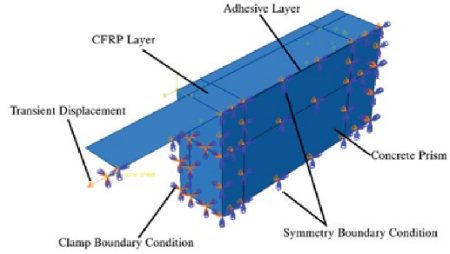
Carbon Fiber Reinforced Polymer (CFRP), known for its high strength-to-weight ratio, is used to reinforce concrete structures, improving durability and performance in demanding and corrosive environments



Mild acidic exposure from rain, soil, and industrial activities can degrade CFRP-concrete bonds, compromising structural integrity

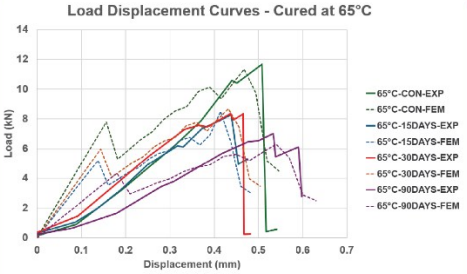
Simulation Approach

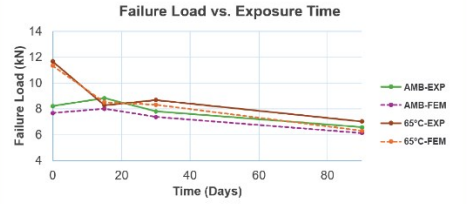




Finite element modeling simulated CFRP-concrete bond behavior under various curing conditions and acidic exposure, accounting for material degradation

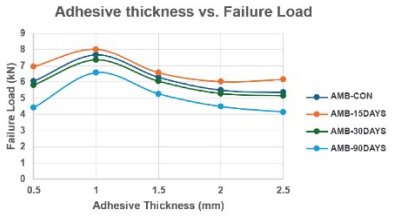
Model Validation



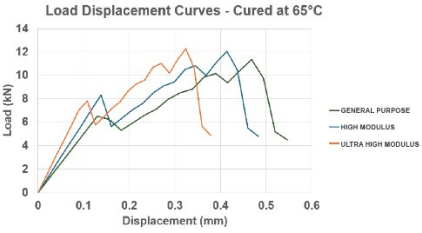


The finite element model accurately predicted load-displacement behavior under both ambient and elevated curing conditions, confirming its reliability

Key Findings



An optimal adhesive thickness of 1 mm maximizes bond strength by balancing coverage and stress within the bond line



Higher modulus CFRP slightly increased peak load, but overall failure behavior remained consistent, indicating a dominant adhesive failure mode

ASSESSING FUTURE LOW-FLOW VARIATIONS IN A DRY ZONE RIVER BASIN UNDER CHANGING CLIMATE CONDITIONS

W.M.S. Tharuka [1, *], H.G.L.N. Gunawardhana [1]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Climate change significantly alters the low-flow regimes of river basins worldwide and presents significant challenges to water-scarce regions, especially in dry regions. This current study investigates the impact of climate change on projected low-flow variations in the Maduru Oya River Basin in Sri Lanka, focusing on the reach to the Padiyathalawa stream-gauge station. The study utilizes a lumped hydrological modeling framework, which used the HEC-HMS rainfall-runoff model to simulate streamflow behavior considering anticipated climate scenarios. Projections for future precipitation were obtained from the CNRM-CM6-1 Global Climate Model (GCM), which is part of the Coupled Model Intercomparison Project Phase 6 (CMIP6), and subsequently downscaled through the Long Ashton Research Station Weather Generator (LARS-WG) according to two Shared Socioeconomic Pathways (SSPs): SSP2-4.5 and SSP5-8.5. The precipitation data, downscaled to the local scale, were integrated into the HEC-HMS model to forecast future river discharge and investigate possible changes in low-flow characteristics.

The 7Q10 low-flow index, which is defined as the minimum average flow in a continuous seven-day period with a recurrence interval of ten years was used for estimating and comparing low-flow characteristics. The model parameters were calibrated and validated using historical data from 1997 to 2019. Three objective functions namely: Nash-Sutcliffe Efficiency (NSE), Mean Relative Absolute Error (MRAE), and Percent Error in Peak Flow (PEPF) were used for optimizing model parameters. Future precipitation was projected for short-term (2021-2040), medium-term (2041-2060), and long-term (2061-2080) durations. The projected precipitation data was subsequently input into the developed HEC-HMS model to obtain future streamflow projections for the specified periods.

The results of the climate change scenario analysis showed that precipitation may vary due to climate change within the range of -16 % to -5 % for the 2021-2040 period, - 4 % to 1 % for the 2041-2060 period, and 1 % to 21 % for the 2061-2080 period. The results indicated a likely increase in low-flow values across both SSP scenarios. The flow-duration analysis showed that the Q_{90} flow, representing the flow level that exceeds 90% of the time, is expected to increase, reflecting an upward change in streamflow for low-flow conditions. These findings are important for water resource managers working in the area to plan for and adapt to the impacts of altered low-flow regimes that can impact water supply, agriculture, and overall ecosystem health. Further studies should consider incorporating the use of hydrological models coupled with diverse climate scenarios to better capture the uncertainties related to climate predictions and land-use changes. These would provide a better understanding of the impacts of climate change on river basin hydrology in dry regions like the Maduru Oya River Basin.

Keywords: 7Q10 Index, CMIP6, GCMs, HEC-HMS, LARS-WG, SSPs

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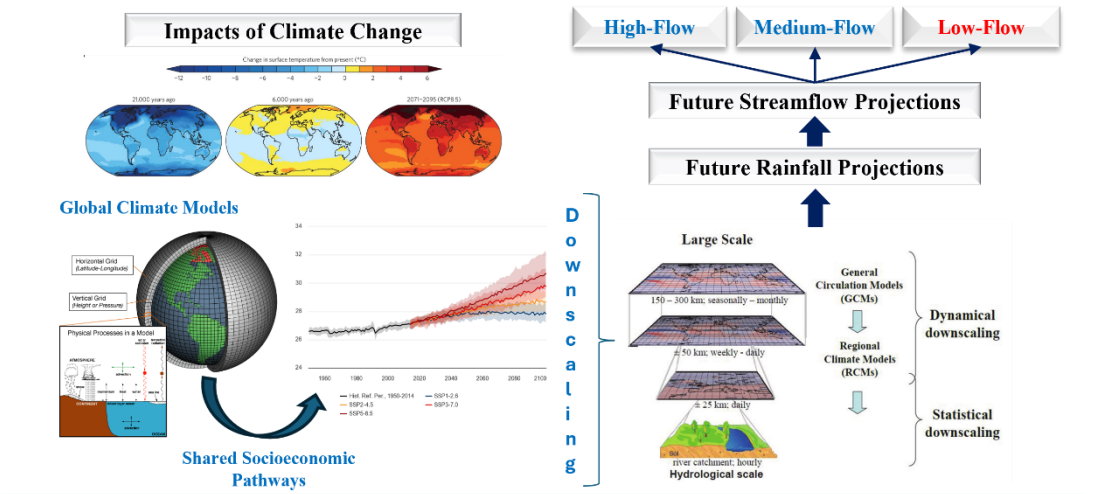
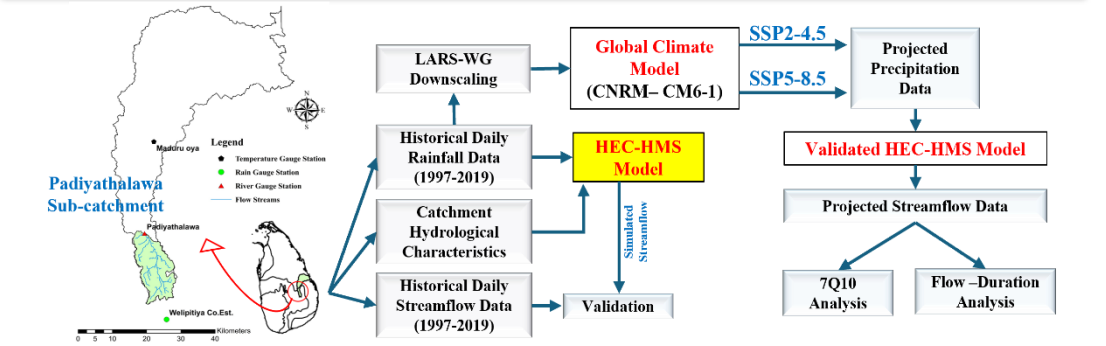
ASSESSING FUTURE LOW-FLOW VARIATIONS IN A DRY ZONE RIVER BASIN UNDER CHANGING CLIMATE CONDITIONS

Background

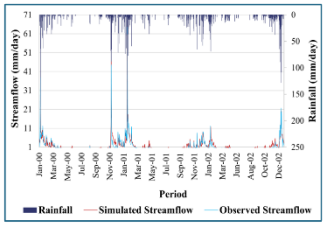


Research Methodology

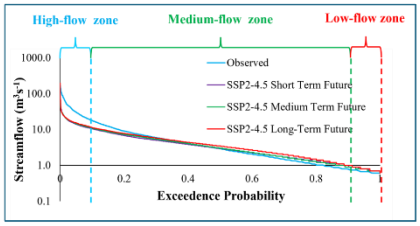


Results

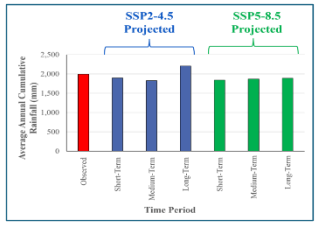
Rainfall-Runoff Hydrograph - Calibration Period



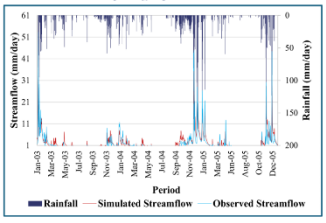
Flow-Duration Curves for the SSP2-4.5



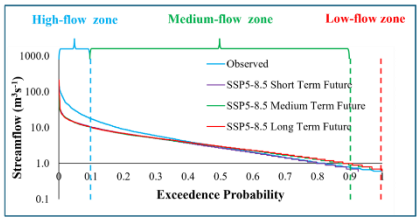
Change in Average Annual Precipitation



Rainfall-Runoff Hydrograph - Validation Period



Flow-Duration Curves for the SSP5-8.5



Model Step	NSE	MRAE	PEPF(%)
Calibration	0.667	4.04	6.18
Validation	0.755	1.99	5.29

-16% to -5%	-4% to 1%	1% to 21%
Change in Precipitation During 2021-2040	Change in Precipitation During 2041-2060	Change in Precipitation During 2061-2080

WEB CRIPPLING BEHAVIOUR OF CURVED COLD-FORMED STEEL UNLIPPED CHANNEL BEAMS

R.D.P.Y.K. Karunaratne [1], H.M.S.T. Herath [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Cold-formed steel (CFS) sections are increasingly utilized in various building applications such as purlins, decks, wall studs, and floor joists, due to their inherent characteristics over hot roll sections. With the increasing popularity of curved structures in architectural and structural designs, understanding the structural performance of curved CFS elements is important. CFS channel sections are prone to localized bearing failures known as web crippling under concentrated forces due to their higher web slenderness. Although numerous studies have been undertaken to investigate web crippling behaviour of straight CFS channel beams, the response of curved CFS beams to web crippling has not been explored yet. Therefore, this study investigates the web crippling behaviour of curved CFS unlipped channel beams.

Through a series of experimental tests conducted on curved CFS unlipped channel beams with different curvatures, including both flanges inward and outward curved, subjected to interior-two-flange (ITF) loading conditions, the study evaluated the resistance of these curved beams to web crippling. The experimental results indicate that the initial curvature has a significant impact on the web crippling capacity. Notably, the flange inward curvature enhances the web crippling capacity, whereas the flange outward curvature diminishes it compared to straight, unlipped channel sections. Furthermore, the design guidelines commonly used for predicting web crippling capacity were evaluated for consistency and reliability compared to the experimental results. It was found that outlining the inconsistencies of using the guidelines developed for straight beams in evaluating the web crippling capacities of curved CFS unlipped channel sections.

In order to further investigate the web crippling response of curved channel beams, finite element models were developed. Finite element models developed for straight beams were validated against experimental results done in this study and available in the literature, demonstrating good agreement in terms of failure modes, capacity, and load-deflection curves. A parametric study was carried out to evaluate the key parameters influencing the web crippling behaviour of curved beams.

In summary, this research carried out experimental and associated numerical studies on curved CFS channel sections subjected to web crippling under the ITF load case. It was found that the curvature of the beam is significant, considerably improving the knowledge and understanding of the web crippling behaviour of curved channel beams.

Keywords: Cold-formed steel, Curved beams, Finite element modelling, Interior two-flange loading, Web crippling, Unlipped channel

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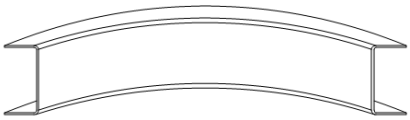
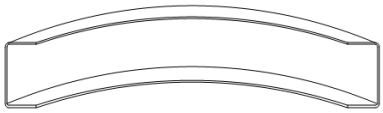
WEB CRIPPLING BEHAVIOUR OF CURVED COLD-FORMED STEEL UNLIPPED CHANNEL BEAMS



Flange-outward curved beam



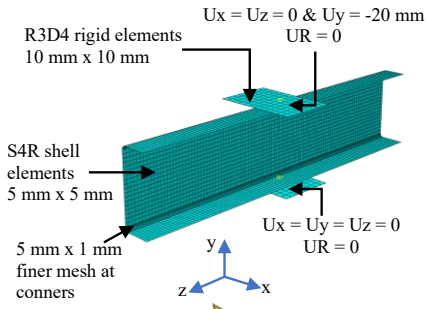
Flange-inward curved beam

Experimental Test Setup

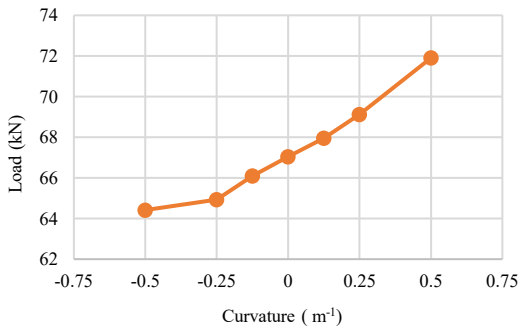
Web Crippling (ITF) Test

Tensile Coupon Test

Finite Element Modelling



Web crippling strength vs Beam curvature



"–" Outward Curvature, "+" Inward Curvature

INVESTIGATION OF THE TRANSFERABILITY OF BASIN HYDROLOGICAL PARAMETERS IN SRI LANKA'S WET ZONE RIVER BASINS

K.M.K. Gayashan [1], R.L.H.L. Rajapakse [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Sustainable water resource management is essential as urbanization and population growth intensify competition for limited freshwater resources. Accurate streamflow estimation in river basins is a key tool for effective management. Hydrologic modelling provides a flexible approach for estimating streamflow, but its application can be challenging in ungauged basins due to data scarcity and other constraints. This research improves streamflow estimation in data-scarce regions, aiding more effective water resource management amid rising demands.

This research explores the applicability of the spatial and temporal transferability approaches for parameter transfer in the semi-lumped HEC-HMS hydrological model. Three sub-basins, namely, Ellagawa, Ratnapura, and Baddegama, were selected for the analysis. All sub-basins are located within Sri Lanka's wet zone and have varying area extents (Ellagawa: 1,393 km², Ratnapura: 603 km², Baddegama: 681 km²). The HEC-HMS model was applied to each sub-basin, with a calibration period from 2006 to 2012. Verification utilized different periods due to limited observed data availability. Model performance was evaluated using the Nash-Sutcliffe Efficiency Coefficient (NSE) and Mean Ratio Absolute Error (MRAE). The spatial transferability approach involved transferring calibrated parameters within basins (Ellagawa and Ratnapura) and across basins (Ratnapura in Kalu Ganga vs Baddegama in Gin Ganga). The temporal approach involved transferring parameters from calibrated models to the same basins for a different time period. Streamflow hydrographs and flow duration curves for low, high, and intermediate flows were used to assess the transferability of calibrated HEC-HMS parameters. The calibrated models for Ellagawa, Ratnapura, and Baddegama achieved satisfactory performance with NSE values ranging from 0.62 to 0.78 and MRAE values between 0.35 and 0.74. Within-basin transferability showed moderate success, with NSE ranging from 0.60 to 0.63 and MRAE varying between 0.51 and 0.84. Initial attempts at across-basin transferability resulted in low accuracy. However, adjusting sensitive parameters (Groundwater 1 Storage, Groundwater 1 Percolation, Groundwater 1 Coefficient, etc.) improved overall model accuracy to 87% in Ratnapura and 85% in Baddegama.

Based on these results, an Excel-based interactive hydrological modelling system (E-HMS) was developed to assess parameter transferability within and across river basins. Calibration becomes achievable with minimal effort and in less time using E-HMS. The temporal transferability approach exhibited greater success, particularly when transferring parameters from the main basin to sub-basins. These findings demonstrate the potential of the HEC-HMS model with transferable parameters for sustainable water resource management in Sri Lanka's wet zone basins. The research highlights the viability of the spatial transferability approach within similar basins and the temporal approach for transferring parameters from main to sub-basins. Further research could explore the applicability of these approaches in different geographical contexts and investigate methods for identifying the most transferable parameters.

Keywords: HEC-HMS model performance, Parameter sensitivity analysis, Sustainable water management strategies, Ungauged watersheds

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Investigation of the Transferability of Basin Hydrological Parameters in Sri Lanka's Wet Zone River Basins

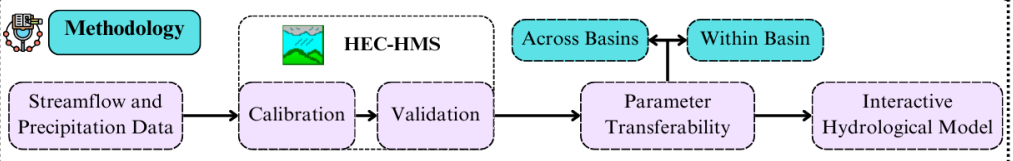
Aim and Objectives

Aim: Investigation of the transferability of hydrological parameters within and across wet zone river basins in Sri Lanka to assess hydrological processes.

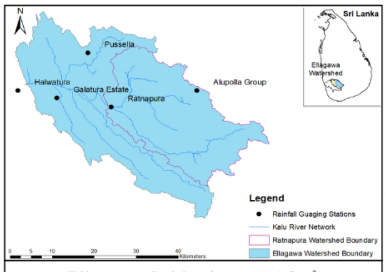
Objectives

- To review recent studies carried out to access the parameter transferability and identification of model parameters
- To develop hydrological models for the identification of an optimized set of model parameters by calibration and validation of data
- To evaluate the possibility of model parameter transferability, implement and analyze the outcomes, and summarise the results
- To develop a web-based interactive hydrological modeling system customized with datasets for Sri Lankan river basins

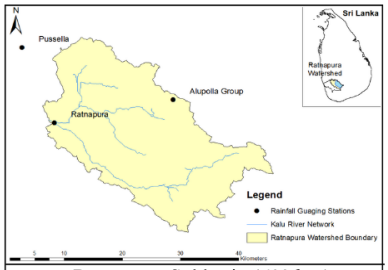
Methodology



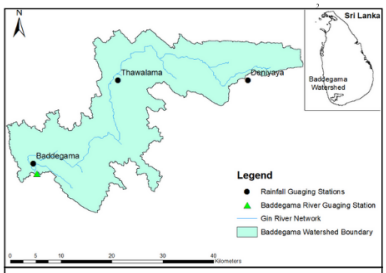
Study Area



Ellagawa Subbasin (*1,393 km²*)



Ratnapura Subbasin (*603 km²*)



Baddegama Subbasin (*681 km²*)

Calibration and Validation

Subbasin	Calibration		Validation	
	NSE	MRAE	NSE	MRAE
Ellagawa	0.78	0.36	0.68	0.35
Ratnapura	0.62	0.74	0.73	0.95
Baddegama	0.78	0.35	0.75	0.37

Parameter Transferability

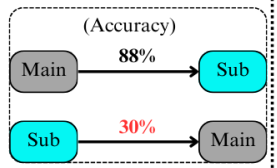
Within Basin ⟶ Direct Transferability

Objective Functions

NSE - Nash-Sutcliffe Efficiency Coefficient

MRAE - Mean Ratio Absolute Error

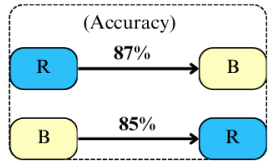
Subbasin	NSE	MRAE
Ellagawa (Main)	0.68	0.84
Ratnapura (sub)	0.60	0.51



Across Basins ⟶ Direct Transferability ⟶ Unsatisfactory Results

Modified Parameter Transferability

Subbasin	NSE	MRAE
Ratnapura (R)	0.61	0.53
Baddegama (B)	0.74	0.33



A NOVEL OPTIMIZATION STRATEGY FOR FORM-FINDING AND STRUCTURAL STABILITY ENHANCEMENT OF DOME-TYPE GRID-SHELL STRUCTURES

H.M.A.M. Abeyrathna [1], H.M.S.T. Herath [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Domes are highly efficient structures designed to span long distances while effectively resisting gravity loads. Traditional domes can be categorized into two types: continuous shells, which are typically constructed from monolithic concrete or masonry, and grid-shells, which utilize lattice members to create depth throughout the shell thickness. Although grid-shells have gained popularity in recent years, the integration of topology optimization and size optimization for the form-finding of these structures remains relatively unexplored.

