BUILDING RESILIENCE
40 Years in Retrospect

13TH ANNUAL RESEARCH SYMPOSIUM 2023

29th February 2024 | Colombo, Sri Lanka

PROCEEDINGS

National Building Research Organisation

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40 Years in Retrospect

BUILDING RESILIENCE - 40 YEARS IN RETROSPECT

PROCEEDINGS OF 13TH ANNUAL RESEARCH SYMPOSIUM 2023

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Foreword

ENG. (DR.) ASIRI KARUNAWARDENA
Director General
National Building Research Organisation

January 2024

It is a great pleasure for me to write this message for the volume of 13th Annual Research Symposium of NBRO at the juncture where NBRO remarks 40th year since its inception in 1984. As NBRO embarks on the symposium for 2023, on the theme of "Building Resilience: 40 Years in Retrospect," it reflects the four decades of its journey and reaffirm our commitment to creating safer and more resilient communities in the face of evolving and uncertain challenges. The symposium theme highlights our dedication to understand the ever-changing dynamics of disaster management and sustainable development.

This volume covers a range of sub themes such as Technology Advancements for Landslide Risk Management, Innovations in Resilience Buildings, Empowering Communities for Resilient Settlements and Sustainable Environment for Healthy Living. NBRO has partnered with eminent researchers, practitioners, policymakers, and experts in disaster management, both locally and internationally. It is through the collaborative efforts of passionate individuals and interdisciplinary teams that we unlock new possibilities and pave the way for progress.

This symposium serves as a valuable platform for researchers associated with NBRO and their counterparts to engage in the exchange of ideas, knowledge, and experiences. We believe that fostering such collaboration is essential for advancing the field of disaster management.

NBRO wish to extend its gratitude to Ministry of Defence and agencies under its purview, government authorities, disaster management agencies, universities, and individuals for their unwavering support. Our appreciation is extended to the Japan International Cooperation Agency (JICA) whose technical and financial assistance has played a crucial role in making this symposium a success. Their sustained support has not only contributed to the success of this annual event but has also significantly strengthened the research and development capabilities of NBRO, enhancing ability to address evolving challenges in disaster management and resilience-building.

I sincerely acknowledge and appreciate the contributions made by authors, presenters, panel members, moderators, and the Organizing Committee for the 13th Annual Research Symposium of NBRO. Their dedication ensures the success of the symposium and contributes to stimulating scientific dialogues and promoting inclusive, disaster-resilient actions both during the event and beyond.

We look forward to another impactful symposium that builds on our legacy of research excellence and commitment to resilience.

Keynote Speaker

D. MOMBAUER
Director / Research & Knowledge Management
SLYCAN Trust Global

Dennis Mombauer has more than a decade of experience in research, management, and administration in the development and the private sector. He is Director: Research & Knowledge Management of SLYCAN Trust, a non-profit think tank focusing on thematic areas related to climate change adaptation, risk management, finance, human mobility, and loss and damage, with a regional presence in Asia, Africa, and Europe. Dennis closely follows the UNFCCC negotiations and is a member of several global forums, networks, and technical expert groups. He has written or contributed to various research publications and regularly publishes in international and local media outlets.

The impacts of climate change are increasingly felt across the world, leading to severe disruptions of societies, economies, and human lives and wellbeing. As a country at the frontlines of the climate crisis, Sri Lanka is faced with significant impacts to its economic growth, development, and prosperity, which are compounded by other global challenges. With a view at 2030 and beyond, it is therefore pivotal for the country to identify pathways towards building long-term resilience and effective strategies for national, sectoral, and local adaptation. Nine years after the Paris Agreement and more than 30 years after the United Nations Framework Convention on Climate Change (UNFCCC), there is a substantial body of knowledge, data, and learnings to build on, but also an increasing awareness of gaps and needs for research, impact assessments, and transformative action. These include, for example, a lack of robust methodologies for assessing climate-induced loss and damage, especially non-economic, slow-onset, indirect, and long-term aspects. Similarly, measuring adaptation success and planning systemic adaptation that goes beyond individual interventions remain important challenges. Globally, 2024 will be a key year for climate action with the operationalization of bodies such as the Santiago Network and the Loss and Damage Fund under the UNFCCC; continued work on the Global Goal on Adaptation; and a new collective goal for climate finance. Sri Lanka can make significant contributions to these processes and pioneer domestic solutions that connect to the UNFCCC and other relevant frameworks, such as those on disaster risk reduction and sustainable development. Evidence-based climate action and resilience-building present critical opportunities for scaling up investment, mobilizing resources for green growth, and developing innovative and inclusive mechanisms that can protect vulnerable communities, assets, and infrastructure.

