ICSBE 2022

The Kandy Conference

The 13th International Conference on

Sustainable Built Environment -2022

Book of Abstracts

16th-18th December 2022 | Earl's Regency Hotel, Kandy, Sri Lanka

PREFACE

It is with great pleasure that we present the proceedings of the 13th International Conference on Sustainable Built Environment (ICSBE) 2022. This is the eleventh consecutively organized conference following a series of international conferences since 2010, keeping its tradition of adhering to engineering excellence.

Taking a step forward from the last ten events, the coverage of specialty areas in this conference has been diversified. This book contains manuscripts of research work from many different sub-specialties. We expect that all these manuscripts will be presented in parallel sessions from 16th to 18th December 2022.

We would like to express our appreciation to all keynote speakers for their invaluable contribution to the development of a sustainable world. We are also very grateful to the authors for contributing research papers of high quality. The manuscripts in this proceeding book have been reviewed by a panel of academic and professional experts who have vast expertise in their respective fields. The enormous work carried out by these reviewers is gratefully appreciated as well. We are also pleased to acknowledge the advice and assistance provided by the members of the international advisory committee and members of the editorial committee along with many others who volunteered to assist to make this very significant event a success. Furthermore, we acknowledge the financial sponsorship provided by many organizations that have been extremely supportive towards the success of this international conference.

It is the earnest wish of the editors that this proceeding book would be used by the research community and practicing engineers who are directly or indirectly involved in studies related to sustainable built environments.

Editorial Committee

The 13th International Conference on Sustainable Built Environment (ICSBE) 2022.
16th to 18th December 2022.

A MESSAGE FROM THE VICE-CHANCELLOR

University of Peradeniya

It is with great pleasure that I forward this message to the 13th International Conference on Sustainable Built Environment (ICSBE) 2022.

I would like to recognize the academic excellence of the Conference achieved since its inception. It has been 13 years of providing an excellent platform to the engineering community, scientists, and researchers to present progress in research and development and report the implementation of new tools and technologies in practical application.

Continuing the tradition, we understand that the Conference is expanding its horizons by including areas such as technical and industrial collaborations. For example, University of Peradeniya, Moratuwa, Ruhuna, Sri Jayewardenepura and the Open University of Sri Lanka are joining as the technical partners in organizing this Conference. Having such a strong foundation will lead this conference to new heights.

Technical sessions of the Conference will feature special sessions aligning with the theme " Sustainable Built Environment (ICSBE) 2022," allowing the participants to have a targeted knowledge exchange in the related areas. The university invites all researchers, professionals, and students to reap the maximum benefits of the Conference. Finally, I congratulate the organizing committee of the ICSBE – 2022 and extend my best wishes for a very successful, memorable, and thought-provoking conference.

Thank you.

Prof. M.D. Lamawansa
Vice-Chancellor
University of Peradeniya

MESSAGE FROM CONFERENCE CO-CHAIRS

It is a pleasure for us to welcome all the participants to the 13ᵗʰ International Conference on Sustainable Built Environment (ICSBE) 2022 in Kandy, Sri Lanka. We, the co-chairs would gratefully like to mention the previous successful conference, which was held for ten consecutive years in Kandy, Sri Lanka. The theme selected for the conference Sustainable Built environment- is extremely relevant for today's world. With the vision of promoting innovative and sustainable research for tomorrow's development. We organize this conference as a meeting place for talents, knowledge, and dedication. Therefore, we trust that the conference will produce great ideas from a variety of research and exchange the knowledge of experts, colleagues, and friends who are working for the world's sustainable development.

The conference focuses on the different sub-topics in the sustainable built environment: such as Bridge design construction and maintenance (IABMAS, Chemical Processes for a Sustainable Future, Concrete Technology and High-Performance Concrete, Construction Management, Fire Safety Engineering, Geotechnical Engineering, Innovations in Building Materials, Innovations in Civil Infrastructures, Life Cycle Assessment Perspectives in Buildings, Resilience of Civil Infrastructure, Sustainable Construction, Tall Buildings, Waste in the Construction Industry, Water Resources Planning and Pollution Control, Technological Advancement for Safe Water Supply, Green Innovations and Green Building Techniques, Challenges from pollution in rural water supply and environment, Project SECRA, RMIT-Sri Lanka Joint Ph.D. Program. The full papers are published in volumes in paper format with a book of abstracts.

We hope that you will enjoy your time in Kandy during the conference. We, the conference co-chairs express our sincere thanks to our guests, keynote speakers, authors, members of the international advisory committee, members of the editorial committee financial sponsors, and many others who volunteered to assist to make this very significant event a success

Co-chairs
Prof. Ranjith Dissanaykae
Prof. S.M.A. Nanayakkara
Prof. Priyan Mendis
Prof. Sudhira De Silva
Eng. Shiromal Fernando
Prof. Kolita Weerasekara
Prof. Chaminda Konthesinghe

MESSAGE FROM THE CHIEF GUEST

EU Ambassador to Sri Lanka and the Maldives

Message for the 13ᵗʰ International Conference on Sustainable Built Environment (ICSBE) 2022

I am pleased to send this message on the occasion of the 13ᵗʰ International Conference on Sustainable Built Environment (ICSBE) 2022.

Introducing and maintaining a sustainable environmental policy is one of the key priority areas of the Government in realizing the vision for a greener and more sustainable Sri Lanka. The objective of the conference is to bring together experts and professionals in the field of the sustainable built environment to aid in creating policies related to the atmosphere, biodiversity, marine resources, cities and settlements is indeed a commendable one. It is the duty of the professionals and academics in this field, especially in these trying times, to disseminate their knowledge and keep abreast with changing trends from which Sri Lanka can also benefit. The focus on environmental education among the general public is also of vital importance.

I take this opportunity to congratulate the organizing committee of the conference on pioneering a successful series of interactional conferences and for organizing it for ten consecutive years. At this 13ᵗʰ conference too, I am certain that the platform will be provided for both local and international participants to share their experiences and exchange new knowledge on recent green innovations and developments in the field of the sustainable built environment. I am confident that the participants of this conference would have a fruitful experience.

I wish the 13ᵗʰ International Conference on Sustainable Built Environment 2022 the very best.

Denis Chaibi
EU Ambassador to Sri Lanka and the Maldives

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Kandy, Sri Lanka. | **16ᵗʰ-18ᵗʰ December 2022**

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TALL BUILDINGS

ACHIEVING NET-ZERO-ENERGY TALL BUILDINGS IN SRI LANKA

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Abstract: Achieving a net-zero-energy tall building with onsite renewables is a challenging task. A low-rise building on a low-density site would have a better chance of being net-zero-energy. Some argue that it is more beneficial to work toward net-zero-energy communities rather than net-zero-energy buildings. In general, most of the onsite building electricity generations do with solar photovoltaics (PV) systems. The prices of solar PV systems have been falling for most of the countries. This article investigates the potential of solar PV on the façades of a hypothetical 20 storey building in three selected locations in Sri Lanka. An hourly weather data file generated for each selected location and TRNSYS software tool are applied to simulate the performance of the solar PV system. We quantify the electrical output of the solar PV system and compare with the electricity consumed in each location. The article reports the potential annual electricity generations of roof top and façade integrated PV in Colombo, Jaffna and Kandy.

Keywords: Solar PV; façade; Colombo; Kandy; Jaffna

ICSBE 2022-95

EFFECTIVENESS OF VARIOUS OUTRIGGER SYSTEMS OF DIFFERENT STRUCTURAL MATERIALS FOR LATERAL LOAD RESISTANCE IN REINFORCED CONCRETE HIGH-RISE BUILDINGS

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Abstract: With the rapid urbanization and fast pace of development in high strength materials, construction of tall structures has become a go-to option. It concerns with considerably reducing the weight of buildings while enhancing the slenderness and flexibility of structures. However, as the height increases the structures become more critical under wind and earthquake induced lateral loads, as it reduces lateral stiffness which is pivotal in maintaining a buildings' structural efficiency. In such cases, outrigger and belt trusses structural systems are often introduced in high rise structures to provide adequate lateral stiffness to maintain the wind deflection and drift criteria within acceptable limits. According to the Authors knowledge, extensive studies done up to date only consist of investigations with outrigger systems of single material, consisting of simple square and rectangular shaped building plan layouts having no consideration for vertical irregularity of the building. Hence this study aims to bring a broader understanding of both conventional outrigger and virtual outrigger systems by identifying the most efficient lateral load resisting outrigger system for a reinforced concrete high rise building by analysing a range of structural materials and alternative arrangements with vertical irregularity. A three-dimensional (3D) numerical model of a high rise building with lateral load resisting systems were developed and validated theoretically. A parametric study was conducted to determine the applicability of selected alternative outrigger systems. Results indicate that the combination of outrigger and belt truss structural system in concrete indicated maximum performance while attaining the maximum reduction of 29.7% and 28.5% in lateral displacement and inter storey drift, respectively. These values tend to vary with each outrigger structural arrangement and the structural material, while all systems seem to significantly enhance the structural performance of the building against wind action, hence resulting in more resilient and sustainable buildings.

Keywords: Outriggers; Reinforced Concrete building; Composite material; Wind load; Lateral Displacement; Inter-storey Drift

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REDUCING REWORK TO ENHANCE THE SUSTAINABILITY OF BUILDING PROJECTS

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Abstract: One of the definitions of rework is reported to be 'the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time'. Construction rework contributes to time and cost overruns in building projects. The costs of rework in building projects can be calculated using different ways looking at construction contract value or based only in construction direct costs, excluding items like profits, overheads, and other management costs. This research looked at a Total Field Rework Factor (TFRF) indicator based on direct costs suggested Construction Industry Institute (CII). Looking at 437 different projects, the value of TFRF was 7.4% in average, with a maximum of 17.5% in nine Design and Construct projects. Minimising rework is a part of the quality management process, and every sustainable building project must consider it. This article aims to identify new management process to help reducing building construction rework making a contribution to improve the sustainability of the project. We reviewed and analysed the applicability and implication of Knowledge Management techniques and Lean principles specific to building construction projects. We also discuss the potential interventions in the building construction industry and practical implementations to enhance the sustainability of the buildings.

Keywords: Rework; building construction sustainability; knowledge management; lean principles; quality control.

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QUANTIFICATION OF DEGREE OF IRREGULARITY IN MASS IRREGULAR RC BUILDINGS USING IRREGULARITY INDEX BASED ON DYNAMIC CHARACTERISTICS

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Abstract: Mass irregular buildings are more vulnerable to seismic loading depending on their degree of irregularity. Therefore, design codes/standards prescribed different irregularity limits to identify the mass irregular buildings. However, design codes/standards are incapable of quantifying the degree of mass irregularity based on its elevation in the building. Furthermore, no effort was made in the past literature to quantify the degree of mass irregularity based on the elevation of the building. Therefore, the present study made an effort to quantify the degree of mass irregularity in reinforced concrete (RC) buildings based on elevation using a proposed Irregularity Index (μ). Furthermore, a comparison of the degree of mass irregularity was evaluated using the existing irregularity indices which are defined to quantify the geometric irregularities by the past literature. All the selected mass irregular RC buildings are numerically modeled using SAP2000 and modal analysis is performed to compute the degree of mass irregularity using the proposed Irregularity Index (μ). It has been found that the proposed Irregularity Index (μ) can well quantify the degree of mass irregularity depending on its elevation in RC buildings. Furthermore, the comparison of the existing irregularity indices shows that Irregularity Index (λ) proposed by Varadharajan et al. can also be used to quantify the degree of mass irregularity in RC buildings though it has been initially defined for the quantification of the geometric irregularities. The Irregularity Index (μ) can help to identify the different degrees of mass irregularity based on its elevation. Furthermore, it also aids in understanding the seismic vulnerability of mass irregular RC buildings and developing a correlation to study the seismic vulnerability with the degree of mass irregularity.

Keywords: Irregularity Index; Mass Irregularity; Modal Analysis; RC Buildings

PARAMETRICISM – A BRIDGE BETWEEN ENGINEERING AND ARCHITECTURE

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Abstract: Parametricism is a movement of architecture. Parametricism is all about using programs, algorithms, and computers to manipulate equations for design purposes. With parametric design technology it is possible to generate complex geometric forms for cities and buildings based on parameters that deserve to be governing the form. In parametric design it is possible to vary the parameters and observe the evolution of the form of the building in real time. This is due to the ability of the computers to perform millions of calculations per second. It is same we see in the postmodern engineering mathematics. Today, engineering design is not about performing a single calculation with pencil and paper. For instance, wind performance calculation of a building is not about identification of the worst wind condition and performing one calculation for that condition. Today, engineering means, parametrification of the wind velocity and adjusting it to the whole range. Get the computer perform all calculations and show us the wind performance of the building in real time. There is little difference between parametric architecture and post-modern engineering design. The parameters that govern the form of a city or a building can be multi-faceted. Such as social, economic, cultural, environmental, functional etc. Structural stability can also become a parameter that govern the form. It is possible to transform sheer forces, bending moments, natural frequency etc. into parameters that govern the form of a building. If we arrange to get both the engineers and architects work on a same visual programming language platform, we can bring out forms to the built environment that are never been imagined. Engineering and Architecture has been there as two separate worlds. This paper elaborates on how close we have come in terms of design. And how wonderful things we can do, if we merge them together.

Keywords: Architecture; parametricism; engineering; mathematics; buildings; cities

EFFECTS OF SPANDREL HEIGHTS ON LEAPFROG EFFECT IN TALL BUILDINGS

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Abstract: Along with the increasing number of tall buildings, more attention is paid to the façade it has a significant influence on the aesthetic appearance of the building. Therefore, architects are strict in their design to create a unique building. Façade fire is a disastrous hazard that can spread rapidly throughout the building. Leapfrog is a type of fire spread that occurs due to excessive heat from flames projecting from the lower floor to the floor above. Code provisions are available to control leapfrog by changing spandrel heights, but in some cases, it is not feasible due to architectural requirements. A performance-based method was used to study the vertical fire spread issues due to leapfrog using a numerical model. Results have shown that limited ventilation with proper compartmentation under the automatic active fire protection provides considerable fire safety avoiding flames ejecting from the broken glass or glasses in glass curtainwall facades.

Keywords: Spandrel; Passive fire protection; Active fire protection; façade; performance-based design

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EFFECTIVENESS OF TUNED MASS DAMPERS IN HIGH RISE BUILDINGS AND CANTILEVERED STRUCTURES

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Abstract: The artistic vision of an architect could be possible with the scientific knowledge of a structural engineer. Dynamic vibration control devices in high rise buildings and cantilevered structure are the perfect example for that. Since all buildings have mass, stiffness and inherent damping motion due to the vibration can be controlled. However, it is not efficient in high rise buildings and mega cantilevered structure. To mitigate this issue auxiliary damping system is introduced to take care of the motion due to the vibration in such structures. In this study the methodology could be followed to install a tuned mass dampers (TMD) and the quantifying the effectiveness of the tuned mass dampers with response factor are proposed.

Keywords: Cantilevered structure; Tuned mass dampers; Inherent damping; Response factor

CONCRETE TECHNOLOGY AND HIGH-PERFORMANCE CONCRETE

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DESIGN OF PERVIOUS CONCRETE PAVING BLOCK BY USE OF WASTE AGGREGATE FOR LIGHT TRAFFIC

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Abstract: This study presents the feasibility of using concrete waste aggregates as a partial replacement material in pervious concrete paving blocks in light traffic ways. Materials used are OPC, sand as fine aggregate, Natural coarse aggregates and Concrete Waste aggregates of two size ranges of coarse aggregate 4.75mm to 10.0mm, 10.0mm to 19.5mm. Concrete Waste Aggregates were prepared with high grade concrete and low grade concrete. Mixes were prepared with the w/c ratio of 0.32 and two a/c ratios; 3:1 and 4:1. Fines were added to 5 % of the total volume to increase the compressive strength. Concrete waste aggregates were replaced in proportions of 25%, 50%, and 75%. To test the suitability of concrete paving blocks; the Compressive Strength and the Skid Resistance were tested in accordance with the (SLS) 1425 Part 1:2011 - Specifications for Concrete Paving Blocks and Pervious properties were checked in accordance with pervious concrete specifications. Cost Analysis was done to check the cost effectiveness of the product.

Key words: Pervious-concrete, Paving-Block, Light-Traffic

EVALUATION OF THERMAL CONDUCTIVITY OF CONCRETE USING FINITE ELEMENT ANALYSIS

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Abstract: The thermal conductivity of concrete is an important parameter due to the concrete's energy, thermal, and fire performance. It depends on the water-cement (w/c) ratio, coarse aggregate volume fraction, fine aggregate volume fraction, age, temperature, and concrete admixtures. Among these parameters mix proportion of cement and aggregate act as a crucial factor since concrete's mechanical properties also depends on the mix proportions. Experimental methods such as steady and transient methods are available to measure the thermal conductivity of concrete. However, conducting experiments for every mix proportion used in the construction industry is not feasible. Therefore, this study develops a Finite Element (FE) model to determine the thermal conductivity of concrete with the known thermal conductivity values of mortar, aggregates and respective mix proportions. The developed FE model considers concrete as a two-phase model with mortar and coarse aggregates in the mesoscale concept. Two-dimensional model was developed with circular shape aggregates, and then the aggregate shapes were changed into two real shape aggregates such as elliptical and polygonal and validated with the experimental results from the literatures. The average difference percentage between the experimental results and FEM results is (-4.30%). Hence the developed FE model was verified to predict the concrete's thermal conductivity with known thermal conductivity values of coarse aggregates and mortar for any mix proportion.

Keywords: Thermal conductivity of concrete; Finite element modelling; Mesoscale; Two phase model; Two-dimensional analysis

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EFFECT OF CARBONATION ON MICROSTRUCTURE OF CEMENT PASTES WITH DIFFERENT WATER-TO-CEMENT RATIOS

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Abstract: The durability of the structures is the main concern in the field of engineering. Reinforcement corrosion is the most common cause of concrete structural deterioration. Corrosion of reinforcement results primarily from chloride ingress and carbonation. Cementitious materials are prone to carbonation as carbon dioxide is present everywhere in the atmosphere. For the durability prediction of cement-based materials, it is crucial to know the effect of carbonation on the microstructure of the cement matrix. This study examines how carbonation affects the microstructure of cement paste made up of Ordinary Portland Cement (OPC) with water-to-cement ratios (w/c) of 0.3, 0.4, and 0.5 with the help of the experiments and the newly developed model predicting the hydration products and porosity of the cement paste during the CO_2 gas diffusion. As part of this study, phenolphthalein was used to determine the carbonation depth. In addition to identifying the hydrated and carbonated products using X-Ray Diffraction (XRD) and Thermal Gravimetric Analysis (TGA), changes in microstructure were detected through Scanning Electron Microscope (SEM). Furthermore, the microstructures of cement paste samples that have been exposed to 5% carbon dioxide concentration for four months were compared. Carbonation products consist predominantly of calcite type polymorph of calcium carbonate, as revealed by XRD. Portlandite and C-S-H get carbonated simultaneously and the carbonation reaction increases with the increasing w/c in accordance with XRD and TGA results. Eventually, the experimental results of calcite and portlandite were compared with the predicted results from a newly developed COMSOL-IPHREEQC interface, and a better prediction of the numerical model was observed.

Keywords: Durability; Carbonation; Microstructure; COMSOL-IPHREEQC

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DEVELOPMENT OF LIGHTWEIGHT AGGREGATE CONCRETE WITH LOCALLY AVAILABLE LIGHTWEIGHT MATERIALS

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Abstract: Alternative building materials are a significant aspect of the construction industry due to the over-exploitation of natural resources and the cost increment of raw materials. Therefore, Past studies have focused on the development of lightweight aggregate concrete (LWAC) using various lightweight materials such as bottom ash, waste Calicut tiles, coconut shells & fibers, wood waste, recycled plastic, expanded polystyrene, and sludge. However, most past research on the development of lightweight aggregate concrete focused on directly replacing locally accessible lightweight materials. Furthermore, no more studies were done on the development of lightweight aggregate concrete by using converted lightweight aggregates from locally accessible lightweight materials. Therefore, this study was focused on developing lightweight aggregate concrete mix designs with locally available lightweight materials. Sludge derived from the water treatment plant, Expanded Polystyrene (EPS), and waste Calicut tiles were used as lightweight materials to develop lightweight aggregate concrete. Sludge obtained from water treatment plants was fired at 1050^0 C for 6-8 hours to convert it into lightweight aggregate while waste Calicut tiles were mechanically crushed to convert it into lightweight aggregate. Furthermore, mineral admixtures such as fly ash and silica fume were added to improve lightweight concrete's fresh and hardened properties. It is observed that the unit weight of the developed lightweight aggregate concrete was in the range of 1130-2280 kgm^{-3}. The 28-day compressive strength of concrete ranges from 3.9 MPa to 44.8 MPa for sludge and EPS-based lightweight concrete respectively. Due to the lower unit weight and compressive strength, sludge-based concrete mix designs can be used for non-loadbearing structural elements in multi-story, which reduces the total deadweight of the structure.

Keywords: Calicut tile; Compressive Strength; Concrete unit weight; Expanded Polystyrene; Lightweight aggregate; Sludge

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EFFECT OF CURING ON STRENGTH DEVELOPMENT AND DURABILITY OF CONCRETE WITH FLY ASH

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Abstract: Fly ash is a common supplementary cementitious material used in the production of green concrete. The effects of fly ash as a partial replacement for Ordinary Portland Cement (OPC) has been studied in past literature. Curing is one of the major parameters affecting the strength and durability of concrete. However, the effect of curing on strength development and durability of concrete with fly ash has not been studied adequately. Although moist curing is still a common practice in the construction industry, recommended period of curing is not practiced as per construction industry standards. Therefore, the present study evaluates the effect of short-term moist curing (0, 3, and 7 days) on the strength development and durability of concrete with Class F fly ash using three partial replacement ratios of OPC with fly ash (0%, 5%, 35% w/w). The results demonstrate that concrete with fly ash shows adequate and higher compressive strength than OPC concrete even with continuous outdoor air curing. Furthermore, the strength has slightly increased with the increment of moist curing period up to 3 and 7 days in all three mixes. Concrete with fly ash has exhibited a considerably higher surface electrical resistivity compared to the OPC mix. However, continuous moist curing for up to 3 and 7 days has caused a drastic increment of 28-day surface electrical resistivity of fly ash concrete unlike in the OPC mix. In conclusion, continuous outdoor air curing itself is adequate and even capable of increasing the strength and durability parameters of concrete with fly ash. However, moist curing of concrete with fly ash even for a shorter period of time drastically increases the surface electrical resistivity which implies higher durability.

Keywords: Compressive Strength; Concrete; Curing; Durability; Fly Ash; Surface electrical resistivity

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ASSESSMENT OF HEAT OF HYDRATION OF HIGH-STRENGTH CONCRETE

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Abstract: Despite the fact that Ordinary Portland Cement(OPC) concrete has been studied for decades, the hydration process of OPC and blended cement are still a source of scientific controversy. The process of hydration is highly complicated as it is combined with various influencing factors on hydration kinetics, dissolution, and precipitation reactions. Since cement hydration is an exothermic process, the low conductivity of concrete leads to an accumulation of heat in the core of the structure. Therefore, a huge temperature gradient will propagate and cause crucial internal cracking. Even though the propagation of thermal cracks is inevitable, it is indispensable to control the temperature development and for that, forecasting the heat evolution is extremely vital. One of the major predominant parameters of early temperature assessment in a given concrete structure is its rate of heat of hydration. Although several experimental methods were employed towards the assessment of heat propagation , upgraded analytical approaches also provide better predictions on quantifying temperature development and heat generation rate of the structure relevant to the given mix proportion. However, there is a dearth of existing data to expand these analytical models in the case of high-strength concrete with different SCM blends. In this light, the conduction of semi-adiabatic experiments to expand the existing databases of the heat of hydration on high-strength concrete mixes and the effect of using silica fume as a supplementary cementitious material was discussed in this context. The increase in silica fume content and carboxylic admixture concentration lengthen the period of dormancy, and the peak temperature rise is directly correlated with binder content, according to the results. Although the FEA approaches provide good correlation with normal strength concrete, analytic models for high strength concrete must be amended.

Keywords: Heat of hydration ; Semi-adiabatic ;High strength concrete ; Silica Fume ; Maturity

RMIT - SRI LANKA JOINT PHD PROGRAM

USE OF RECYCLED GLASS IN NON-STRUCTURAL BUILDING ELEMENTS FOR IMPROVED FIRE PERFORMANCE

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Abstract: Sustainable materials always benefit the environment. In the global green concept, there are lots of materials that are recycled and reused in different forms by adapting different techniques. Among different materials, the amount of recycled glass is less than the usage even though there are many applications with glass material in various construction. Therefore, the aim of this study is to promote the use of waste glass as a composite material with polymer material in non-structural applications such as interior and exterior walls in buildings. While selecting the polymer material, the thermal performance needs to be focused with mechanical performance as polymers are weak and highly flammable under thermal loadings. The thermal performance can be evaluated by experimental or numerical analysis. In this research, numerical tools are used to investigate thermal performance. The numerical analysis is conducted using computational fluid dynamic (CFD) simulations to simulate a combustibility test for the composite material. Further, a verified simplified cone calorimeter test model is used to investigate the impact of polymer material. From this research, it is proposed that increasing the percentage of recycled glass will help to improve the thermal performance of glass-polymer composite materials while enhancing sustainability. Moreover, it has been demonstrated that the peak heat release rate is reduced by 50% when 30% of glass fiber is added to 70% polymer in comparison to pure polymer. The results from the study will benefit Engineers to use sustainable materials in building construction rather relying on conventional building constructions.