This paper presents a novel framework for optimizing deep grid-shell structures through topology and size optimization techniques. The framework is structured as a multi-phase process. Initially, a deep grid-shell structure and the associated load type are defined. Subsequently, an equivalent continuous shell structure is established and subjected to an optimization process aimed at minimizing strain energy to determine the optimal grid arrangement. This arrangement is then utilized for size optimization to identify the optimal member sizes. Finally, a linear elastic analysis is conducted to compare the structural performance of the initial grid-shell, the topology-optimized continuous shell, and the grid-shell inspired by structural optimization.

Two case studies demonstrate the framework's capability to generate innovative and practical grid-shell structures. In test case 01, a ring load of 1 N was applied at the apex of a deep dome with a radius of 12 m, resulting in a corresponding structural optimization-inspired grid-shell. The buckling capacity increased from 3.5 MN to 31.5 MN, while maximum stress decreased from 4.2 Pa to 3.0 Pa, and maximum displacement was reduced from 31.5 nm to 25.3 nm when compared to the initial defined grid-shell. In test case 02, a total point load of 1 N was applied to the same deep dome, yielding another structural optimization-inspired grid-shell. The buckling capacity improved from 8.5 MN to 10.1 MN, maximum stress decreased from 0.9 Pa to 0.2 Pa, and maximum displacement was reduced from 10.1 nm to 2.5 nm compared to the initial defined grid-shell.

The results indicate significant enhancements in material efficiency and structural performance, with optimized designs achieving over a hundred percent increase in buckling capacities and reductions in stresses and displacements exceeding seventy percent. Future work will investigate the complexities of topology optimization for shallow versus deep shells, assess the impact of more realistic load applications on structural stability, and explore the flexural capacities of grid-shells with topology-optimized continuous arrangements. Additionally, potential challenges related to node connections due to wider members resulting from optimization will require further investigation to refine the framework for broader applications.

Keywords: Buckling capacity, Form-finding, Grid-shells, Size optimization, Topology optimization

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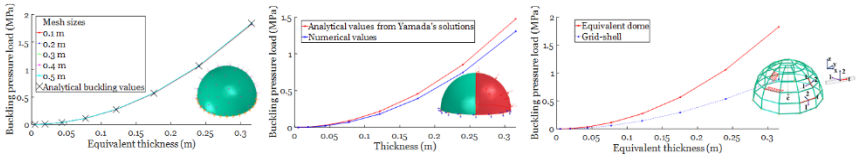
A NOVEL OPTIMIZATION STRATEGY FOR FORM-FINDING AND STRUCTURAL STABILITY ENHANCEMENT OF DOME-TYPE GRID-SHELL STRUCTURES

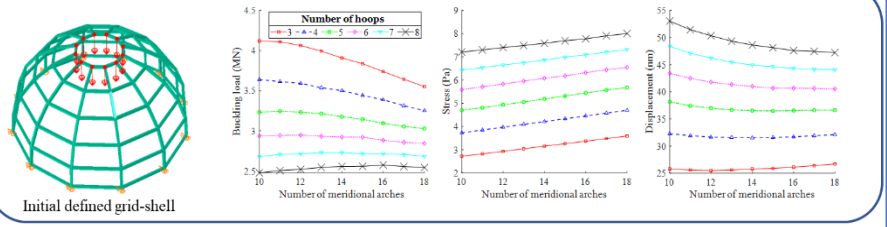
Model Validation



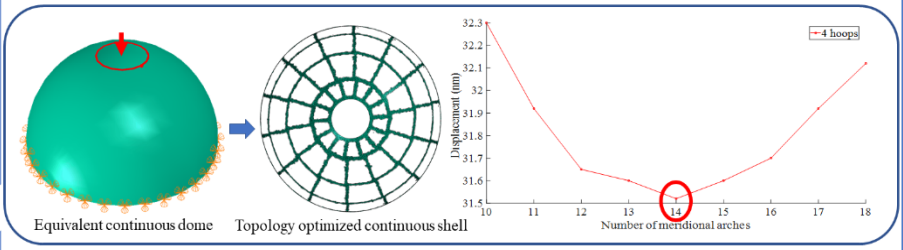
$$q_{cr}=\frac{2E}{\sqrt{3(1-\nu^2)}}\left(\frac{t_{eq}}{R}\right)^2$$ (Timoshenko, 1961)

$$\lambda=\sqrt[4]{12(1-\nu^2)}\left(\frac{R}{t}\right)^{1/2}2\sin(\varphi/2)$$ (Yamada et al., 1983)

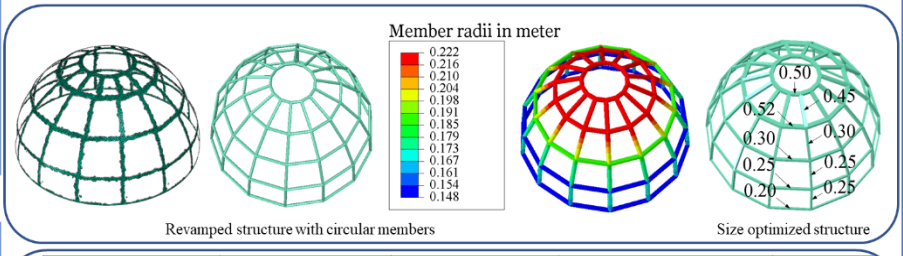
Parametric Study



Topology Optimization



Size Optimization



Structural Comparison

	Initial defined grid-shell		Topology-optimized continuous shell		Structural optimization inspired grid-shell		
Buckling capacity (MN)		3.5		4.2		31.5	↑ 30 %
Maximum stress (Pa)		4.2		4.5		3.0	↓ 30 %
Maximum displacement (nm)		31.5		3.0		25.3	↓ 20 %

APPLICATION OF LOAD BEARING CEMENT HOLLOW BLOCK WALLS FOR MULTI STOREY HOUSING

Y.A.D.K.H. Wijayarathna [1, *], M.T.R. Jayasinghe [1]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

The economic challenges facing Sri Lanka have highlighted the need for affordable housing solutions. This study investigates the viability of load-bearing hollow block walls within a hybrid construction system for multistory residential buildings, utilizing precast slab panels and concrete hollow blocks as lightweight construction materials. The study aims to redefine traditional construction practices and propose an economically viable approach.

Structural analysis was conducted using the "Manual for the Design of Plain Masonry in Building Structures to Eurocode 6", to evaluate the load-bearing capacity and structural integrity of the hybrid system across varying building heights (three to eight stories). Two alternative wall configurations were assessed: (1) walls supporting simply supported beams that carry slab panel loads, and (2) walls directly supporting slab panels. The concrete hollow blocks used are standardized at 200 mm x 190 mm x 390 mm with 47% voids, and the height of wall panel is 3 m with a thickness of 200 mm. The block density is 22 kN/mm², with the mortar strength being 4.0 N/mm².

The study showed that the wall configuration of Alternative 2 requires less block strength while maintaining efficient load-bearing capacity compared to Alternative 1 for buildings up to eight stories. Additionally, the Alternative 2 configuration can be applied to buildings up to six stories without needing additional frame support. For buildings with up to three stories, both wall configurations were found to be feasible under the current allowable block strength of 8 N/mm². Moreover, the block strength requirements for buildings up to eight stories using Alternative 2 were determined to be within the achievable limits of current manufacturing practices.

This study contributes to the growing body of knowledge aimed at enhancing sustainable construction practices in the region. It offers a practical pathway for structural engineers to meet the increasing demand for affordable housing in urban areas while promoting sustainability of the construction industry. Furthermore, the findings emphasize the potential of using precast slab panels and hollow blocks to enhance the efficiency and sustainability of housing projects. Further exploration of the application of this hybrid system in seismic conditions is recommended as additional reinforcement measures might be necessary to ensure safety and durability under seismic loads. Also, it is recommended that methods to improve the strength of hollow blocks be explored further, particularly for taller structures. Adopting this innovative approach could significantly contribute to meeting Sri Lanka's urgent demand for affordable housing while promoting sustainable construction practices.

Keywords: Lightweight hybrid construction, Load-bearing walls, Multistorey apartment design, Precast slabs

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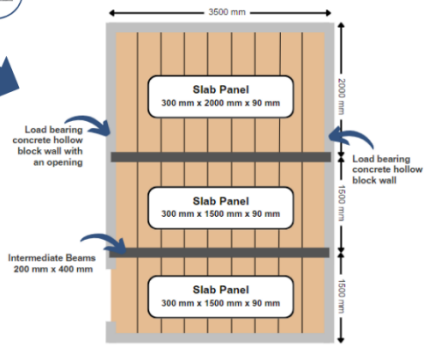
APPLICATION OF LOAD BEARING CEMENT HOLLOW BLOCK WALLS FOR MULTI STOREY HOUSING

A Hybrid System

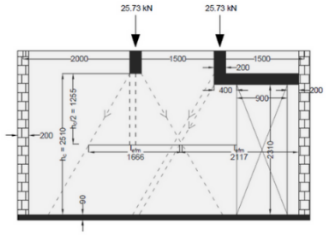
Design Alternatives

Design Alternative 01

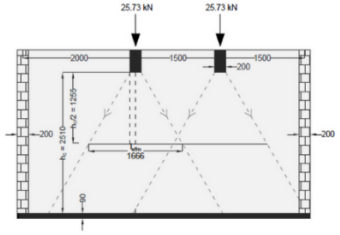


Load Distribution

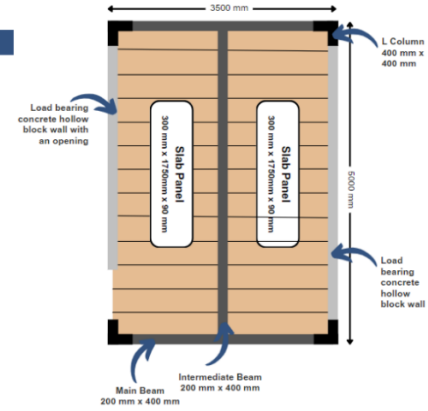
With an Opening

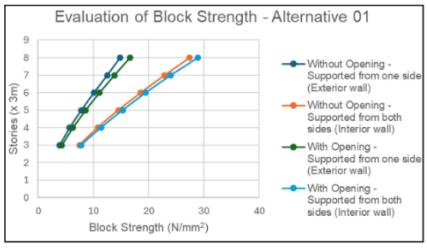


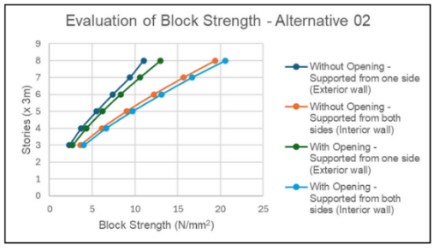
Without an Opening



Design Alternative 02







EVALUATING THE STRUCTURAL PERFORMANCE OF MASONRY WALL PANELS CONSTRUCTED WITH GLASS WASTE AGGREGATE BLOCKS

R.M.M.N.D. Mapa [1, *], C. Jayasinghe [1], I.E. Ariyaratne [1]

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The construction industry faces a significant challenge in the form of high costs associated with construction materials. As a means of addressing this challenge, the industry has explored various alternatives to reduce costs. One such effort includes the use of alternative or waste materials in construction. The adoption of waste materials in the construction industry offers a viable solution to natural resource depletion while providing an opportunity for proper solid waste management.

The construction industry relies heavily on the use of bricks and blocks, which require significant quantities of natural resources. As a result, considerable research has focused on the introduction of waste materials into the bricks and blocks manufacturing process, such as Glass Waste, waste tea, rice husk ash, crumb rubber, and cement kiln dust, as a substitute for sand. Among these materials, glass waste plays a particularly prominent role in increasing municipal solid waste.

According to current literature, the compressive strength of masonry units is dependent on the percentage of glass waste used, with peak strength observed at 20%-25% replacement. Beyond this threshold, subsidence becomes noticeable. The maximum replacement percentage that can be used without significantly reducing the compressive strength of general masonry units is 50%. However, it is essential to evaluate masonry strengths, rather than just masonry unit strengths, when designing walls within the framework of construction quality. This research aims to evaluate the compressive and flexural strength of wall panels cast from masonry units in which 50% of the fine aggregate has been replaced with glass waste. The study will compare the results obtained with that of the strength requirement specified in the BS EN 1996-1-1.

The compressive strength of GWAB is observed to be higher than that of CSB, as reported in the literature. However, experimental values indicate a significant reduction in compressive strength as compared to the values calculated from BS EN 1996-1-1. In light of this, $K_{GWAB} = 0.48$ factor has been defined for the design of wall panels according to equation 3.1 in BS EN 1996-1-1 using general-purpose mortar and GWAB. Furthermore, the equation 3.1 in BS EN 1996-1-1 can be redefined as follows with the K_{GWAB} factor. $f_k = K_{GWAB} K f_b^{\alpha} f_m^{\beta}$, definitions of other parameters in the equation defined in BS EN 1996-1-1. This factor is crucial for ensuring optimal performance and durability of the wall panels.

The characteristic flexural strength of GWAB wall panels perpendicular to the bed joint and parallel to the bed joint was compared with the theoretical and experimental values of CSB wall panels and graphically represented in the charts.

Keywords: Compressive strength of wall panels, Flexural strength of wall panels, Glass waste, Wall panel testing

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Evaluating the Structural Performance of Masonry Wall Panels constructed with Glass Waste Aggregate Blocks (GWAB)

Background

Strength properties and accordance to the design codes of masonry units which constructed using Glass Waste Aggregate Blocks were evaluated in the research

Objectives

Evaluating the compressive and flexural strength of wall panels constructed using Glass Waste Aggregate Blocks

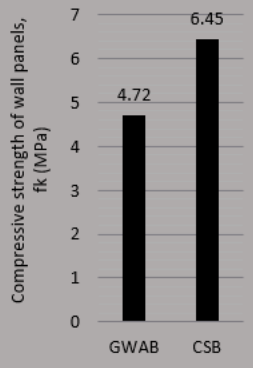
Methodology

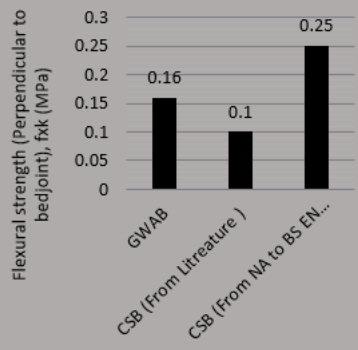
- Literature review
- Resource gathering and GWAB manufacturing

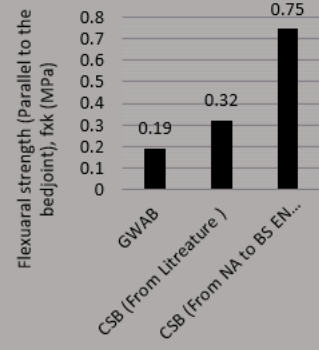


- Material testing
  - Sieve analysis test
  - Water absorption test
  - Compressive strength test for GWAB
- Casting the required number of wall panels using mix design in Table 2
  - 3 panels For compressive strength testing
  - 5 panels for flexural strength testing in directions of parallel to the bed joint
  - 5 panels for flexural strength testing in perpendicular to the bed joint
- GWAB wall panel testing
  - Compressive strength test
  - Flexural strength test in directions of parallel to the bed joint
  - Flexural strength test in directions of perpendicular to the bed joint
- Comparison of strength properties with reference material properties
  - Characteristic compressive strength
  - Characteristic flexural strength in directions of parallel to the bed joint
  - Characteristic flexural strength in directions of perpendicular to the bed joint

Summary of the strength properties of GWAB wall panels







INFLUENCE OF NUMBER OF PLIES ON FLEXURAL BEHAVIOUR OF ULTRA-THIN WOVEN COMPOSITES

W.M.C.S. Wanasinghe [1], H.M.Y.C. Mallikarachchi [1, *]

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Deep space missions necessitate the development of weight-sensitive structures capable of supporting multiple operational configurations. The high strength-to-weight ratio and flexible material properties of woven fibre composites make them ideal for aerospace structures. Epoxy laminates reinforced with carbon fibre are often used in primary and secondary aircraft structures. Woven fibre composites have greater advantages compared to unidirectional fibre lamina. The number of fibres in a yarn and the type of weave determine the material properties. The high curvature experienced by space structures during folding and deployment points out the critical importance of understanding their bending behaviour for optimising future designs. Experimental studies show a significant reduction in the bending stiffness of ultra-thin woven composites when subjected to high curvatures according to the literature. The in-plane properties of woven laminates have been estimated through the development of numerous micromechanical analytical methods. Although in-plane properties can be accurately determined through Classical Lamination Theory (CLT) for thin woven composites, the flexural properties tend to over-predict by 200 – 400%.

This paper introduces micro-mechanical models to capture the impact of ply count on the mechanical characteristics of thin woven fibre composites. Accordingly, this study expresses a geometric model with solid elements that simulate the effect of the two waviness with increasing plies in a Representative Unit Cell (RUC) to analyse the bending stiffness reduction near failure. The study focuses on a plain-woven carbon fibre composite having fibres arranged in an in-phase configuration. A finite element pre-processor, TexGen software, is used to generate the representative unit cell geometry. This generated RUC model is then imported into the commercial finite element software Abaqus/Standard to simulate the mechanical behaviour. The numerical results are validated with experimental results obtained from the literature.

In addition, the study aims to investigate the behaviour of results derived from CLT under varying numbers of plies. The reduction in bending stiffness between CLT predictions and finite element (FE) simulations across all ply configurations varies from approximately 500% for single-ply laminates to 90% for three-ply laminates while 150% for two-ply laminates, highlighting the efficacy of the CLT approach in accurately predicting bending properties with increasing number of plies. One reason for this deviation is that CLT does not account for the inherent waviness of woven fibre composites, which generally exhibit a sinusoidal wave pattern. This waviness is reduced with an increasing number of plies, leading to a closer alignment between CLT and FE results.