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Technology Advancements for Landslide Risk Management

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Accuracy assessment of LiDAR-derived contours for landslide mapping in Kegalle district Sri Lanka

HHSS Rathnayake, CN Subasinghe, GPWSU Jayarathne, KGDS Wijesiri

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Abstract

The study aims to comprehensively assess the efficacy of Light Detection and Ranging (LiDAR)-derived contours in the identification and prediction of landslide locations in Kegalle district. LiDAR Digital Elevation Models (DEMs) were acquired from the Survey Department and processed to generate precise 2-meter interval contours. The assessment involved overlaying known landslide locations onto the LiDAR-derived contours, with field verification conducted at selected sites to enhance accuracy. Furthermore, recent major landslide events were identified and overlaid onto pre-event LiDAR contours, enabling a detailed analysis of the predictive capabilities and visual representation of landslides using LiDAR data. The primary objective of the study is to determine the reliability of LiDAR-derived contours in capturing both historical landslide occurrences and predicting potential landslide-prone areas. The methodology involves a meticulous examination of the correspondence between identified landslides and the LiDAR contours, providing insights into the precision and effectiveness of LiDAR technology in landslide mapping. Additionally, the research explores the illustrative capabilities of LiDAR data in predicting and representing recent landslide events, offering valuable information for future hazard mitigation strategies in landslide-prone regions. The findings from this research contribute to the advancement of remote sensing applications in landslide studies and hold practical implications for disaster management and land-use planning in areas susceptible to mass movements. This study serves as a valuable reference for landslide risk assessment, landslide susceptibility mapping, landslide inventory mapping, and mitigation strategies in similar geographical contexts.

Keywords: LiDAR, Landslide mapping, Digital Elevation Models, Hazard mitigation, Remote sensing

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Analysing decision-making criteria for landslide susceptibility mapping in Sri Lanka: A machine learning-enabled GIS approach

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Abstract

The study focused on evaluating decision-making criteria for predicting landslide prone areas of Sri Lanka, utilizing a Machine Learning approach within a Geographic Information System (GIS) framework. By employing Random Forest classification and regression models, this research aimed to analyse and enhance the accuracy of landslide susceptibility mapping. The objective was to better understand the factors contributing to landslides, utilizing sophisticated models to improve predictive capabilities despite the complexities inherent in natural processes and data uncertainties. In this analysis, the study specifically addressed the challenges arising from the combination of categorical and continuous variables, often utilizing factors that functioned as both variable types within the context of landslide susceptibility mapping in Sri Lanka. The analysis focused on six decision-making criteria for landslide susceptibility mapping, transforming these factors from continuous to categorical variables. Moreover, the study examined the variations in the importance of these six factors as they underwent distinct alterations, shedding light on their differential impacts on predictive models. To enhance the accuracy of hazard mapping, fine-tuning the slope factor was recommended as a priority. Subsequently, field verification of landform and land use factors post their integration within GIS mapping was crucial for refining predictive models. Furthermore, the evident correlation between slope and hydrology underscored the necessity of considering hydrological factors in conjunction with slope analysis for a more comprehensive understanding of landslide susceptibility.

Keywords: Geographic Information System (GIS), Machine Learning, Random Forest classification and regression models, categorical and continuous variables

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Analysing landslide susceptibility factors in Sri Lanka (Study area-Bulathkohupitiya catchment): A comparative machine learning approach integrating DEM-derived data and decision-making criteria in GIS

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Abstract

This study assessed landslide susceptibility factors in Sri Lanka, through a comparative Machine Learning Approach that integrate decision-making criteria and Digital Elevation Model (DEM)-derived data within a Geographic Information System (GIS). Employing Random Forest classification and regression models, the analysis juxtapose six pivotal decision-making criteria with factors derived from DEM data to uncover their distinct and collective impacts on landslide susceptibility assessment. In the comparative analysis, individual assessment of decision-making criteria reveals superior predictive accuracy in identifying landslide-prone areas compared to DEM-derived data. However, the true strength of this study lies in the synergistic fusion of these datasets, leading to a substantial enhancement in precision for delineating landslide-prone zones. Significantly, the amalgamation of decision-making criteria and DEM-derived factors underscored the pivotal role of slope in influencing areas susceptible to landslides. This research highlighted the importance of leveraging both decision-making criteria and DEM-derived data, emphasizing their strengths and from that utilization of these data sets an unparalleled accuracy in pinpointing landslide-prone areas within Sri Lanka's landscape. The findings of this study emphasize the significance of considering multiple factors in landslide susceptibility assessments, providing valuable insights for effective hazard management and risk reduction.