Keywords: CFD simulation; Polymer composite material; Recycled glass; Sustainable development; Thermal performance

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CLIMATE CHANGE ADAPTATION MEASURES IN THE CONTEXT OF ELECTRICITY INFRASTRUCTURE: A CASE STUDY

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Abstract: Over the past years, buildings and CIs have been largely affected by climate change-related extreme events. Being a tropical nation, Sri Lanka is adversely impacted by the current climate change landscape. Many nations have taken actions, generally known as Climate Change Adaptation (CCA) strategies, to mitigate the negative impacts on the infrastructure. The present study seeks to identify the CCA measures for the electricity sector, selecting Sri Lanka as a case point. The open-ended expert interviews with professionals from several organizations who are working in the electricity sector were conducted to determine the most suitable CCA measures. Accordingly, expert interviews pave the way to identify the different CCA measures for electricity infrastructure. Several adaptation measures for the different stages of the infrastructure life cycle were identified after analysing the qualitative data. Accordingly, six, seven and five adaptation measures were identified with respect to infrastructure planning, design and construction and maintenance and retrofitting stages, respectively. The majority of respondents say that three factors are crucial for the planning stage of the electricity infrastructures (i.e., proper planning of evacuation routes, risk-informed infrastructure development, and adopting tools for evaluating risk, vulnerability, and exposure of infrastructure). Five measures (i.e., proper stormwater management techniques/drainage system designs, considering safe engineering designs, using protective measures, raising the elevation of infrastructure, and alternative infrastructure designs) were also cited by all respondents as crucial CCA measures during the design and construction phases. For all the selected CCA measures, the respondents' phase percentage for maintenance and retrofitting is greater than 80%. The finding of this study will be useful for asset managers and decision-makers in the context of the electricity sector in building climate resilience within the electricity sector in Sri Lanka.

Keywords: Climate Change; Climate Change Adaptation; Electricity sector; Adaptation measures

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DEVELOPMENT OF A WEB-BASED PLATFORM TO SUPPORT MULTI-HAZARD EARLY WARNING DISSEMINATION AND EMERGENCY RESPONSE MECHANISMS

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Abstract: This research study presents, a design and development of a web-based platform facilitated by an SMS alert service to address the current inefficiencies in the warning dissemination process, as well as stakeholder management in emergency responses of at-risk communities and authorities. During disastrous situations, authorities are involved in various activities such as collecting relevant situational information at the community level, updating real-time disaster information, search and rescue missions, allocating resources, and distributing relief to the affected communities. As a result, the emergency response phase of a disaster necessitates the collaboration of many agencies and stakeholders engaged in the overall response process. Thus, the proposed platform was designed under the guidance of the Disaster Management Centre (DMC), Sri Lanka, in accordance with the National Disaster Management Plan (NDMP), Disaster Management Act, Standard Operational Procedures (SOPs) of warning dissemination and the National Emergency Operation Plan (NEOP). Moreover, currently at district levels, District Emergency Operational Plans (DEOPs) are being developed and executed. Hence, the DEOPs are also referred to design the proposed web-based platform. Also, the proposed platform addressed specific gaps like reaching the last mile-last man and bottlenecks in communication links during the warning dissemination process. To identify the gaps in the existing warning mechanism and emergency response strategies, a comprehensive literature review was conducted and followed by a series of key informant interviews with different stakeholders who are engaged in Disaster Risk Management (DRM) activities. These stakeholders include officials from DMC and authorities from the district and divisional levels. After finalizing the framework for the identified requirements (features), web architecture was developed. The proposed solution provides a technology-enabled mechanism to enhance MHEW dissemination and emergency response strategies. However, it is recommended to conduct pilot studies engaging at-risk communities to identify the gaps and possible improvements that can be made to the web-based platform.

Keywords: Dis-Map; Web-based platform; Warning dissemination; Emergency response; Authorities; At-risk communities

BRIDGE DESIGN CONSTRUCTION AND MAINTENANCE

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NONDESTRUCTIVE VISUALIZATION OF THE INTERIOR OF A CONCRETE MEMBER WITH COMPLICATED DETAILS

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Abstract: A 265 ft long posttensioned girder was fabricated. The 3.25 ft wide and 4 ft deep section included 12 empty posttension ducts and a highly congested reinforcement detail. During concrete placement, one of the trucks delivered concrete with a lower slump than specified. This necessitated a nondestructive investigation of the girder interior for indications of insufficient consolidation. Ultrasonic tomography was selected as a suitable technique. Signal propagation through the 3.25 ft wide and 4 ft deep reinforced concrete section (with and without ducts) was simulated to evaluate the likelihood of detecting backwall reflections. Backwall reflection detection was required for the calibration of phase values for the classification of reflector types (i.e., the internal details and voids). Simulation indicated the possibility of visualizing only the empty ducts and longitudinal reinforcement located near the scanned surface with very light reflections from the empty ducts at the 2nd column located at a distance of 19.5 in. from the vertical surface. Based on the simulation results and the understating of girder details, data collection protocols were developed and executed. This presentation will cover structural details of the posttension concrete girder, simulation results, data collection plan, findings, and the capabilities and limitations of the state-of-the-art technology for visualizing concrete interior.

Keywords: Concrete; nondestructive testing; posttension; ultrasonic tomography; simulation

EFFECT OF LIVE LOAD INCREMENT OF OLD STEEL RAILWAY BRIDGES IN SRI LANKA

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Abstract: In Sri Lanka, most of the railway steel bridges are about 100 years old, and they were built during the British colonial period. But nowadays there are existences of various failures on bridges due to the increasing weight and speed of modern trains. At the time of the construction of the railway bridges in Sri Lanka, the speed of the trains used for transport ranged between 45 km/h to 50 km/h and the weight of the trains was 60 tons. But at the present weight of trains has significantly increased to 120 tons and the speed is 120 km/h. This issue is more prominent in the Northern railway line after Mahawa railway station. Most of the bridges on a Northern railway line have deteriorated among them Malwathu Oya and Kala Oya bridges were identified as critical by the railway department. On those two bridges loosening nuts and bolts and cracking of bridge members are visible. Using the visual condition and field visit data gathered, highly deteriorated bridge members were selected to evaluate the occurrence of the vibration effect. The modern vibration test was used to find vibration responses, and bridge material was tested to find the basic mechanical properties. The selected bridges were modelled with SAP2000 V.16, general-purpose structural analysis software, and moving load nonlinear analysis was done using the data of historical locomotives operated over the bridge. Here the locomotive loads were multiplied by a factor to simulate the dynamic effect. SAP2000 results were used to find the stresses of critical members of those two bridges. Then numerical results of the validated analytical modal were verified through the experimental result. The results show that there was a significant dynamic effect due to the live load increment of these two bridges.

Keywords: Steel bridges; Vibration analysis; Live load increment; Finite element analysis

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USE OF MARKOV CHAIN METHOD TO PREDICT SERVICE LIFE OF REINFORCED CONCRETE BRIDGE DECKS

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Abstract: Bridges are recognized as the most salient module in road and highway infrastructure in a country due to their unparalleled line of service to the nation's transportation framework. Therefore, the availability of a comprehensive Bridge Management System (BMS) in a country
to evaluate aging bridges for long-term performance and life expectancy is highly productive and rewarding in terms of ensuring the structural reliability of commissioned bridges in that country. Currently, Sri Lanka has about 4800 bridges on National Highway Network (A & B class roads) spanning over the country. Aggressive environmental conditions, such as Chloride and CO_2 contamination in the atmosphere make reinforced concrete bridge structures corrode over time reducing their maximum designed service life (life expectancy). Therefore, the present research study was intended to develop a bridge remaining service life prediction model (bridge deterioration model) using the State-based Markov chain modelling process that involves bridge condition ratings assigned for 24 concrete bridges in Sri Lanka based on first hand visual inspection and Non-destructive testing evaluation (NDTE) conducted on the reinforced concrete bridges.

Keywords: Markov chain; Bridge Management System (BMS); Service life prediction; State-based modelling; Non-destructive testing evaluation (NDTE); Condition rating

THIN-WALLED HOLLOW STEEL BOX PIERS WITH ENERGY DISSIPATION MECHANISM UNDER BI-DIRECTIONAL CYCLIC LOADING

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Abstract: The seismic design of bridge piers is often conducted using horizontal dynamic analysis employing several orthogonal directional seismic acceleration data. This simplistic treatment, however, does not account for the effect of complex earthquake loading as a structural response to inelastic interactions. This study explores the hysteretic behaviour of a proposed thin-walled steel square box column with an energy dissipation mechanism under constant axial force and linear and non-linear cyclic lateral loading. First, the adopted finite element model (FEM) in ABAQUS is validated with experimental results from the published research and then used for analysis. Then, several linear and non-linear idealised loading patterns are used to evaluate the strength and ductility of the proposed and standard columns. In addition, the failure mechanisms of each proposed column were explored for specified loading patterns.

Keywords: Cyclic lateral loading; Ductility; Load Pattern; Non-linear finite element simulation; Strength; Thin-walled steel box column

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PRELIMINARY INVESTIGATIONS RELATING CFRP/STEEL HYBRID SYSTEMS FOR RETROFITTING STEEL STRUCTURES

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Abstract: CFRP material has become very popular in the past two decades and a large number of authors have confirmed merits regarding this technology. In this study the CFRP/steel bond performance was evaluated under four different testing conditions which was related to structural testing. This included tensile, compressive, flexural and fatigue tests, performed to evaluate the CFRP bond performance which is directly related to the failure of the structural element. Significant tensile strength gains of CFRP strengthened steel was reported at a 90 % of humidity level. On average , 37% to 42% strength gain was noticed with the delays of the buckling failure mode under compressive load. The flexural load carrying capacity was enhanced from 40% to 52% by the CFRP. The fatigue performance was in the range of 26 % to 36 % yield strength gain compared to the non-strengthened specimen with the number of load cycles ranging from 0 to 10,000 in 2000 cycle steps. According to test results of the preliminary investigation , CFRP seems to be feasible for strengthening purposes of elements of steel structures even in tropical environmental conditions.

Keywords: CFRP; Axial tensile; Compressive; Flexural; Fatigue

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DAMAGE PREDICTION BY USING NONLINEARITY OF DAMPING

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Abstract: Lack of rapid, simple, and reliable techniques in damage detection of large civil engineering structures has hindered the frequent application of available vibration based structural health monitoring and damage detection methods. Prerequisite of baseline data of undamaged structure, detailed finite element models or need of namouras expensive sensors has further distanced the technique from practice. Thus, in this study, application of simple, baseline free time domain damage detection technique using acceleration data is discussed. The investigation is made using analysis of nonlinearity in damping extracted from ambient vibration data for identification of existence of damage in a structure. It is known that the dominant mechanism of energy dissipation in the presence of structural defects such as cracks, defective connections etc. is due to dry Coulomb friction and this type of damping is considered as nonlinear. Contrary to this, in the undamaged state of structures, the dissipation of energy is mostly due to material damping which is considered macroscopically viscous and constant type of damping. Thus, analysis of nonlinearity in damping and identification of contribution of Coulomb friction in modal damping could itself reveal the existence of damage or defects in a structure. This study presents the application of the method to an experimental system at the laboratory to show the competency of the method. The experimental estimates obtained from the proposed method illustrate the effectiveness and efficiency of the method in portraying the existence of damage and approximate quantification.

Keywords: Nonlinear damping; Damage detection; Coulomb damping, Viscous damping, Ambient vibration

RESILIENCE OF CIVIL INFRASTRUCTURES

OPTICAL FIBER SENSING AND DEEP LEARNING-BASED DISASTER AND CLIMATE CHANGE RISK ASSESSMENTS OF CIVIL INFRASTRUCTURE: CURRENT STATUS AND FUTURE PERSPECTIVE

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Abstract: Civil infrastructures are affected by climate change including sea level rise, changes in snowfall, ice, and permafrost and effects on hydrological systems, including precipitation floods and droughts, tropical cyclones, storms, and sea-wave heights. Also, disasters such as earthquakes, landslides and tsunamis worldwide disrupt people's lives and cause significant property damage. This study investigates the recent advancements toward damage mitigation of civil infrastructures through early detection of natural disasters and climatic changes using the measurements of optical fibre sensing (OFS) followed by deep learning (DL) models. It was shown that pointed and distributed OFS was effective for measuring strain, temperature and pressure to trace the changes in seismological, hydrological and geological data at surface level, sub-surface level and submerged. OFS is a rapidly growing research area for improving inspection accuracy and performance due to its advantageous properties of being lightweight, reliable, small in size, immunity to external electromagnetic perturbations, low power, high sensitivity, multiplexing capability, and wide bandwidth. Distributed optical fibre sensing (DOFS) has gained immense interest in engineering as they offer unique advantages for spatially distributed measurements for hundreds of kilometres. DOFS could detect the damage's precise location, magnitude, and propagation over time. Climate changes and disasters triggered propagating damage to structures including buildings, bridges, highways and dams can be identified in terms of cracks, fatigue, creep and slip. Big data-driven methods for disaster management are developed with DL, most frequently through convolutional neural networks. DL-based disaster-predicting systems that can be identified with seismological data have been developed with precision and a recall of over 90%. This review reveals that disasters due to earth movements and pore water pressure can be precisely detected through OFS followed by DL models. There is ample room for further development of combinational studies between OFS and DL for disaster and climate change risk assessment.

Keywords: Disaster prediction; Fibre optic sensing; Deep learning; Structural health monitoring; Climate resilient infrastructure

NUMERICAL INVESTIGATION ON THE IMPACT OF CORROSION ON THE ULTIMATE COMPRESSIVE STRENGTH OF A STEEL ANGLE MEMBER USING THICKNESS REDUCTION METHOD

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Abstract: Steel structures are a vital component in the construction industry, but over time, their capacities are declined due to various causes such as corrosion, which causes adverse effects on the mechanical and geometrical properties of the members, when they are subjected to severe exposure conditions. Due to this reason, incidents of steel structure failures have been witnessed around the world, which have drawn the engineers' attention on preventing such failures by proper structural health monitoring and damage assessment practices. There have been several attempts by various researchers on this subject to identify the behaviour of corroded steel members under different loading conditions. This study mainly concentrates on the steel angle members, which are mostly used as axially loaded members in various applications. Since it has been identified that most of the code-based standards do not directly address the corrosion effect on the capacity of steel members, a numerical approach has been investigated to obtain reliable and exact compression capacities of steel angle members. Since enough information on experimental and numerical studies are available on this subject, they have been used to create and validate a Finite Element model to assess the residual compression capacity of the corroded steel angle members. Then, using the validated finite element model, ten different hypothetical corrosion patterns with 39 corroded members have been modelled and numerically analysed to obtain the compression capacities. In conclusion, the results obtained in the numerical approach have been evaluated to assess the amount of damage caused by different corrosion patterns, and to identify the most critical scenarios.

Keywords: Steel angle members; Corrosion; Structural health monitoring; Residual compression capacity; Finite element analysis

CODE-BASED INVESTIGATION ON THE APPLICABILITY OF SECTION REDUCTION TO ACCUMULATE DEGRADATION CAUSED BY CORROSION

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Abstract: Steel structures have been playing a major role in the construction industry for a long period of time. When these structures are exposed to severe environmental conditions over time, corrosion takes place on the steel surfaces causing adverse effects on their properties and characteristics. Assessing the damage caused by corrosion, is vital to decide on the repairing and replacement strategies of a deteriorated steel structure. Several researchers have conducted various analyses to understand the behaviour of corroded steel under different scenarios. This study specifically concentrates on the steel angle members, which are mostly used as axially loaded members in different applications. As a code-based measure, the approaches of BS 5950-1:2000, EN 1993-1-1, ASCE 10-15 and ANSI/AISC 360-16 standards have been evaluated to identify the effect of different mechanical and geometrical parameters on the residual compression capacity. Furthermore, it is investigated whether they are applicable to obtain the exact residual compression capacities of the corroded members by comparing the code-based calculated capacities with the related experimental data taken from previous studies. Since the corrosion of steel is not directly addressed by any of these standards, the concept of section reduction due to corrosion, is adopted to represent corrosion equivalent properties in this code-based analysis.

Keywords: Steel angle members; Corrosion; Structural health monitoring; Residual compression capacity; Code based analysis

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CONSERVATION AND MANAGEMENT OF ANCIENT STUPA USING DIGITAL TWINS: A CASE STUDY OF UAV BASED 3D PHOTOGRAMMETRIC DIGITIZATION OF RANKOTH WEHERA STUPA

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Abstract: Stupa structures in Sri Lanka are regarded as world heritage sites with rich archaeological and artistic value, some nearing a lifetime of almost 2 millennia. Conservation and management efforts are currently hindered due to the lack of practice of modern Building Information Modelling (BIM) techniques. Recently, Digital Twins (DT) as a tool for Historic Building Information Modelling (HBIM) has gained traction worldwide. This paper summarises the initial work that has been carried out to apply modern HBIM techniques for Sri Lankan heritage sites, to manage and preserve these structures for the future. To this end this article details a case study of Rankoth Wehera in Sri Lanka and the 3-D photogrammetric model creation for the application of DT principles. A drone survey of the structure was done with the assistance of the Central Cultural Fund of Sri Lanka to obtain high resolution images of the location. Following a feature detection and homography calculation step using Scale Invariant Feature Transform (SIFT), the high-fidelity features were fed to an opensource 3D point cloud generation software, Meshroom. A 3D textured mesh was generated to observe the existing structural defects in the stupa dome and the superstructure. Obtained images can be used in conjunction with processing techniques using Image processing and Deep learning fundamentals to automatically detect the defects and pinpoint the location of the defect on the Digital Twin model. Moreover, the generated high-resolution mesh is able to be fed for Finite Element Modelling (FEM) software to carry out nonlinear analysis when required. With this premiering work, the authors intend to inspire and urge researchers and authorities to integrate intelligent HBIM techniques for the conservation and management of Sri Lankan heritage sites.

Keywords: Digital Twin, Photogrammetry, Drones, Image processing, HBIM, Deep Learning

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FRAGILITY PREDICTION FOR EARTHQUAKE-INDUCED EMBANKMENT FAILURES THROUGH EMPIRICAL METHODS

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Abstract: In this paper, a time-conserving fragility curve formulation methodology for extreme events is discussed. Uncertainty is a parameter that has a significant effect on the probabilistic estimations of infrastructure failures. Structural damages to civil infrastructure range from minor defects to collapse relative to serviceability or restoration measures. In this paper, earthquake-induced landslides are used as a sample case study, to study empirical methods of fragility curve formulation. Method of maximum likelihood and best-fit regression methods are applied to an extreme event, and fragility curves are derived. Monte Carlo stimulation is applied to analyse the behaviour of uncertainty parameter concerning standard sections of highway and railway embankments. Finally, the coefficient of determination was calculated to illustrate the correlation between developed curves and data points. The proposed method suggests an optimum method to quantify the failure probability from an available data sample or a real incident-based data sample, which is computationally very effective. Improvement in vulnerability estimations provides high maintenance and efficient restoration schemes for transportation networks which are prone to extreme event such as landslide.

Keywords: Fragility curves; Earthquake induced landslides; Maximum likelihood; Monte Carlo

GREEN INNOVATIONS AND GREEN BUILDING TECHNIQUES

RISK MITIGATION MEASURES IN GREEN BUILDING PROJECTS: AN INVESTIGATION

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Abstract: Building construction projects encounter various uncertainties in achieving their objectives because of a wide range of causes, such as finance, technology, weather. And the effects of these uncertainties on the project objectives are different during each stage of its life cycle (design, construction, and operation). However, due to the high level of sustainability objectives, green building projects can face even more inaccurate cost estimation, uncertain workforce availability, and green material availability risks. Green building projects are reported to confront more risks than conventional buildings because of the need to achieve sustainability goals. This article aims to explore risk mitigation measures in green building projects. To accomplish this, we review the fundamental risk treatment strategies (avoidance, transference, mitigation, escalation, and acceptance) documented in 'The Project Management Body of Knowledge (PMBOK® Guide)'. We also review and analyse green building project case studies reported in the literature and the standard risk mitigation methods for green building projects.

Keywords: Green building; project management; risk treatment; review; case study

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ROOFTOP SOLAR PHOTOVOLTAIC (PV) SYSTEMS IN AN OFFICE BUILDING; A CASE STUDY IN VAVUNIYA, SRI LANKA

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Abstract: Electricity is the most versatile form of energy derived from the commonly used primary energy source. Sri Lanka forecasts a 6.5% annual growth in electricity demand. The use of renewable energy sources for electricity generation has become a trend. Electricity generation through rooftop solar photovoltaic (PV) systems is emerging in Sri Lanka; however, the financial and environmental benefits have not been properly recorded in the past in the Sri Lankan context. This paper analyses the generation pattern, cost-effectiveness, and possible environmental consequences, arising out of electricity generation from the rooftop solar PV in an office building in Vavuniya, Sri Lanka. The solar PV consists of 108 panels placed facing the southeast direction. The electricity generated and exported to the grid and imported from the grid were analysed for 25 consecutive months from a 35 kW capacity solar PV system commissioned under a net metering mechanism at a capital cost of LKR. 4.8 million. The average annual electricity generation from solar PV is 47,750 kWh. The office functions on regular working days and has an average annual consumption of 46,000 kWh out of which 34,800 kWh was catered by solar PV. The monthly electricity expense was reduced by 74% after implementing this solar PV. The financial analysis shows the breakeven point of the investment on this solar PV as 5.25 years, the net present value of LKR. 4.56 million considering 10 years lifetime with a rate of return of 5.5%. The profitability index was observed to be 1.95. In addition, this solar PV plant offsets 8,408 kg of CO_2 annually and brings environmental benefits equivalent to planting 280 medium-growing trees annually. This type of rooftop solar PV shall be implemented in the office building which can throw back not only the financial benefit to the building owners but also environmental benefits to the earth.

Keywords: Cost-effective analysis; Net metering; Renewable energy; Rooftop solar PV; Self-sufficiency

INVESTIGATION OF THE IMPORTANCE OF PURCHASING GREEN PRODUCTS IN SRI LANKA

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Abstract: Products those are protecting the environment or improving the environmental performance during its manufacture, usage, or disposal, are referred to as "green products." This is done by saving resources and avoiding hazardous substances, pollution, and trash as much as possible. Green goods, therefore, can be advantageous for both the environment and human health. Customers who care about the environment have consequently expressed a larger interest in them. Industries committed to sustainability have been forced to alter their concentration to creating green products as a result of consumer preferences, environmental activism, and strict legislation. This paper explains all details of green products. Such as what is a green product, its advantage & disadvantages of it and the buying habits of our industry's consumers, and how they decide whether or not to buy environmentally friendly goods. Customers that care about the environment are more likely to purchase environmentally sustainable goods. It explains the variables influencing customers' green behaviors and decision-making. This paper's main goal was to examine green products for sustainable construction. A questionnaire was used for this paper. The sample was 200 respondents within the age range of 18-60 age limit. Details were collected from students, workers, and businessmen in the construction industry. Findings show that there was a strong positive impact of green products and it helps for sustainable development. Finally, this study will help decision-makers to select green products for their future projects. This paper concludes with suggestions that can help give to sustainable/green buildings.

Keywords: Green product; sustainable; environment; impacts of the green product; construction industry.

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ANALYSIS OF PASSIVE SOLAR DESIGN AND THERMAL MASS OPTIMIZATION TO REDUCE COOLING ENERGY DEMAND OF EXISTING BUILDING

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Abstract: Nearly half the global energy production is spent on building energy with major fraction of that contributing to HVAC. With the projected increase of temperature under different climate change scenarios, the energy demand for cooling will increase significantly. This increase of energy demand, if not well managed, can be a threat to the energy sector of a developing country like Sri Lanka which predominantly relies on non-renewable sources for energy generation. The already hot and humid climate being subjected to global warming will become an important factor for higher cooling energy demand forecasts. Hence, prediction of energy demand and implementing cooling load increase mitigation tactics is an important step in building energy sustainability in Sri Lanka. Although steps have been taken to ensure energy efficiency in new buildings, the existing buildings pose a significant threat in terms of energy increase due to climate change. There are different types of models adapted to predict the cooling load of existing buildings. This paper presents a hybrid data driven model to calculate the air conditioning demand predictions for several buildings in Colombo, Sri Lanka and uses the model to evaluate building thermal mass optimization and use of passive solar designs to reduce heat infiltration into buildings as cooling energy demand increase mitigation strategies. The model is used to predict the cooling load increase of the eight selected zones of three different buildings for year 2090 under two climate change scenarios and to evaluate the energy saving possible with the two countermeasures proposed. It was concluded that most zones will have a substantial reduction in cooling load: 20% on average by thermal load optimization with or without night time ventilation while zones showed a significant cooling load reduction by up to 60% with optimized solar designs by 2090.

Keywords: Cooling energy demand prediction; Energy demand mitigation; HVAC; Global warming; Passive solar design

GREEN BUILDING INNOVATIONS

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GREEN BUILT ENVIRONMENT AS A DEVELOPMENT ASPECT AND VEGETATION BELTS ON URBAN ROAD CORRIDORS: A CASE STUDY FROM KANDY, SRI LANKA

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Abstract: The green built environment has become the main theme in physical development activities in any country as a solution to the obstacles associated with the urban environment. Previous research identified Kandy City, due to its existing physical characteristics and anthropogenic activities, as becoming an area with an urban heat island effect. To minimize these problems, green built environment techniques have been an integral part of every development activity in the Kandy City area since 2018. The establishment of vegetation belt plantations along urban road corridors will be identified as a key action in this regard, particularly in the Kandy Grid City area. However, there is a question as to whether the intended objectives were achieved. This research is mainly aimed at analysing the effectiveness of the vegetation belts on urban road corridors in Kandy Grid City. Field observations and Google Earth images were used to identify the current status of vegetation belts. Questionnaire surveys and interviews were the primary data sources to assess the effectiveness of the vegetation belts. Screen digitizing methods and descriptive statistics methods are used to recognize the spatial distribution of vegetation belts and their current status. A SWOT analysis was used to identify the strengths, weaknesses, opportunities, and threats associated with vegetation belts on urban road corridors. The data was analysed using ArcGIS 10.8, Google Earth Pro and MS Excel 2013. The study found 28 vegetation belts in the Kandy Grid City area, and the total length of those vegetation belts is 2926.26 meters. There are four growth stages of vegetation belts that are observed according to the tree height; the 1st stage (1m – 3m), Second stage (3m-5m), third stage (5m-7m), and fourth stage (over 7m). There are strengths include controlling the dust and smoke (72%); Weaknesses include Plant growth in disturbed due to the cutting of branches during "*Kandy Perahara Season*" (60%); opportunities include protection of the pedestrians and street vendors (64%); threats include shop damage and space blocking (72%) have identified. These studies help researchers, planners, and decision-makers understand the actual state of development actions and improve future projects.