Keywords: ABD matrix, Micro-mechanical modelling, Thickness effect, Woven fibre composites

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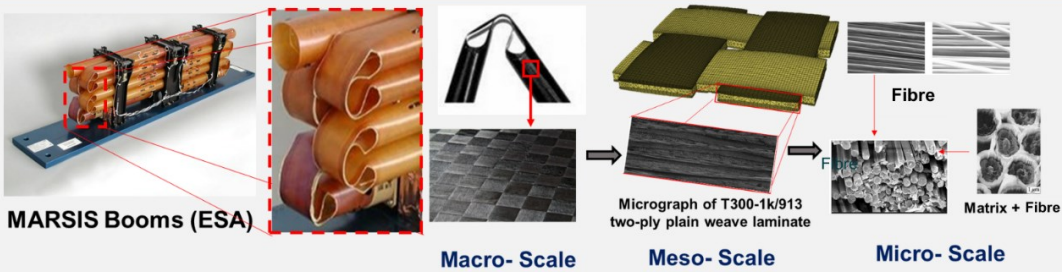
Influence of Number of Plies on Flexural Behaviour of Ultra-thin Woven Composites

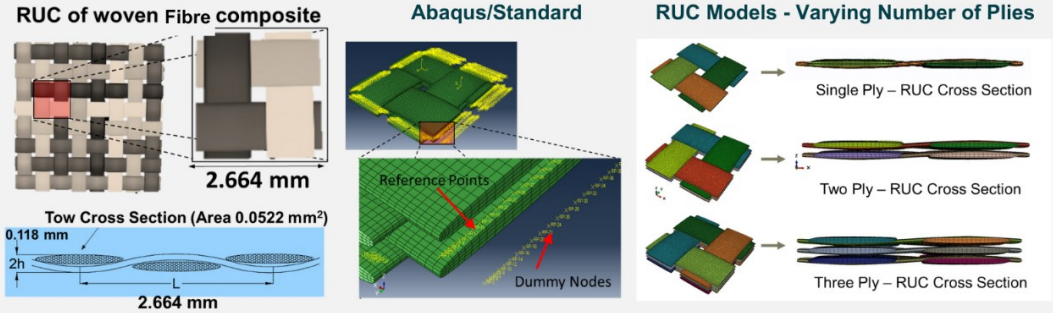
Background



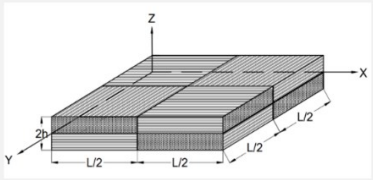
Multiscale Modelling

Research Methodology

Meso-Mechanical Modelling



Classical Lamination Theory Approach



Simplified model of a single ply laminate

Sub Stiffness Matrix

$$A_{ij} = nh\left(Q_{ij}^{0} + Q_{ij}^{90}\right)$$

$$B_{ij} = 0$$

$$D_{ij} = n^{3}\frac{h^{3}}{3}\left(Q_{ij}^{0} + Q_{ij}^{90}\right)$$

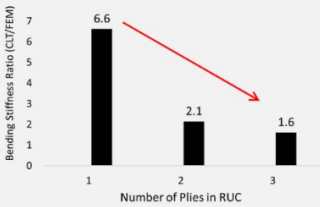
ABD Matrix

$$\begin{pmatrix} N \\ M \end{pmatrix} = \begin{bmatrix} A & B \\ B & D \end{bmatrix} \begin{pmatrix} \varepsilon \\ \kappa \end{pmatrix}$$

Output

Results

Property	Experimental Value	FEM	CLT
D11	37.84	39.6	84.56
1/a11	12833	10000	17349
1/a66	833	333	797
V12	0.11	0.001	0.22



INCORPORATING RAINFALL PROJECTIONS INTO HYDROLOGICAL MODELING FOR ENHANCED DESIGN HYDROGRAPH ESTIMATION

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In the context of changing climate conditions, the design of hydrographs faces increasing uncertainties due to shifts in precipitation patterns, hydrological regimes, and a rise in extreme weather events. This study assesses potential uncertainties in design hydrographs linked to future climate change in the Kalu River Basin, Sri Lanka, focusing on the Ellagawa sub-basin. The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) was selected based on a comprehensive literature review to account for anticipated changes in rainfall patterns and their impact on streamflow. Seven precipitation gauging stations (Alupolla, Balangoda, Galatura, Halwathura, Pussella, Ratnapura, and Wellandura) were chosen following World Meteorological Organization (WMO) guidelines, based on data availability and percentages of missing data. Streamflow data for Ellagawa and Ratnapura stations were obtained from the Sri Lankan Irrigation Department, with daily precipitation and streamflow data from 1980 to 2017 used for analysis. The model was calibrated and validated using data from four extreme events identified through frequency analysis, each associated with daily precipitation levels corresponding to a 100-year return period. Future changes in precipitation extremes were evaluated using outputs from three General Circulation Models (GCMs): CNRM-CM6-1, HadGEM3-GC31-LL, and MRI-ESM2-0, under two Shared Socioeconomic Pathways (SSP2 and SSP5) from the Coupled Model Intercomparison Project Phase 6 (CMIP6), downscaled to local scale, focusing on the period from 2081-2100. The annual maximum daily precipitation for both observed and projected scenarios was analyzed using Generalized Extreme Value (GEV), Weibull, and Gamma distribution functions. The Nash-Sutcliffe efficiency (NSE) coefficients, ranging from 0.79 to 0.85 during calibration and validation, indicated a close match between simulated and observed river flows. Different GCMs and SSPs predicted varying changes in rainfall regimes and design hydrographs. Specifically, factors such as the frequency and intensity of extreme precipitation events, changes in the seasonal distribution of rainfall, and prolonged dry spells were identified as critical drivers affecting peak flow in the future. Compared to the baseline period (1980-2017), annual total rainfall is projected to increase by -8% to 40% under SSP2-4.5 and -10% to 36% under SSP5-8.5. The maximum daily precipitation is expected to rise from 79 mm to 139 mm under SSP2-4.5 and from 82 mm to 138 mm under SSP5-8.5. Consequently, the peak flow of the design hydrograph may increase by 3% to 106%. These findings underscore the importance of considering climate change uncertainties in hydrological and hydraulic design. By integrating future climate projections into design processes, engineers and policymakers can better adapt infrastructure and planning to evolve conditions, enhancing resilience and sustainability in water management systems.

Keywords: CMIP6, GCMs, HEC-HMS, LARS-WG, SSPs

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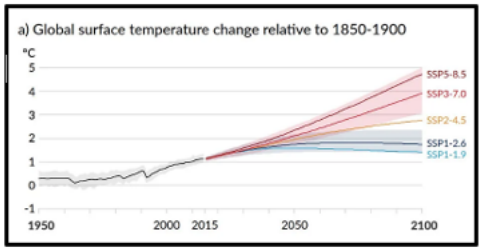
Incorporating Rainfall Projections into Hydrological Modelling for Enhanced Design Hydrograph Estimation

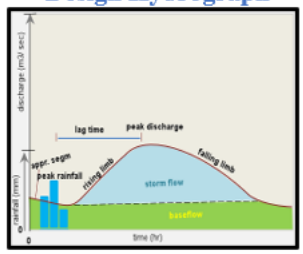
Background

Climate Change Effects



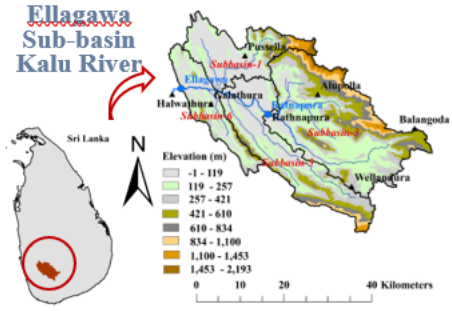
Introduces Uncertainties on Design Hydrographs

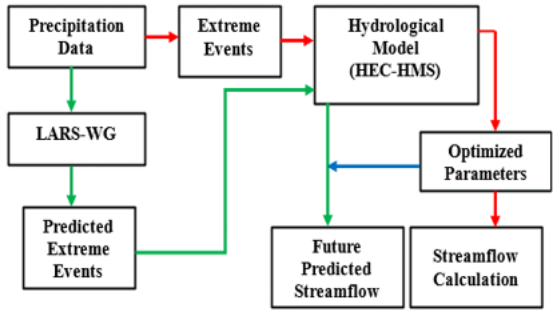
Design Hydrograph



Source: Climate Change Widespread, Rapid, and Intensifying – IPCC — IPCC, 2021. https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/

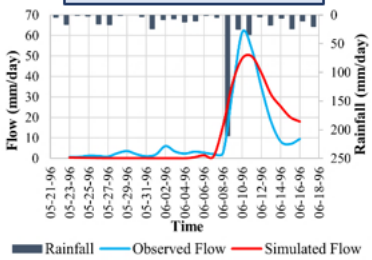
Research Methodology



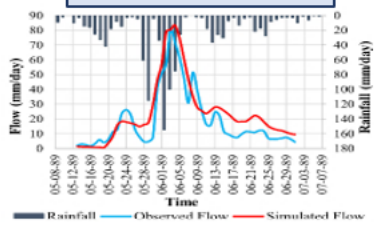


Results

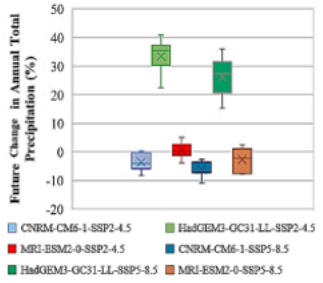
Model Calibration



Model Validation

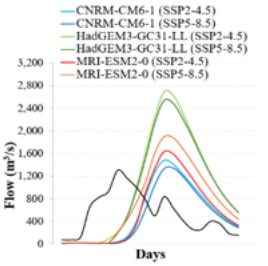


Future Rainfall Variation (In seven Gauging Stations)



Model	Scenario	Maximum
CNRM-CM6-1	SSP2-4.5	169 - 281
	SSP5-8.5	186 - 355
HadGEM3-GC31-LL	SSP2-4.5	244 - 607
	SSP5-8.5	263 - 602
MRI-ESM2-0	SSP2-4.5	201 - 362
	SSP5-8.5	201 - 393

Future Streamflow Variation



Observed Peak Flow	1,308 m³/s	
Model	Percentage Increase in Projected Peak Flow	
	SSP2-4.5	SSP5-8.5
CNRM-CM-6	13%	3%
HadGEM3-GC31-LL	106%	94%
MRI-ESM2-0	25%	45%

USE OF BOTTOM ASH FROM WASTE TO ENERGY PLANT IN MANUFACTURING CEMENT BLOCKS

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Bottom ash (BA), a byproduct of coal or solid fuel combustion in power plants, poses environmental and health risks due to inadequate disposal methods. Bottom ash from waste to energy plants contains recoverable materials like metals and coal power plant bottom ash consists mainly of silicates and oxides, with fewer recoverable materials and more toxic substances, limiting its reuse and posing environmental risks. Bottom ash from waste to energy plant offers greater recycling potential. Utilizing bottom ash in manufacturing cement blocks offers a promising solution. This study investigated the optimal water/cement ratio for producing cement blocks using bottom ash as a substitute for fine aggregate. It assessed bottom ash characteristics and examined the mechanical and durability properties of the blocks. The research produced solid cement blocks measuring 300 mm x 100 mm x 150mm, using a mixture of 1:4:2:3 cement: sand (60% sand and 40% bottom ash): quarry dust: quarry chips volume ratio, with water/cement ratios ranging from 0.8 to 1.4 in conventional table vibratory method and 0.6 to 1.4 in hydraulic compaction method. Conventional table vibratory compaction and hydraulic compaction method were employed for casting the blocks. To assess the wet and dry compressive strength of the blocks and the modulus of rupture, a CTM-2000 digital compression testing machine was used. Compressive strength tests were conducted after the 14^{th}, 28^{th}, and 56^{th} days. The spray erosion test was carried out as per SLS 1382-2: 2009 to determine the erosion resistance of bottom ash cement blocks. The modulus of rupture test was conducted in accordance with ASTM C293 to assess the tensile strength of BA cement blocks. The moisture content and water absorption values of blocks were determined on the 14^{th}, 28^{th} and 56^{th} days in accordance with SLS 855-1: 1989's specifications. In accordance with the specifications provided in SLS 855-2: 1989, drying shrinkage tests were done. The results suggest that manufacturing cement blocks using bottom ash for small and medium-scale conventional cement block production for loadbearing walls of residential buildings up to four storeys using the conventional table vibratory method and up to five storeys using the hydraulic compaction method is an effective way for utilizing bottom ash. According to this study, it's viable to replace up to 40% of fine aggregate with 5 mm sieved waste-to-energy plant bottom ash. According to the study, BA from a waste-to-energy plant can be replaced with fine aggregate in cement blocks and satisfy the requirements with a replacement level of 40% BA with 1.0-1.2 water/cement ratio with a compressive strength of 5.42 N/mm^2 and 5.49 N/mm^2 (more than the minimum required value of 5.2 N/mm^2) is better for conventional table vibratory method and 0.8-1.0 water/cement ratio with a compressive strength of 8.57 N/mm^2 and 8.80 N/mm^2 (more than the minimum required value of 6.5 N/mm^2) is better for hydraulic compaction method. The limitations for water absorption, moisture content, drying shrinkage and spray erosion tests are satisfied with the above water/cement ratios. No health hazards are linked to the handling or use of BA cement blocks. Hence, cement blocks incorporating 40% BA as a sand-replacing material are deemed safe and appropriate for construction purposes.

Keywords: Bottom ash, Cement blocks, Water/Cement ratio, Conventional table vibratory method, Hydraulic compaction method

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USE OF BOTTOM ASH FROM WASTE TO ENERGY PLANT IN MANUFACTURING CEMENT BLOCKS

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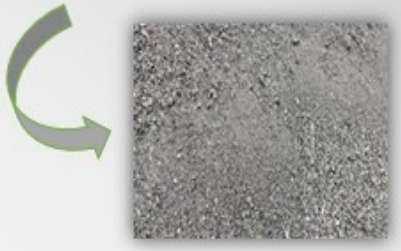
* Correspondence: walpitagamawgas.19@uom.lk

Bottom ash?

Bottom ash has a sand-like or gravelly appearance which is a by-product generated from the combustion of coal or other solid fuels in power plants.



MIX PROPORTION

Cement	Sand	Bottom ash	Quarry dust	Quarry chip
	60%	40%		
1	4		2	3

Water/cement ratios ranging from 0.8 to 1.4 in conventional table vibratory method and 0.6 to 1.4 in hydraulic compaction method

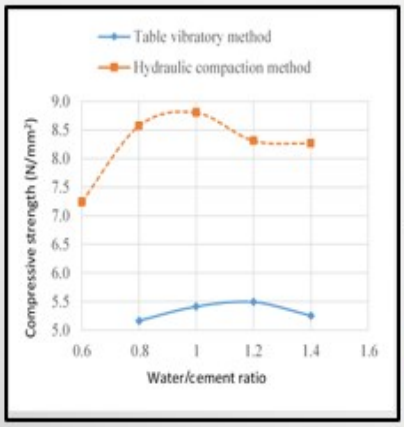
Block Manufacturing

Standards used for tests

Compressive strength, Water absorption, Moisture content, Drying shrinkage - SLS 855: Part 1: 1989

Modulus of rupture - ASTM C293-00

Spray erosion test - SLS 1382-2: 2009



Compressive strength vs water/cement

CONCLUSIONS

- Bottom ash (BA) from a waste-to-energy plant can be replaced with fine aggregate in cement blocks and satisfy the requirements with a replacement level of 40% bottom ash with 1.0-1.2 water/cement ratio with a compressive strength above the required value of 5.2 N/mm^2 is better for conventional table vibratory method and 0.8-1.0 water/cement ratio with a compressive strength above the required value of 6.5 N/mm^2 is better for hydraulic compaction method.
- The limitations for water absorption, moisture content, drying shrinkage and spray erosion tests are satisfied with the above water/cement ratios.
- No health hazards are linked to the handling or use of bottom ash cement blocks.

EFFECT OF URBAN VEGETATION COVER ON CO_2 REDUCTION IN THE CITY

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Rising urban carbon dioxide levels have emerged as a critical issue due to their adverse effects on public health and the environment. Trees are a natural and sustainable solution to mitigate urban carbon dioxide (CO_2) concentrations, as they absorb CO_2 from the atmosphere through photosynthesis. However, the specific relationship between tree density and CO_2 concentration within cities is unclear. The main objectives of this research are to determine the relationship between tree density and CO_2 concentration reduction in cities and to identify the optimum tree density to reduce the CO_2 level in the city to obtain the required CO_2 level.

For this study, data were collected in the densely urbanized city of Colombo and various urban areas within the Hambantota district. Tree densities and CO_2 concentration reduction data were collected from 300 sample plots, each with a fixed size of 50m x 50m, near roads in selected urban areas. When calculating tree density, it is important to calculate canopy volumes of trees. It depends on canopy height, crown diameter and canopy shape. The tree density of the sample plot was calculated by dividing the total canopy volume by the area of the sample plot. A digital portable CO_2 meter was used to measure the CO_2 level. First the CO_2 concentration was measured at the centre of the road and then the CO_2 concentration was measured at the centre of the sample plot. The reduction in CO_2 level was calculated by the difference between these two readings.

By analysing tree densities and CO_2 concentration data collected through field data studies, a linear relationship was obtained between tree density and CO_2 concentration reduction in urban areas. The plotted line got a R^2 value of 0.8806 indicating a well-fitting model. Therefore, this linear plotted line can be described as a reasonable fitted line representing all collected data. Also, the data was classified based on the CO_2 concentration in the centre of the road and the behaviour of the CO_2 concentration reduction Vs tree density relationship was studied in each range. A linear relationship was obtained in each of those ranges. When all the collected data were classified as residential and non-residential based on the usage of the sample plots, the R^2 values obtained from those graphs were higher than the R^2 value of the graph drawn without classification. The R^2 value of the graph for non-residential areas has increased relative to the value of the graph for residential areas. Accordingly, classifying in this manner led to an increase in the accuracy of the relationship. Using these relationships, the optimum tree density required to obtain the required CO_2 reduction in urban areas can be identified. The results of this study will be valuable for policymakers and urban planners looking for ways to improve air quality and create more sustainable urban environments.

Keywords: Canopy volume, CO_2 concentration reduction, Urban air quality, Urban planning, Urban tree density

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EFFECT OF URBAN VEGETATION COVER ON CO_2 REDUCTION IN THE CITY

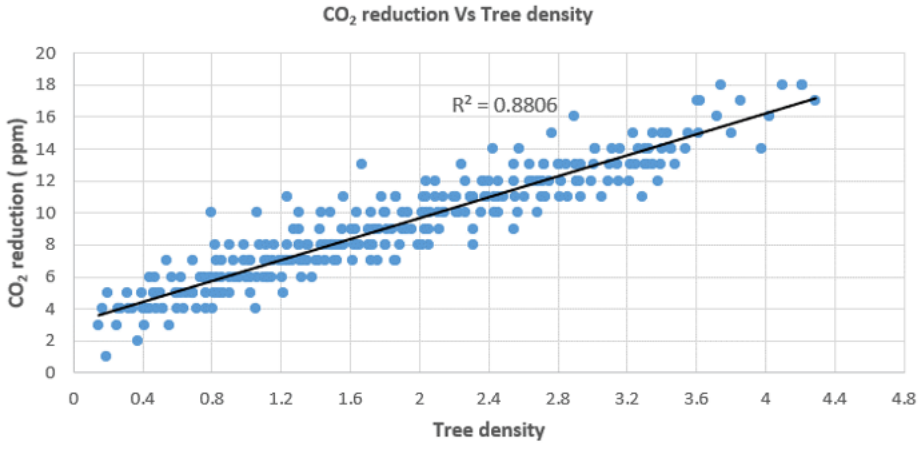
2. OBJECTIVES

- To determine the relationship between tree density and CO_2 concentration reduction in cities.
- To identify the optimum tree density to reduce the CO_2 level in the city to a required CO_2 level.

3. METHODOLOGY

1. **Study Area Selection**
2. **Tree Density Calculation**
3. **CO_2 Concentration Monitering**
4. **Data Analysis**
5. **Identifying Optimum Tree Density**

3. RESULTS



The relationship between CO_2 concentration reduction and tree density in urban areas.

FULL-FIELD DEFORMATION MEASUREMENT SYSTEM FOR EARLY AGE CONCRETE CRACKING

Nirodha S.S. Silva[1, *], E.S. Gamage [1] H.M.Y.C. Mallikarachchi [1]

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Identification of the risk of early age shrinkage cracks in fresh concrete is essential as they can lead structures to unserviceable conditions. These cracks occur when the shrinkage induced stresses exceed its tensile strength capacity of fresh concrete. In general, the risk of early age shrinkage cracks is evaluated by inspecting the tensile strain development of fresh concrete. Hence measurement of strain distribution of early age concrete is essential. However, measuring displacements and strains in fresh concrete is challenging due to its semi-solid state, which prevents the direct use of contact-based deformation measuring tools.

There were several techniques used to measure the deformations of early age concrete. Some studies have used strain gauges attached to the moulds while some measured deformations by attaching strain gauges to posts cast into the concrete. However, deformations of moulds are not the same as that of concrete and semi-solid state of fresh concrete leads to relative movements between posts and accuracy can be compromised. Recent research has processed images, taken at specific time intervals, to calculate the deformation of preidentified targets. This overcame the challenges faced with contact-based methods but suffered from poor resolution and required image corrections. With recent rapid advancements in computer processing units and camera technology, avenues are now available to use machine vision techniques such as Digital Image Correlation (DIC).

This study aims to develop an in house DIC based measurement system for evaluating full-field deformation of early-age concrete. An in-house 3D digital image correlation-based system was utilized for this purpose with a direct tensile apparatus, with modifications made to enhance accuracy. Great care was taken during the experiment procedure to distribute the speckle pattern on the semi-solid concrete surface. The modified DIC system was capable of generating full-field deformations and strain distributions of fresh concrete which is after 1 hour from casting.

The suitability of the modified system was evaluated through experimental analysis. Physical measurements were obtained using a vernier calliper and the results depict that the developed technique can measure strains with an accuracy of over 94%.