Keywords: Geographic Information System (GIS), Machine Learning, Random Forest classification and regression models, Digital Elevation Model (DEM)

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Back analysis of ground instabilities in Thiessen Polygons during heavy rainfall events: A case study in Kegalle district

DMCP Bandara[1], NC Weerasinghe[1], WKSM Wakwella[1], DIU Jayawardane[1], DR Jayalath[1], BC Amunugama[1], SRDM Senanayake[2], GRNR Thilakarathna[2]

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Abstract

The Landslide Early Warning (EW) System is a non-structural method in landslide risk reduction (LRR) in Sri Lanka. The EW is issued based on real-time rainfall data obtained through automated rain gauges. Hence, it is important to study the special distribution of incidents within the Thiessen polygon, to identify vulnerable communities in LRR activities.Twenty-four number of rain gauges in Kegalle and adjacent districts established by the National Building Research Organisation (NBRO), were selected to prepare Thiessen polygons. Five-hundred forty-one incidents occurred from March to November 2023 in Kegalle District were plotted using Arc GIS 10.3. Notably, the highest number of incidents (47) were recorded in Kagalu Maha Vidyalaya polygon. Nearly thirty incidents occurred in each Aranayaka, Kotawela, Sapumalkanda Gatiyamulla, Yatiyanthota and Boyagama polygons. In contrast, two incidents were recorded in Dehiovita, Hemmathagama, Kithulgala area while there were no incidents in Imbulpitiya. Priority should be given to gauges associated with higher incident count, in issuing EW. Conversely, gauges in areas with lower incident frequencies may still play a crucial role in understanding local factors influencing landslide susceptibility. Hence, the study provides a practical tool for leveraging spatial analysis using Thiessen polygons, to assess the priority of automated rain gauges enhancing LRR activities. The result is only based on a short period event, and long-term data can be enhanced the accuracy and sensitivity of the results. Decision-makers can use similar technique to prioritize areas based on incident frequencies.

Keywords: : Thiessen polygons, Rain gauge, Early Warning, Spatial analysis

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Detection of groundwater level, pipe and soakage pit using step frequency Ground Penetrating Radar (GPR) - Case study in Sri Lanka with typical step frequency GPR signatures

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Abstract

Ground penetrating radar (GPR) is a non-destructive geophysical method that uses changes in dielectric properties to identify subsurface objects or regions. Step frequency GPR systems use a step frequency signal with a wide bandwidth continuous wave of the EM spectrum, rather than an impulse signal ("Pulses") as used by most commercial systems. Clay and Silt rich soil profiles tend to attenuate the EM waves (due to high conductivity) such that no clear Radargram (GPR image) could be obtained.In this study, typical signatures of Groundwater level (GWL), PVC pipe and Soakage pit embedded in Clayey soil, were clearly recorded within the single Radargram. Field verifications were done by excavations and clear visual observations.Detection of exact GWL using step frequency GPR is somewhat complex as it usually involves a zone of "Multiples" or "Ringing" with several planar reflections due to the combination of (1) Capillary fringe, (2) Groundwater level and (3) Reverberations below GWL. A simple method is developed here to consider GWL is at the depth of the zone of "Multiples" or "Ringing" in Clayey soils, based on field verifications. However, this method should be further clarified.

Keywords: step frequency GPR; Radargram; GPR signatures; Groundwater level

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Establishment of soil water characteristic curve and hydraulic conductivity functions for Sri Lankan Colluvial soils

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Abstract

Colluvial soils are downslope movements of soil and rocks accumulated at the toe area of the slope. Often, slope instabilities may occur in colluvial soils due to heterogeneity and relative weakness. Rainfall infiltration is a common trigger for slope instabilities in these soils, leading to a reduction in shear strength and an increase in pore water pressure. In tropical regions, the groundwater table is typically deep, resulting in unsaturated soil layers near the surface. The infiltration of water into unsaturated soil depends on the matric suction and hydraulic conductivity. The ability to retain water under matric suction in unsaturated soil is defined using the Soil Water Characteristic Curve (SWCC) and the hydraulic conductivity variation with the matric suction can be defined using the Hydraulic Conductivity Function (HCF). These two functions can be obtained using laboratory experiments or empirical correlations and are important in slope stability evaluation using unsaturated soils. Such studies have not been conducted for the colluvial soils in Sri Lanka. In this study, the SWCC for two colluvial samples was experimentally evaluated using a soil water potential meter for two samples collected from Kithulgala and Avissawella areas. Then the results were curve-fitted with the Van Genutchen empirical equation, which can be used in slope stability evaluation. HCF was deduced using the saturated hydraulic conductivity and the SWCC function for the soil based on the Van Genutchen method. The soil component of the colluvial soil was classified as Silty Sand (SM). Van Genutchen curve fitting parameters of a=31.09 and n=1.631 can be used for the first sample, and for the second sample, a=288.76 and n=2.175 can be used. The SWCC showed that the water retention in the first sample was higher than in the second sample.