Keywords: Green built environment; Development aspect; Vegetation belts; Urban heat island effect; Kandy Grid City

A REVIEW ON FORECASTING NET LOAD BY CONSIDERING GENERATION FROM INTERMITTENT RENEWABLES FOR EFFICIENT GRID MANAGEMENT

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Abstract: Accurate load forecasts are needed to utilise demand response strategies effectively. Hence, a large amount of literature on load forecasting has accumulated over the years. Nevertheless, load forecasting, while considering inherent variability in load along with variability due to highly volatile generation from intermittent renewables, has become a challenging, yet a crucial research area. Generally, net load can be defined as the difference between total load and intermittent renewable generation. Therefore, forecasting net load is an important approach for addressing both types of variabilities. Among intermittent renewables used, solar power has received prominence recently caused by many factors which include policies related to eco-friendly generation options, and it has the potential of becoming a significant contributor in the future. Thus, it is necessary to explore forecasting methodologies and factors associated with net load. Therefore, this paper reviews studies on net load forecasting and explores major work on forecasting solar power generation. Methodologies used in net load forecasting can be divided into sub-categories in different ways namely, direct or indirect forecasting; individual-level or aggregated forecasting; and point or probabilistic forecasting. Statistical models such as quantile regression and time series models, artificial intelligence methods such as gradient boosting regression tree, support vector machine and neural networks and hybrid methods have been used to forecast net load. Furthermore, it will be worthwhile to incorporate time related features, historical net load, electricity prices, weather parameters and other factors associated with load and intermittent renewable generation to forecast net load. Meteorological factors such as solar irradiance and cloud coverage, time and geographical location related features and characteristics of solar panels were identified as factors associated with solar power generation. Hence, considering probabilistic methods, different levels of aggregation and factors associated is highly recommended in net load forecasting, given the uncertain nature of intermittent renewable generation.

Keywords: Intermittent renewables; Load forecasting; Net electricity load; Solar power generation; Probabilistic forecasting; Accuracy

APPLICATION OF NITROGEN-ENRICHED RICE HUSK BIOCHAR TO INCREASE THE EFFICIENCY OF NITROGEN FERTILIZERS IN RICE (*ORYZA SATIVA*) CULTIVATION.

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Abstract: Sustainable agriculture is one of the most talked about topics in science today. Many studies have shown that biochar has a positive effect on modern agriculture. Rice husk is one of the main by-products of rice production in Sri Lanka as such farmers use half-burned paddy husk (HBPH)/Rice husk biochar (RHB), as a soil conditioner. Utilizing the large surface area of half-burned paddy husk, nitrogen enriched HBPH was produced and greenhouse pot experiments and field trials were conducted during the 2021 Yala season to investigate the effect of enriched biochar on growth, the number of tillers, the SPAD meter reading, and the total yield of rice (*Oryza sativa*). Urea and potassium nitrate were used as N fertilizers to produce N enriched biochar. A leaching experiment was conducted to find out the nitrogen leaching from biochar particles. There were 7 treatments for pot experiments and 3 experiments for field experiment combinations, all set up in a completely random design with 4 replicas. Nitrogen content in the biochar has increased from 0.8 % to 6% nitrogen after enrichment. Leaching experiments show that there was no nitrogen leaching in enriched HBRH. The number of tillers, SPAD meter readings, and total yield increased due to enriched biochar and the values were significantly higher than that of urea alone. Experimental results show that HBRH was a good carrier for nitrogen fertilizer. Nitrogen-enriched RHB increased the efficiency of nitrogen fertilizer and as such, it is a good fertilizer material for rice. Urea is a better enriching substance for HBRH than Potassium nitrate.

Keywords: Biochar, half-burned paddy husk, Nitrogen enrichment, Rice, fertilizer

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SINGLE ROTATING PACKED BED FOR CARBON CAPTURING OF PRODUCER GAS

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Abstract: Rotating Packed Bed (RPB) is a novel technology of mixing fluids under higher acceleration fields to enhance mass transfer between two fluids. The RPB features its advantages as compactness and relatively easy maintenance compared to packed bed columns. The RPB absorber facilitate the absorption of Carbon Dioxide (CO_2) into Mono Ethyl Ammine (MEA) solution that is utilized to remove CO_2 from Producer gas mixtures. Producer gas generated by gasification of biomass, which is a Carbon Neutral Energy source, can be used to run Internal Combustion engines. RPB provides relatively higher centrifugal acceleration fields on the particles at its boundary which enhance mass transfer rates compared to conventional mass transfer process in wet packed bed columns. This paper discusses sizing and simulation of the RPB absorber designed for a 50 kW gasifier. The CO_2 absorption efficiency of the RPB and final CO_2 concentrations of the producer gas leaving the RPB were determined using computer simulations. Since biomass is certain energy source in tropical countries like Sri Lanka, a supply properly cleansed, and filtered producer gas would enable the generation of low-cost and environmentally friendly clean energy for a sustainable society.

Keywords: Carbon capturing; Rotating packed bed; Absorption; Biomass Gasification; Producer gas cleaning

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IMPLICATIONS OF DESIGN AND BUILD PROCUREMENT ON SUSTAINABLE CONSTRUCTION PRACTICES- ECONOMIC PERSPECTIVE

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Abstract: Despite Sustainable Construction Practices (SCP) being a prior concern of the construction industry, economic sustainability is less attained in construction projects. This is extensively observed in design and build (D&B) construction projects, which has been identified as the most favourable solution for implementing SCP. Accordingly, this study investigates the influence of D&B concepts on the implementation of economically SCP (ESCP) in Sri Lanka. An extensive literature review was conducted to review key ESCP and D&B concepts. Substantially, a survey strategy under a mixed research approach was accompanied to attain the research aim with three Staged data collection. The first stage includes conducting four preliminary interviews with professionals selected on convenience sampling. Next, fifty respondents from the construction industry with knowledge and experience in SCP and D&B concepts were selected purposively for the questionnaire survey. Concurrently, nine interviews were conducted with purposively selected experts on sustainability and D&B concepts during the third stage. Thematic analysis and Relative Importance Index value calculations were respectively used to analyse the qualitative and quantitative data obtained. Findings reveal that reduction of taxes and levies, active engagement of material manufacturers, and accomplishing competitive advantage are difficult to address through D&B concepts as an ESCP. Time, technology, knowledge and cost concepts of D&B are positively influenced in assuring ESCP. However, knowledge is negatively influenced in Sri Lanka consequent to knowledge deficiencies of construction teams. Communication, quality and flexibility of D&B, are negatively influenced the assurance of ESCP in construction projects. Conversely, some positive insights have been captured which are needed to be induced in Sri Lanka. Overall, these identifications will ensure the strength of the client's decision to attain D&B procurement for sustainability concerned projects. Further, the contribution of D&B contractors to ESCP can be enhanced.

Keywords: Design and Build (D&B); Sustainable Construction Practices (SCP); Economic; Influence

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OVERVIEW OF PERMEABLE PAVING SYSTEMS AND SELECTION OF THE IDEAL PAVING SYSTEM FOR HOME GARDENS

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Abstract: With the rapid technological development, many people moved towards living an online life with much of their work related to the internet. This eventually resulted in more work reducing humans' free time. This behaviour leads people to move toward items that require less maintenance, which is less work. Therefore, the traditional lawns with grass covers are now being faded away. It was replaced with hard-paved surfaces. However, these paving systems resulted in the trapping of stormwater, increasing the risk of flooding. Therefore, it led to the development of permeable paving systems. This paper focuses on an overview of four leading permeable paving systems, including Porous Asphalt Pavements (PAP), Permeable Concrete Pavements (PCP), Permeable Interlocking Concrete Pavements (PICP), and Plastic Grid Pavements (PGP). The advantages and disadvantages of each paving system are discussed along with a comparison of characteristics between the paving systems. Finally, concluding as permeable interlocking concrete paving as the most suitable pavement system to be used in home gardens.

Keywords: Permeable pavements; Interlocking blocks; Porous pavements; Plastic grid pavers; Permeable concrete

SYNTHESIS AND CHARACTERIZATION OF ZEOLITE PREPARED FROM COAL FLY ASH FOR ADSORPTION APPLICATIONS

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Abstract: Coal Fly ash (CFA) is an industrial waste product and the estimated global production exceeds 750 million tons per annum. In Sri Lanka, 150 tons of CFA is generated per year during the coal combustion process. While about 20% of CFA is used productively and the remainder is openly dumped. Fly Ash Zeolite (FAZ) was synthesized in this study using CFA through a 24 h hydrothermal reaction with NaOH. pH of zero-point charge (pHzpc), particle diameter, specific surface area and pore size, cation exchange capacity (CEC), change in surface morphology, crystalline structure and surface functional groups of CFA and FAZ were characterized. Characterization results confirm the formation of NaP1 zeolitic material. Further, FAZ has a higher cation exchange capacity, porous microstructure and specific surface area, revealing the applicability of FAZ as a potential adsorbent.

Keywords: Adsorption, Coal Fly Ash; Fly ash Zeolite; Characterisation

WATER RESOURCES PLANNING AND POLLUTION CONTROL

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SIGNIFICANCE OF ORGANIC & INORGANIC POLLUTANT ACCUMULATED ON URBAN PAVED SURFACES

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Abstract: Pollutants accumulated on urban paved surfaces are the primary sources of urban pollutants in stormwater runoff. Heavy metals, organic carbon, suspended solids, nutrients, and hydrocarbons have become the major pollutants on urban surfaces. Past researchers have found that among the pollutant types accumulating in the bodies of water, organic and inorganic pollutants are the major pollutants that exist in the environment for a longer period of time and negatively affect due to the bioaccumulation. Total suspended solids (TSS) increase the turbidity and provide a surface to adsorb the organic and inorganic pollutants. So, research mainly reviewed the characteristics and distribution of heavy metals, polycyclic aromatic hydrocarbons (PAHs), and TSS with traffic intensity, land use patterns, and particle size fraction. Further published data collected from the Lau & Stenstrom, (2005) study, which was carried out in the USA were analysed. According to the findings, both heavy metals and PAH concentrations are abundant in commercial and industrial areas, with Zn being the dominant heavy metal and Benzo(a) pyrene being significant on roads. With the traffic intensity, the pollutant load was increased simultaneously, and a higher load can be identified in the fine particle size fraction. The PCA analysis was carried out to find correlations among the heavy metals, PAHs, particle size fraction, and land use patterns. This study showed that the solids particles are significant as a carrier for organic and inorganic pollutants persistence on urban paved surfaces.

Keywords: Urban water quality; Pollutant build-up; Traffic related activities; Heavy metals; PAHs; Particle size

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SUITABILITY OF STANDARD PRECIPITATION INDEX (SPI) AND DROUGHT RESPONSE LAG: A STUDY ON SRI LANKA'S DRY ZONE

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Abstract: It is widely known that droughts in 2016-17 and mid-2020 made it harder to deal with the current economic crisis in Sri Lanka that was looming at those times. In this study, a gridded rainfall dataset was used which was made available by Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) to identify the droughts that occurred in the past 40 years (1981-2021) in Anuradhapura (in dry zone) and Colombo district (in wet zone), Sri Lanka. Standardized Precipitation Index (SPI) was calculated, and the droughts and their characteristics were identified and listed. Then we did a meta data collection to find when the "official" droughts that were announced using the data obtained from Disaster Information Management System of Sri Lanka (DESINVENTAR). We assumed that the official drought identification as a stage where remediation actions were initiated. The calculated time of drought onset and the time when droughts were identified are compared to understand the response lag. Drought conditions and response of Colombo district was studied as a reference for Anuradhapura as Colombo is in the wet zone of Sri Lanka. Both areas have experienced a significant dry period during 1981-1990. We identified that SPI-6 months scale captured most of the droughts occurred in the Anuradhapura and Colombo.

Keywords: Standard Precipitation Index; Drought; Drought Response; Response Lag

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IMPORTANCE OF LEAVING INTERMITTENT RIVERS AND EPHEMERAL STREAMS (IRES) UNTOUCHED IN A SUSTAINABLE BUILT ENVIRONMENT

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Abstract: Intermittent rivers and ephemeral streams (IRES) are temporary waterways that flow only at certain periods of the year, and consist of more than half of the world's total stream/river length. They have essential hydro-ecological functions and provide many ecosystem services but are widely ignored and considered as mere surface flow or trenches, and Sri Lanka is no exception. That is why we do not see such streams even in semi-urban townships, an indication those have been either reclaimed or replaced with man-made (e.g., concrete-lined) drainages. In this study, we discuss the importance and sustainable management of IRES in the dry climatic zone of Sri Lanka which has townships, extensive agriculture, and tourism infrastructure, where the built environment shows signs of expansion. A unique characteristic observed in IRES of the study area was their signature high infiltration at the stream bed (about 40 times that of the catchment), and somewhat high infiltrations in the low-flow areas. High infiltration of the beds contributes to groundwater recharge, where all rainfall received during the dry season (including that flow from the catchment) is infiltrated (therefore, no flow in the stream), and to flood control in the wet season, where a large portion of the runoff is infiltrated as well. However high percolation rates (more than 10 times than that of the catchment) indicated that water draining into the soil does not undergo any type of natural filtration processes, therefore groundwater contamination is potentially high. These findings indicate the importance of consideration of IRES in city planning during urbanization, in the context of groundwater recharge, flood control, and siltation of reservoirs. In this regard we emphasize that even the treated wastewater should not be released into such dry stream beds to avoid groundwater contamination; no lining be done to be safe from floods and to avoid silting reservoirs. Alteration of the natural status quo of IRES in any manner would have adverse effects on the natural and built environment, and it is imperative that awareness and understanding of these streams are improved.

Keywords: Intermittent rivers and ephemeral streams; infiltration; percolation; groundwater recharge; flood control

ICSBE 2022-09

MODELLING HYDRODYNAMIC CHARACTERISTICS OF PUTTALAM LAGOON, SRI LANKA USING DELFT 3D

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Abstract: Puttalam lagoon, located in the Northwest coast of Sri Lanka attracts many stakeholders due to the immense resources it has and many people living around the lagoon depend on the lagoon resources for their sustenance. However, recent studies show that the water quality of Puttalam lagoon has been degrading due to various anthropogenic activities happening around the lagoon and as a result, productivity of the lagoon has been decreasing. The water quality of a lagoon is altered by the hydrodynamic properties such as water flow, circulation, transportation, mixing and exchange. Therefore, it is clear that understanding the hydrodynamic characteristics of a lagoon is an important and integral part for improving its water quality and sustainable management of lagoon resources. In this study, hydrodynamic model of Puttalam lagoon was set-up using Delft 3D software package. The model was calibrated and validated using water level and velocity measurements collected from a previous study. The validated model was used to assess the effects caused by the Tides on the hydrodynamic characteristics of Puttalam lagoon. In addition, the model was also used to calculate residence time at various locations of Puttalam lagoon. The results of model simulations show that the range of water level fluctuations gradually decrease by about 35% when propagating the tidal fluctuations at locations from Kalpitiya to Etalai, Whereas, the range of water level fluctuations gradually decrease by about 65% at locations from Kalpitiya to Puttalam basin which is the lagoon head. In addition, model results also show that the residence time varies between 40 days (at downstream of Kalpitiya) to 100 days (at Puttalam basin) in the lagoon.

Keywords: Lagoon; Hydrodynamic; Hydrodynamic Modelling; Delft 3D; Tides; Residence Time

TECHNOLOGICAL ADVANCEMENT FOR SAFE WATER SUPPLY

ICSBE 2022-06

ADVANCES IN COAGULATION TECHNIQUE FOR COD REMOVAL OF PETROLEUM WASTEWATER –A REVIEW

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Abstract: The COD concentration in petroleum wastewater (PWW) varies widely depending on the type of crude oil and the method used for refining. Coagulation provides a feasible method for removing turbidity, colour, TSS, and TP from wastewater. However, this technique has its own limitations when dealing with highly COD-concentrated PWW above 6000mg/l. In this paper, the traditional coagulation technique and its limitations are discussed. This review provides insights into the latest developments of coagulation for COD treatment from highly concentrated PWW. The initial pollutant load of PWW was discovered to be one of the most main considerations of coagulation treatment efficiency. It was revealed that a modified coagulant known as PFASi is the best approach to treat highly COD concentrated wastewater (up to 20000mg/l).

Keywords: Coagulation; Flocculation; Petroleum wastewater; COD; Advanced technologies

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DEVELOPING A RESERVOIR OPERATION STRATEGY INTEGRATING HEC-HMS & HEC-RESSIM FOR TABBOWA RESERVOIR OF THE MI OYA RIVER BASIN SRI LANKA

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Abstract: Heavy floods in downstream of the Mi Oya basin, Sri Lanka due to sudden water releases from the Tabbowa reservoir have become a critical issue. In the current study, an operational rule for the Tabbowa reservoir is proposed to find a solution for the downstream flooding which connects with the flood mitigation of that area. In order to attain an operational rule, the inflow to the reservoir was investigated using the HEC-HMS while the reservoir simulation was conducted using the HEC-ResSim. The results of investigated models were compared with reservoir inflow with outflow data to calibration and validation referring a rainfall event from 22nd October 2018 to 11th November 2018 and an event from 28th November 2019 to 28th December 2019, respectively. The developed hydrological model results provide the high accuracy according to their skill matrices with a Normalized objective function (NOF), Nash–Sutcliffe efficiency (R^2_{NS}) and percentage bias (δb) of 0.6, 0.62, 12.6%, respectively during the calibration event and 0.5, 0.79, 18.6%, respectively during the validation event. The reservoir simulation model showed high accuracy with a Nash and Sutcliffe coefficient (NSE) of 0.95 and the Runoff Ratio (RR) of 0.97 for calibration and 0.95, and 0.99 for the validation, respectively. Finally, a real-time flood formulation was conducted considering a 2016 flood event and a recent rain event in 2021 by simulating the required number of opening gates and their heights using available weather forecast within the basin. These simulation results provide a profound understanding of the operating rules and outflow estimation to minimize downstream flooding.

Keywords: Reservoir operational rule, Hydrological simulation, Reservoir simulation, Flood forecasting

GREYWATER TREATMENT BY VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLANDS PLANTED WITH *Cyperus involucratus*

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Abstract: In recent decades, constructed wetlands (CWs) have been identified as a cost-effective technique which mimics natural processes in treating wastewater. Reduction of land area requirement while achieving high treatment capabilities is one of the major concerns currently. Therefore, this study evaluated the impact of greenhouse technology on greywater treatment. The experimental setup consists of Eight vertical subsurface flow (VSSF) constructed wetland (CW) units planted with emergent macrophyte; *Cyperus involucratus* (Umbrella palm). Each wetland unit sized 45 cm x 65 cm (diameter x height), prepared using 8-10 mm gravel as the bed media and planted with four shoots of Umbrella palm, approximately 30 cm high. Then, four wetland units were kept inside a greenhouse, while the remaining four were kept outside the greenhouse. Each wetland unit had fed with synthetic greywater at a 30 cm/day hydraulic loading rate (HLR). Water quality parameters such as pH, electrical conductivity (EC), five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen (TN), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total organic carbon (TOC) and Copper (Cu) were measured in water samples that were collected from the influent and effluents of each wetland unit. Further, TN and Cu uptake by umbrella palm with respect to plant growth were monitored throughout the study period. Results showed that VSSF CWs planted with locally available emergent macrophyte; *Cyperus involucratus* (Umbrella palm) found to be efficient in removing BOD_5, TSS, Cu and NO_3-N from greywater, while NH_4-N, TN and TOC, had a considerable removal in both inside the greenhouse (82%, 87%, 97%, 76%, 32%, 51% and 45% respectively) and outside greenhouse (82%, 85%, 97%, 60%, 48%, 53% and 60% respectively) wetland systems. No significant difference between the two wetland systems was obtained except for NO_3-N removal, which showed a higher removal inside the greenhouse wetland system. Similarly, no significant difference in Cu and TN uptake by Umbrella palms was observed in VSSF CWs kept inside and outside the greenhouse throughout the study period.

Keywords: greenhouse conditions; *Cyperus involucratus*; synthetic greywater; vertical subsurface flow constructed wetlands

LIFE CYCLE COMPARISON OF PATHWAYS FOR NITROGEN RECOVERY FROM WASTEWATER

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Abstract: The Haber Bosch process that served as the conventional nitrogen (N) fertilizer production process has now been identified as an energy-intensive method with high environmental impacts. A circular economy solution to this dilemma could be the recovery of N from waste sources. Since most of these recovery methods are yet on a lab scale, there is a research gap about their environmental impacts. As such, this study evaluated the life cycle impact of air stripping and gas-permeable membrane (GPM) separation methods when used to recover ammonium sulfate as the fertilizer from the waste source, centrate of digested swine manure. Two lab-scale studies done in European countries and other life cycle assessments done for products and processes were referred to collect the necessary data for this analysis. A cradle-to-gate approach was considered for the functional unit of 1 kg of N recovered as the fertilizer. Global warming potential, eutrophication potential, and acidification potential were manually calculated for three life cycle phases: raw material extraction, transportation, and production while considering infrastructure, energy, chemical, and transportation requirement in each phase. The results showed that the GPM method contributed to the highest global warming potential of 1.17×10^6 g CO_2 eq while the air stripping method contributed to the highest eutrophication potential and acidification potential (5.15×10^2 g PO^{4-} eq and 3.38×10^3 g SO_2 eq respectively). The analysis revealed that these impacts were mainly due to infrastructure materials used in both methods. The air stripping method resulted in more environmental impacts than GPM separation due to higher energy and chemical demand at the operational stage. In conclusion, both methods have their pros and cons, and it is suggested that this study should be further investigated to evaluate the environmental impacts of other recovery methods as well.

Keywords: life cycle assessment; nitrogen recovery; air stripping; gas-permeable membrane separation; waste valorization

ICSBE 2022-58

REUSE POTENTIAL OF DRINKING WATER TREATMENT PLANT SLUDGE FOR THE MANUFACTURE OF CONCRETE PAVING BLOCKS

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Abstract: This research intends to identify the reuse potential of drinking water treatment plant (DWTP) sludge in concrete paving blocks (CPB). In the current market, the traditional fine aggregate (sand) is completely replaced by quarry dust (QD) due to the increased price and sand mining issues. This study will discuss the suitability of DWTP sludge as an alternative to fine aggregate for the manufacturing of CPB considering the seasonal variation of DWTP sludge. CPBs were cast with the dried WTPS from the Ulapone water treatment plant. The fine aggregate was replaced with WTPS in 30%, 40%, and 50% by mass (w/w). In addition, Sika Plast®-208 PC (Sika), a high-range water reducing admixture for early strength concrete was added to every 100 g of cement in the range of 1.0- 2.0 ml as per the manufacturer's recommendation. The control sample was cast with the mass mix ratio of 1:2:4 (cement: QD: coarse aggregate). The water/cement (w/c) ratio was varied within the range of 0.5–1.0 in every mix. Compressive strength tests were conducted on the cast samples after 7 days of curing. The 30%, 40% and 50% DWTP sludge replaced mix attained 14.08 MPa at 0.6w/c, 14.26 MPa at 0.8w/c and 11 MPa at 0.75w/c, respectively, where the required compressive strength for Class-4 CPB is 15 MPa as per the SLS 1425 Part 2:2011. In future, the possibility of replacing 50% DWTP sludge to quarry dust can be investigated along with compressive strength tests and durability check.

Keywords: Compressive strength; Concrete paving block; Reuse of sludge; Water/cement ratio; Water reducing admixture; Water treatment plant sludge

ICSBE 2022-86

SIMULATION OF THE DYNAMIC BEHAVIOUR OF POLLUTANTS RELEASING FROM A LONG SEA OUTFALL

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Abstract: To identify the dynamic behaviour of pollutants released from the Wellawatte long sea outfall, the present study was carried out. Accordingly, dispersive and assimilative capacities of the pollutants, plume directions, plume areas and critical areas of selected pollutants were identified. Faecal Coliform, BOD5 and Total Suspended Solids (TSS) were selected as the main pollutants. Near-field and far-field simulations were carried out using CORMIX and MIKE 21 modelling systems for the defined scenarios. As the outcome of the near-field simulation, a low concentration of pollutants was identified at the discharge location during the southwest (SW) monsoon with high dilution. From the far-field simulation, the plume dispersion direction for SW monsoon was identified as directed to the north direction and it was to the south direction for northeast (NE) and inter-monsoon (IM) seasons. Based on the identified critical zones, it was observed that primary and secondary recreational activities are limited during SW monsoon season due to the presence of larger critical areas off the shoreline. However, recreational activities are desirable during the SW monsoon near the shoreline as isolines of critical zones are not close to the shoreline.

Keywords: MIKE 21; CORMIX; dispersion; plume; critical areas

COASTAL POLLUTION IN SRI LANKA: PERSPECTIVES ON THE CURRENT STATUS, POLICY IMPLEMENTATION AND INSTITUTIONAL MECHANISM

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Abstract: Coastal Pollution in Sri Lanka was assessed from the perspective of the current status of water quality, policy implementation and legal/institutional mechanisms. Identification of the status of coastal water pollution is one of the main objectives of this study. Further, evaluation of the effectiveness of past management policies, strategies and actions proposed through Coastal Zone Management Plans (CZMPs) and making effective policy recommendations related to coastal water pollution are other main focus areas of this study. The assessment was carried out by analyzing the secondary data obtained from different agencies and sources. Thus, the causes and sources of coastal pollution and the current status of coastal pollution in Sri Lanka were assessed. After reviewing the current legal and institutional mechanism, and mitigation measures of coastal pollution, proposals to make effective policies related to coastal water pollution were recommended. Moreover, on the basis of available water quality data, Coastal Zoning for designated uses was preliminary developed for Sri Lanka in this study.