The precision of the system can be enhanced by optimizing the distribution of the speckle pattern. It is intended to utilise the developed DIC system to investigate the tensile properties of early-age concrete for different mix proportions.

Keywords: Digital image correlation, Early-age concrete, Full-field deformation, Shrinkage, Tensile properties

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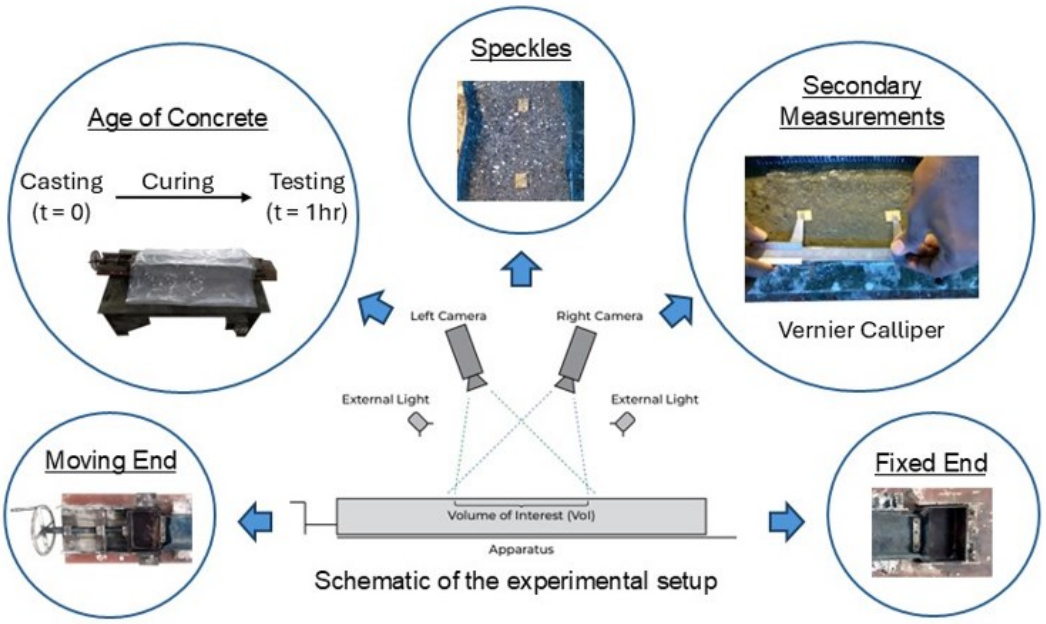
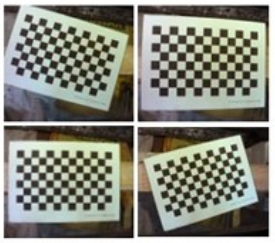
FULL-FIELD DEFORMATION MEASUREMENT SYSTEM FOR EARLY AGE CONCRETE CRACKING



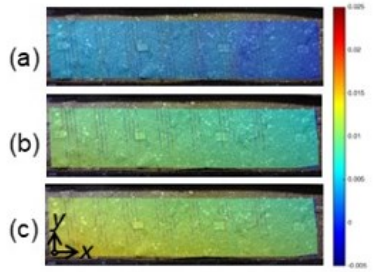
Schematic of the experimental setup



Camera calibration

Developed DIC system

x displacement (mm) of VoI after (a) 4.5 (b) 6 and (c) 7.5 mm total displacement



xx strains of VoI after (a) 4.5 (b) 6 and (c) 7.5 mm total displacement

Test apparatus

STUDY ON THE IMPACTS OF RAIL VIBRATIONS IN SLOPE FAILURES

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The Up-Country Railway in Sri Lanka, essential for connecting the central highlands, is increasingly threatened by slope failures that endanger both infrastructure and passenger safety. These failures are suspected to be exacerbated by train-induced vibrations, particularly in areas where maintenance is inadequate. The combination of heavy rainfall and vibrations can destabilize slopes, leading to frequent collapses. This research aims to explore the relationship between train vibrations and slope stability along the Up-Country Railway, providing insights that could guide improved maintenance practices and reduce the risk of such failures.

To investigate the relationship between train-induced vibrations and slope stability, the study utilized numerical modeling with finite element software specialized for geotechnical applications. The models were designed to simulate the impacts of varying track maintenance levels, train speeds, and slope angles. Local material properties, such as lateritic soil for the subgrade and crushed stone for ballast, were integrated to ensure the models accurately reflected the actual conditions along the Up-Country Railway. The finite element modeling provided detailed simulations of the railway substructure, capturing interactions between the sleeper, ballast, and sub-ballast layers. The models considered both static and dynamic loads, representing the weight of the train and the vibrations induced by train movements, respectively, to evaluate their effects on slope stability. The accuracy of the simulations was ensured by accounting for boundary conditions, soil types, and track geometry specific to the railway, allowing for a comprehensive analysis of the factors influencing the Factor of Safety (FoS) under different conditions.

The analysis revealed that poor track maintenance, especially under dynamic conditions, significantly reduced the Factor of Safety (FoS). For train speeds exceeding 60 km/h with poor maintenance, the FoS dropped from 0.9054 in static conditions to 0.8438 in dynamic conditions, indicating a higher risk of slope failure. Steeper slopes were particularly vulnerable, with a 55° slope showing a FoS of 0.8438 under dynamic conditions, while a 30° slope remained stable at 1.464. Variations in soil properties, such as cohesion and friction angles, also had a significant impact. Increasing cohesion from 5 kPa to 20 kPa at a 30° slope raised the FoS from 0.7462 to 1.406, highlighting the importance of accurate geotechnical evaluations in ensuring slope stability.

The study concluded that train-induced vibrations, particularly when combined with inadequate track maintenance, are a key factor in slope failures along the Up-Country Railway. Improved maintenance practices are essential to maintaining a higher FoS and mitigating the risk of slope collapses. The findings highlight the importance of ongoing monitoring and targeted interventions to enhance the stability and safety of this critical railway network, ensuring its continued operation in a challenging environment.

Keywords: FEM modeling, Landslides, Pseudo–static analysis, Track maintenance

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STUDY ON THE IMPACTS OF RAIL VIBRATIONS IN SLOPE FAILURES

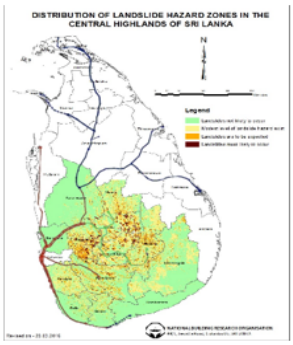
BACKGROUND

PROBLEM STATEMENT

Recurrent slope collapses threaten the Up-Country Railway.

Causes: train vibrations and poor maintenance.

Limited research hinders effective mitigation.



OBJECTIVES

Investigate train vibrations and slope failures.

Create models to analyze slope stability.

Assess maintenance and develop strategies to reduce collapses.

RESEARCH METHODOLOGY

Litreture Review → Familiarization of Finite Element Modelling → Create Finite Element (FE) models by adjusting key parameters. → Analysis and Interpretation of Results → Comparative analysis of the selected scenarios.

FINITE ELEMENT MODEL

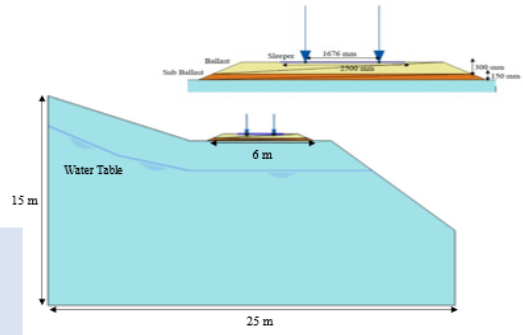
Finite Element Analysis

Plain Strain Idealization & Mohr-Coulomb Model

Static Load: 82.2 kN/m (Train axle load)

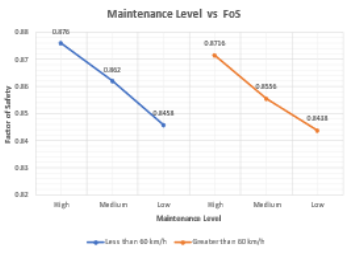
Dynamic Factor: Variable based on train speed and maintenance

- **Subgrade** - Lateritic soil
- **Ballast** - Crushed stone
- **Sub-ballast Material** -Sandy gravel
- **Sleeper Material** - Concrete (Elastic)

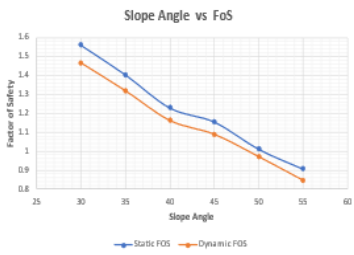


Geometrical Representation of Model Layout

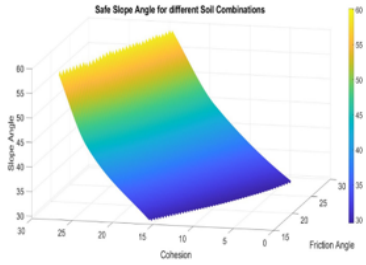
ANALYSIS



Fos vs Maintenance levels



FoS variation with various slope angles



Safe slope angles for different soil combinations

DEVELOPMENT OF AN OPTIMUM MIX FOR PAVING BLOCKS, USING WASTE STEEL SLAG AND CRUSHED TILE WASTE AS PART REPLACEMENT OF AGGREGATES

J. Nirainenchan [1, *], J.C.P.H. Gamage [1] and E.R.K. Chandrathilaka [1]

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In contemporary construction practices, paving blocks are essential for creating durable and aesthetically pleasing surfaces in urban and suburban areas, such as pedestrian walkways, driveways, and plazas. However, traditional paving blocks are often associated with considerable weight and high production costs, which can limit their widespread use and contribute to environmental degradation due to the extensive use of natural aggregates. This research aims to address these challenges by developing a lightweight and cost-effective mix design for eco-friendly paving blocks.

The proposed design incorporates waste materials from the steel industry, specifically steel slag, as well as crushed tile waste from construction industry, both of which are typically discarded as industrial and construction waste. By repurposing these materials, the study seeks to minimize the environmental impact of paving block production while providing a sustainable and economical alternative to conventional paving blocks.

The experimental program involved replacing traditional fine aggregates in the paving block mix with steel slag at varying proportions of 10%, 20%, and 30% by volume. Additionally, coarse aggregates were partially substituted with 25% crushed tile waste. The mechanical performance of the various paving block mixes was thoroughly assessed through a series of standardized tests, including density, compressive strength, split tensile strength, and flexural strength. These tests were conducted to determine the structural integrity and suitability of the eco-friendly paving blocks for practical applications.

The results of the study revealed that the paving block mix containing 30% steel slag and 25% crushed tile waste achieved an optimal balance between weight reduction, cost efficiency, and mechanical performance. This mix exhibited a compressive strength of 16.6 MPa after 28 days, making it suitable for non-traffic areas such as walkways, garden paths, and recreational spaces. Although this strength is marginally lower than the compressive strength of 17.5 MPa observed in conventional paving blocks, the eco-friendly mix offers several advantages, including a significant reduction in weight and production costs.

Furthermore, a detailed cost analysis was performed to compare the economic feasibility of the eco-friendly paving block mix with that of traditional paving blocks. The analysis indicated that the use of waste materials such as steel slag and crushed tile waste not only reduces the consumption of natural resources but also results in considerable cost savings. The cost of paving blocks decreases with the substitution, showing a reduction rate of approximately 4.6% from Mix 01 to Mix 02, and continuing consistently up to Mix 05, making it economically feasible. In conclusion, this study contributes to the ongoing efforts to develop sustainable construction materials by demonstrating the viability of using industrial and construction waste in paving block production.

Keywords: Mechanical properties, Paving blocks, Steel slag, Tile waste

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DEVELOPMENT OF AN OPTIMUM MIX FOR PAVING BLOCKS, USING WASTE STEEL SLAG AND CRUSHED TILE WASTE AS PART REPLACEMENT OF AGGREGATES

AUTHORS

J.Nirainenchan
Dr. E.R.K. Kanishka Chandrathilaka
Prof.(Mrs) Kumari Gamage

INTRODUCTION

Managing industrial waste and preserving natural resources are critical challenges today. Concrete paving blocks, using recycled materials, provide an efficient and visually appealing solution for footpaths.

RELATED LITERATURE

Several researchers have reported that peak compressive strength is achieved with slag replacement ratios of natural river sand ranging from 15% to 30%.

METHODOLOGY

- **Material Collection**
- **Material Characterization**
- **Mix Design**
- **Testing**
- **Analysis**
- **Economic Assessment.**

OBJECTIVE

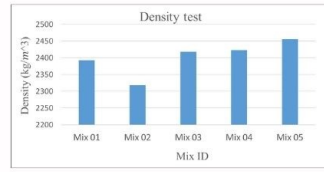
To analyze **steel industry waste materials for their suitability in paving block production**, evaluate the mechanical and physical properties of the developed blocks, and assess their economic viability compared to conventional paving blocks.

ANALYSIS

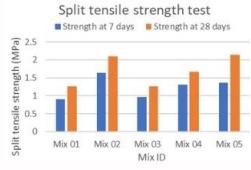
Materials selection included testing concrete for density, flexural strength, split tensile strength, and compressive strength, while aggregate underwent sieve analysis to determine particle size distribution.

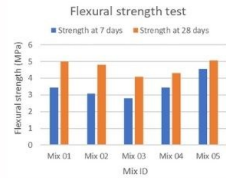
MIX ID	Cement (%)	Steel slag (%)	Fine Agg. (%)	Normal crushed Agg. (%)	Tile waste (%)
MIX1 (Control)	100	0	100	100	0
MIX2	100	0	100	75	25
MIX3	100	10	90	75	25
MIX4	100	20	80	75	25
MIX5	100	30	70	75	25

Mix Design



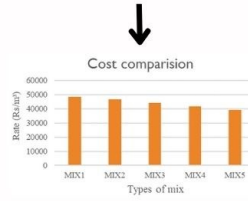
Density of varies mixes.





RESULTS/FINDINGS

- **Incorporating tile waste into the concrete mixture resulted in a 3.2% reduction in density. Conversely, the density increased by 2.93% with a 30% steel slag replacement.**
- **The compressive and flexural strength decreased by 8.3% and 9.6%, respectively, when 25% of the coarse aggregates were replaced with tile waste. However, strength increases with an increase in slag content.**
- **The tensile strength increased by 59.5% when 25% of the coarse aggregates were replaced with tile waste. Conversely, the strength increased by 64.6% with a 30% replacement of steel slag.**
- **The cost of paving blocks decreases with the substitution, showing a reduction rate of approximately 4.6% from Mix 01 to Mix 02, and continuing consistently up to Mix 05, making it economically feasible.**



CONCLUSION

Mix 05 is fixed as an optimum mix for this study, and it gave compressive strength of above 15 MPa after 28 days, split tensile strength and flexural strength were also found to be comparatively higher.

DEVELOPMENT OF A DAMAGE ASSESSMENT MATRIX FOR LOAD-BEARING MASONRY HOUSES

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Masonry houses are common types of buildings constructed using materials like bricks, stones, or concrete blocks. They are popular due to their durability and aesthetic appeal. However, as masonry structures age, they become vulnerable to various forms of crack damage that can potentially compromise their structural integrity and the safety and comfort of their occupants. While numerous studies have examined the condition assessment of buildings, they primarily rely on visual inspection conducted by inspectors who often base their evaluations on personal experience, biases, and risk attitudes. Recognizing the absence of a standardized method for assessing wall crack damages, this research study was aimed at developing a crack damage assessment matrix specifically focusing on single-story, load-bearing masonry houses. A database surrounding over 270 instances of cracks in approximately 60 houses from the Higurankgoda area in Sri Lanka, is considered to determine the key factors influencing the damage severity and safety of the house. Severity considerations include crack length, width, and number of cracks in the wall, while safety factors encompass crack severity level, separation level of the crack, surface condition of the cracked wall, crack location, crack direction, and structural degradations. To construct a data-driven prioritization matrix, the study employs the Analytical Hierarchy Process (AHP) and a probability-based approach, utilizing real-world data to assign reliable weightage to each parameter. This research determines the influence weightage of each parameter on overall safety and stability. The calculated weightage results indicate that the parameter with the highest impact is from the structural degradations, while the parameter with the lowest impact is from the crack direction. This matrix facilitates a Risk Level Index (RLI) to assess the overall impact of individual cracks and a systematic approach is proposed to determine the overall risk level of the house. The systematic approach illustrates the risk level for the house when it has varying numbers of wall cracks based on the generated RLI value and the number of cracks in each influence category. Fifteen single-story load-bearing masonry houses were selected for the testing and verification of the developed matrix, and the outcomes of the matrix were compared with the already assigned risk levels by experts for each house. The proposed matrix was tested and validated with more than 80% accuracy level. This prioritization matrix will empower engineers, and homeowners to efficiently prioritize repair efforts and allocate resources based on potential risk. The proposed approach integrates advanced analytical techniques with practical insights to enhance decision-making in addressing wall crack damages in masonry houses.

Keywords: Analytical hierarchy process, Damage assessment, Masonry cracks, Severity and safety

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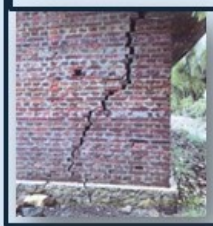
DEVELOPMENT OF A DAMAGE ASSESSMENT MATRIX FOR LOAD-BEARING MASONRY HOUSES

Introduction



This research addresses the challenge of crack damage in single-story load-bearing masonry houses. It aims to:

- Identify and quantify key parameters influencing crack damage
- Develop a damage assessment matrix for assessing the overall safety impact of crack damages
- Case study: 270 instances of cracks around 60 houses

Research Methodology

Field Investigation	• Understanding the current condition, and primary information on the damages
Data Collection	• Crack damages in single storey masonry houses
Preparation of the Database	• Categorized based on selected variables
Data Analysis	• Using statistical techniques and analytical tools
Development of Risk Prioritization Matrix	• Variable identification & Assigning weightages • Development of the matrix • Framework to assess the risk level • Validation of the model

Results

$$\begin{pmatrix} RLI_1 \\ RLI_2 \\ RLI_3 \\ . \\ . \\ . \\ RLI_n \end{pmatrix} = \begin{pmatrix} F_{11} & F_{21} & F_{31} & F_{41} & F_{51} & F_{61} \\ F_{12} & F_{22} & F_{32} & F_{42} & F_{52} & F_{62} \\ F_{13} & F_{23} & F_{33} & F_{43} & F_{53} & F_{63} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ F_{1n} & F_{2n} & F_{3n} & F_{4n} & F_{5n} & F_{6n} \end{pmatrix} \begin{pmatrix} 0.0561 \\ 0.0952 \\ 0.1654 \\ 0.1455 \\ 0.3078 \\ 0.2298 \end{pmatrix}$$

Data-driven matrix was developed to rank crack damages

Determination of the overall risk level of the entire house

In the matrix, each row represents a single wall crack, and the entire matrix encompasses all wall cracks within a single house. Here, F_{1i}, F_{2i}, F_{3i}, F_{4i}, F_{5i}, and F_{6i} denote the cell scores assigned to the influenced level of crack direction, surface condition of the cracked wall, separation level of the crack, crack location, signs of immediate collapse, and crack sensitivity, respectively.

Risk Level Index(RLI) Range	Influence level	Notation
RLI <= 1.6	Very Low	C_{VL}
1.6 < RLI <= 2.5	Moderately Low	C_{ML}
2.5 < RLI <= 3.4	Moderately High	C_{MH}
RLI > 3.4	Very High	C_{VH}

Risk level classification of cracks with RLI

EVALUATING THE IMPACT OF DROUGHT SPATIAL DISTRIBUTION ON RIVER FLOW DYNAMICS USING REMOTE SENSING DATA

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Drought is a complex and challenging weather-related disaster with significant economic, social, and environmental impacts. Traditional drought monitoring, which primarily relies on ground observations, often falls short due to limited spatial coverage and data scarcity. Most existing drought indices focus on a single variable, which may not adequately capture the full scope of drought conditions. To address this, integrating multiple parameters from remote sensing data presents a promising approach, providing spatially distributed and real-time information for a more accurate and comprehensive drought analysis.