Keywords: slope stability, unsaturated, colluvial, SWCC, hydraulic conductivity

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Impact of poor landuse management in reactivation of Paleolandslide: Case study on potential landslide in Bathgoda, Haldummulla

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Abstract

Landslides are natural and potentially hazardous phenomena that mainly occur in a variety of geologic settings in the Sri Lanka every year causing a significant hazard to human lives and infrastructure. Landslides naturally occur because of several factors, which can act alone or in combination, including geologic, geomorphologic, hydrologic, and land-use factors and mainly triggered by rainfall leading to potentially destructive landslides. The study of these natural factors is important on all slopes, for prior identification of landslides, risk assessment, issuing landslide early warnings, introducing proper land use guidelines and in landslide mitigation. Most of these studies have been carried out in the slopes with residual soil and the importance of landslides in colluvium has not been much studied.Remarkably intense rainstorms have triggered catastrophic landslides and reactivation of paleo landslides in colluvium at several locations in the Badulla District and this study was carried out in the potential landslide in Bathgoda area which belongs to Beragala Gramaniladhari division of Haldummulla Divisional Secretariat Division in Badulla District of Uva province of Sri lanka. This study revealed that, in the recent past improper land-use practices by humans have significantly affected how stable slopes are increasing the chances of landslide and this is much more prominent in the slopes consisting of colluvium than the slopes with residual soil. Due to the ubiquitous nature of colluvium and its distribution within many mountainous areas, the instabilities of colluvial slopes have caused considerable economic damage to human life, infrastructure, and agricultural lands. Therefore, landslides in colluvium must be evaluated to determine their underlying causes in the prospect that this information would be useful in preventing such type of future disasters.

Keywords: Colluvium, Slope failure, Paleo landslide, Residual soil, Rainfall

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Integrated multi-hazard mapping for disaster risk reduction in the Kalu river basin, Sri Lanka

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Abstract

This study focuses on the Kalu River Basin in Sri Lanka. The region prone to recurrent hazards, particularly floods and rain-induced landslides during the monsoon season. Employing an advanced Geographic Information System (GIS) approach, this research simultaneously maps and analyzes landslide and flood hazards to provide a comprehensive understanding of the risks in the area. The landslide hazard zonation map is meticulously crafted using digital elevation model (DEM)-derived data, incorporating crucial factors such as land use, drainage distance, and soil type. Concurrently, a flood inundation map is generated from DEM and is processed through ArcGIS hydrology tools, offering a detailed overview of flood-prone areas in the basin. The integration of these hazard maps results in a sophisticated multi-hazard map, a vital tool for policy-makers seeking a holistic understanding of the risks faced by the Kalu River Basin. These maps play a crucial role in the formulation of effective disaster risk reduction strategies. Identification of evacuation plans, routes, and centers becomes imperative for preparedness and response efforts. By considering all potential natural hazards in the region, policy-makers can make well-informed decisions to mitigate the impact of disasters. This study significantly contributes to the field of hazard mapping by offering an integrated approach that addresses both landslide and flood hazards concurrently. The implications extend beyond the Kalu River Basin, providing valuable insights for enhancing the resilience of similar regions facing comparable challenges.

Keywords: Landslide Hazard, Flood Hazard, Multi-hazard analysis, Disaster Risk Reduction, Policy-making

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Landslide susceptibility mapping by integrating terrain data, hydrological data: A case study at Victorian region, Australia