Keywords: Water quality; solid waste; institutional strengthening; water zoning

ICSBE 2022-135

A RELIABLE AND SIMPLE APPROACH TO ENUMERATE *ESCHERICHIA COLI* IN RIVER WATER AND WASTEWATER BY MEASURING B-D-GLUCURONIDASE (GUS) ACTIVITY VIA A MICROPLATE READER

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Abstract: Contamination of surface water and wastewater through pathogenic microorganisms is a severe issue. Nevertheless, direct monitoring of pathogenic bodies is a comprehensive process with complex procedures requiring laborious work and costly tests. Hence, this research aims to provide a reliable, cost-effective, and efficient protocol for measuring *E. coli* in surface water and wastewater. For this purpose, determination of β-D-glucuronidase (GUS) activity of *E. coli* was employed where 98% of *E. coli* strains undertook this activity. The enumeration is based on detecting fluorogenic signals liberated from fluorogenic substrate methylumbelliferyl-β-D-glucuronide (MUG) through GUS activity using a microplate reader. Samples were taken from 3 urban rivers representing surface water sources and a primary sedimentation tank (wastewater) in Sapporo, Japan. *E. coli* of Yasuharu and Barato-Kohoku Rivers were enumerated by filtration with a 0.45-μm-pore mixed-cellulose-ester membrane filter and incubation of the filter paper on a six-well plate. The slope of the fluorogenic signal intensity curve of the samples was used for enumeration. The same sample was applied to the membrane filtration method using Chromocult® Coliform Agar in triplicate. The correlation between both methods (slope and cfu/L) was analyzed. Results showed that Sosei river and primary sedimentation tank effluents correlated with deterministic coefficients0.63 and 0.69, respectively. The combined river water and primary sedimentation tank effluent results illustrated a correlation of 0.85. Six well methods used for Yasuharu and Barato-kouhoku Rivers showed 0.77 and 0.73, respectively. Therefore, this simple method provided a total throughput in *E. coli* enumeration to provide relatively reliable, cost-effective, and efficient monitoring of fecal pollution in water and wastewater.

Keywords: *E. coli*; Enumeration; GUS activity; Fluorogenic; Microplate reader; Simple assay

CHEMICAL PROCESSES FOR A SUSTAINABLE FUTURE

ICSBE 2022-04

VALORIZATION OF TEXTILE WASTE – CHEMICAL APPROACH: A REVIEW

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Abstract: Textile industry is one of the fastest-growing industries as the demand for textiles increases with population growth and economic development. Hence, textile waste generation has been growing rapidly parallel to the textile production. Incineration and landfilling are the commonly used disposal methods for textile waste, which contribute to many environmental damages. In that context, valorization of textile waste is identified as one of the methods to minimize the sustainable issues related to textile waste and to re-introduce the waste into material cycle. There are three major textile valorization routes: mechanical, chemical and biological routes. In the current study, the focus was given to chemically valorization of textile waste by reviewing the researches performed in past two decades. The review was carried out according to different types of textile wastes, which are wool, cotton, nylon and blended textiles. The review identified that, from each textile types, different kind of value-added products can be produced under various chemical techniques. However, valorization options also have challenges in environmentally, economically and socially.

Keywords: Lagoon; Hydrodynamic; Hydrodynamic Modelling; Delft 3D; Tides; Residence Time

ICSBE 2022-24

EFFECTS OF REFINED COCONUT OIL AND VEGETABLE OIL ON THE MECHANICAL, THERMAL, MORPHOLOGICAL, AND BIODEGRADABLE PROPERTIES OF CASSAVA STARCH-BASED THERMOPLASTIC (TPS) FILMS

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Abstract: The effect of addition of different concentrations of refined coconut oil (CO) and vegetable oil (palm olein oil) (VO) on the mechanical and thermal properties, as well as water absorption, biodegradability and morphology of cassava starch-based TPS films were investigated. Cassava starch-based TPS films were prepared by solvent casting method using glycerol as the plasticizer incorporation with varying concentrations of CO and VO at 5,10,20, and 40 wt % based on cassava starch. The X-ray diffractometry (XRD), Fourier transform infrared (FTIR) spectroscopy, thermogravimetric analysis (TGA), and scanning electron microscopy (SEM) analysis were carried out to observe the interactions between the starch matrix and oil, thermal stability, decomposition temperature and morphology of films. An increase in tensile strength was observed with the increment of both CO and VO concentration while the maximum tensile strength was observed at the oil concentration of 10 wt % for both CO and VO. However, films containing VO has higher tensile strength (4.18 MPa) than the films containing CO (3.56 MPa). Tensile strain at break decreased when increasing the oil concentration till 10 wt % for both CO and VO. Water absorption of the films increased when increasing the oil concentration. However, the value was less than the reference sample till the oil concentration of 20 wt % for both CO and VO. Moreover, all the samples are biodegradable. Cassava starch, refined coconut oil, and vegetable oil are natural resources that can be used to produce alternative materials that cause minor environmental impact.

Keywords: cassava starch; coconut oil; vegetable oil; thermoplastic film

ICSBE 2022-49

BATCH ADSORPTION STUDY FOR THE REMOVAL OF TEXTILE DYES FROM AQUEOUS SOLUTIONS USING PANDANUS AMARYLLIFOLIUS (RAMPE) LEAVES

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Abstract: The adsorption of selected textile dyes, methylene blue (MB), crystal violet (CV), congo red (CR), reactive red 24: 1 (RR) and reactive black b (RBB) from aqueous solutions onto dried leaf powder of *Pandanus amaryllifolius* (Rampe) (PALP) was studied. Batch adsorption experiments were conducted at room temperature to investigate the adsorption capacity. The experimental results showed that the adsorbent could remove MB, CV, and CR up to 95%, 90%, and 81%, respectively. However, both reactive dyes did not show significant removal. Kinetic and equilibrium studies were performed for MB, CV, and CR dyes. Kinetic data revealed that dye uptake was fast, with 90% or more of the adsorption occurring within the first 15 to 20 min of contact time. The kinetic data fit to the pseudo-second order model with correlation coefficients greater than 0.99. The equilibrium data were satisfactorily fitted to the Langmuir, Freundlich, and Temkin isotherms. The intra-particle diffusion model confirmed that the adsorption of dyes onto the adsorbent is controlled not only by intraparticle diffusion but also film diffusion plays an important role. Fourier transform infrared (FTIR) spectroscopy and Scanning electron microscopy (SEM) analysis of the adsorbent before and after adsorption revealed that MB, CV, and CR were adsorbed to PALP with chemisorption by creating hydrogen bonds. A significant amount of mass transfer has occurred through papillose cells on the surface of the PALP.

Keywords: Batch adsorption; *Pandanus amaryllifolius* leaves; Textile dye

ICSBE 2022-72

TEA WASTE BIO-CHAR AS AN ABSORBENT FOR THE REMOVAL OF PB(II) IN THE INDUSTRIAL WASTEWATER

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Abstract: Wastewater that contains Pb(II) creates serious health and environmental issues and this study was conducted to characterize the adsorption of Pb(II) by tea waste bio-char (TWBC) prepared by slow pyrolysis. As an adsorbent, raw tea waste has an issue of decomposing in the liquid phase. Therefore, bio-char prepared from tea waste generated at a tea factory in Sri Lanka was used as the adsorbent for the laboratory experiments. Adsorption of Pb(II) at different pH, initial metal concentrations, and contact times between adsorbent and adsorbate were measured. The surface characteristics of TWBC before and after the adsorption were examined by the scanning electron microscope (SEM), Energy Dispersive X-ray Spectroscopy (EDX), and Fourier transform infrared spectroscopy (FT-IR), in order to explain the results. Results indicate that adsorption of Pb(II) ions by TWBC gets an optimum value at pH 6.5. The Langmuir and Freundlich isotherm models were used in this study to analyse the data obtained, and the data was fitted to both isotherm models. The correlation coefficient is highest for the pseudo-second-order model, which suggests that chemisorption is the rate-limiting mechanism for the adsorption of Pb(II) onto TWBC. The results of SEM, EDX and FT-IR confirm that TWBC can be considered as a better adsorbent and the adsorption capacity is 46.23 mg/g for Pb (II), which is comparable to some of the treated biomaterials. Therefore, biochar prepared using Sri Lankan tea waste can be considered as a low-cost adsorbent for the removal of Pb(II) ions from industrial wastewater.

Keywords: Tea waste biochar; Lead; Adsorption; Biomaterial; Pyrolysis

ICSBE 2022-84

INVESTIGATION OF INDUSTRIAL CERAMIC BISCUIT WASTE AS AN ALTERNATIVE TO QUARRY DUST AS A FILLER MATERIAL IN ASPHALT CONCRETE

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Abstract: With the rapid development of the country, there's a huge development in road consruction industry, mainly highways with asphalt concreted surfacing. For the construction of those roads huge amounts of filler materials are being used. Most commonly used filler materials are sand and quarry dust. These are costly and depleting and hence necessary to find alternative materials. The research investigates the usage of ceramic biscuit waste as filler material in asphalt concrete in road surfacing. The properties of ceramic biscuit waste was compared with the commonly used filler material (quarry dust) to assess the suitability of the substitute as a filler material for hotmix asphalt concrete. The Particle size distribution, Water absorption and Specific gravity tests were performed to evluate the suitability of the filler material. The Marshall Test was carried out to evaluate the performance criteria of different blends of hot mix asphalt with varying bitumen content and ceramic biscuit waste content and the performance criteria (stability, flow, voids in the mix, percentage voids filled with bitumen) was compared with local authority (Road Development Authority /ICTAD) specifications for filler material in Sri Lanka. Samples were made using consecutive mixes of 10%:90%, 40%:60%, 70%:30%, 100%:0% of ceramic biscuit waste : conventional filler by weight for bitumen contents of 5.5, 5.8, 6.2, 6.5. All the samples gave acceptable Marshall Stability values and flow values according to ICTAD specification. However, the optimum binder content was 5.9%. Therefore, ceramic biscuit waste can be used as a viable alternative material in hot mix asphalt paving mixes.

Keywords: ceramic biscuit waste; asphalt concrete; filler material; Marshall Test

ICSBE 2022-105

INVESTIGATION FOR ESTABLISHMENT OF SMALL-SCALE BIOETHANOL PLANTS IN SRI LANKA

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Abstract- Even though bioethanol is used as a transportation fuel in many countries, the transportation fuel requirement in Sri Lanka is completely fulfilled by imported fossil fuels. Hence, this research is about an investigation for establishment of small-scale bioethanol plants in several locations in Sri Lanka for introducing bio ethanol-gasoline blended fuel to reduce gasoline usage. This will also aid to reduce waste handling processes by using waste fruits for bioethanol production. Considering the limited agricultural lands to grow bioethanol feedstocks in Sri Lanka, this research intends to use available fruit wastes as feedstocks for bioethanol production. Initially, details regarding available fruit waste data from selected fruit distribution centers, worship places, and main fruit markets were collected. Considering the fruit waste availability data, arbitrary plant locations were selected, and suitable processes to produce bioethanol were proposed. The distance from each feedstock location to the proposed arbitrary plant locations have been estimated with the assistance of Google Map (route maps). The shortest path has been identified using mathematical optimization algorithms such as Spanning Trees and Shortest Path Algorithms, (Critical Path Analysis) and the plant load has also been evaluated. Accordingly, the best destination for locating the plant was found to be near Embilipitiya (Sabaragamuwa Province), owing to the availability of waste fruits and other requirements for a bioethanol plant. Furthermore, the layout of the best-proposed plant was prepared considering suitable processes and types of machinery. Finally, the piping and instrumentation diagram along with the plant layout was designed with the aid of SolidWorks software.

Keywords: Sri Lanka; Bioethanol; plant locations; fruit wastes; shortest path analysis

ICSBE 2022-112

PREFABRICATED CONSTRUCTION IN SRI LANKA: FROM A SUSTAINABILITY PERSPECTIVE

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Abstract: Prefabricated construction is increasingly applied in the global construction sector due to offering a range of advantages compared to traditional construction. Improved product quality, enhanced productivity, reduced overall construction times and environmental benefits such as reduced waste generation and energy savings are some advantages highlighted by recent research publications. However, the prefabricated construction adoption in Sri Lanka is comparatively less compared to developed and industrialised economies. More research is required in the Sri Lankan context to evaluate, compare, and promote these prefabrication practices. Hence, the current study aims to explore the sustainability of construction practices in Sri Lanka which accompany prefabrication. Relevant information is collected through site visits and through, questionnaires and digital communications. The potential sustainability aspects of the ongoing construction of a three-storey family house using prefabricated components and selected wall panel prefabrication processes in Sri Lanka are explored. Moreover, a life cycle assessment is conducted to assess the environmental sustainability of prefabricated wall panels in Sri Lanka. LCA outcomes show that wall panels produced using paddy-straw fibres have greater savings than cellular lightweight concrete wall panels manufactured using concrete foaming and precast concrete wall panels. However, decisions should be based on specific applications and conditions, such as non-load-bearing applications and temporary housing implementations. The current study aims to increase the awareness of prefabricated practices in Sri Lanka and to give some insights into the sustainability perspective of these prefabrication methods focusing on construction stakeholders.

Keywords: Life cycle assessment (LCA); Prefabricated construction; Sri Lanka; Prefabricated wall panels; Sustainability

DEVELOPMENT OF A HYDROPHOBIC RUBBER VULCANIZATE TO CREATE A SUSTAINABLE SELF-CLEANING SHOE FOXING

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Abstract: Hydrophobic surfaces make water droplets bead up and roll off their surface gifting special properties such as self-cleaning, anti-staining, and anti-microbial characteristics to the surface. The basic strategy to generate hydrophobicity in substrates is the combination of hierarchical roughness and low surface energy materials. This study discusses a revolutionary technique for enhancing hydrophobicity in natural rubber (NR) vulcanizates. This approach gives the NR vulcanizates an inherent hydrophobic character, unlike the temporary hydrophobic character given by coatings which decay over time. The method uses a chemically treated filler called Diatomaceous Earth (DE). DE itself has a nano-roughness, and it is chemically treated with hexadecyltrimethoxy silane to obtain low surface energy. The combination of the necessary hierarchical roughness and low surface energy gives this filler a hydrophobic character. At its highest, the treated DE filler displayed a superhydrophobic WCA of 152.1°. NR compounded with 20 phr filler was able to obtain an enhanced water contact angle of 135.5°, compared to the WCA of 91.8° of the virgin material. The developed material displayed improved tensile, and tear properties compared to the natural dry rubber vulcanizate. The rubber formulation was developed specifically to manufacture shoe foxing. The mechanical properties of the treated rubber sample were compatible with the values expected from a typical shoe foxing. Due to the incorporated hydrophobic property, the foxing contains a self-cleaning ability in addition. A reduction of scorch time was detected in DE filler-added samples. This was due to components in DE acting as activators in the vulcanization process. The method can be utilized as a low-energy, low-material process. Since the product provides the same mechanical properties of a typical shoe foxing with additional self-cleaning characteristics at a reduced cost, the method can be considered a sustainable method to create a self-cleaning shoe foxing.

Keywords: Hydrophobicity; Natural rubber; Shoe foxing; Mechanical properties; Self-cleaning; Sustainability

ICSBE 2022-161

THE GREEN RATING OF KNOWLEDGE CITY MALABE (KCM)

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Abstract: In this paper, the carbon footprint (CF) is calculated for a newly constructed educational building in Colombo, Sri Lanka. The entire project of KCM consists of several buildings, however, the main focus was given to the Building A of the project as it was the first to be constructed and where the green rating was carried out. The university building has maximized the natural daylight and ventilation for the building. KCM Building A's annual carbon emission per unit area is calculated to be 18.74 $KgCO2_e/m2/year$. With regards to this value, the construction stage showed a 75 % of the contribution to the Global Warming Potential (GWP). Purchasing of materials for the project from several locations in the construction phase was identified to be an important contributor for this value.

Keywords: carbon footprint; natural daylight; ventilation; carbon emission; global warming potential; contributor

LIFE CYCLE ASSESSMENT PERSPECTIVES IN BUILDINGS

ICSBE 2022-02

A STUDY OF CIRCULAR ECONOMY STRATEGIES FOR THE LIFE CYCLE OF BUILDING CONSTRUCTION PROJECTS: A SYSTEMATIC REVIEW

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Abstract: The Circular Economy (CE) is a philosophy that aims to alter current consumption and output trends that are putting a tremendous strain on the earth and its environmental. It has been extensively reviewed throughout the world as an alternative to the old economic model, namely, "purchase, consumption and dispose", as well as a solution to the complication of efficient use of resources and environmental pollutions. CE applies theories from environmental economics, ecological economics, and industrial ecology to the business-sustainability relationship. By adopting particular CE strategies, savings may occur by creating proper systems to retain value and keep the resources flowing in a circular manner. This approach would close materials and components, energy, and water loops and minimize the associated potential environmental impacts. This has driven recent researchers to investigate the CE strategies for construction industry. However, those studies are limited to given local contexts, thus, the knowledge is scattered. Therefore, this paper aims to analysing CE strategies for life cycle of building collectively using a systematic review towards understanding the significance. Filtering the search for the period of 2015 to 2022 offered 18 out of 113 research articles suitable for the analysis. The collected data extracted shows high variability related to different stages of building and suitable CE strategies for building life cycle. According to the review, the Preconstruction, Construction and building renovation, Use and operate, Demolitions and repurpose and Material recovery and production stages accounts for the highest portion of the life cycle of building that CE strategies could be highly incorporated. Further, it is expected that this collective reviews regarding building stages would better guide the categorisation of CE strategies in the built environment.

Keywords: Circular Economy; Strategies; Life Cycle of Building and Built environment

ICSBE 2022-11

THE LIFE CYCLE ENVIRONMENTAL IMPACT ASSESSMENT OF BUILDING CONSTRUCTION INDUSTRY IN SRI LANKA: A LIFE CYCLE ASSESSMENT-BASED CONCEPTUAL FRAMEWORK

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Abstract: The building and construction industry sector is one of the main contributors to adverse Environmental impacts (EIs). Extensive use of material and energy throughout the life cycle stages of the buildings is one of the main reasons for negative EIs. Therefore, the relationship between the building and construction sector industries and EIs should be thoroughly discussed in a close association in each stage of the building life cycle. Life Cycle Assessment (LCA) is globally recognized as a robust tool for measuring EIs, especially in the building and construction sector. Accordingly, Sri Lanka has already identified the importance of the life cycle approach in EI assessment as a national need to mitigate EIs associated with the building and construction sector. Even though the life cycle approach-based EIs assessment in the building construction sector has been broadly discussed in the international arena, it is much unknown in the Sri Lankan context due to the lack of country-specific data sets, cost, and complexity of conducting EIs assessments. This study presents a user-friendly, life cycle approach-based EIs assessment framework customized to the Sri Lankan context. The data were collected by literature review and through expert interviews. The collected data were used to develop the conceptual framework which is presented in this paper. The development of a conceptual framework is based on the ISO 14040:2006 and 14044: 2006 Standards. The proposed conceptual framework performs as an early design phase decision-making model which predicts and evaluates EIs throughout the life cycle of a building. The proposed framework supports environmentally friendly decision-making, promoting sustainable construction practices in the country with the EIs applications such as identifying hot spots, the geographical distribution of EIs, EI footprints, and alternative comparisons.

Keywords: Building and Construction Sector; Environmental Impacts (EIs); Life Cycle Assessment (LCA); Sri Lanka

A STUDY ON THE APPLICABILITY OF SUSTAINABLE FEATURES TO SRI LANKAN ROAD CONSTRUCTION

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Abstract: One of the most significant contributions to environmental damage is construction activities. The main environmental challenges of Sri Lanka are soil erosion, loss of wildlife habitat, coastal degradation, water pollution, waste disposal, urban air pollution, marine pollution, and hydrological and climate changes. According to the final result of the survey of construction industries in Sri Lanka 2017-2018 (2020), roads and railways have the largest contract value out of all contract types. Sri Lanka has a road network of roughly 100,000 km, according to the Sri Lanka Road Network Assessment. The road sector creates the highest level of greenhouse gas directly, by fossil energy used in mining, transportation, and paving works, and indirectly emissions coming from vehicles. This has driven recent researchers to investigate sustainable approaches to the road construction industry. However, those studies are limited to given local contexts, thus, the knowledge is scattered. Therefore, this paper aims to analyse the applicability of sustainable features to Sri Lankan Road construction toward understanding the significance. The research apprehends a qualitative approach inclusive of expert interviews and manual content analysis for data analysis. When compared to others, energy harvesters (sun energy, thermoelectric energy, geothermal energy, piezoelectric energy, and composite energy) and xanthan gum biopolymer as an alternative material had a lower application. Furthermore, as new sustainable features for Sri Lankan Road construction, solar power lights for roads, tire retaining walls, tree planting, reducing road noise with asphalt pavement design, construction waste management, advanced dust controlling methods, sustainable excavation methods, and alternative materials such as fly ash were identified.

Keywords: Road Construction; Sustainable Features; Pollution; Alternatives

ICSBE 2022-30

ASSESSMENT OF INDOOR AIR QUALITY AND SICK BUILDING SYNDROME IN APARTMENT BUILDINGS

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Abstract: Residential apartment buildings are widely adopted in Sri Lanka due to rapid urbanization and land scarcity. The confined spaces and controlled ventilation in such apartments could result in adverse health effects, including Sick Building Syndrome (SBS). Use of chemical products such as incense sticks in such compact spaces for religious activities in South Asia, SBS could be catalyzed. This study is one of the first field studies to establish an association between the indoor air quality of apartment buildings in Colombo, Sri Lanka, with various chemicals, including incense products and SBS. Measurements were taken from multiple locations in 50 apartments for various indoor environment parameters. Significant Total Volatile Organic Compound (TVOC) concentrations (up to 4.500ppm) were associated with the use of chemicals, particularly cube-type incense products. Higher CO_2 concentrations were associated with migraine and headaches. The association of chemical and incense products with higher levels of TVOC and SBS symptoms calls for urgent attention by the key urban planning stakeholders in Sri Lanka to improve ventilation and avoid using those products indoors.

Keywords: Sick Building Syndrome; Indoor air pollution; Incense products; Urban high risers; TVOC Concentration

LIFE CYCLE ASSESSMENT (LCA) OF A TEXTILE WASTE THERMOPLASTIC COMPOSITE MATERIAL FOR WALL PARTITIONING APPLICATIONS

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Abstract: As one of the most polluting industries in the world, the textile industry generates large volumes of waste at the end of its manufacturing process. This waste is frequently dumped in open areas or is openly burned, contributing to GHG emissions. In recent years, emphasis has been placed on developing new materials from textile waste to promote a circular textile economy. The construction industry is one application for these novel materials. The construction industry consumes a lot of resources and energy. As a result, recycled and upcycled building materials are gaining popularity in the construction industry. The research team developed a new composite material for non-structural applications using polyester textile waste and thermoplastic packaging waste. This study aimed to conduct a Life Cycle Assessment (LCA) to determine the sustainability of this new material as a substitute for partitioning wall materials available in the market. The goal of the LCA study was to compare the Global Warming Potential (including biogenic CO_2) of the production phase of the composite material against the gypsum partitioning board. The scope of the study focused on the Sri Lankan context. The functional unit for this study was considered as $1m^2$ of each type of material. The modeling was carried out using GaBi LCA modeling software (V8.7.1.3). The LCI inputs for the production phase of the composite were based on literature data, the GaBi database (V8.7.1.3), and the Ecoinvent 3.8 database. According to the analysis, the production of $1m^2$ of the new composite board as an alternative material saves GHG 8.4617 kg CO_2 eq compared to virgin gypsum boards. These findings suggest that using waste resources to create new construction materials aids the sustainability efforts of both industries. The findings are also useful in making decisions on using waste-based composites in specific applications.

Keywords: GHG; Global Warming Potential; LCA; wall partitioning material, textile waste; thermoplastic composite

ICSBE 2022-66

LEAN AND GREEN: HOW THE SYNERGY CAN PROMOTE SUSTAINABLE CONSTRUCTION

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Abstract: Lean construction aims to improve efficiency through reduction of wasteful activities. These waste reduction activities also indirectly improve the sustainability approach used by organisations. Our paper examines the definition of lean construction (LC), LC activities and green construction as understood by academics through a focused literature review. It then examines these practices in the light of how these activities contribute towards enhancing sustainability of the built environment and the organisation. Our findings suggest that not all waste reduction activities have the same degree of effect on sustainability improvements. Some lean tools such as standardisation and just-in-time (JIT) for production scheduling can have better effect, especially, if the key performance indicators (KPI) specifically targets sustainability indicators. "Lean and Green" is not a myth and is very much achievable in the construction industry with the current efforts towards industry 4.0/5.0. Combining these two concepts remains a challenge. This paper aims to learn from what we already know and suggests ways how "Lean and Green" can be achieved in the future. The paper includes a discussion on leveraging lean and green concepts to achieve the sustainable development goals promoted by the United Nations.

Keywords: lean construction; green construction; sustainability; lean and green

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LIFE CYCLE ASSESSMENT OF A TYPICAL MODERN RESIDENTIAL BUILDING IN NEPAL

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Abstract: The rapid urbanization process in Nepal is increasing the building construction activities and changing building construction materials from traditional practices. This has amplified the resource and energy demand leading to cumulative pressure on environment and increased emission. To comprehend the environmental impact of the building construction activities, understanding of each step of the building construction work along with its associated emission is required. This study assesses the carbon dioxide equivalent emissions in complete life stages of a three-storey modern residential house from the production of building construction materials to end-of-life of the building through Life Cycle Assessment (LCA). The approach applied in the study is attributional LCA tool based on ISO 14040. The study assessed each material consumed for the construction and determined primary energy (PE) of each of those material. Then carbon dioxide equivalent CO_2e) emission is calculated using ecoinvent Version 3.8 (2021) database with consideration of transportation need and energy mix of manufacturers and Nepal. The production stage of building materials and installations represent highest percentage of the total carbon dioxide equivalent emissions in whole life stage of the buildings. The energy use during the operation stage of the building is lower due to increasing use of electricity for cooking and there is very minimal use of energy for building heating and cooling. The increasing hydroelectricity production in Nepal is improving electricity mix as the electricity import from India which is based on fossil fuel is being replaced with low emission-based hydroelectricity. Similarly, the operational emission of the building is also declining as LPG used for cooking is slowly being replaced by electric cooker and induction cooking stoves. The primary energy indicator shows the largest share in the material production phase.