This study aims to utilize multiple remote sensing parameters to provide a comprehensive analysis of droughts in the Padiyathalawa catchment area, a dry zone river basin in Sri Lanka covering 171 km². Three satellite-derived indices, namely the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI), derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data, and Standardized Precipitation (SP) from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), were integrated using Principal Component Analysis (PCA) to derive a Combined Drought Index (CDI). In this analysis, Principal Component (PC) one, capturing 58% of the total variance, was used to develop the CDI. Validation showed a strong visual correlation between the normalized CDI and river flow over time. However, the Kolmogorov-Smirnov (KS) test revealed that the CDI needs improvement, as it does not fully capture streamflow dynamics during significant rainfall events. Despite this, the CDI effectively reflected seasonal variations, indicating dry conditions from June to August and wetter periods influenced by the northeast monsoon.

Using the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS), the area was modelled as a semi-distributed system with five sub-catchments, based on the spatial variation of drought in developed 1 km resolution CDI maps. Model calibration was conducted for the period 1999-2005, followed by validation from 2005-2010, employing the Nash–Sutcliffe model efficiency coefficient (NSE) and mean relative absolute error (MRAE). The results indicated that the HEC-HMS model effectively simulated streamflow, with NSE values of 0.78 and 0.92, and MRAE values of 0.86 and 2.44. However, the model exhibited limitations in simulating low-flow conditions, failing to accurately represent discharges below 0.1 m³/sec. Further analysis of drought-prone areas identified by the CDI was performed using the HEC-HMS, incorporating hypothetical drought scenarios.

The study found that river flow decreases as drought severity intensifies, with the impact lessening in sub-catchments farther from the catchment outlet. It highlights the potential of integrating remote sensing data, PCA, and hydrological modelling for effective drought assessment, benefiting farming communities and decision-makers in understanding drought severity on river flow and taking necessary action.

Keywords: Combined drought index, HEC-HMS, Principal component analysis, Temperature condition index, Vegetation condition index

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INTEGRATING REMOTE SENSING DATA WITH HYDROLOGICAL MODELING FOR DROUGHT ANALYSIS

1. Background

Traditional drought Indices → Most rely on one variable → Insufficient to accurately represent complex droughts

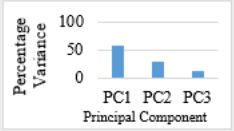
Ground observations → Lack of spatial coverage; Data quality issues; Data scarcity

Aim: As a solution this study develops a **Combined Drought Index (CDI)** from three remote sensing parameters to analyse drought effects on river flow.

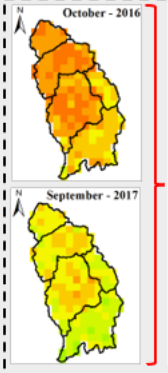
2. Methodology

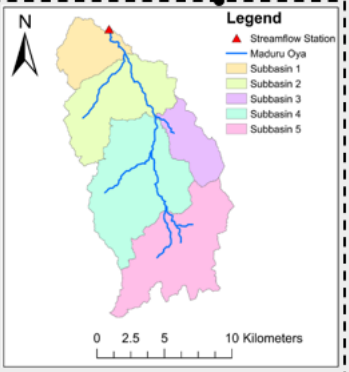
Derived 1 km resolution maps for selected satellite indices. → **Principal Component Analysis (PCA)** → CDI → Validate and calibrate **HEC-HMS model**

Satellite sources: **Temperature Condition Index, Vegetation Condition Index Standardized Precipitation**



Principal component 1 was considered in developing CDI.





Study area (**Padiyathalawa upper catchment**) was divided into **5 sub-catchments** based on CDI maps.

Calibration: NSE:0.78 MRAE:0.86

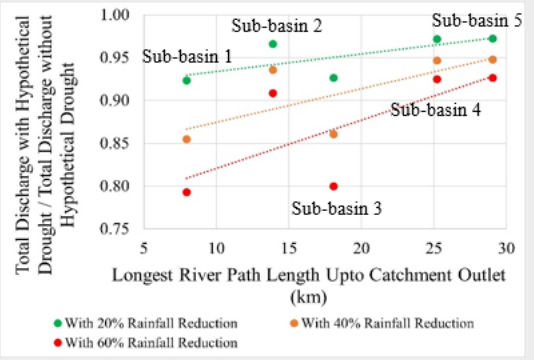
Validation: NSE:0.92 MRAE:2.44

Simulated hypothetical drought scenarios to assess drought impact on river flow.

3. Results & Conclusions

Developed CDI was able to **capture seasonal variation** within the catchment.

As the **distance from the outlet to the centroid of the sub-catchment increases, the drought's impact on total river discharge decreases.**



EVALUATING THE IMPACT OF TRANS-BASIN WATER TRANSFER ON WATER SECURITY IN SRI LANKA: A CASE STUDY OF THE HURULUWEWA CATCHMENT, SRI LANKA

M.N.N.K. Peiris [1], R.L.H.L. Rajapakse [1, *]

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Many river basins are becoming increasingly vulnerable to extreme fluctuations both in high and low flows due to climate change. Trans-basin water transfers offer a sustainable solution by redistributing surplus water to areas with shortages, helping balance uneven distribution. This study assesses the water balance in the Huruluwewa catchment (with an area extent of 183.1 km^2), located in the North Central dry zone of Sri Lanka. It aims to identify periods of water stress and surplus while exploring trans-basin management strategies for improved water resource management.

To estimate daily inflow to the Huruluwewa reservoir, 30 years of precipitation data were analyzed to establish long-term climate trends. The HEC-HMS (Hydrologic Engineering Center's Hydrologic Modeling System) model was employed for rainfall-runoff modelling. The catchment was divided into two sub-basins at the model development to enhance model accuracy. The calibrated model demonstrated satisfactory performance, as evidenced by favourable Nash-Sutcliffe, RMSE, R^2, and percent bias values. Flow Duration Curves (FDC) were utilized to verify and further refine the model simulations.

To assess the impact of climate change on streamflow for the near future (2030-2049), projected precipitation and temperature data from the CNRM-CM6-1-HR model were used under two SSP (Shared Socioeconomic Pathways) scenarios. The LARS WG (Long Ashton Research Station Weather Generator) software was utilized to downscale the climate data. The SSP1-2.6 scenario predicts a 6.4% increase in total annual rainfall while the SSP5-8.5 scenario forecasts a 5.5% increase. Projected future precipitation data indicates increased monsoonal rainfall in the study area. During the Southwest Monsoon, precipitation is expected to rise by 17.2% under SSP1-2.6 and 14.68% under SSP5-8.5. For the Northeast Monsoon, increases are 8.77% and 8.57%, respectively. Future average temperature is projected to rise significantly, with an increase of 1°C each month compared to the base period under the SSP5-8.5 scenario. This temperature rise will lead to higher evaporation rates.

The current water demand for paddy cultivation in the Maha and Yala seasons is 1,270 mm and 1,327 mm, respectively. However, future demand is expected to rise due to increased evapotranspiration from higher temperatures. Based on the estimated analysis results, it has been determined that the water availability in the Huruluwewa catchment is insufficient to meet the irrigation water requirements. An additional 20.7 MCM (Million Cubic Meters) of water is required to cultivate the entire command area under the reservoir. However, this water deficit had reduced to 4.2 MCM due to the potential of trans-basin water transfer. Furthermore, the current water deficit is projected to escalate to 24.7 MCM and 29.4 MCM under the anticipated climate scenarios (SSP1-2.6 and SSP5-8.5, respectively) for the period spanning 2030 to 2049 and it is imperative to implement proactive water management strategies to ensure sustainable water management in the region.

Keywords: Climate change, Monsoonal precipitation, Rainfall-runoff Modelling, reservoir water balance, Trans-basin water transfer

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EVALUATING THE IMPACT OF TRANS-BASIN WATER TRANSFER ON WATER SECURITY IN SRI LANKA: A CASE STUDY OF THE HURULUWEWA CATCHMENT, SRI LANKA

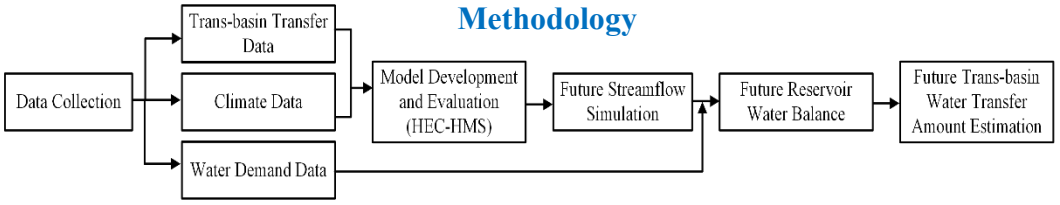
Aim

To assess the water balance and identify potential water stress and surplus periods within the Huruluwewa catchment situated in the North Central dry zone of Sri Lanka which is frequently subjected to water scarcity while focusing on trans-basin water management.

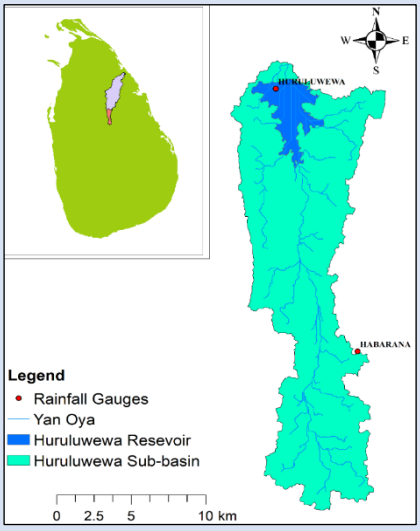
Specific Objectives

- To assess the current and future water availability.
- To assess the water demand in the selected catchment.
- To identify potential water stress/surplus periods.
- To assess the effect of trans-basin water transfer on the selected catchment

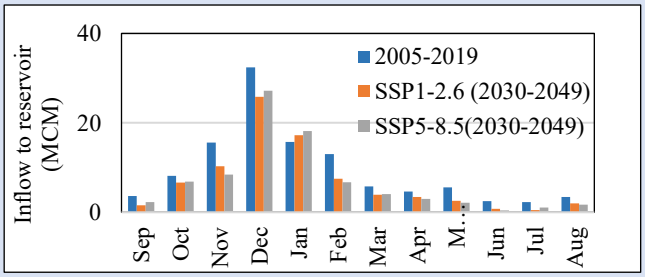
Methodology



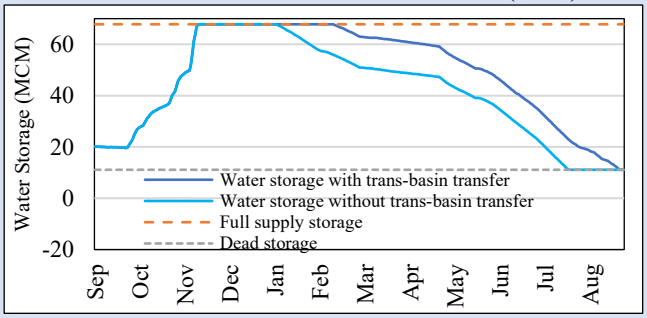
Results and Conclusion



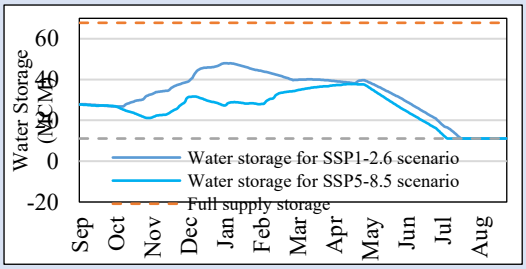
Study Area – Huruluwewa Catchment



Current and Future Inflow to Reservoir (MCM)



Current Reservoir Storage Variation



Future Reservoir Storage Variation

Current Water Deficit Without Trans-basin Transfer – 20.7 MCM

Current Water Deficit With Trans-basin Transfer – 4.2 MCM

Required Future Trans-basin Water Transfer Under SSP1-2.6 Scenario – 24.7 MCM

Required Future Trans-basin Water Transfer

INVESTIGATING RESIDUAL PROPERTIES OF MASONRY UNITS AT ELEVATED TEMPERATURES

T.D.C.M. Rajapaksha [1, *], I.E. Ariyaratne [1], C. Jayasinghe [1]

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Masonry structures are renowned globally for their strength, durability, affordability, and thermal and sound insulation properties. However, there is limited information on the residual properties of masonry units after exposure to elevated temperatures. This research addresses the aforementioned gap by investigating the residual properties of four representative masonry units; clay bricks, concrete blocks, compressed stabilized earth blocks and lightweight foam blocks. The study aimed at determining variations in physical and mechanical properties, including visual appearance, density, and compressive strength of these masonry units after exposure to elevated temperatures. Additionally, conventional cement-sand mortar (1:6) was also tested both in their ambient state and after exposure to elevated temperatures.

The study involved an experimental approach where four types of masonry units named clay bricks, concrete blocks, compressed stabilized earth blocks (CSEB), and lightweight foam blocks were subjected to controlled elevated temperatures up to 1200°C using a muffle furnace. Physical and mechanical properties, including density and compressive strength were measured both prior and post stages of exposure to these temperatures. Variations in these properties were then analyzed to assess the residual performance of each masonry unit. Visual observations and Scanning Electron Microscopy (SEM) were examined to document surface alterations and microstructural changes after exposure to elevated temperatures. Further, characteristic compressive strength values of the masonry assembly were also calculated using an empirical equation in the ambient and residual states. Finally, a comparative analysis between ambient and elevated temperature conditions was conducted to assess the impact of elevated temperatures on the masonry units and mortar.

The results indicate that the compressive strength values of masonry units and mortar decrease after exposure to temperatures up to 1200°C. The reduction factor in compressive strength of each unit after full heating process were observed as 0.57, 1, 0.68, 0.88 for clay brick, CSEB, lightweight foam block and CMU respectively. Clay bricks exhibited better resistance than other types, retaining most of their initial strength after exposure to elevated temperatures. Compressed stabilized earth block was observed to fail into a brittle failure after exposure to 1200°C. Dry density of all four types decreased significantly after exposure to elevated temperature conditions. Additionally, residual compressive strength of generally used mortar (1:6) exhibited a clear reduction after exposure to elevated temperature conditions.

The study's primary contributions include the investigation of the residual state behaviour of masonry structures after exposure to elevated temperatures which simulates the close behavior of a masonry structure at post-fire condition. This understanding aids in selecting appropriate masonry materials in a fire-prone area in future masonry construction.

Keywords: Compressive strength, Elevated temperature, Masonry units, Physical properties, Residual properties

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INVESTIGATING RESIDUAL PROPERTIES OF MASONRY UNITS AT ELEVATED TEMPERATURES

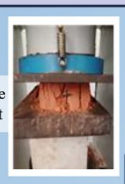
Background

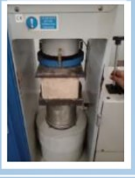
- Masonry structures are known for their strength, durability, and insulation properties in ambient condition.
- Understanding the residual state behavior after exposure to elevated temperatures is crucial for safety assessments.
- This study examines the behavior of masonry materials after elevated-temperature exposure, offering insights into their post-fire performance.

Objectives

- Investigate the physical and mechanical properties of masonry materials before and after exposure to elevated temperatures.
- Conduct a comparative analysis of residual and ambient behavior of selected masonry unit types.
- Provide a calculated compressive strength value for the masonry assembly using empirical equation.

Methodology


Compressive strength test


Residual compressive strength test


SEM test setup

Testing ambient properties

Testing residual properties

Sample preparation

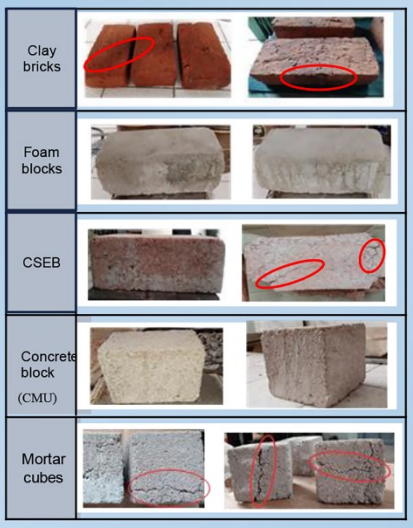
Exposure to elevated temperatures


Collected masonry units


Casting mortar cubes

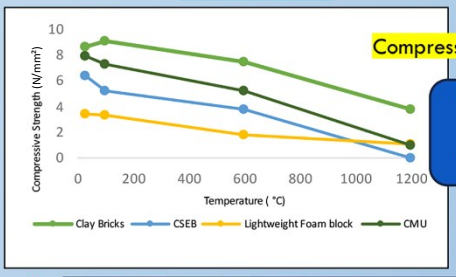

Heated in muffle furnace

Visual observations



Residual Compressive strength of generally used mortar (1:6) has a clear reduction after exposure to elevated temperature conditions.

Results



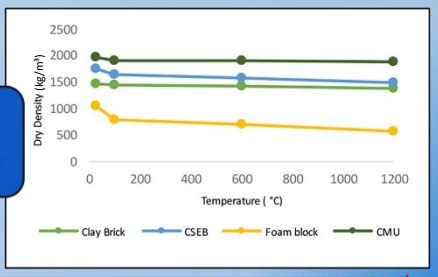
Compressive strength

CSEB block is observed to fail after exposure to 1200 ° C.

Clay brick > Lightweight foam block > CMU > CSEB

Dry density

Clay brick and CMU shows a smaller reduction in dry density



CMU > CSEB > Clay brick > Lightweight foam block

IDENTIFYING POTENTIAL GEO-HAZARDS IN HINGURAKGODA AREA LINKED TO DAMAGED HOUSES

S. Thushyanthan [1], U.P. Nawagamuwa [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Expansive soils pose significant challenges for construction projects worldwide due to their dynamic response to changes in moisture levels. This study focuses on identifying and categorizing expansive soils in the Hingurakgoda region, using data from the National Building Research Organization (NBRO) alongside advanced analytical techniques. By examining key soil parameters such as Atterberg limits, clay content, moisture content, and swell pressure, the research aims to understand the underlying causes of structural issues affecting buildings in the area. Spatial analysis tools like ArcGIS and Google Earth Pro were utilized to develop effective methods for recognizing expansive soils and understanding their geological relationship with marble layer cavities. The presence of minerals like smectite, montmorillonite , and illite in expansive soils significantly influences their swelling and shrinking behaviors. The study thoroughly investigates the geotechnical aspects of the soil, revealing complex underground conditions such as alluvial deposits and karstic formations, which exacerbate the challenges posed by expansive soils. The research emphasizes the importance of accurately identifying and categorizing these soils to predict soil movement and potential structural damage effectively. By combining insights from extensive data analysis and geotechnical studies, the study offers valuable recommendations for minimizing risks associated with expansive soils, thereby enhancing the security and durability of structures in the Hingurakgoda region.

In this study, six different methods were utilized to assess the swelling potential of expansive soils: Seed et al. (1960, 1962a), Ladd et al. (1961), Ranganatham and Satyanarayana (1965), Carter and Bentley (1991), Chen (1988), and Vander Merwe (1964). Among these methods, the Vander Merwe (1964) method demonstrated the highest level of similarity in predicting soil swelling potential. The method's consistent performance across various test results suggests that it is the most appropriate approach for classifying expansive soils in the Hingurakgoda area. The accuracy and reliability of the Vander Merwe (1964) method make it a valuable tool for evaluating soil expansiveness and managing associated risks, providing a strong foundation for construction and mitigation strategies in regions prone to soil swelling.

To further build on these findings, future research should prioritize increasing the number of soil sampling locations in Hingurakgoda. Expanding the sampling distribution would lead to more comprehensive data, allowing for more accurate spatial mapping and improved predictions of swelling potential. This approach would enable a more precise identification of high-risk areas, contributing to better-targeted risk mitigation strategies. By adopting an enhanced sampling strategy, future studies can significantly improve the reliability of soil classification and provide more effective guidelines for construction practices in regions affected by expansive soils.

In conclusion, the study's findings underscore the critical role of accurate soil classification methods, particularly the Vander Merwe (1964) method, in mitigating the risks associated with expansive soils and ensuring the long-term stability of structures in the Hingurakgoda region

Keywords: Expansive soil, Hingurakgoda, Swelling potential, Soil Shrinkage

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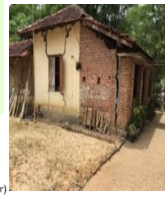
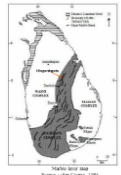
IDENTIFYING POTENTIAL GEO-HAZARDS IN HINGURAKGODA AREA LINKED TO DAMAGED HOUSES

1.Background

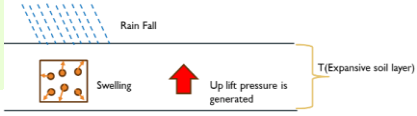
Hingurakgoda, situated in Polonnaruwa, Sri Lanka, is experiencing a concerning issue of house damage

AIM: To understand the causes of structural cracking and other damage in the Hingurakgoda region. By examining soil expansiveness, geological factors, and the relationship with marble layer cavities, the goal is to identify effective methods to **detect expansive soil** and propose strategies to mitigate related building risks.