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Abstract

Natural hazards such as landslide, subsidence and floods in Victorian region of Australia are most pressing natural disasters in the recent past, which have been associated with intense rainfall during monsoon and inter-monsoon seasons. Among them, the occurrence of landslide is the most common disaster in the country. Rainfall is the triggering factor for landslides occurring in the Victorian region and hence, next to rainfall and slope angle, geology plays a major role in landslide and slope failure occurrences.Most of the landslides were occurred in the southern region of the Victorian volcanic plain. The area consists of steeper slopes, prominent geological features and combination of climate conditions that provide the required conditions. Apart from the rainfall triggering factor, sandstone and mudstone are the most landslide-prone rocks of the South West Victorian region in terms of geological units. A landslide susceptibility map can be used to identify the areas that are subject to landslides. GIS platforms help in the calculation and visualization of the cumulative effects of conditioning factors on landslides. Observed and collected data of the predominant landslides were plotted in maps in order to study the landslide phenomenon in detail.The features affecting such as slope, soil type and the impact of the water flow in the area are considered in further prior to the preparation of susceptibility map using GIS which is used to plot the landslide data on a 3D map. In this paper, the method of data analysis and the development of a landslide susceptibility map for the study area are explained, thus explaining the spatial distribution of landslides. This paper provides valuable information on stability conditions over the study area to identify the occurrence of landslides using the landslide susceptibility mapping method and to provide a cost and time effective method for estimating vulnerable areas in case of the future developments.

Keywords: Landslide susceptibility, mapping, landslides, triggering factors

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Occurrence of precious metal mineralization : A case study from Seruwila, Sri Lanka

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Abstract

The geological formation of the Sri Lankan basement rock is exclusively important to determine the availability of specific geological features in the subsurface. Where the main focus is on the boundary between the Highland complex and the Vijayan complex for the occurrence of precious metal (such as Ni, Cr, Co, Mn) mineralization. However, it is considered to be a mineralized zone which attracted geologist to investigate more about this boundary. Since there is some lack of investigations on the precious metal occurrence in Sri Lanka. It is important to identify the possibility of the occurrence of them at Seruwila area, Trincomalee district, Eastern province of Sri Lanka. The identification based on the geophysical and geochemical analysis of core samples obtained by the core drilling. To find out the availability of precious metals like gold, copper, necessity to reveal the geological data related to Highland-Vijayan lithological boundary with the evidences from core samples extending to few hundreds of meters in depth which has been proceeded with geochemical analyses including Inductive Coupled Plasma, X-ray diffraction method (XRD, ICP-MS) in simultaneously with thin section preparation.Further, the concentration of gold obtained by the ICP MS had some doubts. So, the researchers were expected to undergo Atomic Absorption Spectroscopy (AAS) analysis to obtain more reliable results. However, Platinum group elements (PGE) also had no considerable concentrations in the analysed set of samples. Apart from that, minerals including hornblende, clinopyroxene, orthopyroxene, garnet, biotite, pyrite were identified within the thin sections and hence, more petrographic studies with Scanning Electron microscope (SEM) photographs may deliver more details about some un-clarified minerals. According to the data analysis, it can be shown that some metallic minerals such as Ti, Fe, Na, Mg, Al, K and Ca have considerable concentrations. Also, more investigations are required to proceed in future to determine the exact possibility of precious metal mineralization at the Seruwila area.

Keywords: precious metals, lithological boundary, geochemical analysis

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Potential landslide occurrence due to the subsurface cavities in Crystalline Limestone (Marble), A case study in Matale district in Sri Lanka

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Abstract

Landslide is a natural phenomenon involving the movement of rock, soil, and debris down a slope under the force of gravity. It can have significant environmental and social impacts, leading to loss of life, property damage and disruption of infrastructure. Major factors that can trigger landslides are intense rainfall, earthquakes, rapid drawdown of ground water level, flooding and undercutting. This study aims to investigate involvement of subsurface cavities within Marble bands in the activation of landslides, studying Punchi Rattota and Dodandeniya potential landslides which were initiated 2010 and 2014. Study conducted based on visual observations, 2D resistivity imaging, Ground Penetrating Radar (GPR) surveys and borehole samples. In Punchi Rattota, highly jointed Garnet Biotite Gneiss rock is found at the crown area. Borehole data indicate cavities with 6–7meter height, filled with eroded materials (50%-60% of height) implies the influence of cavities triggering landslide. Dodandeniya, the potential landslide area exhibits thick old landslide deposits. Underline Marble layers are present at middle and lower regions. Solution cavities in the Marble layers are encountered by GPR surveys. Fine sand and mica flakes flowing out of the nearby springs connected to those cavities indicate the underground materials are being eroded away triggering landslide. There are no obvious signs of uplift in the toe area of both regions, except some cracks caused by compression, suggesting that the materials that slid down are filling the cavities below the surface. The study reveals the importance of considering Marble layers and the presence of cavities in activation of landslides. This finding will facilitate to enhance the accuracy of future landslide identification and landslide hazard mapping activities.