Keywords: Life Cycle Assessment; Embodied Energy; Greenhouse Gas; CO_2e emission; Residential building

A CRITICAL REVIEW ON DEFINITIONS OF CIRCULAR ECONOMY IN THE BUILT ENVIRONMENT

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Abstract: Currently, the circular economy (CE) concept is receiving encouraging attention among scholars and practitioners as a convenient solution to moving away from the linear economy concept without neglecting the goals of sustainable development. However, adaption of circular economy concept in the built environment is challenging due to its nature. In addition, the built environment plays a crucial part in this transition since it consumes a lot of resources, which results in massive waste, greenhouse gas emissions, environmental effects, and also exerts great pressure on natural resources. Although several studies reviewed the term circular economy, there is still a lack of conceptual clarity and missing an accepted definition of circular economy. Hence, this study aims to propose a definition of circular economy from the built environment perspective. A systematic literature review was carried out using Preferred Reporting Items for Systematic Reviews (PRISMA) as the analysis tool, a total of 24 papers were analysed. Rasmussen's Abstraction Hierarchy (AH) framework was used to analyse the summarised eleven definitions. The study has proposed a definition for circular economy in the built environment where CE is viewed in terms of the key questions of where, why, what, and how towards providing a clear and comprehensive understanding of the CE concept.

Keywords: Abstraction Hierarchy (AH); Built Environment; Circular Economy (CE); Definition; Literature Review; Preferred Reporting Items for Systematic Reviews (PRISMA)

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PREFABRICATED CONSTRUCTION IN SRI LANKA: FROM A SUSTAINABILITY PERSPECTIVE

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Abstract: Prefabricated construction is increasingly applied in the global construction sector due to offering a range of advantages compared to traditional construction. Improved product quality, enhanced productivity, reduced overall construction times and environmental benefits such as reduced waste generation and energy savings are some advantages highlighted by recent research publications. However, the prefabricated construction adoption in Sri Lanka is comparatively less compared to developed and industrialised economies. More research is required in the Sri Lankan context to evaluate, compare, and promote these prefabrication practices. Hence, the current study aims to explore the sustainability of construction practices in Sri Lanka which accompany prefabrication. Relevant information is collected through site visits and through, questionnaires and digital communications. The potential sustainability aspects of the ongoing construction of a three-storey family house using prefabricated components and selected wall panel prefabrication processes in Sri Lanka are explored. Moreover, a life cycle assessment is conducted to assess the environmental sustainability of prefabricated wall panels in Sri Lanka. LCA outcomes show that wall panels produced using paddy-straw fibres have greater savings than cellular lightweight concrete wall panels manufactured using concrete foaming and precast concrete wall panels. However, decisions should be based on specific applications and conditions, such as non-load-bearing applications and temporary housing implementations. The current study aims to increase the awareness of prefabricated practices in Sri Lanka and to give some insights into the sustainability perspective of these prefabrication methods focusing on construction stakeholders.

Keywords: Life cycle assessment (LCA); Prefabricated construction; Sri Lanka; Prefabricated wall panels; Sustainability

GEOTECHNICAL ENGINEERING

ICSBE 2022-57

DENSIFICATION OF SANDY SOIL USING GEOPOLYMER-MODIFIED MICROBIAL INDUCED CARBONATE PRECIPITATION

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Abstract: Bio-grout has been identified as a cost-effective and ecologically friendly way to treat problematic soils over conventional cement and chemical grouting. Among the bio grouting technologies, recently, microbial induced carbonate precipitation (MICP) has been recognized as an environmentally friendly and sustainable approach to densify the weak soils. MICP is a bio-geochemical process which is driven by the microbial urease. The urease has a capability to hydrolyze the urea and produce calcium carbonate ($CaCO_3$) artificially in the presence of calcium ions. This biogenic $CaCO_3$ has an ability to make stronger bonds between the soil particles and improve the properties of the weak soils. The efficiency of the MICP process can be further improved by adding additives, and the use of geopolymer would be a better approach. In this research, the effects of the rice husk ash (RHA) on the MICP treated soil were investigated. Laboratory scaled sand densification experiments were conducted without additives and with rice husk ash by hydrolysis of urea using ureolytic bacteria *Sporosarcina pasteurii*. Unconfined compressive strength (UCS) of the treated soil samples were evaluated after 14 days of curing period. In the presence of rice husk ash, well cemented sand specimen could be obtained than without additives. Higher UCS values were obtained for the sample treated with geopolymer-modified MICP than the control one. Optimum RHA content was found to be 5 % of the dry weight of the sand. RHA assisted to increase the efficiency of the MICP process by filling the pore spaces, facilitate better bridges between the soil particles and promote the better cementation. In conclusion, the $CaCO_3$ produced by geopolymer-modified MICP can be used as an effective bio-grouting material.

Keywords: Geopolymer; Rice husk ash; Microbial induced carbonate precipitation (MICP); Ureolytic bacteria; Calcium carbonate

ICSBE 2022-79

EVALUATION OF SUITABILITY OF SHREDDED RUBBER TYRE MIXED WITH AGGREGATE BASE COURSE MATERIAL FOR RAILWAY TRACK SUB-BALLAST

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Abstract: The ballasted track is the most common form of construction used in railway transportation due to several benefits in comparison with other solutions such as a slab track. The sub-ballast layer can improve railways to cope up with heavy traffic volume, heavier loads and higher speed rail and preservation of the cost of maintenance. Lack of bearing pressure will result in deformation, settlement and mud pumping of railway tracks. Therefore, this paper focuses on the waste shredded rubber crumbs which is a recyclable, elastic, durable material mixed with traditional aggregate base course material to assess the suitability of the substitute and reduce the consumption of natural aggregates. For this reason, the influence of different percentages of crumb rubber (2.5%, 5.0%, 7.5% and 10% by weight) of range 15mm to 20mm was studied by carrying out laboratory experiments. Initially, to select the aggregate base course of conventional aggregates, particle distribution test, California bearing ratio (CBR) test, standard proctor compaction test, aggregate crushing value, aggregate impact value, water absorption test and specific gravity test were carried out. Thereafter, the particle distribution, California bearing ratio (CBR), standard proctor compaction, water absorption and specific gravity tests were performed to examine the properties of aggregate base course material (control sample) and blended samples and to assess whether the properties were in conformity with the specifications used by the Sri Lanka Railway Department. The results reveal that the CBR, maximum dry density, water absorption and specific gravity values are acceptable only for 2.5% and 5% (by weight) of blended samples as per the specifications. Hence the performance of the bearing capacity is satisfied up to 5% of blended samples. However, the water absorption and the specific gravity of all the blended samples did comply with the specifications. Hence, the quality of the blended samples is acceptable for all the selected percentages. The 5% of blended sample layer can save approximately 5.3% by weight of natural aggregates. Therefore, the alternative reduces the consumption of natural aggregates and hence the reduction of cost as well. Therefore, shredded rubber tyre crumbs can be used as an alternative substitute material for sub ballets layer at an optimum rubber content of 5% (by weight).

Keywords: sub-ballast; rubber tyre crumbs; California bearing ratio; Sri Lanka railway department, aggregate base course

INFLUENCE OF RECYCLED USP ON SHEAR BEHAVIOUR OF RAILWAY BALLAST: EXPERIMENTAL AND NUMERICAL APPROACH

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Abstract: The shear resistance at the sleeper-ballast interface plays a major role in maintaining proper track stability of ballasted railway tracks. The Under Sleeper Pad (USP) application at the sleeper-ballast interface of ballasted railway tracks has become a regular practice among many railway authorities for reducing ballast degradation while enhancing track performance. However, the shear behaviour at the sleeper-ballast interface with and without the adoption of USP is not properly investigated. Therefore, the influence of recycled USP on shear behaviour at the sleeper-ballast interface was investigated in this study through large-scale direct shear tests and discrete element method (DEM) simulations. The large-scale direct shear tests were performed on Ballast-Ballast, Ballast-Concrete, and Ballast-USP interfaces under 60 kPa normal load. Based on the results, the Ballast-Ballast interface exhibited the highest shear stress variation, followed by the Ballast-USP and Ballast-Concrete interfaces. Also, the ballast particle breakage was quantified for each interface using experimental data. The results confirmed that the application of recycled USP has reduced particle breakage by 23% compared to the Ballast-Concrete interface. Then numerical models of large-scale direct shear tests were developed in DEM and validated using experimental data. The validated numerical models were used to evaluate the shear behaviour of different interfaces under 30, 60, 90, 120, 150, and 180 kPa normal loads. Based on the numerical results, linear and non-linear Mohr-Coulomb failure envelops were obtained for each interface and the peak friction angles were calculated. According to the findings, the Ballast-Ballast interface exhibited the highest friction angle value, followed by the Ballast-USP and Ballast-Concrete interfaces.

Keywords: Ballast, DEM simulation; Large-scale direct shear test; Recycled under sleeper pad; Shear behaviour

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EXPERIMENTAL AND NUMERICAL STUDY ON THE SHEAR-STRAIN BEHAVIOR OF BALLAST WITH DIFFERENT GRADATIONS

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Abstract: Rockfill materials are widely used in many infrastructure constructions including earth dams, rail tracks, retaining walls, highways, etc. The major role of these coarse granular materials is to stabilize the body of the structure and maintain the geometry. Ballast is one such material used primarily in rail track substructures. Several factors are governing the mechanical properties of the ballast layer such as particle size, shape, angularity, gradation, particle density, hardness, etc. Ballast gradations are varying from country to country based on geology, climatic condition, source of parent rock, and economics. In Sri Lanka, biotite gneiss is used as ballast material and there is no specific gradation for ballast. Further, the shear strength behavior of ballast is not fully understood with different gradations. Therefore, this study was carried out to analyze the effect of gradations on the shear behavior of ballast using experimental and numerical analysis for Sri Lanka. Shear stress increased with normal stress increment due to the improved and intensified contact between particles. About a 30 % increment in shear stress was obtained from the laboratory test results for gradation with a high amount of larger particles. Generated numerical results showed a good acceptance with experimental results and led to carry out a parametric study with different normal stresses. The findings of this study suggest that the presence of larger size particles causes higher friction therefore an increase in shear strength.

Keywords: Ballast; Contact; Gradation; Mechanical properties; Shear strength

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SUB-STRUCTURE SOIL STRENGTHENING USING "LOW-PRESSURE GROUTING" AFTER THE SUBSIDENCE INCIDENT OF A HISTORIC UNREFINED BUILDING – A CASE STUDY

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Abstract: This article is based on the condition assessment and substructure rectification works that were conducted after a soil subsidence incident for a historic unrefined building in the heart of Colombo. This subsidence incident was caused by poor workmanship during the construction of the secant pile soil retaining structure for its adjacent construction site, which led to continuous leakage (of soil and water) that ultimately resulted in the soil subsidence of this building. This paper discusses the immediate and long-term mitigation and rectification works that took place to control, restore, and ensure the stability of the whole structure using the low-pressure grouting method.

Keywords: Sub-structure; Soil-strengthening; Subsidence; Low-pressure grouting

ICSBE 2022-93

FORMULATE AN ANALYTICAL SOLUTION TO CYLINDER UNIT FAILURE IN DEUTZ MARINE DIESEL ENGINES DURING TRANSIENT LOAD CHANGES

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Abstract: The problem of cylinder liner seizure of DEUTZ marine engines fitted on-board Fast Attack Craft (FAC) is an outstanding issue in Sri Lanka Navy (SLN).This failure has resulted in the wastage of money, manpower, reliability and non-operation of craft fitted with these engines. The Original Equipment Manufacturer (OEM) has tried to solve this issue by extensive investigations. However, the problem has not been fully resolved. This research is mainly focused on geometrical aspects, surface texture, parameters of cylinder liner and low load running as these are the most influential factors for a failure of a cylinder liner. The parameters of the engine were investigated experimentally by preparing an instrumented cylinder liner and installing it on 04 engines. The surface texture and geometry of cylinder liners were inspected by obtaining sample cylinder liners from stock, and Low Load Running was examined on 04 Nos. engines for 06 months duration. Literature survey revealed that most of the researches are related to thermal cracking, excessive wear down and lubrication oil failure. However, less attention has been paid towards the cooling water system of the engine. Therefore, engines were operated in steady state condition and also in various transient load conditions with experimented cylinder liners to understand the behavior of the coolant system and related parameters. It was revealed that the coolant system of this DEUTZ engine is not responding properly to cater to transient load changes of the engine. As a result, the cooling water temperature and the cylinder liner wall temperature could not achieve the required temperature to maintain sufficient clearance between piston and cylinder liner, thus causing a risk of cylinder liner seizure. Hence, a more sensitive thermostatic control valve was introduced, which can respond very quickly in order to maintain specified elevated temperature values of the engine and resolved the problem.

Keywords: Marine Engine; Cylinder Liner Seizure; Cooling System; Surface Texture

ICSBE 2022-107

EXPERIMENTAL INVESTIGATION OF DEBRIS TRANSPORT DUE TO EXTREME HYDRODYNAMIC FLOWS INDUCED BY TSUNAMI

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Abstract: Entrainment of floating objects and their impacts in disaster-prone coastal areas were well-observed phenomena during the forensic surveys of the aftermath of extreme coastal disasters such as tsunamis. The impacts of floating objects have not been very well understood recently. This paper presents a series of hydraulic experiments conducted with the various arrangements of cuboid elements subjected to disparate dam break waves to identify the behaviour of the movements and resultant dispersion over a mildly sloped bed. The motion of the cuboids was tracked through a high-speed camera to estimate the moving velocity of the debris and to identify the trajectories. Results indicated that the velocity of the debris was predicted with reasonable accuracy compared with the empirical formulation. Also, debris transport could be expressed as a normal distribution, symmetrically dispersed over the plane. Furthermore, it was observed that the initial configuration parameter and flow characteristics played a crucial role in debris transport modes.

Keywords: tsunami, debris transport, dam break, hydraulic experiment

INNOVATIONS IN CIVIL INFRASTRUCTURES

ICSBE 2022-23

EVALUATION OF ACCURACY OF NATURAL LIGHTING SIMULATION AND FEASIBILITY OF IMPLEMENTING NATURAL LIGHTING IN SRI LANKAN CONTEXT

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Abstract: Daylighting or natural lighting is the freely available lighting source which can be utilized for internal lighting of buildings specifically in tropical countries like Sri Lanka where the sunlight is available throughout the year. However in many commercial buildings in Sri Lanka daylighting is not utilized effectively as a reliable lighting source. This may be due to the fact that daylighting levels generally vary over the year and during the day. Therefore designing a lighting system with natural lighting is a complex process and simulation software are used to predict the amount of daylight levels available at a given point at a given time. Hence accuracy of the software is crucial in order to design accurate daylighting system for the buildings. This study looks at a typical room in a building in Sri Lanka and compares the results produced by two such simulation software with actual measurement and also compares the results obtained by the two software in order to verify how realistic the simulated values are. Also the possibility of incorporating daylighting to the selected room is also looked at using experimental and simulated data with an analysis of the variation of daylighting over the day and the year.

Keywords: *Daylighting; Simulation; accuracy; Sri Lanka*

ICSBE 2022-25

NON-PERSONAL IDENTITY FOR SAFER STREETS: EVALUATING THE IMPACT OF CO-PRESENCE ON THE SENSE OF SAFETY IN URBAN STREETS

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Abstract: The concept of 'eyes on street' first mentioned by Jane Jacobs in her influential book 'Death and Life of American Cities' has been discussed frequently in many fields related to urban designing and planning. This ground-breaking concept implies that people in streets (individuals who know each other in terms of non-personal identity or occupational identity; yet are still strangers) provide informal surveillance creating safer environments for the users. Following this concept, this study tries to evaluate the impact of copresence on the sense of safety of the users. Phase one of the study is a case study assessment with 12 selected streets in urban Colombo including commercial, residential, and mixed land use areas with pedestrian oriented and vehicular oriented streets. Direct interviews with the users of these streets, literature surveys and intense observations provided more insights into the layout, arrangements, past records, variety of usage and other information. In the second phase of the study, a team of experts selected the best photographs which represent the attributes. A total of 36 photographs (3 photographs from each case study) were selected and assessed for the levels of safety with 30 experts (snowball sampling) in the disciplines related to perception studies through a semi-structured questionnaire. The results depicted that mixed-use streets are rated safer compared to commercial and residential streets. The streets with vehicle access are safer when compared to the pedestrian-centred alleyways as drivers act as indirect surveillance in case of an emergency. Furthermore, it was discovered that direct and indirect surveillance are profoundly contributing to the sense of safety of the users in urban streets. In conclusion, this study reveals that Jacobs idea of copresence is still valid and practical in the present day and streets should provide amenities to increase 'eyes on street' for a safer use.

Keywords: streets; copresence; sense of safety; land use

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EVALUATING PHYSICAL SAFETY AND COMFORT OF USERS IN URBAN CIVIC SPACES IN COLOMBO

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Abstract: In urban context, civic spaces are public platforms which act as extension of the community. Consecutively, civic space could be an ideal sample to reflect the quality of life of a city. Sustainable urban development includes developing spaces for effective use by the intended users. Effective usage of a space is determined by its physical and psychological safety and comfort. Accordingly, it is vital to ensure that a space is not merely designed, but also maintained with standards that provide safety and comfort to users. Lack of: illumination, disabled access, waste disposal, ample shading, water draining methods etc. are identified to be causing threat to safety and comfort of urban public realm. Hence it is essential to assess safety and comfort of users in such civic spaces periodically to improve the quality and thereby encourage the usage. Therefore, this study aims to evaluate physical safety and comfort of the existing civic spaces in Colombo based on a quantitative assessment method, in order to improve and maintain the quality of public realm in Colombo. The objectives of the study are to: (1) identify the components of civic spaces that determine user physical safety and comfort based on literature review, (2) evaluate user physical safety and comfort at civic spaces in Colombo by conducting case studies, (3) propose methods of improving the physical safety and comfort of users at case study areas. Case studies were conducted at Arcade Independence Square, Echelon square, and Fort station forecourt, thus representing three types of civic spaces: square, plaza, and forecourt respectively. The results revealed that Fort station forecourt is the least physically safe and comfortable space, and other two spaces are somewhat equally moderately comfortable. This study contributes as a precedent to assess and improve any urban civic spaces in Colombo as a sustainability measure.

Key words: Civic spaces; Colombo; evaluation; physical; safety & comfort

OFFICE DESIGN FOR EMPLOYEES' SATISFACTION.
A STUDY ON STATE SECTOR OFFICES IN HOMAGAMA

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Abstract: Homagama area is being developed as a TechCity with an increased employable population. Consistent efficiency of work, and workforce satisfaction during the eight-hour duration spent at work requires a healthy environment. The objective of this study is to investigate the design strategies in Homagama offices with regard to the degree of employees' satisfaction. The design components such as building orientation, interior colour, method and comfort of light and ventilation of the office spaces were evaluated based on the information available in the literature. A field survey, and a structured interview were conducted among randomly selected employees in three selected state offices. The data were analyzed in relation to the level of satisfaction against design. According to the literature, light -coloured interior, and climatic-responsive buildings reveal more employee satisfaction. Two of the three buildings have used mechanical systems for lighting and ventilation. Passive design strategies have rarely been used. However, the office design with the highest satisfaction has applied positive climatic responses. It has been identified that the lack of ventilation and excessive glare in the building are the most critical design problems which need to be improved in these offices. It is concluded that the offices have to specifically consider the health, and well-being of the employees. The architectural design of office spaces must be upgraded using the principles and the strategies of passive design, which can improve the office well-being of the employees, their efficiency, and reduce the energy demand. It will contribute to creating user-friendly, energy-efficient, and environmentally responsive, sustainable healthy workplaces.

Keywords: Employees' satisfaction; Subtle colour; Artificial lighting; Cognitive function.

IMPACTS OF SELECTED URBAN TREE SPECIES ON OUTDOOR THERMAL COMFORT IN COLOMBO CITY

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Abstract: The warm, humid tropical climate of Colombo alongside the rapid urbanization exert a pressure on the city intensifying thermal discomfort. This could further create a negative influence on performing outdoor activities restricting the quality of life of urban dwellers. Therefore, creating a thermally comfortable urban space is of significant importance, yet identifying suitable tree species to provide better thermal comfort in Colombo has seldom been discussed. This study evaluates the impact on outdoor thermal comfort based on the physiologically equivalent temperature (PET) of five common species in Colombo; *Cassia fistula, Tectona grandis, Plumeria obtuse, Mangifera indica,* and *Terminalia catappa.* The field data collection was conducted on the sites of selected five species under both sunny and cloudy conditions. The parameters which contribute to assess urban thermal environment; sky view factor, relative humidity, air temperature, surface temperature, wind speed, solar radiation, and cloud cover were measured, and RayMan model was used to estimate the thermal comfort by calculating PET values. The results indicated that the shading of trees can considerably influence outdoor thermal comfort expressed by PET. The lower PET values under the tree canopies indicated a lower level of thermal discomfort compared to an adjacent site, which was not directly shaded. Moreover, One-way ANOVA test (p=0.027) indicated that thermal comfort under *Terminalia catappa* were statistically different compared to *Plumeria obtuse* on sunny days. Additionally, among the selected species, *Terminalia catappa* were identified to be the most suitable species for improving thermal comfort in outdoor urban settings. The findings assist the identification of species that offer greater thermal comfort in Colombo. As the use of appropriate tree species for shading is critical in alleviating heat stress, the results achieved can be employed as a measure of enhancing the outdoor thermal comfort and as a vital initiative to achieve sustainability in Colombo.

Keywords: Urban Microclimate; Outdoor thermal comfort; Urban Greening; Sky View Factor(SVF); Physiologically equivalent temperature(PET); Colombo

MAINTAINABILITY OF SRI LANKAN URBAN STREETS: A STUDY FROM COLOMBO METROPOLITAN AREA

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Abstract: Increasing urbanization has resulted in heavy use of the existing street system, frequent rehabilitation, and new street construction. The need for design for maintainability (DfM) considerations has become significant as maintenance of the such street system is known to be complicated. Resource scarcity, traffic safety, pedestrian and worker safety, continuous mobility, lack of interdepartmental coordination between stakeholder authorities, and poor management are some of the factors for difficult maintainability. This research aims to identify the level of maintainability of the existing urban street system based on significant maintainability factors to consider during the design stage. Maintainability assessment factors and indicators to measure the maintainability level were identified through qualitative content analysis and institutional visits to urban space management authorities in Sri Lanka. Three case studies were conducted representing commercial, residential, and mixed-use streets to determine the maintainability level and identify the significant maintainability gaps in existing urban streets. The results showed that Sri Lankan urban streets display maintainability gaps. These include inadequate space to perform maintenance on streetscape components, improper placement of utility access points, poor quality in drainage systems and sidewalk construction, poorly planned and maintained streetscape vegetation, and poor attention to detail and specifications related to components. The findings give insight into the DfM considerations of the existing urban streets and further guide the urban street planners, designers, and constructors to deliver a maintainable urban street system.

Keywords: Urban streets; Maintainability; Design for maintainability factors; Maintainability Score

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A SYSTEMS-BASED APPROACH TO OPTIMIZE HOSPITAL FUNCTIONALITY AGAINST COMPOUND HAZARD EVENTS DURING A BIOLOGICAL OUTBREAK

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Abstract: With the impacts of COVID-19 and concurrent hazards repurposing and reshaping healthcare facilities to accommodate the demand for future multi-hazard events has become a major concern. Especially during a biological outbreak, since there are several alterations in the hospital settings for addressing the potential cascading impacts of infectious diseases such as loss of health workforce and super-spreaders of the virus, hospitals must be resilient and withstand multi-risks of concurrent hazards as well. In the current context of Sri Lanka, indicator-based approaches are in place to identify possible challenges and threats against hospital safety and resilience. However, the use of indicator-based approaches mostly depends on the perspective users and does not incorporate the systemic nature of hospital components, thus hindering the optimization of hospital functionality. In such as context, this study has aimed at developing an approach to understanding the hospital as a complex system in optimizing the hospital functionality against a compound hazard event during a biological outbreak. In this regard the study consists of a systematic literature review and a series of key informant interviews with nine professionals from the public health sector. Accordingly, the study identifies the key concepts of hospital resilience and functionality. Based on the concept of functionality, a set of sub-systems within the hospital and their interrelationships have been identified during the study. The proposed approach consists of a conceptual model which is developed using causal loop diagrams and stock and flows. It works as a basis for understanding the dynamic processes within a hospital. Furthermore, the proposed approach can be further developed for a model that can optimize hospital functionality. It allows the hospital administration to observe how the functionality varies with different changes in the hospital setting.