The presence of minerals like smectite, montmorillonite , and illite in expansive soils significantly influences their swelling and shrinking behaviors

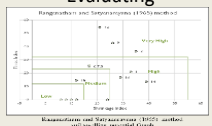


2. Methodology

Data

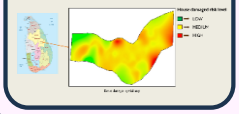
Data Collection
- Structural damage severity
- Soil Properties
  - Atterberg limits
  - Clay content
  - Free swell index
  - Shrinkage limit

Evaluating



Analysis

Spatial Analysis



Classification of soil sample

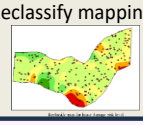
Swelling potential	Ranganatham and Satyanarayana (1965)		Seed et al. (1960, 1962a)		Ladd et al. (1961)		After Chen (1988)		Carter Benly (1991)
	PI	SI	S%	PI	PI	LL	LL	Clay%	PI
Low	<12	<15	0-1.5	0-10	<12	20-35	30	<30	0-15
Medium	12-23	15-30	1.5-5	10-20	12-23	35-50	30-40	30-60	10-30
High	23<	30<	5<	20<	23<	50<	40<	60<	30<

Comparison

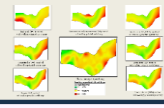
Comparison weightage system

Methods / House damage	Low		Medium		High	
	1	2	3	4	5	6
Low	1	1	0.8	0.5	0.4	0.2	0.1
	2	0.8	1	0.6	0.5	0.3	0.2
Medium	3	0.5	0.6	1	0.8	0.4	0.3
	4	0.4	0.5	0.8	1	0.6	0.4
High	5	0.2	0.3	0.5	0.6	1	0.8
	6	0.1	0.2	0.3	0.4	0.8	1

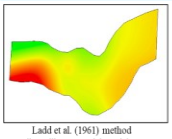
Reclassify mapping

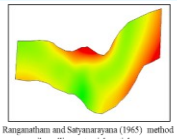


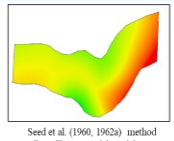
Methods and house damage map

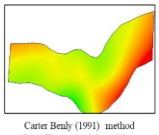


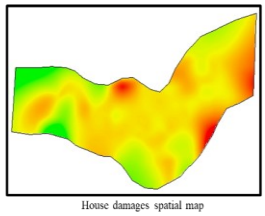
3. Result


Ladd et al. (1961) method soil swelling potential spatial map

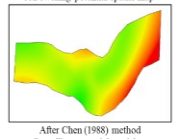

Ranganatham and Satyanarayana (1965) method soil swelling potential spatial map

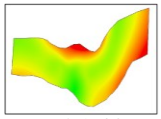

Seed et al. (1960, 1962a) method soil swelling potential spatial map

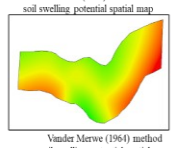

Carter Benly (1991) method soil swelling potential spatial map



House damages spatial map


After Chen (1988) method soil swelling potential spatial map


Ramani(1967) method soil swelling potential spatial map


Vander Merwe (1961) method soil swelling potential spatial map

	Ranganatham and Satyanarayana (1965)	Seed et al. (1960, 1962a)	Ladd et al. (1961)	After Chen (1988)	Carter Benly (1991)	Vander Merwe (1964
Similarity Percentage	59.5%	54.92%	58.6 %	52.12 %	59.47%	63.23%

ArcGIS mapping techniques were crucial for identifying high-risk areas and visualizing soil swelling potential, while the **Vander Merwe (1964) method** showed a high level of similarity when comparing soil expansiveness with house risk levels.

VALIDATING NUMERICAL MODEL FOR BRIDGE PIER SCOUR ESTIMATION THROUGH PHYSICAL MODELLING – CASE STUDY OF KELANISIRI BRIDGE

K.K.H.M. Rathnayake [1, *], A. Thembiliyagoda [1], P.K.C. De Silva [1]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Bridge scour is the erosion of sediment around bridge piers by flowing water, causing a significant risk to bridge stability and safety. Scour depth, the extent of sediment erosion around bridge piers or other structures caused by flowing water, is a critical parameter in bridge engineering. Generally, there are three types of scour phenomena that impact the performance and safety of bridges as local scour, contraction scour, and degradational scour. Understanding these are essential for identifying and reducing any dangers to the stability and safety of bridges.

This research aims to investigate the scouring phenomenon around the bridge piers of the Kelanisiri Bridge in Sri Lanka, understand its mechanisms, develop predictive models, and propose effective mitigation measures. The Kelanisiri bridge spans 134 m and is 10.4 m wide, has two cylindrical piers with a diameter of 2.5 m and has undergone scouring around piers, posing a severe danger to its stability. Also, this aims to contribute to the creation of sustainable solutions by examining the scouring processes and assessing the effects of variables like sediment types, flow velocities, and hydrological conditions through a combination of field investigations, laboratory experiments, and numerical modelling techniques. Further, this research will help to improve Sri Lanka's transportation infrastructure by ensuring the country's road network remains resilient and connected in the face of changing hydraulic conditions and sediment transport processes in river systems.

In this research, a laboratory scale physical model is developed to validate the results obtained from a numerical model developed using HEC-RAS software. The physical model replicates the bridge pier and surrounding riverbed at a scaled-down size, using similar materials. This allows for direct visualization of the scour process and the collection of detailed scour depth data at various locations around the pier. In the numerical model, HEC-RAS has capability to incorporate sediment transport equations, conduct extensive flow pattern studies, simulate complex river geometries, and offer a broad array of analytical tools. Comparing the scour depths obtained in the physical model with the predictions from the numerical model allows for an assessment of the validity and limitations of the numerical simulations.

The performance of the HEC-RAS model in replicating the physical model's scour depth measurements was assessed using R-squared (R^2) and Root Mean Squared Error (RMSE). R^2, ranging from 0 to 1, indicates the proportion of variance in the observed scour depths explained by the model's predictions. A good model exhibits both a high R^2 (strong correlation) and a low RMSE. The outcomes of the physical model comply well with the HEC-RAS numerical model results, with R^2 value of 0.87 and RMSE value of 0.12. Therefore, the accuracy of the numerical model, which had been designed to predict scour depth for the bridge piers at Kelanisiri bridge can be validated through this laboratory-scale experimentation. Finally, these discoveries will be critical in assuring the safety and durability of bridge constructions in Sri Lanka.

Keywords: Bridge pier, Scour depth, Sediment, Physical modelling

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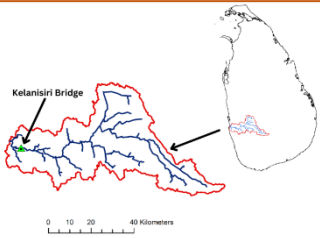
VALIDATING NUMERICAL MODEL FOR BRIDGE PIER SCOUR ESTIMATION THROUGH PHYSICAL MODELLING – CASE STUDY OF KELANISIRI BRIDGE

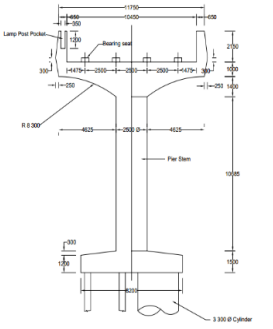
01. Background

Bridge scouring — Cause a significant risk to stability and safety of the bridges

- Scour phenomena
  - Local scour
  - Contraction scour
  - Degradational scour



Location map of Kelanisiri bridge


Details of Kelanisri bridge pier (Dimensions in mm)

Aim of the research — To investigate the scouring phenomenon around the bridge piers of the Kelanisiri Bridge, understand its mechanisms, develop predictive models, & propose effective mitigation measures.

02. Methodology

Several equations were used to determine Froude number, velocity and time

Froude Number	$Fr = \frac{U}{(gH)^{\frac{1}{2}}}$
Velocity	$E(U) = E(H)^{\frac{1}{2}}$
Time	$E(T) = \frac{E(L)}{E(H)^{\frac{1}{2}}}$

Physical model setup

Calculation of scale factors

Horizontal Scale	Vertical Scale
The width of the Kelani River near the bridge is about 81 meters. Width of flume = 0.9 m Selected scale = 81/0.9 = 90	Average height of bridge piers = 13.5 m Height of flume = 0.85 m Selected scale = 13.5/0.85 = 16

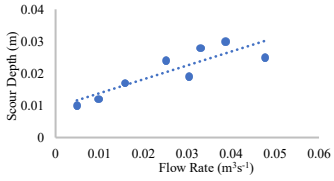
A PVC tube and an acrylic tube were used to model the bridge pier.


Model of bridge pier (PVC)

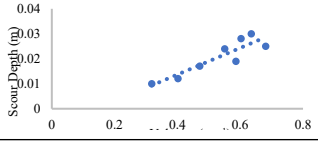

Model of bridge pier (Acrylic Plastic)

02. Methodology

Flow rate vs scour depth graph

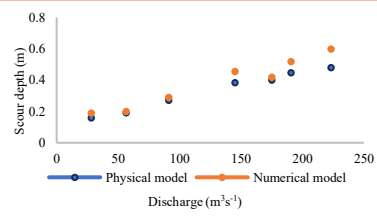


Velocity vs scour depth graph



Comparison between the Physical Model and the Numerical Model

Flow Rate (m^3/s)	Scour depth (m)	
	Physical model	Numerical model
27.89	0.16	0.185
56.44	0.192	0.2
91	0.272	0.28
144.9	0.384	0.441
175.15	0.4	0.43
190.5	0.448	0.51
223.11	0.48	0.58



Scour depth vs discharge comparison between the numerical and physical model

The R^2 value between the two datasets was 0.87 indicating a strong positive correlation. Additionally, the RMSE was 0.12, suggesting a good agreement between the measured and modelled values. This high level of consistency between the physical and numerical models strengthens the confidence in the applicability of the HEC-RAS model for this study.

BEHAVIOUR OF ROCK SOCKETED PILE GROUPS

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Department of Civil Engineering, University of Moratuwa, Moratuwa

Rock socketed pile groups are extensively employed in the construction industry due to their effectiveness in maximizing space utilization while supporting substantial structural loads, thereby enabling efficient vertical construction. This technique is particularly relevant in Sri Lanka, where bedrock is frequently encountered at shallow depths. However, despite the widespread use of rock socketed pile groups, the accurate determination of their bearing capacity remains insufficiently explored in existing literature. The conventional method, which involves simply aggregating the bearing capacities of individual piles, often lacks precision and necessitates further investigation.

This study seeks to characterize the behaviour of rock socketed pile groups by estimating their bearing capacity, taking into account key parameters of pile groups such as pile spacing, socket length, and bedrock properties, as well as evaluating the overall efficiency of these pile groups. This study aims to achieve objectives through a thorough three-dimensional finite element (FE) analysis. This analysis involves developing a detailed model to assess the impact of key parameters of the pile group on both the bearing capacity and efficiency.

This study seeks to confirm the accuracy and relevance of the finite element analysis results by cross-referencing them with experimental data from local sources. The study employs instrumental pile load test (IPT) data from a 1200 mm diameter, 10 m long test pile, implemented in the Port Access Elevated Highway project in Sri Lanka, to validate the FE model. The initial elastic modulus achieved 67% accuracy, which improved to 70% when doubled, and reached a peak of 75% with a tripled elastic modulus. Following model validation, a comprehensive FE analysis was conducted, adjusting bedrock properties and pile group parameters such as spacing and socket length to assess bearing capacity and group efficiency. The study focused on 2x2 pile groups, each with a 1200 mm diameter, assessing group efficiency by comparing individual pile performance to behaviour of the entire group.

Increasing the spacing between piles does not affect the settlement for pile groups embedded in very strong bedrock. Similarly, extending the socket length for pile groups in very strong bedrock also does not alter settlement. In such cases, group efficiency remains constant regardless of changes in pile spacing or socket length, and the efficiency typically exceeds 1. In contrast, for pile groups installed in weak bedrock, increasing the spacing between piles leads to greater settlement, while extending the socket length results in reduced settlement. For these weaker bedrock conditions, group efficiency improves with increased socket length but declines with greater pile spacing. Despite these variations, group efficiency remains below unity for weak bedrock, though it approaches unity as socket length increases. The study shows that current practice method is effective for pile groups in strong bedrock but less reliable in weak bedrock. It emphasizes the need to account for group parameters and bedrock conditions when selecting rock socketed pile groups for effective structural load support.

Keywords: Bearing Capacity, Finite Element Analysis, Group Efficiency, Pile Groups, Rock Socket

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Behaviour of Rock Socketed Pile Groups

Background of the study

In Sri Lanka, the behavior of rock socketed pile groups regarding bearing capacity and group efficiency is underexplored.

Aim

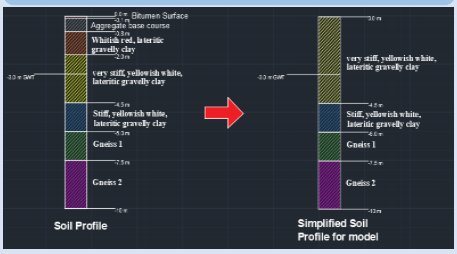
Characterize the behaviour of rock socketed pile groups

Objectives

Investigate the effect of the pile spacing, Socket Length and Bed Rock

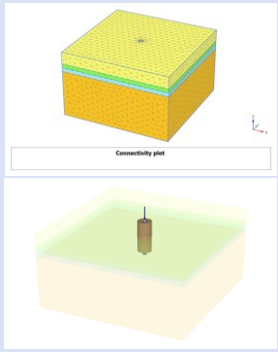
Methodology

Data collection



Bore hole data & Instrumental pile load test (IPT) results of test pile at the Port Access Elevated Highway project in Sri Lanka

Model Development



Material properties

Soils — Pile — Bed rock

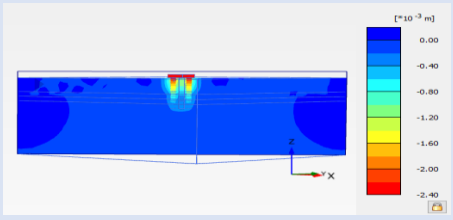
Parameters of pile

Length – 10 m

Material models

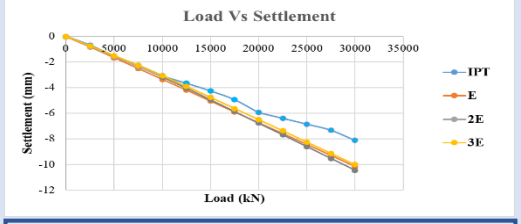
Mohr-coulomb
Linear elastic

FE Analysis & Results



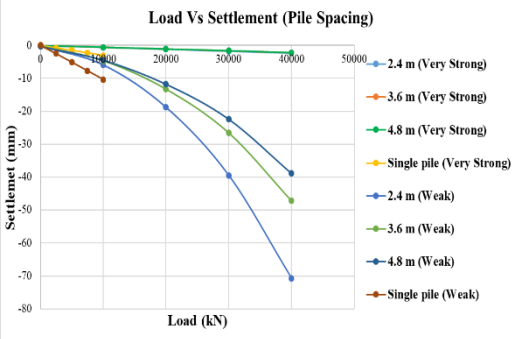
FE analysis with varying pile spacing, socket

Model Validation

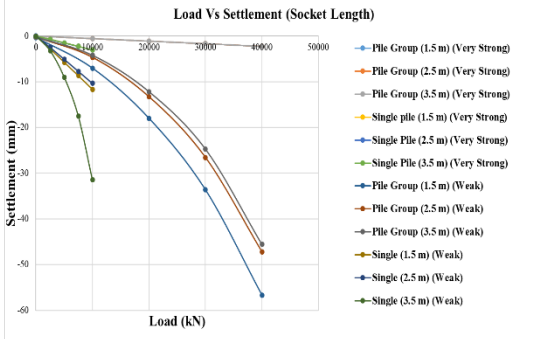


75% accuracy of FEM with IPT when Elastic modulus

Results



- Group Efficiency $_{\text{(very strong bed rock)}} > 1$



- Group Efficiency $_{\text{(Weak bed rock)}} < 1$

USING MACHINE LEARNING TO PREDICT FIRE RESISTANCE OF FRP STRENGTHENED CONCRETE BEAMS

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Fiber-Reinforced Polymer (FRP) materials are increasingly utilized over conventional repair techniques for reinforced concrete due to their advantageous properties, including lightweight, high strength, and corrosion resistance. However, these materials are susceptible to degradation under fire conditions, which can weaken the polymer resin, reduce material strength and stiffness, and ultimately compromise structural integrity. Given the necessity of assessing the fire resistance of FRP-strengthened beams, traditional evaluation methods, despite their accuracy, are constrained by significant time and resource demands. To overcome these challenges, several ML-based prediction models have been developed, offering a more efficient and accurate alternative, further optimized through advanced methods.

A comprehensive dataset, encompassing geometric, material, and loading parameters alongside fire resistance outcomes from both experimental and numerical studies, was compiled. During the preprocessing phase, all input parameters were retained despite low individual correlations, as their combined effects were found to significantly influence model performance. Six ML models, including both ensemble methods including Light Gradient Boosting (LGB), Random Forest (RF) and traditional algorithms including Decision Tree (DT), K-Nearest Neighbour (KNN), Linear Regression (LR), and Polynomial Regression (PR), were developed and evaluated using Python in Google Colaboratory. The models were optimized using Grid Search for hyperparameter tuning, ensuring that the best combination of hyperparameters was identified to maximize model accuracy. Additionally, K-fold cross-validation was employed to assess model performance across multiple data splits, mitigating overfitting and ensuring robust predictions.

The LGB model emerged as the most accurate, achieving an R^2 value of 0.9230 and a mean CV score of 0.9345, outperforming traditional ML models by a considerable margin. Ensemble models such as LGB and RF demonstrated exceptional generalizability, with CV scores below 2%, indicating strong potential for application in real-world scenarios. To further elucidate the factors influencing model predictions, Explainable AI (XAI) techniques such as SHAP analysis were employed, identifying key factors such as loading ratio, depth of insulation, and tensile steel reinforcement area as significant contributors to fire resistance. It has been concluded that ensemble models, particularly LGB and RF, provide a highly accurate and efficient method for predicting the fire resistance of FRP-strengthened concrete beams. This research underscores the limitations of traditional correlation analysis in high-dimensional datasets and highlights the critical role of machine learning in advancing fire resistance prediction methodologies. Further, the efficiency, and applicability of these ML models in real-world scenarios can be enhanced by training these models over a wider range of datasets.