Keywords: Potential Landslide, Crystalline Limestone, Subsurface Cavities

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Site specific landslide risk identification: A case study on Podape landslide in Aranayaka, Kegalle district

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Abstract

The National Building Research Organisation (NBRO) is the focal point for landslide risk (LR) management in Sri Lanka, utilizing direct and indirect methods for identification of landslides. Among these, site specific landslide (SSL) investigations serve as a crucial direct approach. Aranayake is a one of landslide-prone Divisional Secretariat Divisions of Kegalle District in the Sri Lanka. Thirty high-risk houses have been decided for resettlement following a significant 2016 rockfall with debris flow in Podape. The Podape landslide reactivated in 2023, emphasizing the recurring impact in 1989 and 1996 on human habitation and future developments in the area, necessitating a focused LR reduction strategy as a debris flow.Satellite images and previous NBRO reports were studied. A drone survey and particle size distribution analysis were carried out. Geological, geomorphological, and element-at-risk (houses and other infrastructures) data were collected. Laboratory tests were performed for undisturbed soil samples to find soil parameters.The demarcated landslide on the google maps revealed affected area of 44,221 m^2 and 45,339 m^2 in 2023 and 2016, respectively. The area is underlain by biotite gneiss with four prominent joint patterns. The 2016 rockfall initiated from the bedrock and both 2016 and 2023 debris flows occurred along the North-West valley, mainly following the joint pattern of the bedrock. The identification of adjacent valleys with similar features underscores potential debris flow paths. The study concludes that the debris flow path is governed by geological features, while deposition is influences by the area's geomorphology. The necessity of demarcating the SSL risk area for the entire slope is emphasized for effective integration into LR management.

Keywords: Landslide, Landslide risk management, Risk identification

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Unpredicted landslides induced by pocket rainfall: Case study on landslides series in Kabaragala, Haldumulla

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Abstract

Landslides become one of the most devastating natural hazard during last decades in recent years. The influence of climatic changes also promotes extreme weather conditions and it leads to an increase in landslide related disasters worldwide. In Sri Lanka, the main triggering factor of landslides is rainfall and thus, forecasting and measuring the rainfall is the best approach to predict the disaster. However, as a result of climatic changes, the usual rainfall pattern has been significantly altered resulting more erratic rainfall which lead to intense rain falling to a small area. It refers as pocket rainfall and cause unforeseen damage to human lives and properties. Due to lack of raingauges installed, this rainfall is usually not recorded and thus issuing early warning become more challenging.A series of slope failures have been occurred in Kabaragala, Poonagala in Badulla district on 19th March 2023 resulting a huge damage to houses and public properties including a hospital. To study the effect of rainfall to this effect, the data from the nearest automated and manual raingauges were analyzed with typical rainfall data for 5 years back. And pre-incidents in recent known history and the influence of geological factors also contributed for this study. The findings revealed that the series of incidents have occurred in the same time with an intense rainfall for the particular location without showing pre-landslide signs. The area wasn't identified as high risk zone before and an alert or evacuation warning haven't been issued to the local community. Thus, in order to identify potential future slope failures, a thorough analysis of the entire slope area must be conducted, and the impact of heavy pocket rainfalls must be taken into account in landslide early warning and mapping methods.

Keywords: Landslides, Slope failures, Climatic changes, Intense rainfall, Pocket rainfall

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Utilizing landslide inventory mapping for an integrated analysis: Bagged Trees and Logistic Regression in assessing landslide susceptibility

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Abstract

Landslides pose significant threats to communities, necessitating advanced techniques for accurate susceptibility assessment. This research presents an integrated methodology that combines landslide inventory mapping with state-of-the-art geospatial analyses. The study unfolds in two parts; initial data exploration and manipulation in ArcPro, followed by predictive modelling using Bagged Trees and Logistic Regression in MATLAB. In ArcPro, a new project was initiated, incorporating diverse data layers such as Digital Elevation Model hillshade, and landslide-related datasets with buffers. Terrain parameters (slope, aspect, and curvature) were derived from the DEM, saved in the '.gdb' geodatabase, and further analyzed using zonal statistics for both landslide and non-landslide zones. The statistical outcomes were exported to Excel for meticulous refinement and preparation for subsequent modelling. The MATLAB environment was then employed for the execution of Bagged Trees and Logistic Regression algorithms on the refined geomorphic statistics. The models underwent rigorous evaluation through training and testing data, confusion matrices, and area under the curve (AUC) analysis. Feature importance and significance were scrutinized, leading to the removal of less pertinent variables in preparation for logistic regression. Returning to ArcPro, statistically significant variable, including standard slope was generated using focal statistics. The logistic regression equation is applied using Map Algebra, resulting in a probability map for landslide susceptibility. The final spatial representation combines the probability raster with a hillshade layer, providing a comprehensive visualization of landslide susceptibility. This research highlights the importance of integrating advanced spatial analysis techniques with landslide inventory mapping for a holistic understanding of landslide hazards and their potential impact on communities.