Keywords: Hospital functionality, Multi-Hazard, Biological outbreaks, Systems approach, Optimization

CAN THE NATURE INSPIRE TO ENHANCE DISASTER RESILIENCE IN COASTAL REGIONS?
AN EXPLONATORY STUDY ON USING BIOMIMICRY FOR COASTAL DISASTER RISK REDUCTION

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Abstract: Coastal zones are highly vulnerable to various natural hazards, including storm surges, tsunamis, coastal erosion and coastal flooding. Such hazards can devastate coastal communities worldwide and are responsible for many deaths and loss of livelihoods. Various interventions have been developed to address such threats, including hard and soft engineering and early warning systems. These have effectively reduced disaster risk in many cases but often fail to protect communities, as evidenced by the increasing number of people affected and economic losses. There has been a growing interest in Nature Based Solutions (NBS), such as growing mangroves and forest vegetation along the coastal belt as an eco-engineering solution for nature-based coastal defenses. Although there has been growing interest in NBS for DRR, there needs to be more attention on using Nature-Inspired Solutions (NIS) as NIS has demonstrated effectiveness in addressing other societal challenges. Accordingly, this research study investigates how NIS solutions could be applied to DRR in coastal regions, its barriers and enablers. The study uses a comprehensive research methodology which comprises a systematic review (Scopus, Science Direct, Emerald), semi-structured expert interviews (15) and a focus group discussion. Currently, the research team is carryout the systematic literature review, which will lead to the developing the initial conceptual framework. Some promising findings are emerging from the systematic review of using NIS for DRR in coastal regions. For examples, case studies on NIS reveal that natural root systems on the sand offer inspiration for designing resilient coastal infrastructure, using native marine organisms to inspire more resilient concrete structures.

Keywords: Coastal Hazards; Disaster Risk Reduction; Nature Inspired Solutions

SCENARIO-BASED FIRE HAZARD MODELING OF A MULTISTORY BUILDING FOR HUMAN SAFETY

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Abstract: The paper presents a scenario-based case study on how fire hazards of a multistory building were modeled and analyzed for the life safety and comfort of occupants. Simulations using the CFAST program were performed on a computer model of a multistory building. Two zones represent each compartment or room, and conservation of mass and energy principles were used for the simulations in the time domain. Several scenarios were created using multiple locations of fire origins, and various targets in different rooms were studied to figure out fire spread throughout the building. The levels of oxygen, carbon dioxide, and smoke distribution are documented and compared to the accepted levels in literature for human comfort and safety. Based on this study, it is possible to determine if humans can evacuate from several building locations in time with windows open or closed and sprinklers active.

Keywords: Fire Hazards; Human Safety; CFAST program; Computer Simulation; Smoke Spread; Multi-Story Building

INNOVATIONS IN BUILDING MATERIALS

ICSBE 2022-32

SHRINK INDEX-BASED TIMBER CLASSIFICATION AND FINGER JOINT PRODUCTION

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Abstract: Inadequate length of sawn timber material is also reported to be a limiting factor for fully utilization of timbers. Finger joint, a method which connects two small pieces of timber together is identified as a sound technique to minimize the wastage. At the finger joint production process, different timber species have to be bonded together for making finger-jointed mixed boards. When mixing of the different timber species together, it should be matched timber pieces based on the dimensional effects. The present study focused on developing a classification system for selected 32 clear timber species based on their shrinkage effect in three different environmental conditioned to assist finger joint technique. Three climatic factors were identified through an analysis to determine the shrink index for the selected timber species. The shrink index values were grouped into five classes as very low, low, medium, high and very high. Cluster analysis was used for grouping the species with similar shrinkage properties. Pearson correlation of Shrink Index and Density was -0.134. So, there is a no significant relationship between the shrink index and density (P>0.05).

Keywords: Finger joint: Timber classification: shrinkage: Shrink index: wood

ICSBE 2022-62

STRUCTURAL PERFORMANCE OF WELDED JOINTS – A NUMERICAL STUDY

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Abstract: Welded joints in steel structures are generally considered as weaker joints in the structures due to the microstructural changes that occur in weld metal and base metal due to heat. In base metal, the zone where the grain structure is affected due to heat is called the heat affected zone. It is important to analyse the effect of heat affected zone to the overall strength of the welded joint. Both experimental and numerical studies have been carried out in this area but the analysis and estimation of structural effects of the heat affected zone is rare. This study is mainly focused on the estimation of effects of the heat affected zone to the tensile strength of welded joints numerically. The experimental data available in literature is used to validate the numerical model. The validated model was used to come up with important conclusions on the structural performances of welded joints. From the results of the simulations, it was found that the material properties and the thickness of the HAZ can be accurately predicted using the hardness test results and that can be used to numerically model and analyse a butt welded joint.

Keywords: Welded joints; Heat affected zone; Finite element modelling; Structural effects

ASSESSMENT ON THE PERFORMANCE OF THERMAL INSULATION COATINGS ON EXTERNAL MASONRY BRICK WALLS IN SRI LANKA

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Abstract: Buildings contribute to a significant fraction of global energy consumption by allocating a large amount as operational energy. In tropical countries like Sri Lanka energy is majorly consumed for active cooling to maintain comfortable temperatures inside buildings. The usage of fans and evaporative air conditioners impacts the environment negatively by consuming a large amount of energy and emitting hazardous pollutants. The application of thermal insulation coatings on the external walls is an effective passive cooling strategy to reduce energy consumption and achieve thermal comfort inside buildings. In this study, a market survey, a literature survey and a thermal and energy simulation were employed to identify the existing thermal insulation external wall coatings and assess their performance and suitability to Sri Lankan climatic conditions. The results show that applying thermal insulation coatings on external masonry brick walls improves thermal comfort and reduces the energy demand up to 40% in buildings in Sri Lanka. Therefore, the application of thermal insulation external wall coatings on masonry brick walls is suitable for most parts of Sri Lanka where outdoor temperatures are relatively high.

Keywords: Thermal Insulation External Wall Coatings; Thermal Comfort; Energy Efficiency; Hot Tropical Climate; Passive Cooling

SUSTAINABILITY OF HOUSING CONSTRUCTION MATERIALS IN KANDY CITY

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Abstract: One of the most alarming features of developing countries is their increasing urban population and density. Changes and the evolution of the social and physical environment of the city affect compact urban growth. Various factors influence urban growth and it should not exceed the optimal use of urban space. Increasing population and housing density within an urban area restricted the needs of urban dwellers. With these consequences, urban dwellers are moving towards an unsustainable use of the urban environment. The main objective of the study is to investigate the sustainability of housing construction materials in the Kandy Municipal Council (KMC) area. Further, the study examines the trends of urban growth by considering the growth of population and housing density within the urban area. Field observations and interviews were conducted within the urban area as primary data and secondary data were collected through the regional administrative offices and the department of census and statistics. Both statistical and descriptive analysis of the study shows a gradual increase in the urban population and housing. Currently, urban dwellers use more permanent housing construction materials such as bricks for walls, cement and tiles for floors and concrete and Asbestos for roofs. Most of the permanent housing materials used within this urban area are not always sustainable construction materials. Urban dwellers should focus more on sustainable housing construction materials since they have increasing population and housing density trends. This study discusses the importance of sustainable use of housing construction materials in the Kandy Municipal Council area for the betterment of urban dwellings.

Keywords: Urban growth; Urban dwelling; Construction materials; sustainability

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EFFECT OF GROUND RICE HUSK ON THE PROPERTIES OF CEMENT BLOCK

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Abstract: The use of solid wastes as a partial or complete replacement in the construction industry is one of the solutions for the scarcity of building materials and the conversion of natural resources. This study analyses the feasibility of using rice husk (RH) waste, a by-product of rice milling as secondary raw material in manufacturing cement blocks. Cement blocks were cast maintaining the cement-to-sand mix proportion of 1:3. River sand which is used in conventional cement blocks, is partially replaced with rice husk at different replacement levels (0%, 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20% and 25%) by volume. The experiments were carried out to determine strength, and physical properties such as dry and bulk density, water absorption, and durability properties. Test results indicate that rice husk incorporated cement blocks fulfilled the strength requirement of ASTM and SLS standards for all the replacement levels, however, cement blocks with 5% rice husk showed reasonable results in terms of strength and durability. Hence, rice husk waste can be utilized in cement block production, resulting in economic and environmental benefits.

Keywords: Building material; Cement blocks; Replacement ratio; Rice husk

ICSBE 2022-114

EFFECTIVENESS OF SRI LANKAN BAMBOO AS A STRUCTURAL MATERIAL

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Abstract: Bamboo is a type of woody grass from the family of *Bambusoideae* and it has been widely spread in most of Asian, African, and South American countries. In Sri Lanka, 10,000 hectares of bamboo cultivation which belongs to seventeen different species have been identified. Bamboo is considered highly renewable, economically feasible and fast-growing, all of which are a hallmark of a sustainable material. When used with proper treatment and comprehension of its properties under different applications, it is a durable and versatile material. The present study aims to determine the key structural properties of four species of bamboo available in Sri Lanka, namely yellow bamboo, green bamboo, giant bamboo, and hybrid bamboo. In order to identify their suitability to adopt as a load-carrying material such as bamboo reinforced concrete, its properties should be evaluated under standard conditions. As such, laboratory experiments for compressive strength, tensile strength (transverse and longitudinal) and shear strength were carried out for representative samples of the four species. All the tests have been carried out according to the standards of ISO 22157:2019 to maintain the accuracy and the reliability of results. This paper presents and discusses the preparation of samples to comply with the standards. The ultimate strength, as well as the stress-strain variation for each of these loading cases, were obtained from the experimental results, and the preliminary findings are also presented. Moreover, failure patterns, especially under longitudinal tensile forces and its significance towards structural design are presented. In conclusion, the outcomes of the present research study will play a significant role in introducing bamboo as an alternative and sustainable material in the construction industry in Sri Lanka.

Keywords: Sri Lankan bamboo; Sustainable materials; Sample preparation; Strength Properties; Failure Patterns

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UTILIZATION OF BOTTOM ASH AS FINE AGGREGATE IN CONCRETE

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Abstract: Bottom ash (BA) is a by-product of the coal incineration process at the coal power plant. This rough, heavy, gritty material, which is collected from the bottom of the furnace, contains many toxins and heavy metals. BA is usually dumped into landfills without proper filtration. The toxic leachate from BA penetrates the groundwater and creates chronic diseases for the families which depend on it. This research aimed to understand and analyze the effects of replacing bottom ash as fine aggregate on the workability and ultimate compressive strength (UCS) of concrete. Accordingly, two trial mixes were conducted by first replacing 50% and 100% volume of fine aggregates with BA and then by changing the fine: coarse aggregate ratio in concrete with bottom ash as its fine aggregate.

Keywords: Bottom ash; Fine aggregates; Concrete

ASSESSMENT OF DISPERSION POTENTIAL OF DISCARDED COCONUT FIBRES IN CONCRETE PAVEMENTS

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Abstract: Natural fibres (coir) have been preferred over their counterparts on account of lower cost, renewability, and accessibility of supply. Generally, Coir fibres having a length greater than 50 mm are considered for various civil engineering applications and the shorter ones are typically discarded/incinerated. The use of these discarded coir fibres (DCF) for concrete pavements seems to be a sustainable approach; however, their lower densities and hydrophilic nature makes concrete manufacturing challenging. To address this, a framework has been developed in the present study primarily to uniformly distribute the DCF in concrete. The present study investigates the distribution of coir fibres in fresh concrete as well as in the hardened state. Coir fibre of lengths 10 mm and 50 mm with a dosage of 0.1, 0.4, and 0.7% by volume of concrete was used, considering different mixing approaches. The coefficient of variation (%) is quantified to assess the distribution of DCF in the fresh concrete and the results revealed that the dispersion of DCF in concrete decreases with an increase in length and dosage. Hardened concrete fracture surfaces were evaluated to assess the fibre dispersion and orientation. The fibre density was found to be less in concrete with low volume fibre dosage, while more in high volume fibre dosage. Further, it was observed that fiber density was higher in the perpendicular direction to the casting face.

Keywords: Concrete Pavements; Coconut Coir fibres; Orientation; Dispersion

CONSTRUCTION MANAGEMENT

ICSBE 2022-14

EFFECTS OF DELAY-CAUSING FACTORS TO BUILDING CONSTRUCTION PROJECT SCHEDULES

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Abstract: Schedule performance is one of the fundamental criteria for success of any project. The construction industry in Sri Lanka has evidently shown a poor performance as a result a huge amount of time and cost overrun. This study assesses the effects of delay causing factors in a building construction project, in order to reduce the schedule delays of construction projects in Sri Lanka. Through a comprehensive literature review, 25 factors that affect schedule performance were identified. Importance of those identified factors were determined through the responses collected using a questionnaire survey of professionals in the construction industry (CS2 to C5 grades contractors). Collected responses were analyzed and the relative importance index (RII) for each factor was calculated. The study introduces a technique that employs web-based tool to integrate Monte Carlo simulation and project-specific conditions to estimate each factor contribution to the overall delay of a project. The developed prediction tool can effectively be used to identify delay causing factors and take and factor-wise mitigation measures to improve schedule performance of building construction projects in Sri Lanka.

Keywords: Building construction projects; Schedule performance; Delay factors; Monte-Carlo Simulation.

ICSBE 2022-15

AN INVESTIGATION ON ACTIVITIES PERFORMED BY A BIDDER DURING THE COMPETITIVE BIDDING PERIOD: DEVELOP A TASK-BASED PROGRAMME

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Abstract: Competitive bidding is recognised to be a popular choice to select the most appropriate contractor in the construction industry. However, a systematic approach for the bidding process is unavailable in the existing construction environment due to the heterogeneous nature of the projects. Hence, the existence of a standard time frame is impracticable. Consequently, insufficient time allocation for the bidding period occurs, causing drawbacks to both parties, the client as well as the bidder. Hence, this study aims to develop a task-based programme for the preparation of a competitive bid proposal. Further, this study has adopted a qualitative research approach and incorporated expert interviews to detect, analyse and validate the tasks-based programme. In addition, collected data were analysed through manual content analysis. The literature findings were advanced and validated through expert interviews due to lack of availability and practicability. Ultimately, overall, 24 tasks were identified, and the findings were demonstrated. This paper's final outcome is developing a scheduled programme of acknowledged tasks/activities.

Keywords: Bidding period, Bidding; Competitive bidding; Task-based programme

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READINESS FOR IMPLEMENTATION OF BUILDING INFORMATION MODELLING IN SRI LANKA

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Abstract: Building Information Modelling (BIM) is a novel advanced technology used globally in Architecture, Engineering and Construction (AEC) industries. High-quality construction and management can be facilitated through the effective use of BIM. Worldwide, AEC industries have adopted and implemented BIM with different maturity levels. This paper reports the findings of a research study aimed at identifying the current BIM maturity level and readiness for BIM implementation in the Sri Lankan AEC industry. Questionnaire surveys and expert interviews were taken place to achieve the objectives of the research. Total of 101 survey responses were collected from the professionals' work in the AEC industry. Data was analysed using SPSS and RStudio software. The study identified though there are multiple benefits associated with BIM implementation as identified by the professionals, the presence of various barriers hinders the fast adoption in the Sri Lankan AEC industry based on the mean value. The most achievable benefits for the Sri Lankan industry are improved visualization, time savings, enhanced collaboration and communication and clash detection, respectively. The most significantly impacted barriers are time and cost for training, time to familiarize with BIM, high initial expenditure and a lack of BIM experts. Overall, the status of barriers in the Sri Lankan AEC industry is significantly high. The findings revealed that the percentage of readiness to implement BIM (67%) in Sri Lanka is at a good level. It is interesting to note that the Sri Lankan AEC industry is at BIM maturity level one.

Keywords: BIM, Readiness; Maturity level; Benefits and Barriers

CRITICAL SELECTION FACTORS FOR CONTRACTORS TO MAKE BID/ NO-BID DECISION IN CONSTRUCTION PROJECTS IN SRI LANKA

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Abstract: During the tender process, bidders' most crucial task is to decide whether to bid /not to bid and that has a high influence on the long-term performance and profitability of the organization. Bidding for a tender may or may not have the chance of winning the bid and a profit; besides, there is a possibility of waste of time, effect & money for the contracting firm. No bidding decision has less risk of loss of assets but there is no opportunity to grow & earn some profit. The aim of the study is to identify the most crucial variables that influence the contractors' decision for bidding on Sri Lankan construction projects. To investigate the study, a mixed-method research strategy was adopted with semi-structured interviews and a questionnaire survey. From the initial literature review, fifty- six (56) factors were identified & it was reduced to thirty-one (31) factors after conducting 10 expert interviews which aimed to confirm, modify, and amalgamate the identified selection factors. In the second stage, a questionnaire survey was conducted among one - hundred twenty (120) different construction professionals to determine the most critical factors for decision-making in the bidding process from the finalized thirty-one (31) factors. Semi-structured interviews were analyzed by using the manual content analysis methods and the most significant selection factors were identified by calculating the Relative Important Index (RII) of selected factors. Size, type and duration of the contract and the project were found to be the most critical selection factors that influence the contractors. The factors which are unable to control by the bidders during the bidding stage or the factors that are mandatory to bid for any kind of tender were ranked the lowest critical selection factors. The findings of this study will contribute to the existing knowledge gap that lies upon the contracting firms and the selection criteria for making the bid/no-bid decision. Moreover, this study can be utilized as a base study for other developing nations.

Keywords: Bid; Contractors; Construction Industry; Critical Selection Factors; Sri Lanka

ICSBE 2022-36

AN ANALYTICAL STUDY OF FOREIGN INSTITUTIONAL INVESTORS EFFECT ON PERFORMANCE OF   INITIAL PUBLIC OFFERING IN INDIA

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Abstract: Present study aims to understand the effect of Foreign institutional investment on Indian stock market and its performances. Post liberalization, Indian stock market has undergone many changes. While comparing other market Indian market seems to be relatively less volatile. Hence Indian market has emerged as one of the most attractive market for investment. Foreign Institutional Investment in Indian Initial Public Offerings market provides a boom for the financial development. The study could find that there is a weak positive correlation between the Foreign Institutional Investors   investments and the returns on the stocks. At the same time there are other factors which influence the development of the stock market.

Keywords: Foreign Institutional Investment, IPO, Stock Market, Volatility.

COST CONTROL TECHNIQUES ON THE DELIVERY OF SUSTAINABLE CONSTRUCTION PROJECTS IN SRI LANKA

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Abstract: With the progressive escalation in the development of sustainable construction projects over the period, the demand for better and greater construction has also intensified. However, the construction industry is constantly faced with various obstacles in the path to achieving these construction demands and it was noted that these issues due on inability to meet cost targets of the projects. Therefore, it is crucial to distinguish the possible problems along the project, with the applicable control techniques to be used in diffusing these concerns. The aim was set to identify the impact of various cost controlling tools and techniques available towards the delivery of sustainable construction projects. The study carried out a literature review, semi-structured interviews and a questionnaire survey to collect data. Among the problems that were found to be constant, cost overruns, time overruns and life cycle costing were identified as the final, end-result of all other problems along with some cost control techniques such as Performance Review, Variance Analysis, Earn Value Management, Forecasting, To-complete Performance Index and etc. After identification of the said problems, thereby, determining the most common techniques used in the mitigation of the problems, which was further illustrated through a framework were presented at the end. It has been emphasised that these techniques can be utilized not merely for cost controlling techniques but also as overall cost management tools of the sustainable construction projects. Overall outcome of the research advances the concept of cost control under the cost management within the context of Sri Lankan construction industry in delivering sustainable projects.

Keywords: Cost Control Techniques; Project Management; Sustainable Construction; Sri Lanka

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AN ASSESSMENT FRAMEWORK ON FACTORS AFFECTING CONSTRUCTION PRODUCTIVITY: THE GLOBAL PERSPECTIVE

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Abstract: Due to varied operating environments across the world, the Construction industry's significant diversity has been one of the most urgent challenges in assessing its productivity. The sector continues to be one of the most subjective industries on a global scale due to the massive range of factors that impact its success on a variety of dimensions. Owing to the fluctuating regional operating procedures and labour force, it has been shown that the elements that impact the industry's productivity comprise many distinct and unique characteristics. Further the distinct characteristics of each location, and the elements influencing global construction productivity even tend to vary, even amongst states that have the same administration. Over the years, numerous methods exist to discover and characterise mentioned aspects that greatly affect construction performance and productivity, with these procedures also varying regionally based on the operational parameters of the sector. Henceforth It is proven that it is required to undertake a unique study in the investigated soil in order to analyse and identify the key aspects of impact, as opposed to simply applying what has been learned to another context, which is tedious and repetitive. Addressing the aforementioned concern, this research study has conducted a comprehensive analysis of 130 studies pertaining to construction productivity on a global scale, followed by their categorization into nine distinct regions, and finally their incorporation into dominant research areas, following the procedures of 1. Identifying nine distinct regions in the world pertaining to the construction trade; 2. Categorising factors of 130 studies into these nine distinct regions; and   3. Identifying the most distinctive traits of each region 4. Comprehensive analysis of all available criteria for evaluating the filtered characteristics 5. Use of Pareto and Frequency Analyses to evaluate and classify existing research on appraisal methodologies utilised in certain locations.

Keywords: Construction; Productivity; Pareto; Frequency; Framework

ICSBE 2022-103

POTENTIAL FOR LOW-COST HOUSING IN SRI LANKA – CASE STUDY

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Abstract: Sri Lankan construction industry is facing huge challenges currently, given the increased cost of construction materials, energy and labour. Imposed limitations on the import of construction materials and the rise in taxes have further escalated the issues of involved cost in construction. Impact of cost has significant consequences when it comes to residential construction and in long run, it can result in unaffordable housing, homelessness and underserved settlements. Therefore, exploring possibilities to address this issue is a timely need. In this light, the paper investigates the potential for low-cost housing options in Sri Lanka. A case study of a two-storeyed house construction is presented where different approaches are adopted to optimise the cost without compromising the structural integrity. For this house, precast prestressed beam and column sections are assembled to form the concrete frame along with some in situ components. Floor slabs are also assembled using precast prestressed slab panels instead of in situ slabs. The conventional interior and exterior masonry walls are replaced with light weight foam concrete wall panels. Smooth finished surface of the foam concrete walls allows to minimise the requirement for rendering and this subsequently reduce the involved cost. Advantages of the aforementioned approaches are discussed considering the aspects of cost, construction speed, sustainability and the overall societal benefits. Comparison of the attributes of the proposed methods and the conventional techniques are explored. Moreover, the main challenges encountered in the practical application of the proposed techniques are discussed. Overall aim of this paper is to increase the awareness about potential for low-cost housing options in Sri Lanka highlighting its advantages.

Keywords: Economic impacts; Low-cost housing; Foam concrete; Slab panels; Wall panels

ICSBE 2022-115

A GLIMSE ON THE PLANNING AND DEVELOPMENT OF MOPA INTERNATIONAL AIRPORT

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Abstract: Airports are necessary for air connectivity of one place to other places, which are generally far away, to save time. The airport which is under construction at Mopa at present is supposed to be a Greenfield airport. This airport will be an international airport in the north district of the state Goa. This project is being completed by GMR group and is expected to be completed by the latter half of this year 2022. The goal will be to manage the international as well as domestic tourists and to reduce the number of excess tourists from the other existing military airport in Goa. This paper discussed the details of Mopa International Airport and its important features. The author has also used the popular CAGR formula to calculate the rate of growth of air passenger traffic over the years in the state Goa and further the author had used it to forecast the number of air passenger traffic in the coming future in normal situation, without considering the negative effects of Covid-19 in the state, in order to support the new international airport project in a way. The paper also highlighted the design aspects of passenger terminal building in the airport project in brief along with the mention of the planning and development of the given airport. Some graphical analysis were done after the author collected data from different sources. Further, it discussed the challenges faced by the project and major benefits of the airport project.

Keywords: Greenfield Airport; DBFOT; CAGR; Runway; Air Passenger Traffic; Passenger Terminal Building

ICSBE 2022-117

KEY FACTORS INFLUENCING CONSTRUCTION SAFETY PERFORMANCE IN A DEVELOPING ECONOMY: EVIDENCE FROM SRI LANKA

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Abstract: This study aimed at identifying key factors affecting safety performance in Sri Lankan construction industry and impacts of poor health and safety (H&S) levels to different stakeholders. Data was obtained from technical staff, labourers, and the neighbouring communities in 31 construction sites within Colombo district and analyzed using the relative importance index (RII) and various statistical tools. The factors were divided into four main groups (company, human, management and communal related). RII indicated that the availability of a functioning safety department (RII = 0.52), working exceeding allocated work time (RII = 0.56), safety meeting conducted daily at site (RII = 0.53), and dust collected from site work (RII = 0.75) were the most significant company, human, management, and communal related factors affecting H&S in construction sites. All stakeholders were affected similarly by the poor H&S conditions. Financial capacity only seemed to impact the company's experience in the construction sector which can be indirectly related to their H&S performance (Pearson's r = -0.5, P < 0.01). Disagreements between stakeholders regarding H&S levels indicated that their psychology would influence the results. H&S factors will have variable levels of importance in different developing countries due to differences in sociocultural and legislative regulations.

Keywords: health; safety; factors; construction; developing countries; Sri Lanka

CIRCULAR ECONOMY (CE) IN FABRICATION AND CONSTRUCTION INDUSTRY: PRIORITIZATION OF END-OF-LIFE SOLUTIONS

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Abstract: Circular economy (CE) targets provide an economic model to focus on the efficient use of resources by minimization of the waste, reduction of the linear consumption of natural resources, long-term value creation, and making material consumption circular. The building and construction sector is responsible for significantly increasing the carbon footprint and linear material consumption. The identification and prioritization of end-of-life solutions during the decommission of the existing pre-cast concrete buildings enable the carbon footprint and linear material consumption to be alleviated. The CE targets enable end-of-life solutions for structural or non/structural components to be identified, while multi-criteria decision analysis enables their prioritization using a hierarchically structured decision model. A principal challenge, therefore, is to identify the assessment criteria for such a prioritization, aligning with the CE targets, and to develop an assessment framework. This presentation aims to demonstrate the use of an analytical tool for end-of-life solutions' prioritization. The decision hierarchy development, prioritization, and sensitivity analysis enable practitioners to integrate the suggested approach via a building information modeling (BIM) system to support implementing CE targets. This enhances the potential for the effective integration of the CE economic model in the fabrication & construction industry to support minimizing the carbon footprint.