Keywords: Ensemble Machine Learning, Fire Resistance, FRP Strengthened Concrete Beams, Machine Learning

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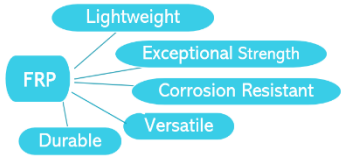
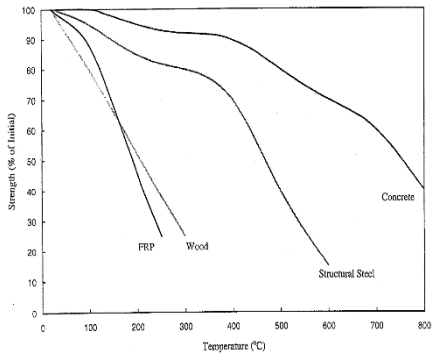
Background

FRP-Strengthened Concrete Beams



Challenges related to experimental and numerical methods

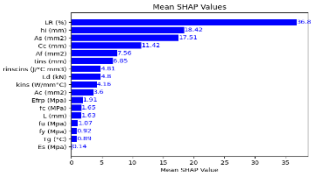
Costly | Time Consuming | Resource Intensive



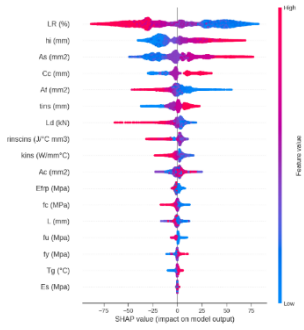
Strength degradation of FRP when exposed to fire

Methodology

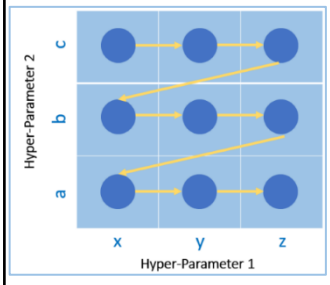
Collecting Database → Processing Data → Developing ML Models → Performance Evaluation → Model Optimization → Obtaining and Interpreting Results



SHAP Feature Importance Plot



SHAP Summary Plot



Grid Search Optimization

Working Principal of K-fold Cross Validation

Results

ML Model	R^2 value	Mean CV score	Standard deviation of CV scores	RMSE	MAE
LGB	0.9230	0.9345	0.0052	20.55	9.81
RF	0.9094	0.9181	0.0090	22.29	11.23
KNN	0.8765	0.8811	0.0063	26.04	14.55
DT	0.8461	0.8562	0.0112	29.06	15.42
PR	0.8238	0.8283	0.0116	31.09	21.26
LR	0.6646	0.6753	0.0122	42.91	32.80

CONCLUSIONS

- Ensemble models like LGB and RF give a high accuracy (>90%) in predicting fire resistance outperforming traditional ML models
- Correlation analysis has limitations in complex datasets and it might miss important interactions between features
- SHAP analysis identified impact of key parameters:
  - Negative: Loading ratio, FRP area, total applied load
  - Positive: Steel reinforcement area, insulation depth, concrete cover
- FRP modulus, glass transition temperature of FRP and yield strength of steel reinforcement exhibit lesser influence

CELLULAR PILE RAFT FOUNDATIONS FOR LIGHTWEIGHT MULTI-STOREY BUILDINGS

N.G.T.M. Sandamal [1, *], M.T.R. Jayasinghe[1], L.I.N. De Silva [1]

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The global demand for housing and urban land scarcity has driven the need for multistorey buildings. The substructure design plays a crucial role in ensuring the stability of these structures, as traditional foundation methods, like piled or piled raft foundations, are essential for distributing the substantial loads. However, the high costs associated with these systems have prompted the exploration of alternative foundation designs. This study's approach seeks to optimize foundation construction by reducing costs without compromising structural integrity, making it a viable solution for sustainable urban development.

This study investigates the feasibility of employing a raft foundation, particularly a weight-compensated cellular raft design for multistorey buildings exceeding 10 floors which typically require costly pile foundations. Unlike traditional piles, Backhoe loaders are proposed for constructing piles filled with Aggregate Base Course (ABC) with cement and inserting reinforced columns for anchoring the cellular raft. The strategy involves settling the building slightly to mobilize the soil capacity, particularly for sandy clay soil conditions. Furthermore, the study explores the potential of lightweight superstructures to significantly reduce construction costs by optimizing structural weight and eliminating the need for pile foundations. Specifically, it explores the utilization of Expanded Polystyrene (EPS) based lightweight panels and precast prestressed concrete beam systems with precast prestressed concrete slabs. Investigating a 10-story reinforced concrete moment resisting frame (MRF) supported by a cellular piled raft foundation, the research employs a direct approach considering soil-structure (SSI) interaction effects. Through construction stage analysis using finite element software (Midas GEN, Midas GTS NX), the study determines optimal gap sizes for the cellular raft and assesses the maximum number of storeys feasible without pile foundations. Overall, this study suggests that on sandy clay soil, constructing taller buildings with a maximum of 14 floors, in addition to the cellular basement, is feasible using lightweight superstructures in conjunction with cellular rafts.

Moreover, the research recommends increasing pile spacing beyond the current 5m x 5m grid configuration to fully mobilize soil capacity. Future studies should also investigate the effectiveness of these foundation systems across various soil types, including silty clay, loamy soil, and sandy loam, to further validate the design's applicability in different geological conditions.

Keywords: EPS light-weight wall panels, Finite element method, Soil–structure interaction, Sustainable construction, Weight compensated foundation

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Cellular Pile Raft Foundations for Lightweight Multi-Storey Buildings

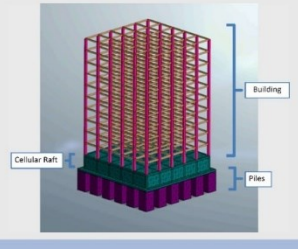
N.G.T.M. Sandamal, M.T.R. Jayasinghe, L.I.N. De Silva
University of Moratuwa

Introduction

Tall buildings exceeding 10 floors typically rely on costly pile foundations, highlighting the need for alternative, cost-effective solutions.
This study delves into the feasibility of raft foundations, particularly weight-compensated designs with cellular rafts, as a viable alternative.Backhoe loaders are proposed for constructing piles filled with Aggregate Base Course (ABC) with cement and inserting reinforced columns for anchoring the cellular raft.

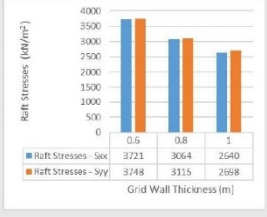
Methods

- A Three-Dimensional Finite Element Model of the proposed structural system was developed with commercially available computer software MIDAS GEN for the superstructure and Midas GTS NX was used for substructure integration.
- Construction stage analysis was carried out for the foundation analysis.

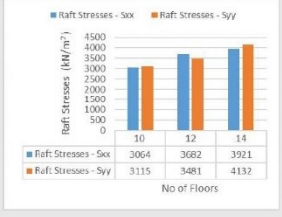


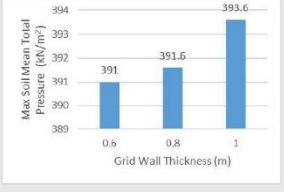
Results

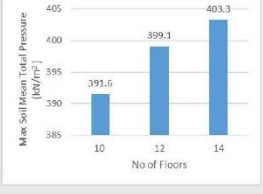
Variation with cellular grid wall thickness

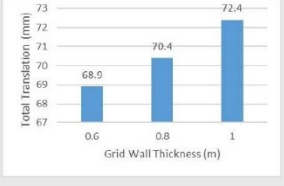


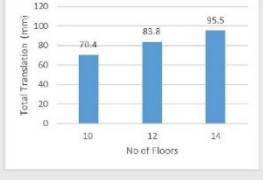
Variation with incremental floor addition





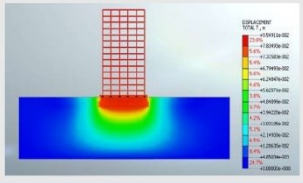






Conclusion

With the settlement for 14 floors reaching 95.5 millimeters, it was determined that further floor additions beyond this point are not feasible due to excessive settlement and limitations in the soil's bearing capacity.



Recommendations

It was observed that the current pile grid configuration of 5m x 5m is insufficient for fully mobilizing soil capacity, it's advised to increase pile spacing.
Moreover, investigating the effectiveness of these foundations across diverse soil types.

References

- Riman, A., "In-ground cellular structure as a foundation system 2017 NZSEE Conference," 2017.
- Shaaban, M., Abouelsaad, M. N., El Bagalaty, S., & El Madawy, M. E., "Seismic Analysis of RC High-Rise Buildings Rested on Cellular Raft," Buildings, vol. 12, no. 11, Art. no. 11, Nov. 2022.

INVESTIGATION OF THE DRIFT PERFORMANCE OF POINT FIXED GLASS FAÇADE SYSTEMS UNDER VARYING FLEXIBILITY OF SPIDER ARM CONNECTIONS

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Glass façade is a key component in contemporary architecture, offering both aesthetic appeal and structural functionality. Among the various facade systems, Point-Fixed Glass Façade (PFGF) systems stand out for their elegance and adaptability. However, their drift performance when subjected to in-plane racking actions due to seismic and wind forces is a significant concern, particularly in regions with low to moderate seismic risk, where such factors are often neglected during the design phase. Additionally, there is a notable scarcity of research on PFGF systems, particularly concerning parametric studies that explore drift capacity while considering the flexibility of spider arms. This study addresses this gap by presenting an in-depth analysis of the in-plane drift performance of PFGF systems.

A comprehensive Three-Dimensional (3D), non-linear Finite Element (FE) model was meticulously developed using ANSYS software, incorporating non-linear material properties and 3D elements to accurately and realistically represent the behavior of spider arms under loading conditions. To ensure a balance between model accuracy and computational efficiency, a detailed mesh sensitivity analysis was conducted to determine the optimal mesh size. The developed FE model was thoroughly validated against experimental data from previous studies, evaluating key parameters such as pushover curves, drift capacity, and maximum in-plane displacements. The validation demonstrated that the FE model achieved a drift capacity of 2.12% with a corresponding force of 15.97 kN, closely matching the reported experimental results. Additionally, a separate 3D linear FE model was developed to compare the outcomes between linearly and non-linearly modelled spider arms, further highlighting the critical importance of incorporating material nonlinearity in significantly enhancing the accuracy of the developed FE model.

The parametric study conducted on the PFGF system provided valuable insights into its drift performance under various configurations. Findings indicated that reducing the thickness of spider arms significantly improves drift performance, albeit with a minor reduction in allowable force. Similarly, decreasing the width of spider arms enhances drift performance, though at the cost of a noticeable reduction in allowable force. Increasing the diameter of the circular and slotted holes in spider arms improved drift performance, with a slight rise in allowable force. Moreover, decreasing the rotational friction at the base connection of the spider arm led to a modest enhancement in drift performance, with minimal impact on the allowable force. These results provide critical insights for engineers designing PFGF systems, emphasizing the importance of optimizing spider arm configurations to enhance drift capacity. The study underscores the need for considering structural interactions in facade system design to mitigate risks associated with seismic and wind loads. The validated FE model and the derived parametric insights are instrumental in guiding future design practices and improving the resilience of PFGF systems in various loading conditions.

Keywords: Point fixed glass façade, in-plane drift capacity, material non-linearity, spider arm flexibility

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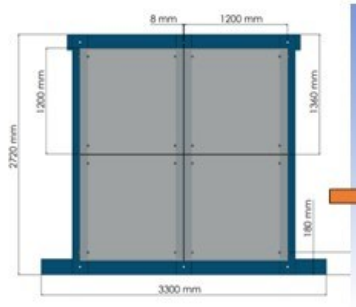
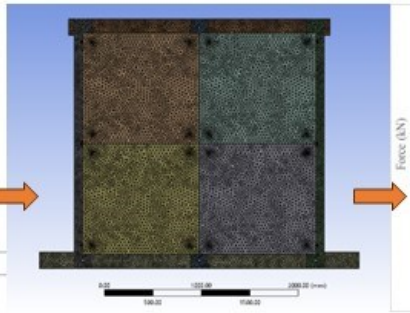
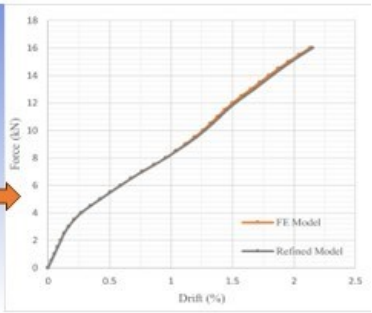
Investigation of the Drift Performance of Point Fixed Glass Façade Systems Under Varying Flexibility of Spider Arm Connections



Dimensions of the Model



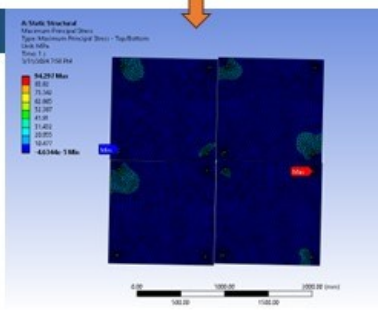
Three-Dimensional (3D), Non-Linear Finite Element (FE) Model

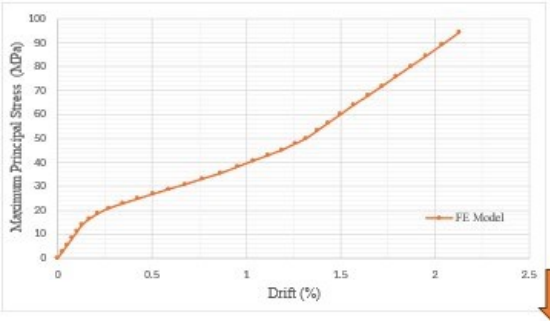


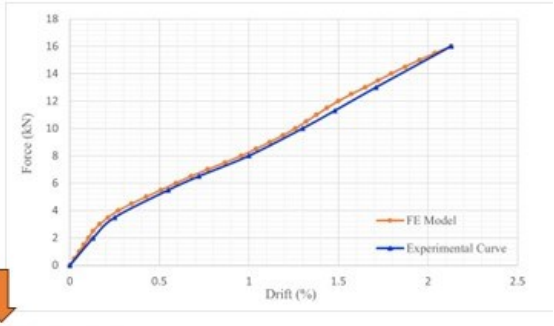
Mesh Sensitivity Analysis

ANALYSIS AND VALIDATION

Results Comparison	Experimental	FE Model	Error (%)
Drift (%)	2.1	2.12	1.13
Displacement (mm)	58	57.76	0.41
Force (kN)	16	15.97	0.18
In-plane glass translation (mm)	51	53.96	7.93







PARAMETRIC STUDY

Results Comparison	FE Model	Spider Arm Thickness		Spider Arm Width		Spider Arm Circular and Slotted Hole Diameter		Rotational Friction of the Spider Arm Base Connection	
		T#1	T#2	T#1	T#2	T#1	T#2	T#1	T#2
		Thickness decreased by 1/5th	Thickness increased by 1/5th	Width decreased by 1/5th	Width increased by 1/5th	Diameter decreased by 1mm	Diameter increased by 1mm	Friction decreased by 1/2nd	Friction increased by 1/2nd
Drift (%)	2.12	2.51	1.94	2.31	2.01	1.93	2.32	2.124	2.124
Displacement (mm)	57.76	68.35	52.72	62.83	54.63	52.56	63.13	57.774	57.759
Force (kN)	15.97	15.10	16.32	14.96	17.07	15.89	16.08	15.971	15.972

INVESTIGATION OF THE FEASIBILITY OF ELECTROCHEMICAL EXTRACTION OF CHLORIDE (Cl) IN RETROFITTING REINFORCED CONCRETE STRUCTURES IN THE COASTAL AREAS

U.S. Lokuge [1], S.M.A. Nanayakkara [1], T.G.P.L. Weerasinghe [1*]

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Corrosion of steel reinforcement is one of the primary modes of deterioration in reinforced concrete structures worldwide, largely driven by chloride attacks from marine environments, de-icing salts, and other sources of chloride ingress. This type of deterioration significantly compromises the structural integrity of concrete, leading to costly repairs and frequent maintenance. Every year, a staggering amount of money is spent on retrofitting and reconstructing these damaged structures, which has prompted extensive research into effective repair and rehabilitation methods. Among the various techniques studied, Electrochemical Chloride Extraction (ECE) has emerged as a promising method for retrofitting deteriorating reinforced concrete structures subjected to chloride attacks. ECE works by applying an electrical current to the concrete, which drives chloride ions away from the embedded steel reinforcement, thereby reducing the risk of corrosion. However, due to the lack of proper standards and guidelines on this method, it has not been widely adopted in the industry. This study aims to quantify the efficiency of chloride extraction and to determine the positive and negative side effects of using ECE as a treatment method for chloride-contaminated reinforced concrete structures through comprehensive laboratory tests. A major challenge in applying ECE in real-world scenarios is the difficulty of immersing large-scale structures in an electrolyte solution. To overcome this, a novel test setup was designed that simulates in-situ conditions and can be scaled up for industry applications. The research focused on monitoring the variation of chloride concentration in both the concrete and the electrolyte solution, assessing these variations over time, depth, and chloride-to-cement ratios of the test specimens. The study also explored the effects of ECE on the physical, mechanical, and chemical properties of the concrete to provide a holistic evaluation of its impact on structural performance. The results of this investigation indicate that ECE can effectively extract chloride ions from concrete, highlighting its potential as a viable corrosion mitigation technique. The study emphasizes the importance of optimizing experimental parameters, including the current density, duration of treatment, and composition of the electrolyte, to enhance the efficiency of chloride removal. Additionally, the development of practical testing methodologies bridges the gap between laboratory research and real-world applications, offering engineers and practitioners valuable guidance for implementing ECE in the field. This research underscores the need for standardized procedures and guidelines to facilitate broader industry adoption of ECE, ultimately enhancing the preservation of aging concrete structures. The findings contribute significantly to improving corrosion mitigation techniques and provide crucial insights for professionals involved in infrastructure maintenance and rehabilitation, paving the way for future advancements in the field.

Keywords: Chloride-induced corrosion, Corrosion mitigation, ECE, Rehabilitation, Reinforced concrete structures

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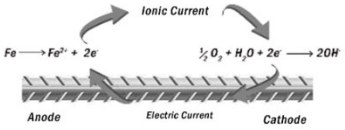
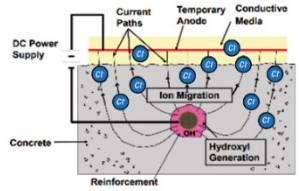
INVESTIGATION OF THE FEASIBILITY OF ELECTROCHEMICAL EXTRACTION OF CHLORIDE (CL) IN RETROFITTING REINFORCED CONCRETE STRUCTURES IN THE COASTAL AREAS

1. THEORY



Basic Equations

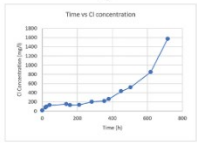
Test Setup



Theory

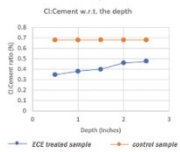
2. EXPERIMENTAL PROCESS

Chloride concentration variation of electrolyte with time



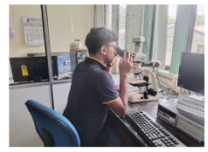
Chloride concentration variation of electrolyte with time

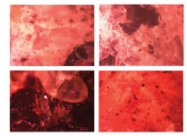
Cl:Cement ratio variation of concrete w.r.t. depth



Cl:Cement ratio variation of concrete w.r.t. depth

Impact of ECE on the physical properties of concrete





Microscopic images of the face of ECE treated test specimen

Impact of ECE on mechanical properties of concrete

Specimen	Failure load (kN)	Compressive strength (N/mm²)
ECE treated sample	465.9	20.7
Control sample	546.2	24.2

Compressive strength test results of ECE treated test specimen and a control sample

Impact of ECE on chemical properties of concrete

Variation of alkalinity of concrete after ECE treatment

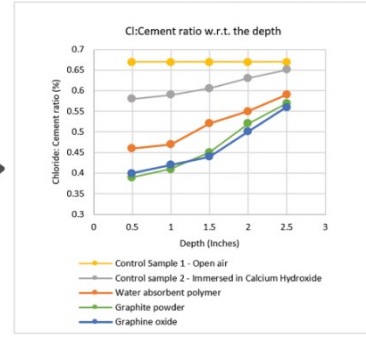
2. EXPERIMENTAL PROCESS FOR INDUSTRY APPLICABILITY

Paper medium soaked with graphene oxide

Cotton and graphite powder medium

water absorbent polymer medium

ECE treatment process



Cl:Cement ratio variation in concrete for tested 3 mediums w.r.t. depth

USE OF TILE WASTE AS AN INTERNAL CURING AGGREGATE (ICA) TO REPLACE COARSE AGGREGATES IN ROLLER COMPACTED CONCRETE (RCC) PRODUCTION

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Roller-compacted concrete (RCC) is gaining recognition for its economic and structural benefits, particularly in heavy-duty pavements, dams, and industrial flooring applications. Unlike traditional concrete, RCC is a low-water, zero-slump mix that can be compacted with vibratory rollers, reducing cement usage, costs, and environmental impact. However, RCC's low water content raises significant curing problems that could compromise the strength, durability, and overall performance of the concrete. Conventional surface curing methods often prove inadequate, leading to incomplete hydration and undesirable concrete properties.

This study explores an innovative approach to RCC production by incorporating clay tile waste as an Internal Curing Aggregate (ICA) to replace coarse aggregates. The aim is to improve hydration and enhance RCC's mechanical properties by addressing internal curing challenges. Clay tile waste, characterized by its porous structure and high-water absorption capacity, is proposed as a sustainable alternative to conventional aggregates, providing additional moisture during the curing process. This research investigates the effects of replacing coarse aggregates with clay tile aggregates (CTA) at 2.5%, 5%, and 7.5% on RCC's mechanical and durability properties.

The results show that a 2.5% replacement of coarse aggregates with CTA significantly improves early compressive strength, with notable gains observed at the 3-day mark. This early strength development is attributed to the effective internal curing provided by the tile waste, which facilitates continued hydration. At 28 days, RCC samples with 2.5% CTA replacement perform similarly to control samples in tensile strength, suggesting CTA's potential as an internal curing agent. Flexural strength tests further support these findings, with 2.5% CTA replacement yielding the highest strength among the tested samples. However, increasing the replacement ratio beyond 2.5% results in diminishing returns across all measured mechanical properties. This decline is likely due to the lower inherent strength of the clay tiles compared to traditional coarse aggregates. Results suggest that a 2.5% CTA replacement improves RCC's mechanical properties, supporting more sustainable construction.