Keywords: Landslide susceptibility, MATLAB, Bagged Trees, Logistic Regression, Geospatial Analysis

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The deployment of drone technology for rapid data acquisition and damage assessment in landslide emergencies: A case study of major landslides reported in Sri Lanka following the second inter monsoon of 2023

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Abstract

A considerable proportion of the land and population in Sri Lanka are located in areas that are prone to landslides. Landslide susceptibility is apparent in more than half (52%) of the administrative districts, covering 30% of the land area (19,500 km²), and impacting 38% of the total population (7.6 million) in 13 out of 25 districts.The activation of the Second Inter-Monsoon of 2023 resulted in increased rainfall in certain areas of Badulla, Galle, Kegalle, Matara, and Ratnapura districts. Additionally, these areas received more than 100 updates regarding landslide early warnings. As a result of intense rains, five severe landslides occurred in the districts of Badulla, Kegalle, Matara, and Ratnapura, causing extensive destruction to property, agricultural land, and infrastructure and resulting in four fatalities. Hence, it is imperative to promptly evaluate the extent of the damage caused by these landslides. This study evaluated the extent of the damage caused by the landslides using rapid evaluation methods. Drone technology was utilized to undertake comprehensive field surveys at each landslide in order to accurately measure the extent of damage to property, agricultural land, and infrastructure. This rapid assessment indicates that the total gross damage and loss across all sectors amounts to LKR 160.1 million. The rapid evaluation of the destruction will provide accurate calculations of both the financial losses suffered and the essential initial investments required for the post-landslide recovery efforts following the landslide.

Keywords: Landslide, Damage Assessment, Landslide Early Warning and Second Inter Monsoon

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Analytical study of the effectiveness of horizontal drains for slope stability based on forecasted rainfall intensity in the Kandy municipal region

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Abstract

Natural or manmade slope failures in tropical regions of the world are frequently occurs mainly due to excessive rainfall. Heavy infiltration causes increase of perched water level and rise of ground water table. Most of the mountain slopes in Kandy region consist of unsaturated residual soil formation. When rainwater infiltration occurs the shear strength between soil particles is reduced due to the build-up of pore water pressure.This research aims to use transient seepage analysis to determine the effect of subsurface horizontal gravity drains reduced the groundwater table and increase numerical modeling was conducted to determine the effect of seepage and slope stability on soil using a coupled program based on the Finite element method (FEM) and Limit equilibrium method (LEM) with SEEP/W and SLOPE/W programs respectively.Typical soil-water characteristic curves and permeability functions of the soil were used in performing seepage analyses of water flow through unsaturated soil slope.Two scenarios were carried out by varying the rainfall parameters with and without subsurface drains. The results showed that horizontal drain can increase the safety factor during uniform rain modeled for 5 days. Results of slope stability analyses indicate regards on the length, inclined angle and location of the horizontal drain installed in the slope.

Keywords: Slope failures, Rainfall, Residual soil, Pore water pressure, Horizontal drains

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Case study on stabilization of unstable slope and rectification measures of damaged building due to slope instability adjacent to the National Institute of Fundamental Studies (NIFS) at Kandy

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Abstract

Followed by a complaint lodged by National Institute of Fundamental Studies, Kandy regarding a severe crack along the joint of the newly added part of the auditorium separated from the main building towards the slope. It was revealed that, the damaged building has been constructed at the crest of a steep slope with an inclination of 48^0 towards South West direction which is currently at a possibility of slope movement, if the prevailing situation is allowed to keep as it is. At the intermediate region of the same slope several households have been set up further accelerating the slope instability. In order to get rid of the problem, both geotechnical and structural engineering solutions were required to be adapted to eliminate the risk prevailed. Based on the results of engineering geological assessments, geotechnical investigation and structural analysis of the existing building, reinforcement with soil nailing and grid beams, drainage improvements with cut off drains, cascade drains, and subsurface directional gravity drains (Horizontal drains), structural retrofitting for existing columns and beams were applied successfully. However, to check the effectiveness of mitigation measures applied, further post monitoring activities may be required.