Keywords: Circular economy; fabrication and construction industry; economic model

WASTE IN THE CONSTRUCTION INDUSTRY

MANUFACTURING OF PAVING BLOCKS USING TILE WASTES

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Abstract: Huge amounts of tile waste are daily generated by ceramic companies and construction sites. As a result, they are piled on empty lands or dumped in land fillings. This type of waste causes environmental pollution and groundwater pollution. This study was accomplished to provide a solution to reduce large quantities of tile waste to some extent. This study is a good reference to identify the benefits of these wasted ceramic tile particles as an alternative material for fine and coarse aggregate in the paving block manufacturing industry. Concrete mixture proportions were suggested according to the Grade 25 concrete mix design. And blocks were prepared according to different (0, 25, 50, 75, and 100%) replacements of both aggregate types from tile waste. The paving blocks were characterized using a flexural strength test, compressive strength test and water absorption test. Compressive strength results were collated with standard strength values in Indian standards for paving blocks. It was observed that with the increment of tile waste particles slump was reduced. All blocks (including the control sample) met 30MPa strength after 28 days of curing for lightweight traffic. The strength of the blocks was increased with the increment of tile waste percentage from 0 to 100%. Results evinced that 50% of both aggregate replacements with tile waste is practicable in the paving block manufacturing process. It is suitable for use on roads and parking slots. This study shows that the use of tile waste in the paving block industry as an alternative material for manufacturing paving blocks is technically a feasible solution.

Keywords: Paving Block; Tile waste; Stone powder; Compressive strength; Water Absorption

ICSBE 2022-03

USE OF WASTE CERAMIC AND ASBESTOS AGGREGATE AS A PARTIAL REPACEMENT OF FINE AND COARSE AGGREGATES IN CONCRETE

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Abstract: Waste generation, waste processing and waste treatment has become a major global challenge in the 21st century. In Sri Lanka, industrial wastes such as ceramic, plastic, glass, rubber and construction waste such as concrete and asbestos account for a large portion of waste generated. Furthermore, the use of natural resources in construction such as river sand natural aggregates has negatively affected sustainable development. The objectives of this study are to determine the suitable composition, technical feasibility, and economic feasibility of using ceramic and asbestos waste to replace fine and coarse aggregates of concrete. This study includes a series of experimental studies involving concrete cubes in which the fine and coarse aggregates are replaced by ceramic and asbestos waste respectively. The experimental tests include the measure of compressive strength, water absorption, workability, and density. The outcomes of this study will contribute to proposing an alternative technical approach to reduce waste disposal on landfill sites by using it in the manufacture of concrete and reducing the use up of natural construction.

Keywords: Ceramic and Asbestos Waste; Compressive Strength; Water Absorption; Workability

ICSBE 2022-99

USE OF WASTE MATERIALS FOR SUSTAINABLE PAVEMENT INDUSTRY IN AUSTRALIA: A REVIEW

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Abstract: The demand for fresh materials for construction and maintenance of pavements is increasing daily with the rapid development of infrastructures. Continuous extraction of natural resources to supply the demand causes environmental, social, and economic dissatisfaction. Recycled materials are the best alternative to replace fresh pavement materials, conversely, to align with the sustainability of the pavement industry. Crumb rubber, reclaimed asphalt pavement, recycled concrete aggregates, crushed bricks, and glass, fly ash and recycled plastics are viable recycled materials. A progressive trend toward recycled materials is recorded worldwide. However, it needs continuous enforcement to standardize specific criteria to retain a steady demand for their applications in every part of the world. Australia is far ahead in employing recycled materials in the pavement industry in different circumstances. This paper presents an overview of recycled materials, their properties and applications in different layers of flexible pavements in Australia.

Keywords: Recycled materials; flexible pavements; reclaimed asphalt pavement; recycled concrete aggregates; recycled plastic; crush glass; fly ash

ICSBE 2022-118

EVALUATION OF ELEMENTAL AND CHEMICAL COMPOSITIONS OF RECYCLED CONCRETE AGGREGATES PRODUCED FROM THE COWAM CENTER, SRI LANKA

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Abstract: Recycled Concrete Aggregate (RCA) is produced from demolished concrete waste generated in the construction industry. RCA is a sustainable construction material that contributes to minimize land pollution. Because of the adhered mortar on the surface of RCA, it has distinct characteristics, which affect quality of the green materials made by RCA. To study them more effectively and scientifically, reviewing elemental and chemical compositions of RCA is essential. This paper presents the findings of XRF (X-Ray Florescence) and XRD (X-Ray Diffractometry) analyses of RCA in Sri Lankan context. For this study, RCA samples were collected from the Construction Waste Management (COWAM) center in Galle. The control samples of Natural Concrete Aggregate (NCA) were obtained from a quarry in Avissawella. The test samples in powder form were examined using XRF test to identify the chemical oxides and by using XRD test to classify the nature of materials consisting in RCA. It concludes that there are higher amounts of CaO and Loss of Ignition (LOI) in RCA than NCA. And also, there are minor portions of chemical oxides namely; SiO_2, Al_2O_3, K_2O, Fe_2O_3, and MgO available in RCA against NCA. Finally, authors recommend further research especially on the findings of loss of ignition (LOI) that could be associated with the release of volatiles.

Keywords: Recycled Concrete Aggregates; elemental compositions; Chemical Compositions; X-Ray Florescence; X-Ray Diffractometry

SUSTAINABLE CONSTRUCTION

ICSBE 2022-17

CO BENEFITS OF ADOPTING GREEN CONCEPT FOR SUSTAINABLE BUILDING CONSTRUCTION IN SRI LANKA

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Abstract: As the world moves closer to achieving sustainable development, the idea of green building has emerged as one of the most important trends in the construction sector around the world. Buildings that are environmentally friendly use less energy and less water, which saves money while preserving natural resources. As a result of growing interest in the topic on a global scale, the development of environmentally friendly buildings has recently appeared as an emerging trend in Sri Lanka. According to the findings of several studies, the initial expenditure required for the construction of environmentally friendly buildings is considerably more than that of conventional buildings. When adopting a green idea for the construction of buildings, a developing nation like Sri Lanka needs to understand the genuine advantages as well as the difficulties that may arise. Therefore, the purpose of the research was to investigate the co-benefits connected with green buildings for a country like Sri Lanka, and then to examine each co-benefit in terms of the amount of time that it may be expected to be realized. The primary method for collecting data was a questionnaire survey, and the statistical approach of the relative importance index was utilized to analyze the collected information. According to the findings, the development of an environmentally friendly building offers various environmental, economic, and social co-benefits to the owners as well as the users of those built environments. Further, the article discusses the relative levels of the significance of each building element within the context of sustainability, green building barriers, and green building approach in Sri Lanka. Furthermore, the majority of co-benefits are only attainable in the long run, which takes generally more than two years following the construction of a green building.

Keywords: Co-Benefits; Construction industry; green buildings; Sustainability.

ICSBE 2022-29

THE ROLE OF LANDSCAPE CHARACTERISTICS ON THERMAL ENVIRONMENT OF RESIDENTIAL STREETS IN WARM-HUMID COLOMBO

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Abstract: Street vegetation greatly affects the thermal comfort of pedestrians, thus creating habitable urban street landscapes. Nevertheless, the unplanned developments along streets have been a course of thermal discomfort at the pedestrian level. Therefore, the morphology of streets should be carefully considered when trees are introduced to improve outdoor thermal comfort (OTC). This research aims to assess the effects of street characteristics on the thermal comfort of residential streets in two selected local climate zones (LCZ) in Colombo. The research was conducted in five stages; (1) onsite measurements, (2) modelling the study area, (3) mapping the microclimatic and thermal comfort conditions, (4) comparing the results temporally and spatially, and (5) developing recommendations. The climate parameters measured on-site were used for simulations in ENVI-met 5.0.3 Bio-met software to analyse the physiologically equivalent temperature (PET) at 1.5 m above ground level on a sunny day at 2.00 pm. Results revealed that comparatively lower Air temperature, relative humidity, and higher wind speed improve OTC levels in warm-humid residential streets. Further, morning thermal discomfort conditions have resulted due to either releasing release of the stored heat in the building or high RH values and low wind speed. Streets located completely in compact low-rise LCZ thermally cause more discomfort than streets completely or partially in open low-rise LCZ. Vegetation is the most effective way to improve OTC, especially using large trees with grass. Homogenous shade coverage consistently distributes thermal comfort. However, irrespective of the street axis orientation, shade coverage is more important in terms of enhancing OTC. Planting large trees in residential land plots along narrow streets and medium trees in centre-median on wider roads is highly recommended. ENVI-met shows a strong correlation between measured and simulated Ta, yet, it is recommended to have nesting grids for more accurate results. These findings help professionals in climate-responsive policy making for urban residential streets since local climate change is in urgent need.

Keywords: outdoor thermal comfort; microclimate; residential streets; Colombo; ENVI-met.

ICSBE 2022-46

EFFECT OF MALIC ACID AS A COMPATIBILIZER IN CHEMICALLY MODIFIED CASSAVA STARCH/POLYVINYL ALCOHOL BLENDS FOR POTENTIAL PACKAGING APPLICATIONS

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Abstract: There has been a growing interest in developing biodegradable materials due to the continuous accumulation of non-degradable plastic wastes across the globe. Therefore, this work focuses on producing and evaluating "green" multifunctional film materials based on a mixed eco-friendly thermoplastic starch (TPS)/polyvinyl alcohol (PVA) matrix compatibilized with malic acid. In this study, the blend films of TPS/PVA were prepared by adopting solution casting method. Herein, starch modification was performed under acidic conditions using tetraethylorthosilicate (TEOS) as the chemical modifying agent. The prepared blends were characterized using Fourier transforms infrared (FTIR) spectroscopy, thermogravimetric analysis (TGA), X-ray diffraction (XRD), differential scanning calorimetry (DSC), and scanning electron microscopy (SEM). Moreover, the water absorption and tensile tests were also carried out according to ASTM standards. The biodegradability test was carried out according to the aerobic compost environment test. The results of FTIR analysis confirmed the successful preparation of modified cassava starch which exhibited enhanced thermal stability and crystallinity. Further, the compatibilized blends exhibited enhanced thermal, mechanical and water-resistant properties with improved blend homogeneity. This suggested the possibility of occurring cross-linking reactions among starch, PVA, glycerol and malic acid upon compatibilization while possessing a dense molecular structure. The biodegradation was slowed upon both starch modification and compatibilization whereas the least water absorption capacity was demonstrated by the TPS/PVA (40/60 w/w) blend compatibilized with 5 wt% malic acid (M4P6-M5) valuing 28.89%, and 42.17% at 2 hours, and 24 hours, respectively. Besides, improved mechanical properties could be obtained by the same blend film valuing 36.25 MPa, and 162.91% for tensile strength, and elongation at break, respectively. Therefore, enhanced mechanical and thermal properties, lower water absorptivity, non-toxicity and low-cost make the compatibilized cassava starch/PVA blended films beneficial for potential packaging applications.

Keywords: Biodegradable TPS/PVA thin films; Compatibilization; Malic acid; Modified cassava starch; TEOS

ICSBE 2022-50

DESIGNING A MODEL OF AN INTEGRATED WASTE MANAGEMENT SYSTEM FOR AN URBAN AREA IN SRI LANKA PERTAINING TO THE CIRCULAR ECONOMY

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Abstract: Waste is a conspicuous factor that builds up a country's image positively as resource utilization and superior sanitation, in vice versa driven negatively by environmental and health impacts due to mismanagement. Convincingly, developed countries resolved their waste management problems by planning a systematic structure, enforcing legislation, digitalization, monitoring, and persuasive education for practicing admirable commitment to waste management. Unfortunately, Sri Lanka has not incorporated a systematic manner in waste management since the waste generation, disposal, and collection to the final destination. This chaotic mechanism has been a leading inducement for improper waste disposal at roadsides, and waste dumps which encounter miscellaneous troubles to society. Hence, disastrous incidents happened with disentitling human lives and personal possessions because of this unsystematic waste management system. Sri Lanka launched different projects, and programs to tackle this problem but was not outmatched with expected outcomes. This is a deep study of the existing Sri Lankan waste management process from the generation to the final destination by identifying the imperfections of inoperative steps under the pathways of biodegradable, non-biodegradable, and hazardous waste categories. This is not limited to exploring only the local waste management system, but also scrutinizing the foreign efficient waste management systems and strategies to find any expedient approach for executing such efficient methods in the local context. The overall waste management system was designed by recapitulating the sub-models created in each researched waste category. The designed waste management system is based on the Circular Economy concept by minimizing dumps, landfilling, and uncovering new business opportunities correlated with waste management.

Keywords: Waste Management; Biodegradable Waste; Non-biodegradable Waste; Hazardous Waste; Circular Economy; Business Opportunities

ICSBE 2022-111

PRODUCING SUSTAINABLE RIGID PAVEMENTS WITH THE ADDITION OF GRAPHENE OXIDE

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Abstract: Graphene has emerged as one of the most trending nanomaterials in material science since it is the strongest and thinnest material on earth, at one atom thick. Graphene oxide (GO) is a graphene derivative material, and it has gained considerable attention for possible use in the construction industry due to its good dispersity in the water because of the presence of oxygen functionalities. The current paper focuses on the sustainability aspects of GO incorporated concrete for rigid pavement applications. In the presented experimental investigation, GO was added to the concrete mix at dosages of 0.02, 0.04, 0.06 and 0.08% by weight of cement. Compressive strength and split tensile strength tests were conducted to evaluate the mechanical properties, and abrasion tests were performed to measure the abrasion resistance of GO concrete. It was observed that the addition of GO from 0% to 0.08%, enhanced the compressive strength, split tensile strength and abrasion resistance by 20.7%, 11.8% and 22.9% at 28 days, respectively. Based on the superior strength and abrasion properties, GO concrete directs towards reducing construction material consumption compared to conventional pavement concrete and hence beneficial in reducing CO_2 emission. This is a preliminary test program that has conducted for GO incorporated concrete and further investigations are going on considering changing parameters like mixing techniques and functionalities of GO to achieve a compressive strength around 30%. Finally, the research contributes to reducing carbon footprint in the construction industry by introducing GO incorporated concrete in rigid pavements, which will be more critical in coming years for a sustainable solution.

Keywords: Graphene Oxide; rigid pavement; sustainable concrete; strength; abrasion resistance

ICSBE 2022-89

DEVELOPMENT OF CELLULOSE FIBER-REINFORCED SOIL-BASED COMPOSITE WALL PANELS USING SELECTED LIGNOCELLULOSIC MATERIALS

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Abstract: The present study focuses on preparation of composite wall panels, those are prepared by reinforcing with three different pre-treated lignocellulosic material fibers - bagasse (B), paddy straw (PS), and banana stem (BS). In this study, soil-based composite wall panels were prepared by mixing cement, laterite soil, and lignocellulosic materials in the weight ratios of 1: 1: 0.025 with a certain amount of water. Then, morphological characteristics, water absorption, flexural strength, and thermal conductivity were tested in prepared wall panels by keeping molded panels curing for 28 days. The characterization results of molded wall panels indicate the variation of flexural strength as 1.82 - 4.02 MPa, percentage of water absorption as 14.9-20.5% and thermal conductivity as 0.133 -0.257 W/mk. Additionally, the characteristics of some molded wall panels in the present study were at a satisfactory level compared to the available wall panels in the market.

Keywords: wall panel; composite cement mixer; lignocellulosic materials; cellulose fibers

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DEVELOPMENT OF SOIL BASED COMPOSITE WALL PANELS USING LOCALLY AVAILABLE LATERITE SOILS

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Abstract: Application of cement-sand based mixtures for wall plastering is one of the conventional methods in building construction industry. The problems associated with the use of conventional plastering mixture such as continuous depletion of resources, adverse effects on the environment, sick building syndromes, high energy involvement and cost led to the modification of the ancient daub mixture in a sustainable manner. This research focuses on developing new composite wall panels to be used as a plastering material while simultaneously addressing the drawbacks of cement-sand mixture and basic requirements of the existing wall panels. The effects of three types of laterite soils found in three different areas in Sri Lanka (Gampaha, Hambantota and Ratnapura) and the effects of various cement proportions on the properties of composite wall panels were investigated. Nine wall panel samples were prepared by mixing three laterite soils with different cement ratios (soil: cement 1:1, 1:0.75, 1:0.5), pretreated fibers and water. The test results indicated that flexural strength, water absorption and thermal conductivity varied within the ranges of 1.73 Nmm^{-2} – 3.4 Nmm^{-2}, 13.88% - 25.59% and 0.169 Wm^{-1}K^{-1} - 0.296 Wm^{-1}K^{-1} respectively. Wall panels composed of soil collected from Gampaha and Hambantota in the ratios of 1:1 and 1:0.75 (soil: cement) were selected as best composite mixtures since their properties are closer to the reference composite wall panel and SLSI 1999 standards.

Keywords: lateritic soils; wall panels; pre-treatment; composite mixture; fibers

ICSBE 2022-101

APPLICATIONS OF SUSTAINABILITY CONCEPTS IN THE LIFECYCLE OF BUILDING FAÇADE: A REVIEW

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Abstract: Construction companies which started to embrace circular economy and sustainable development concepts in their organisational mission are often faced with technical and managerial challenges. The reason is that the use of sustainable building materials is not well understood. The aim of this article is to review the applications of sustainability concepts in the entire lifecycle of building façade and to assess the alignment with the universally recognised sustainable practices such as the United Nations Sustainable Development Goals. The novelty of this article is the tracing the whole lifecycle of the most commonly used type of façade from design and material selection to end of life, focusing particularly on the management of wastes for achieving sustainability of the built environment. We review state-of-the-art in facade waste management in Australia using published scholarly articles and industry practices. The findings show that while certain lifecycle stages, such as manufacturing and construction, are directly connected to the concept of sustainability, a few gaps within the application of sustainable core values have been revealed. The most significant knowledge gaps were identified: a lack of comparison of environmental impacts of recycled and virgin materials used, lack of consideration of transportation routes and distances, and the end-of-life waste management to divert façade waste from the landfill. This article contributes to the façade waste management domain by summarising the current knowledge.

Keywords: façade materials; waste management; sustainable building materials; circular economy

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ASSESSING CARBON FOOTPRINT OF HOTELS DURING COVID PANDEMIC: THE CASE STUDY OF SRI LANKAN TOURISM INDUSTRY

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Abstract: The outbreak of coronavirus disease has caused a significant reduction in CO_2 emissions as a result of economic decline all over the world. The mitigation of climate change has become a main global concern, and greenhouse gas emissions are the main cause of global climate change. Thus, the need to limit greenhouse gas emissions has been well-recognized around the world. Though, the carbon emissions of hotels in developing countries remain to be a less explored field. Therefore, the carbon emissions of Sri Lankan hotels were explored as a case study approach. A 4-star hotel in Sigiriya was explored considering pre-Covid, Covid, and post-Covid periods from December 2019 to August 2020. Furthermore, based on the preliminary exploration observations, the carbon emissions of the hotel were evaluated under the three main scopes. Under the main scopes, the usage of electricity, water, fuel, paper, and gas was considered the major parameter to calculate carbon emission. According to the calculations the hotel released more than 558 tons of carbon in all three periods. Each period was considered as 3 months and the hotel released 236.78 tons, 113.1 tons, and 208.96 tons of carbon respectively in each period. Results further indicated the emission of carbon was less during the Covid period due to the heavy restrictions on tourism and the highest emission was recorded in the pre-Covid period. Recommendations were suggested to overcome the issues identified during data collection as well as to reduce the carbon emissions from hotel operations. More importantly, the initiation of recycling, organic gardening eco-friendly refrigerants, and the installation of sub-meters for water and electricity would be ideal for the reduction of greenhouse gas emissions and will influence the intensity of the economy and reduction of carbon emissions.

Keywords: Carbon emissions; Covid; Sri Lanka; Tourism; Green Building

ICSBE 2022-131

PARADOX IN CLIMATE CHANGE MITIGATION: BEHAVIOURAL ATTITUDES AMONG RESIDENTS OF SRI LANKAN HOUSEHOLDS

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Abstract: Due to increasing frequency of extreme weather events worldwide, there is greater demanding on climate change awareness and mitigation among the population. Therefore, it is crucial to identifying behaviuotral attitudes on climate change mitigation among residents. Three focus group discussions (FGD) were conducted among residents already practising climate change mitigative activities, people living in unplanned communities and rural residents to identify the behavioural attitudes on climate mitigation in the district of Colombo. Eight adult residents aged 18 years or above were purposively selected for each discussion. The principal investigator conducted all discussions with the assistance of a note-taker, using a semi-structured FGD guide. The thematic analysis was carried out to identify the beahvioural attitudes. Of the 24 participants, 14 were men and 10 were women, while 10 were <40 years of age. Views on the existance of climate change were based on recent increase in temperature and natural disasters. Behavioural attitudes on climate change mitigation were generated under several themes: causes for climate change, perceptions on vulnerability to effects of climate change, negative attitudes towards climate mitigation, new technologies used for climate mitigation, carbon tax, green test and views on government responsibilities towards climate mitigation. The findings showed that behavioural attitudes are more driven by poor scientific knowledge, poverty and cultural beliefs which should be addressed by mitigative actions.

Keywords: behavioural attitudes, carbon footprint, climate change mitigation, greenhouse gases

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DO URBAN HOUSES EMIT MORE GREENHOUSE GASES COMPARED TO RURAL HOUSES IN THE DISTRICT OF COLOMBO SRI LANKA

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Abstract: Carbon dioxide emissions caused by household consumption become one of the key sources of greenhouse gas (GHG) emissions, thus, identifying high emission sources is of great significance to energy conservation and emissions reduction. Therefore, this study aimed to compare the carbon footprint (CFP) among urban and rural Sri Lankan houses and individulas in the district of Colombo using a validated population-specific tool. A community-based cross-sectional study was conducted among 1640 houses representing 1260 urban and 380 rural houses, selected using stratified cluster sampling. The average CFP was calculated and presented. Individual and household CFP (in total and for each domain) in urban and rural sectors were compared using Mann-Witney U test and significant was considered at 0.05. Total GHG emission was significantly higher in urban houses (3515.6 kgCO_{2e}; standard deviation [SD]=1138.4) compared to rural houses (2766.8 kgCO_{2e}; SD=942.5) (p=0.000). Electricity (p=0.000) and indirect emissions (p=0.000) were significantly higher in urban houses. In urban houses, the highest emission was related to energy (1049.7 kgCO_{2e}), while it was due to travel in rural houses (834.7 kgCO_{2e}). Energy (p=0.000) and housing (p=0.000) related emissions were also significantly higher in urban houses, while consumption of food & beverages, and travel showed no significant urban-rural difference (p>0.05). The carbon emission of an average consumer in the urban sector was 1010.1 kgCO_{2e} (SD=333.9) compared to 794.9 kgCO_{2e} (SD=278.8) in the rural sector with statistically significant difference (p=0.010). The carbon emission due to bread consumption was significantly higher in rural areas (12.1 kgCO_{2e}), whereas emissions due to electricity, waste & water consumption were significantly higher in urban areas (p=0.000). low-carbon awareness to household behaviour in energy and other spheres of consumption by addressing household carbon emission factors and by incorporating fast-changing urban household consumption behaviour in rapidly demographic and socio-economic transitions into regional development trajectory is recommended.

Keywords: carbon footprint, greenhouse gases, urban households, rural households

OPPORTUNITIES AND CONSTRAINTS FOR INTEGRATING THE REQUIREMENTS OF THE PARIS AGREEMENT WITH THE SDGS AND THE SENDAI FRAMEWORK IN THE CONTEXT OF BUILT ENVIRONMENT IN THE UK

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Abstract: In 2015, three landmark global agendas were adapted by the global community: the Paris Agreement; the Sustainable Development Goals (SDGs) within the framework of the 2030 Agenda for Sustainable Development; and the Sendai Framework for Disaster Risk Reduction 2015–2030. Given interconnectedness of climate change, sustainable development, and disaster risk reduction, and their multidimensional impact on the built environment it is necessary pursuing the three global agendas collaboratively within the context of built environment. Accordingly, the study investigates the opportunities and constraints associated with pursuing the three global agendas collaboratively within the context of built environment in the United Kingdom. The study is based on a desk review on current national level policies and practices on climate change adaptation, sustainable development, and disaster risk reduction. The findings reveal that the integration of the three development areas is mostly institutionally disconnected. Current organisational architecture along with funding streams and mechanisms further contribute to this lack of coherence. Furthermore, the current information gaps, data gathering, monitoring and evaluation difficulties further challenge the integration. Opportunities are mainly situated in the infrastructure sector which has more data and is quite well monitored. Public-private partnerships in the built environment present an avenue for further integration.

Keywords: Climate change; sustainable development; built environment; disaster risk reduction

ICSBE 2022-139

THE ROLE OF PROFESSIONALS INVOLVED IN THE BUILT ENVIRONMENT IN CONTRIBUTING TO CLIMATE CHANGE ADAPTATION IN SRI LANKA

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Abstract: Climate change (CC) has turned into a global challenge, and its ramifications have continued to affect, endanger, and influence most people's livelihoods worldwide. Sri Lanka is an island vulnerable to disasters and extreme weather events. In general, urban areas are in danger due to a lack of Climate Change Adaptation (CCA) strategies in growth plans. Within this context, the built environment professional has a great responsibility in implementing CCA measures within the built environment. This study attempts to identify the roles and responsibilities of the built environment professional in adapting the built environment to climate change and building climate resilience within the built environment. A semi-structured interview series was designed and conducted inquiring about the concerns about corporate accountability, disclosure practices related to climate change, and roles, responsibilities, and challenges faced by the built environment professional in implementing the CCA strategies. Accordingly, a variety of stakeholder groups representatives from professional bodies, which include government and semi-government organizations, NGOs and intergovernmental organizations, private organizations, and independent professional organizations, were interviewed. Significant qualitative data about the roles and responsibilities of built environment stakeholders involved in climate adaptation measures, as well as details on their formal education and training, challenges they have encountered, data sharing strategies, and knowledge gaps based on climate change strategies, were obtained from the interview series. It was identified that there is a considerable knowledge gap among the built environment professionals about effective responses and adaptation mechanisms to address the climate change impacts within the built environment. Additionally, the appropriate framework for accessing climate-related data should be maintained. The findings from this study could help built environment organizations to strengthen the capabilities of the professionals within their organizations to adapt to climate change and make the climate resilient of the built environment.