The study provides important insights into using waste materials for sustainable RCC production. Incorporating clay tile waste as an ICA improves internal curing, enhancing hydration, early strength, and overall RCC performance. These findings support the development of sustainable construction materials and provide practical recommendations for optimizing RCC mix designs. Future work will involve field validation of these results and further exploration of long-term durability aspects under different environmental conditions.

Keywords: Clay tile aggregate, Concrete pavement, Internal curing aggregate, Roller compacted concrete

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Use of Tile Waste as an Internal Curing Aggregate (ICA) to Replace Coarse Aggregates in Roller Compacted Concrete (RCC) Production

BACKGROUND

Challenges in traditional curing methods

Depletion of natural resources

→ **Implementing internal curing and alternatives to traditional aggregates** → **Using clay tile as an Internal Curing Aggregate**

METHODOLOGY

Aggregate Preparation

- Crushing
- Sieving

Testing of Aggregates

- Water Absorption
- Water Desorption
- Relative Density

Determining the OMC

- For Conventional RCC
- For 5% CTA induced RCC

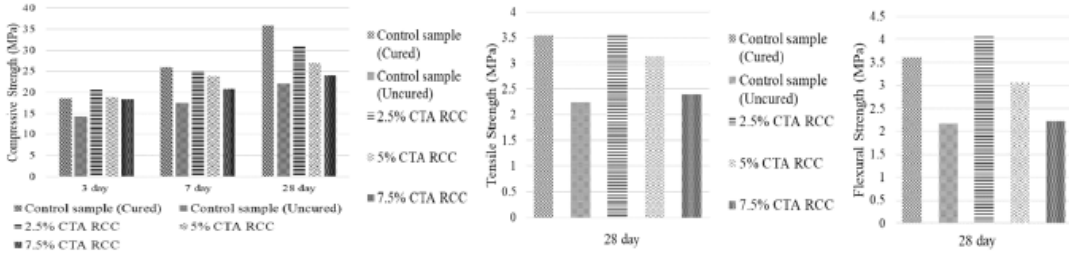
Casting of Concrete Samples

- Non-cured conventional RCC
- Externally cured conventional RCC
- Non- cured
  - 2.5% CTA induced RCC
  - 5% CTA induced RCC
  - 7.5% CTA induced RCC

Testing Samples

- Compressive strength
- Tensile strength
- Flexural strength

FINDINGS



2.5% CTA demonstrates the highest early strength, tensile strength, and flexural strength

Optimal Replacement → **2.5%**

DESIGN GUIDELINES FOR LATERAL CLEARANCE AT HORIZONTAL CURVES IN EXPRESSWAYS

A.W.A.K.D. Harshana [1], W.K. Mampearachchi [1, *]

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Design guidelines for lateral clearance require designing expressways by confirming drivers' line of sight is not obstructed by the objects at the horizontal curves. It gives sufficient sight distance to drivers ensuring safety of drivers and passengers. There are guidelines for lateral clearance design such as AASHTO Green Book. In the expressway, lateral clearance is measured from the centreline of the inner lane to the guard rail. Lateral clearance distance is varied with the radius of the curve and speed of the vehicle. Sometimes widening should be done to reach the required lateral clearance. If the driver's line of sight isn't obstructed by guard rail, there is no requirement to go for road widening with additional cost. This study was done to evaluate whether the existing lateral clearance is enough to fulfil the lateral clearance guidelines for various radii of curves and speeds. Subsequently, if the existing clearance is not enough, the line of sight is obstructed by the guard rail is checked, by using road geometry, height of guard rail and design speed. If the available lateral clearance is not enough at the centreline of the road, widening must be done because, even the line of sight is not obstructed by the guard rail, line of sight can be obstructed from vehicles that are going in the other direction. But at the outer shoulder sometimes even the available lateral clearance is not enough, widening is not necessary because the line of sight is not obstructed by guard rail. Therefore, drivers can see sufficient stopping sight distance.

This research underscores the critical importance of lateral clearance in ensuring the safety of expressways, particularly at horizontal curves. By verifying the effectiveness of design guidelines, such as those outlined in the AASHTO Green Book, the study highlights the necessity of maintaining adequate lateral clearance to preserve drivers' line of sight and prevent potential accidents. The findings reveal that while widening roadways may be necessary in cases of insufficient lateral clearance, careful consideration of factors such as curve radius, design speed, and superelevation is essential. Moreover, the study emphasizes the paramount importance of prioritizing safety in roadway design, underscoring the need to implement measures that guarantee an unobstructed line of sight for drivers.

According to the results, at inner shoulder, if sufficient lateral clearance is not provided, even driver's line of sight doesn't cross the guard rail, road widening is necessary. Because in such situations, the driver's line of sight crosses by the vehicles coming from opposite direction. At the outer shoulder, for the 120 kmph design speed, if the radius is less than 1650 m, the initial and final 250 m of the curve should be widened. Also, for the design speed of 110 kmph, if the radius is less than 1300 m, the initial and final 220 m distance of the curve should be widened. The initial and final 185 m distance of the curve should be widened for a design speed of 100 kmph if the radius is less than 900 m. If the radius is less than 695 m for a design speed of 90 kmph, the initial and final 160 m of the curve should be widened. So, at least 33% of road widening costs can be saved from the recommended suggestions, without affecting the safety of drivers and passengers.

Keywords: Guard rail, Line of sight, Obstruction, Sight distance

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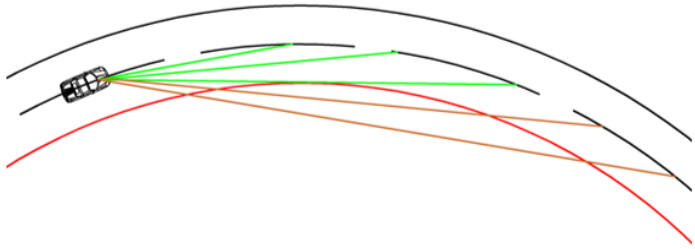
BACKGROUND

At the horizontal curves in expressways, if sufficient lateral clearance is not provided, the line of sight is obstructed by the various type of barriers like Guard rail, Noise barriers, Sign boards, Bird fences, etc.

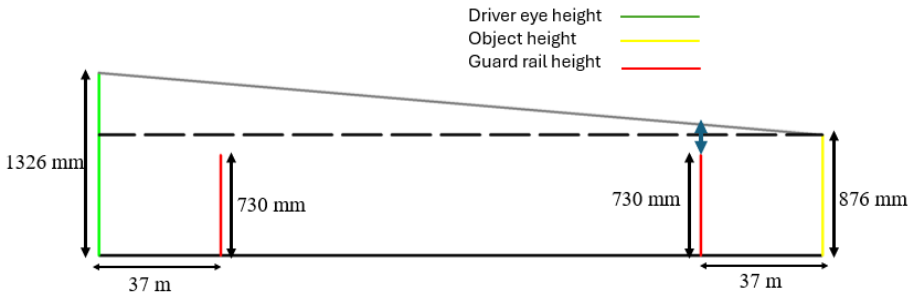


Methodology

DATA
Check available lateral clearance at each speed, radius and super elevation

CALCULATION
Calculate height difference between top of the guard rail and line of sight

- ✓ Driver and object both are at superelevated curve section
- ✓ Driver at the tangent section and object at the superelevated curve section
- ✓ Driver at the superelevated curve section and object at the tangent section



Difference between line of sight and top of the guard rail at 37 m distance from object's location

$$0.876 + 37 \times \left(\frac{1.326 - 0.876}{220}\right) - 0.730 = 0.221\ m$$

Therefore, difference between line of sight and top of the guard rail is 221 mm

UTILIZATION OF WASTE PLASTIC HDPE WITH FILLER MATERIALS (FLYASH AND BOTTOM ASH / CERAMIC WASTE) AS ALTERNATIVES TO NATURAL COARSE AGGREGATES; STRENGTH PROPERTIES

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The increasing costs of construction materials and the rapid depletion of natural aggregates have highlighted the urgent need for sustainable alternatives in the construction industry. In this context, plastic waste, particularly high-density polyethylene (HDPE), has become a significant environmental challenge due to the global surge in plastic production and disposal. This study investigates the feasibility of using synthetic coarse aggregates derived from post-consumer HDPE plastic waste, combined with various filler materials, as an environmentally friendly substitute for natural aggregates in concrete.

The research focuses on developing two types of synthetic aggregates, one consisting of HDPE mixed with fly ash and bottom ash and the other comprising HDPE combined with ceramic waste powder. The synthetic aggregates were created by varying the proportions of HDPE and filler materials, followed by extensive testing of the resulting plastic aggregate cubes for compressive strength and shrinkage. The results revealed that the optimal mix for the first type of aggregate consisted of 60% HDPE, 15% fly ash, and 25% bottom ash, while the second type achieved the best performance with a blend of 80% HDPE and 20% ceramic waste. These compositions demonstrated the highest compressive strength, making them the most effective synthetic aggregate blends for potential use in construction.

Subsequent to developing these optimal mixes, concrete cubes of different grades (15, 20, 25, and 30) were cast using both natural aggregates and a full (100%) replacement with the developed plastic aggregates. The findings of the study indicate that concrete made with synthetic plastic aggregates exhibited lower compressive strength and density compared to traditional concrete. However, these materials also resulted in significantly reduced production costs. Notably, replacing conventional natural aggregates with synthetic aggregates in higher-grade concrete mixes led to substantial cost savings, with reductions in production expenses ranging from 20% to 24% per footing in a sample building.

The research underscores the potential of incorporating synthetic coarse aggregates made from HDPE plastic waste, along with fly ash, bottom ash, and ceramic waste, as a sustainable and economically viable alternative to natural aggregates in concrete construction. The use of such synthetic aggregates not only addresses environmental concerns related to plastic waste but also offers a cost-effective solution that does not compromise the structural integrity of the concrete. These findings contribute to the growing body of knowledge on sustainable construction practices, presenting a promising pathway for the industry to reduce its environmental footprint while maintaining economic efficiency.

Keywords: Compressive strength, Cost reduction, Sustainability, Synthetic aggregates

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UTILIZATION OF WASTE PLASTIC HDPE WITH FILLER MATERIALS (FLY ASH AND BOTTOM ASH / CERAMIC WASTE) AS ALTERNATIVES TO NATURAL COARSE AGGREGATES ; STRENGTH PROPERTIES

1 BACKGROUND

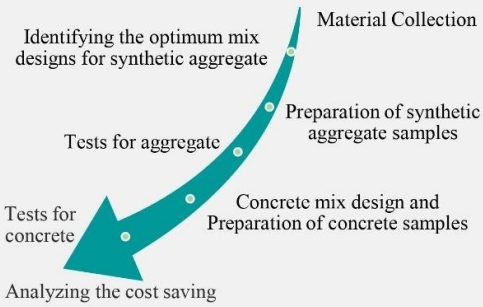
- Depletion of Natural Resources due to Extensive Extraction
- Environmental Pollution due to plastic consumption
- Escalating cost and demand of natural aggregates

Solution?

HDPE + Filler material → Synthetic aggregate

Fly ash/ Bottom Ash Ceramic waste

2 METHODOLOGY



Shredded HDPE

A Cast aggregate cube sample

Synthetic Aggregate Sample

3 RESULTS

Proportion for synthetic aggregates based on compressive strength

Alt 01	HDPE : Fly Ash: Bottom Ash	=	60 : 15: 25
Alt 02	HDPE : Ceramic waste	=	80: 20

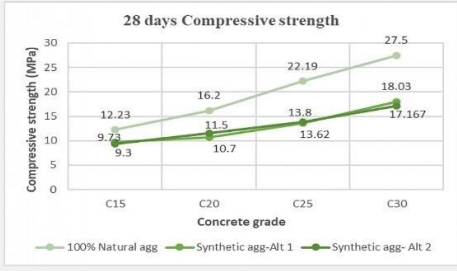
SEM analysis

Grade 25 concrete with synthetic agg- Alt 1

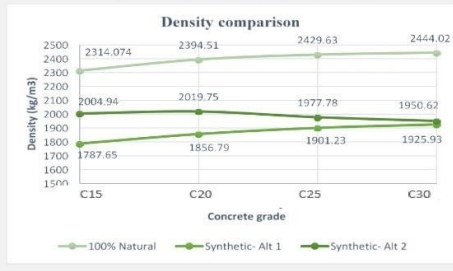
Specific Gravity and Water Absorption tests

	Specific Gravity	Water absorption
Natural Aggregate	2.72	0.49%
Alt 01- HDPE: Fly ash/Bottom ash	1.21	0.97%
Alt 02- HDPE: Ceramic waste	1.186	0.64%

Avg. Compressive strength at 28 days of Concrete samples

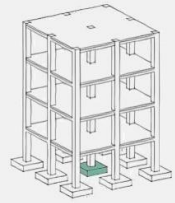


Avg. density of concrete samples



Cost saving per unit volume of concrete

Percentage cost saving	C 15	C 20	C 25	C 30
Concrete with Alt 01	8.51%	7.51%	8.05%	7.85%
Concrete with Alt 02	7.34%	6.41%	6.99%	6.85%



The cost reductions per footing ranged from 20% to 24%

EFFECT OF LOCALLY MANUFACTURED GRAPHENE OXIDE ON CONCRETE STRENGTH

E.G.V. Elapatha [1, *], R.U. Halwatura [1]

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The research investigates the impact of locally manufactured Graphene Oxide (GO) from Ceylon Graphene Technologies on the properties of concrete, focusing on compressive strength, sorptivity, early heat of hydration, and SEM analysis, to determine if GO can be a cost-effective method for concrete construction. Three concrete grades were tested withvarying GO concentrations (0.02%, 0.04%, 0.06%) and compared to control samples at 7- and28-day curing periods.

For grade 25 concrete, the compressive strength increased by 24.84% to 52.58% at 7 days and 13.82% to 46.74% at 28 days for GO concentrations of 0.02% to 0.06%, respectively. Grade 30 concrete exhibited even more substantial improvements, with compressive strength increases of 44.1% to 68.34% at 7 days and 11.9% to 27.45% at 28 days for the same GO concentrations. Grade 35 concrete showed modest gains, with 7-day increases of 10.5% to 10.534% and 28-day increases of 2.98% to 16.59%. These results demonstrate that higher GO concentrations lead to more significant enhancements in compressive strength, underscoring GO's potential to improve concrete strength and durability cost-effectively.

In addition to compressive strength, sorptivity tests on grade 30 concrete samples revealed that higher GO content results in lower water absorption rates. This reduction in sorptivity indicates enhanced durability and resistance to water ingress, crucial for the longevity of concrete structures. The early heat of hydration tests on grade 30 concrete indicated that GO increases heat production during the hydration process, with temperatures rising as GO percentages increased. This dose-dependent impact suggests that GO accelerates the hydration process, contributing to quicker strength gain. SEM analysis provided further insights into the microstructural changes induced by GO. The SEM images of GO-mixed concrete showcased a significant increase in hydrated products compared to conventional concrete.

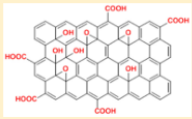
These findings highlight the ability of GO to improve infrastructure durability by reducing sorptivity and enhancing structural resilience. The integration of GO into concrete formulations can lead to more durable and resilient structures, offering substantial benefits for the construction industry. GO's ability to enhance concrete properties suggests it could be a cost-effective, transformative material for future infrastructure projects. The study concludes that incorporating GO into concrete not only boosts its compressive strength but also reduces water absorption and accelerates the hydration process. These improvements, evident across different concrete grades and GO concentrations, indicate that GO is a promising additive for developing stronger, more durable concrete in a cost-effective manner. The research provides valuable insights for future studies and practical applications, suggesting that GO can significantly contribute to the advancement of construction materials and methods, ultimately leading to more robust and enduring infrastructure.

Keywords: Compressive strength, Concentration, Graphene oxide, Hydration, Sorptivity

* Correspondence: rangika@uom.lk

EFFECT OF LOCALLY MANUFACTURED GRAPHENE OXIDE ON CONCRETE STRENGTH

1. Background



Graphene oxide molecule

Material properties

Bonding

Physical form

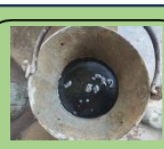
Concentration

- Ceylon Graphene Technologies
- Water dispersions
- 10 g/l
- Room temperature

Concrete grades 25, 30, 35 with varying concentrations of graphene oxide at 0%, 0.02%. 0.04% and 0.06%

2. Research Methodology

Sample casting



GO mixing with water

Cube Casting

Cylinder casting

Curing

Compressive strength

Three cubes from each sample – 7 & 28-days water curing

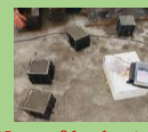
Sorptivity

~ 28 d water curing
~ 50 ^{0} C heat curing for 3 days
~ Air curing for 15 days

Testing

Cube testing

Sorptivity

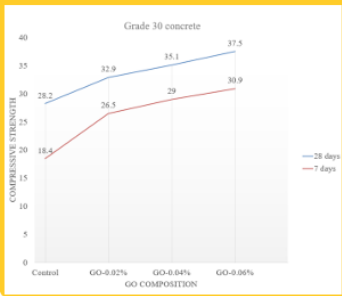


Heat of hydration

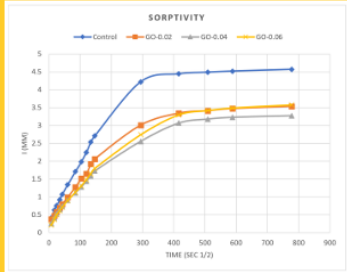
SEM

3. Results

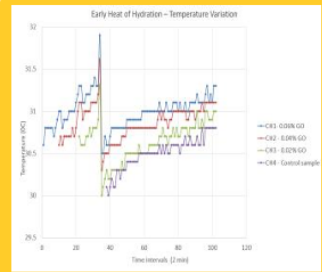
Compressive strength (C30)



Sorptivity (C30)



Heat of hydration (C30)



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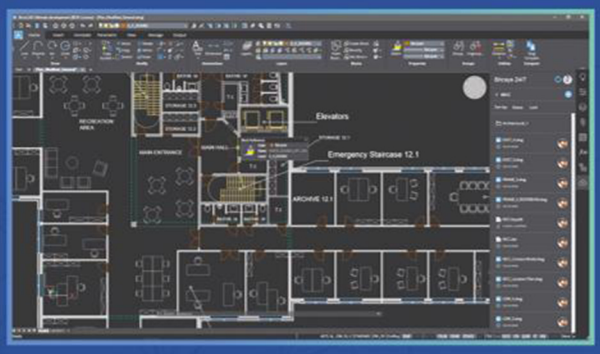

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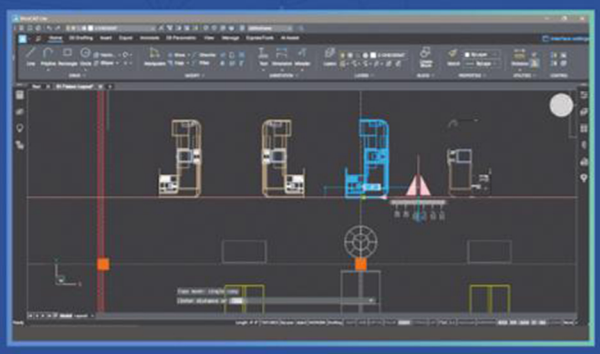

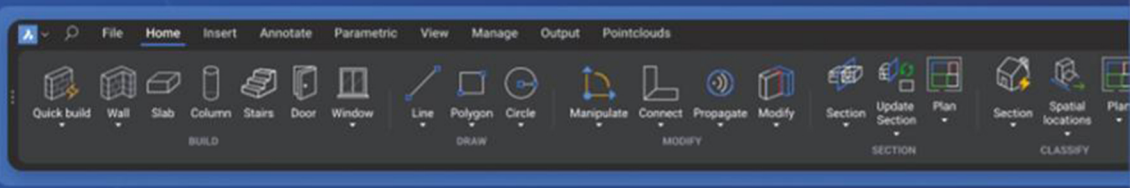

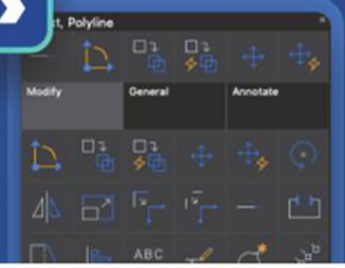

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