Keywords: Built environment professionals; Climate change; Climate change adaptation; Profes-sional bodies

ICSBE 2022-159

A SYSTEMATIC LITERATURE REVIEW ON CLIMATE CHANGE ADAPTATION MEASURES FOR COASTAL BUILT ENVIRONMENT

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Abstract: The built environment has been adversely affected due to the increased impacts of climate change over the past decades. Especially the coastal built environment is more vulnerable to such impacts since the areas are frequently subjected to climate extremes. Adapting to such impacts and functioning during climate extremes are vital for the coastal built environment as they substantially contribute to the economy of the country. However, incorporating adaptation measures only for physical assets of the built environment is inadequate as climate change impacts adversely affect the economy, society, and environment because of the interrelationship with the physical assets. Hence a Systematic Literature Review (SLR) is employed to explore Climate Change Adaptation (CCA) measures which can be implemented to protect the built environment components. From 2379 suggested articles on the Scopus, Science Direct and Web of Science scientific databases, 106 most related articles were selected for the study through a structured screening process. Adaptation measures which can be implemented to protect the physical assets of the built environment as well as the economy, society and environment were retrieved from the selected articles and discussed in this study. Also, identified governance and institutional measures for facilitating the CCA were discussed. The different sectors of physical assets of the built environment, such as transportation infrastructures, residential and commercial buildings, water infrastructures, telecommunication infrastructures and electricity and energy infrastructures covered by the identified CCA measures. Those measures have been correlated to the applicable life cycle phase to clearly determine the applicable life cycle phase of employing each adaptation measure. The findings provide a comprehensive list of adaptation measures that apply to the built environment components and will help professionals in the built environment adjust to and lessen the effects of climate change.

Keywords: Climate Change Adaptation; Coastal built environment; Systematic Literature Review; Life cycle phases; BEACON

SPECIAL SESSION ON STRENGTHENING UNIVERSITY-ENTERPRISE COLLABORATION FOR RESILIENT COMMUNITIES IN ASIA (SECRA)

ICSBE 2022-130

SUCCESS FACTORS FOR UNIVERSITY INDUSTRY TECHNOLOGY TRANSFERS: EVIDENCE FROM THE UNIVERSITY OF SRI JAYEWARDENEPURA, SRI LANKA

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Abstract: Technology transfer between universities and industries has long been regarded as the pinnacle of science and innovation strategy. Governments encourage universities and businesses to work collaboratively on research initiatives, consultancy and advisory programs to increase their respective capacities for innovation and commercialization of technologies and products. The Triple Helix Model emphasizes the contribution of the university network in transferring knowledge and technology to develop merchantable products and services, rather not confining to conventional teaching and research functions. This study aims to determine the success factors governing the University-industry Technology Transfers (UITT) that occurred recently (2018 to 2022) between the university of Sri Jayewardenepura and the external stakeholders. All the cases reported on the UBL cell official website of the University of Sri Jayewardenepura were considered for the current study. The cases of the UITT process were delineated under three main categories; (i) ready to commercialize technologies (9 cases) (ii) consultancy and advisory (not defined) and (iii) research and development (11 cases). We conducted face-to-face interviews with the Director and the Manager of the UBL Cell of the University of Sri Jayewardenepura and the responsible stakeholders under the cases being studied. The collected data were analysed qualitatively using critical reviewing and content analysis techniques. The key success factors of UITT were commercialization opportunities, university incentives, highly qualified and well-experienced academic staff, and/or curricular valorization including prestige, reputation and visibility. The most frequently reported obstacles included rigid academic policies and negotiations with businesses, lack of funds for research and development activities to further expand the invention into a marketable form, and the limited commercial potential of a patent. In conclusion, effective collaborations between universities and enterprises seemed favourable in all three categories of the University-industry Technology Transfer that had been studied. Further, the present study opens up new arenas and acts as a guide for successful future UITT programs between universities and external stakeholders.

Keywords: University-industry Technology Transfer; Triple Helix Model; Success factors; Sri Lanka

ICSBE 2022-176

A UNIVERSITY-ENTERPRISE COLLABORATIVE FRAMEWORK FOR DISASTER RESILIENCE

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Abstract: Recent research indicates that strengthening disaster resilience cannot be accomplished by working in isolation. It requires a multi-stakeholder approach at various levels of engagement, but this is a significant challenge in Asia, a region especially vulnerable to natural disasters and home to many vulnerable populations. Furthermore, across the region's countries, the level of university-enterprise collaboration (UEC) for disaster resilience is uneven and poorly thought of. Recognizing this pressing need, a group of Asian researchers launched a project with European Union funding to address the region's high vulnerability to disasters. This study aims to develop a relational framework to guide future university-enterprise collaboration for a resilient society as part of the project. This research included a comprehensive literature review as well as expert workshops. The peer-reviewed academic papers used in the review were chosen for their relevance and timeliness. The data was thematically analysed to emphasise the importance of UECs for disaster resilience, particularly during the pandemic. Data was also analysed in order to identify the factors influencing UECs, identify existing collaborative frameworks, and emphasise the importance of a relational framework for strengthening UECs. These factors were presented at project workshops in 2021 and were improved with the assistance of subject matter experts. Based on the literature review, several strategies for addressing the identified challenges were identified. The identified factors were divided into four thematic categories: cultural, material, relational, and structural. The factors were further subdivided into three levels: macro, meso, and micro. Based on the preliminary findings, the study proposed a multi-level UEC collaborative framework that included stakeholders, challenges, and recommendations at the three levels mentioned above, as well as recommendations to improve future training programmes for both university and industry partners. The framework will be tested further in the partner countries (Sri Lanka, Thailand, and the Philippines) in order to validate and provide feasible solutions to improve university-enterprise collaboration for the development of resilient communities.

Keywords: Disasters; University-Enterprise collaborations; Asia; Framework

ROLE OF UNIVERSITY ENTERPRISE COLLABORATION (UEC) IN SRI LANKA

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Abstract: The University Enterprise Collaborations (UEC) play a vital role in promoting innovation and providing an interface for higher education systems and industry to encourage knowledge and technology exchange for advancing the socio-economic conditions of nations. This report aims to investigate the present situation related to UEC endeavours in Sri Lanka through a vigorous literature survey. This initiative will contribute to making a realistic assessment of UECs and to understanding required policy interventions to ensure strong collaborations between two parties to overcome the development challenges of the country. Extant literature indicated that there is an inadequate number of studies conducted about the UEC in the Sri Lankan context and it directed this research study to identify the key policies developed by the government, corporations and universities in Sri Lanka to develop UEC, types of existing UEC models and their components, gaps and enablers that support UEC, barriers that hinder UEC, requirements in term of developing UEC, best practice of UEC and research trends focusing on UEC. There is a UEC in Sri Lanka with a low level of contribution to each other. But this concept is not a common and popular phenomenon for most universities. In order to implement an effective university-industry landscape, well-defined policies and regulations are needed. Also, there is a necessity to further implementation of collaboration concepts in Sri Lanka Universities and industries. This is important for scholars who need comprehensive information on UEC and it can also be used as a reference for them to bring further studies on this topic. Finally, recommendations are made to fill the information gap between strengthening UEC for resilient communities in Sri Lanka.

Keywords: University-Enterprise Collaborations(UEC); Asia; Sri Lanka; Framework

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UNIVERSITY-ENTERPRISE COLLABORATIONS: A SOCIAL NETWORK PERSPECTIVE

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Abstract: The salience of university–enterprise collaboration (UEC) for the fruitful exchange of ideas and knowledge is well documented in the literature. UECs are often promoted as a critical factor for innovation and economic development and are a feature of a variety of disciplines, from engineering and medicine to social sciences and humanities. Robust university–enterprise relationships are reported to constitute fertile ground for innovation, knowledge flow, and professional development. While studies have mainly focused on the institutional arrangements and organisational mechanisms to support UECs, there is a lack of knowledge on the importance of individual relationships between faculty members and members of organizations outside the university. To understand these personal relationships better from a structural point of view, the ERASMUS+ project SECRA included an ego-net analysis carried out in nine universities in the Philippines, Sri Lanka, and Thailand. Results revealed statistically significant differences among countries, between men and women, and among academic disciplines in selected ego-network characteristics and measures. An indicative example concerns gender homophily in ego networks: the women among the partner university faculty members are slightly more often connected to male than female external contacts, making for gender-balanced personal networks.

Keywords: university-enterprise; university-industry; collaboration; ego-net analysis; gender

CHEMICAL AND MICROBIAL POLLUTION IN THE ENVIRONMENT AND RURAL WATER

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MICROBIAL POLLUTION OF WATER SOURCES OF DRINKING WATER

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Abstract: Water sources like river and well provide drinking water for humans. These water sources must be protected from microbial pollution as certain microorganisms cause severe gastroenteritis and thus diarrhoea in immunocompromised persons, children and the elderly. Bacteria, protozoans and viruses can pollute water sources through human and animal faeces as most of the microbial load reach water sources from human and animal excreta. World Health Organization guidelines on Water Safety Plans emphasizes the importance of catchment management of water sources to provide safe drinking water to humans. However, there is a lack of testing methods for onsite identification of microbial contaminants and dynamic exchanges of pathogens. The soluble contaminant load is assessed by optical response using turbidometry and this is a solution to identify hazardous situations of water microbial contamination. The turbidity measurement is limited, since these measurements are influenced by colloids, which interfere the turbidity results. To obtain details of the microbial agents including bacteria, viruses and protozoans, aggregation and resuspension of water is needed. Once the resuspension is done, microbial identification can be done using special staining and microscopy for screening for protozoans like Cryptosporidia. Then the Crptosporidia can be further characterized by DNA extraction of the aggregates followed by PCR and sequencing. The bacteria in water are characterized by conventional and molecular methods. Water contaminating viruses are characterized by RNA extraction of the aggregates followed by PCR and sequencing. Detailed characterization of these microorganisms assist in obtaining epidemiological details to reduce the microbial contamination of water sources. Monitoring the natural water sources is an important measure to identify the microbial load. This needs a multidisciplinary approach between hydrologists, chemists, microbiologists, water treatment managers and epidemiologists. The outcomes of microbial load monitoring will give useful data for water treatment plants to modify or adapt the water treatment processes.

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DECENTRALIZED WASTEWATER TREATMENT TECHNOLOGIES AND MANAGEMENT IN CHINESE VILLAGES

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Abstract: Increases in the number of flush toilets and fertilizer use in rural areas have led to the dramatic deterioration of water quality in many rural waterways. Rural areas now emit approximately 50% of the entire Chinese emissions of major water pollutants, including 43% of the chemical oxygen demand (COD), 57% of the total nitrogen (T-N), and 67% of the total phosphorus (TP). However, only 30% of rural areas had spray drainage and wastewater treatment systems by the end of 2016, according to an investigation conducted by the Ministry of Housing and Urban–Rural Development of the People's Republic of China (MHURD). The large volumes of untreated sewage that are discharged into rural lakes and rivers are becoming major sources of environmental pollution and potential health hazards for the local populations. The demands of public health and water quality goals must be met using decentralized rural sewage treatment technologies. We investigated 62 typical facilities that had been operating for more than one year, to assess the sewage technologies currently used in rural areas in China. We reviewed the main decentralized wastewater treatment processes that are used in rural areas, and assessed the current rural sewage treatment situation. The technical aspects and running costs of each technology were compared to evaluate their practical suitability for use in rural areas. We also assessed the challenges involved in developing rural sewage treatment technologies, and the potential solutions.

Keywords: Decentralized wastewater treatment; Rural wastewater; Technologies; Management

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EFFECTIVE TREATMENT OF SULFATE RICH WASTEWATER GENRATED FROM CONCENTRATED LATEX INDUSTRY USING INTEGRATED AN MBR AND A/O MBR PROCESS

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Abstract: Skim latex serum (SLS) is a high strength wastewater containing high amount of nitrogen and sulfur. This work involves Anaerobic MBR couples with Anoxic and Oxic MBR setup to treat the wastewater generated from concentrated latex industry. Sulfate-reducing microorganisms utilize sulfate as the terminal electron acceptor at anaerobic reactor generating S^{2-}, while sulfur-driven autotrophic denitrification (SDAD) appearing in the anoxic reactor. Processes of sulfate reduction, autotrophic denitrification and nitrification integrated (SANI) system has been regarded as the key nitrogen removal bioprocess. Therefore, this laboratory reactor setup explore the impacts of influent conditions on the reactor performance. The results revealed that more than 80% of removal can be achieved with the COD while maintaining COD/SO_4^{2-} ratio is around 4. The significant consumption of NH_4^+ indicated that nitrification process in the aerobic zone and even take a dominant role (up to 58.9%) in overall N removal. As a result, NO_2^-/NO_3^- could accumulate for the subsequent SDAD process. Overall N removal was maintained above 60% with uprising trend at ongoing research. Finally, integrated An MBR and A/O MBR system configuration based on the effective use of SDAD process was proposed to improve the efficiency of the treatment of sulfate-rich concentrated latex industry wastewater.

Keywords: Concentrated latex industry; MBR; sulfate reducing microorganisms; sulfur-driven autotrophic denitrification

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RESPONSE OF PROKARYOTIC, EUKARYOTIC AND ALGAL COMMUNITIES TO HEAVY RAINFALL IN A RESERVOIR SUPPLIED WITH RECLAIMED WATER

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Abstract: The heavy stormwater occurs more often due to the global climate change, and results in the non-point source pollution which would exacerbate the risk to the water ecological environment. In this study, a reservoir (Shahe reservoir, Beijing, China) supplied with reclaimed water was selected to investigate how spatiotemporal changes in the quantity and diversity of prokaryotic, eukaryotic, and algal communities response to heavy rainfall. Results showed that heavy rainfall could directly impact the composition of the prokaryotic community by introducing amounts of runoff closely associated bacterium especially for the human potential pathogens of *Aliarcobacter*, *Aeromonas*, and *Pseudomonas* in the Shahe reservoir area. While the eukaryotic community was rather stable, and the development and changes of algal community happened not the beginning of the heavy rainfall but after it. The fast expectation-maximization microbial source tracking (FEAST) indicated that the Nansha river (S) was the major contributor to the development of all the three concerned communities in the reservoir, where they were all strongly and positively connected with Chl-a, pH, turbidity, COD, and TOC, but negatively correlated with NO_3^--N ($P<0.01$). The eukaryote played a key role in the interaction network among the three communities, and were more likely to interact with algae and prokaryotes. It was suggested that the controlling of human potential pathogens associated with prokaryotic community should be emphasized at the beginning of the heavy rainfall, but the prevention of the eutrophication bloom should be another focus after the heavy rainfall. This study provided valuable information concerning the role of heavy rainfall on the water ecological environment from the perspective of microbial community.

Keywords: Reservoir; Heavy rainfall; Prokaryotic community; Eukaryotic community; Algal community

ICSBE 2022-155

BYPASS AND OFF-LINE RIVER PURIFICATION SYSTEM: THEORY AND APPLICATION

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Abstract: According to the natural-based solutions principle, the concept of bypass and off-line river purification system was developed for polluted river water quality improvement in urban, and such concept was applied in the Longdao Stream, a branch of Wenyu River. The project consisted of a naturalized Stream in Longdao and a constructed wetland in East Lake of Luoma. The practical application results showed that the bypass and off-line river purifier system greatly improved the water quality and biological habitat. The average concentrations of chemical oxygen demand (COD), ammonia nitrogen and total nitrogen (TN) were decreased from (71.86 ± 14.94), (10.70 ± 1.20), (16.14 ± 1.37) mg·L^{-1} to (47.59 ± 6.13), (1.17 ± 0.27), (3.65 ± 1.73) mg·L^{-1}, and their removal rates were 31.8%, 89.5% and 77.4%, respectively. Water quality based on ammonia nitrogen concentration was upgraded from inferior Ⅴ to Ⅳ. The habitat quality score in Longdao Stream increased from the "general" rank of 94 to the "good" rank of 151. The technology and system has many advantages, such as non-changing the original state of the main stream channel, non-affecting the flood prevention of the main stream, good performance of water quality purification and ecological restoration. Therefore this technology and system is suitable for the ecological treatment and restoration of polluted rivers with abundant tributaries or dense drainage and irrigation channels or well-developed pits and ponds.

Keywords: bypass and off-line river purification system; Wenyu River; ecological management

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CHRONIC EXPOSURE TO FLUORIDE, HARDNESS AND HEAVY METALS IN DRINKING WATER VS WHO WATER QUALITY STANDARDS ON LIVER, HEART, LUNG AND BRAIN TISSUES

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Abstract: The quality of drinking water plays a vital role in public health concerns as waterborne diseases are rising alarmingly. Further, it is a pressing need in the SDG of 'Good health and wellbeing'. Many researchers reported high Fluoride and hardness levels in CKDu-prevalent areas in Sri Lanka. Also, in our previous work, the correlation analysis demonstrated a significant harmful synergistic relationship of Fluoride, Hardness and Cadmium with the incidence of CKDu. Furthermore, at the recommended levels by the WHO, those combinations caused considerable renal damage (like CKDu lesions) in mice. However, despite of many correlation analysis works, few studies reported on the toxic synergic effects of contaminants in drinking water through animal trials. Yet, the dose of exposure is comparatively high and most of the studies are acute rather than chronic. Hence, could not mimic the natural environmental conditions. Moreover, the effects of focusing on other main tissues are inadequate. By identifying these research gaps, we investigated the effect(s) of Fluoride, Hardness, Cadmium, Lead and Arsenic in drinking water in a chronic co-exposed manner (Treated with hard water containing other elements on par with and double the WHO standards, soft water with F, Cd, and As) on liver, heart, lung and brain tissues of mice. ICR mice (n=120) were used in this study. Twelve groups of animals were formed who received treatment for twenty-eight weeks. Ethical approval was obtained from the Postgraduate Institute of Science's ethics committee of the University of Peradeniya in Sri Lanka. Our research findings clearly indicated that there may be a synergistic impact or effects, particularly with Cd, F, and water hardness combination (even at the WHO recommended levels for a single element), which could cause notable hepatocellular degeneration specially around the centrilobular region. However, heart, lung and brain tissues demonstrated tolerable nature in histopathological findings. It was discovered that the degree of liver damage was dependent on both the levels of contaminant and their combination effects. Therefore, when defining the water quality at WHO's maximum recommended levels, the combination effect(s) of trace metals, fluoride, and hardness present in drinking water should also be rigorously examined.

Keywords: Chronic; Fluoride; Hardness; Heavy metals; Water quality; WHO standards

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A PRELIMINARY STUDY ON THE OCCURRENCE OF ANTIMICROBIAL RESISTANT BACTERIA IN SOIL AND A WATER BODY SURROUNDING A WILDLIFE REHABILITATION CENTER IN SRI LANKA

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Abstract: The Elephant Transit Home (ETH) in Udawalawa, Sri Lanka managed by the Department of Wildlife Conservation rehabilitates orphaned and injured wild elephant calves. It borders the Udawalwe reservoir within the Udawalawa national park. Antimicrobial resistance (AMR) profiles of *Escherichia coli* isolates from the environment surrounding the ETH were investigated in this study with the objective to assess whether AMR patterns are related to antibiotic usage and waste disposal practices at ETH and whether the reservoir was contaminated with antibiotic-resistant bacteria (ARB). Sampling sites were selected based on the slope of the terrain and proximity to points of potentially high ARB contamination, including dung piles, the effluent outflow of the veterinary hospital and animal holding pens. Thirty-seven (37) composite samples (9 dung, 12 soil & 16 water) were tested. *Escherichia coli* was isolated on McConkey agar and identified using conventional biochemical methods. Antibiotic susceptibility testing was performed for 03 isolates per sample using disk diffusion method against frequently used antibiotics at ETH. Amoxicillin was the highest used antibiotic followed by enrofloxacin, trimethoprim-sulfamethoxazole, cefuroxime and tetracycline, based on quantities used during the last three years. *Escherichia coli* was isolated from 32 samples (96 isolates). Comparatively higher resistance was observed against frequently used antibiotics [amoxicillin (82.3 %, 79/96) and enrofloxacin (11.5%, 11/96)] relative to the antibiotics with lower usage (4.1%, 4/96 for trimethoprim-sulphamethoxazole, and 3.1%, 3/96 each for tetracycline and cefuroxime). The highest combined resistance (9.3%, 9/96) was observed for amoxicillin and enrofloxacin. Multidrug resistance was observed in 5 isolates (5.2%, 5/96). Overall, relatively high AMR was observed in sampling sites downstream of hospital effluent outflow or holding pens compared to other sites. ARB were detected in 83% (25/30) of isolates from the reservoir water samples, collected close to the edge, with only amoxicillin (83%, 25/30) and enrofloxacin (6.6%, 2/30) resistance.

Key words: Antibiotics, Antibiotic-resistant bacteria (ARB), ARB in soil, Elephant Transit Home (ETH)

STUDY ON MICROBIAL AND CHEMICAL POLLUTION OF MAHAWELI WATER AT WATER TREATMENT PLANTS LOCATED BETWEEN KOTMALE AND VICTORIA RESERVOIRS

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Abstract: Mahaweli river is the main drinking water source for the people live in Kandy district. As per the WHO Water Safety Plans, ensuring catchment management of the river for safe delivery of drinking water is of paramount importance. Present study was conducted to identify bacterial and protozoan pathogen load, and chemical pollutant load in both raw and treated water at 14 water treatment plants (WTPs) situated along the Mahaweli river and its major tributaries between Kotmale and Victoria reservoirs. Water samples were collected for analysis during dry (June) and wet (September) weather conditions in 2022. Onsite measurements were taken for pH, turbidity and electroconductivity. Anion and heavy metal concentrations were determined by ion chromatography (IC) and Inductive Coupled Plasma Mass Spectrometry (ICP-MS) respectively. Membrane filtration followed by culturing techniques were used to determine total bacteria counts, coliforms and fecal coliforms. Sub-cultured colonies of *Escherichia coli* were tested for antibiotic susceptibility using six antibiotics *i.e.*, amoxicillin, streptomycin, tetracycline, sulfonamide, ciprofloxacin and ceftazidime to represent commonly used antibiotic classes in Sri Lanka. Pathogenic protozoa were investigated by membrane filtration followed by microscopic techniques.

Results showed higher microbial pollution towards the lower part of the river especially downstream to the Kandy South WTP. Although the pathogenic protozoan *Giardia* was absent in all the samples tested, *Cryptosporidium* was present in the raw water of the lower part of the river segment. Antimicrobial resistance of *E. coli* was highest against amoxicillin followed by tetracycline and sulfonamide. Multi drug resistance (MDR) was observed at Thalawakelle, Pundaluoya, Nawalapitiya and Paradeka. Anion and heavy metal concentrations, pH, turbidity and electroconductivity were within the safety limits of SLS 614-2013. Results are expected to be analyzed against the land use pattern of the area. The knowledge gather through this study will be vital to plan safe delivery of drinking water.

Key words: Antimicrobial resistance, Chemical pollution, heavy metals, pathogenic protozoa, Mahaweli river water, watershed management

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MICROBIAL POLLUTION IN A TYPICAL RURAL VILLAGE OF NORTH CHINA

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Abstract: The biosafety of surface water is an important field related to people's lives and health. The control of pathogenic microorganism pollution in water body is of great importance. Besides, it puts forward higher requirements for water environment management of river basin.This study takes the North Canal Basin- Dawangzhuang village in Wuqing district, a typical village in North China as research area, and conducts PCR (HT-qPCR) technology to quantify 69 marker genes against 37 human pathogens, 42 fecal markers for 11 hosts objects, and 33 ARGs.The main pollution sources in Dawangzhuang village are aquaculture and domestic sewage discharge, which leads to a certain degree of pollution in the township. The abundance of marker genes of Bacillus, Pseudomonas aeruginosa and Helicobacter pylori is high, and they are the pathogens with high ,risk; the concentrations of TN, TP, COD and NH_3-N in rainfall runoff exceed the class V water standard in the national surface water environmental quality standard, and the degree of non-point source pollution is affected by rainfall. In all land use types, the concentration of pollutants in rainfall runoff increases with time. The concentration of suspended solids can be reduced by 89% in 15 minutes. Also, the breeding area and public toilets are heavily polluted areas, the streets and ditches are moderately polluted areas, and the resident areas are relatively clean. ARGs were detected at all sampling points, and the main types were Aminoglycosides, Sulfonamides, Multidrug and MLSB. There are many sources of fecal pollution in Dawangzhuang, and it is distributed widely, the main sources are human, poultry and cattle manure. Due to the influence of rainfall, pathogens attached to the particles will migrate with the surface runoff, resulting in a certain degree of non-point source pollution.

Keywords: Pathogens; High throughput sequencing technology; Rural non-point source pollution

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RESILIENCE OF ANAMMOX APPLICATION FROM SIDESTREAM TO MAINSTREAM: A COMBINED SYSTEM COUPLING DENITRIFICATION, PARTIAL NITRITATION AND PARTIAL DENITRIFICATION WITH ANAMMOX

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Abstract: The anaerobic ammonium oxidation (anammox) is a potential process to achieve neutralization of energy and carbon. Due to the low concentration and variation of municipal sewage, the application of mainstream anammox is hard to be implemented. For spreading mainstream anammox in practice, several key issues and bottlenecks including the start-up, stable supply of NO_2^--N, maintenance and dominance of AnAOB with high activity, prevention of NO_3^--N buildup, reduction of AnAOB sludge loss, adaption to the seasonal water temperature and alleviation of influent COD impacts on AnAOB are discussed and summarized in this review in order to improve its startup, stable operation and resilience of mainstream anammox. Hence a combined biological nitrogen removal (CBNR) system based on conventional denitrification, shortcut nitrification-denitrification, Partial Nitritation and partial Denitrification combined Anammox (PANDA) process through organic matter and nitrate management is proposed correspondingly aiming at adaptation to the variations of seasonal temperature and pollutants in influent.