Keywords: Slope Stability, Soil Nailing, Grid Beams, Structural Retrofitting

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Evaluation of prediction power of road slope risk assessment for its improvement: A case studies from the Kagalle - Bulathkohupitiya & Passara - Bibile roads, Sri Lanka

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Abstract

The current practice of road construction and widening process over the mountainous area of Sri Lanka causes frequent cutting failures, and landslides induced by them resulting in frequent road closures, property damages, and tragic loss of lives, causing socio-economic issues. In order to address the need for identifying the risks associated with the failure of road cuts, an overall road slope risk assessment method which was previously developed, still requires its further improvements. This case study focuses on determining its degree of accuracy with regard to its prediction power. The study focuses on the applicability of the checklist already developed by the National Building Research Organisation, which was applied to the Kagalle-Bulathkohupitiya and Passara-Bibila main roads as case studies. To assess the prediction power of the checklist, the pre and post-failure situations were assessed, and the main criteria that need to be considered for improvements of the checklist were identified based on the observations. It was emphasized that the prediction power of the checklist developed was ranged from 30%-40% which may be due to the lack of incorporation of most critical factors which actually caused cut slope failure into the risk assessment model. During the case study, it was reviewed that fine-tuning of scoring shall be further done by considering the pattern of inconsistency, degree of weathering, and prevailing drainage condition apart from the current criteria considered. It is suggested to add relative weightages representing actual driving components. Additionally, the study recommends conducting post-failure assessments on roads located in diverse terrain conditions, encompassing variations in geology, soil composition, morphology, and climatological conditions.

Keywords: Road slope failure, Risk assessment

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Evaluation of USDA taxonomy through geotechnical investigation – A case study at the Nallathanniya site

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Abstract

The use of the United States Department of Agriculture (USDA) texture triangle for classifying soil is indeed crucial in both the agricultural and geotechnical engineering sectors. The texture triangle helps in understanding the composition of soil based on the relative proportions of sand, silt, and clay. This classification is valuable in predicting various soil properties, such as water retention, drainage, and nutrient availability, in the context of agriculture. It was explored the suitability of applying the USDA taxonomy to a soil nailing site in Sri Lanka which is a common method for stabilizing cut slope failures, and it involves reinforcing the soil with nails or bars to enhance the integrity of unstable soil mass. The key point of concern is the assumption of an even distribution of soil design parameters throughout the entire mitigation region. Practical scenarios may deviate from these assumptions, and it becomes essential to evaluate the soil taxonomy on-site to tailor the mitigation measures accurately for different regions. This research involves conducting specific geotechnical laboratory tests to assess the soil properties in the soil nailing site. Aiming to bridge the gap between assumed design parameters and the actual site conditions. Enabling a more precise and effective design for soil nailing in different regions of the mitigation site. This research contributes to enhancing of the reliability and efficiency of soil nailing projects in Sri Lanka by addressing the variability of soil conditions and optimizing the design parameters accordingly.

Keywords: Texture triangle, USDA, Cut slope, Soil nailing, Design

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Experimental study on the shearing behavior of soil using Ring Shear tests

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Abstract

Understanding the shearing behavior of soil in landslide prone areas is important to study rapid and long-traveling landslides. However, the studies on residual shear strength of soils are very limited in Sri Lanka. Undrained ring shear apparatus is the major tool used in the analysis of residual shear strength of soil. For this study, soil samples were taken from Athwelthota landslide area. The shearing behavior of soil samples were examined extensively by performing ring shear tests on the soil samples containing different fine contents. By performing the tests at different initial void ratios, the shear behaviour of the soils at different initial void ratios was presented and discussed. It was also found that peak and steady-state shear strengths decreased when the fine content increased, resulting a higher brittleness index. The shear behavior of soil under different effective normal stress conditions was observed. The results showed that a small cohesion was exhibited at low effective normal stress conditions and the mobilized friction angle became constant at higher normal stresses. For fine-grained soils undrained monotonic shear-stress control ring shear tests were conducted to study the influence of void ratio on the shearing behaviour. Monitoring the pore water pressure during the shearing shows an increase with shear displacement. A significant reduction in the shear strength could result from the shear failure due to the buildup of excess pore-water pressure within the shear zone. The specimen confined under identical stress conditions generated higher excess pore water pressure within the shear zone when the fine content became higher.

Keywords: Ring shear test, shear strength, fine content

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Landslide mitigation measures on Colluvium/talus soil : Case study of design and construction of Kadugannawa at Colombo-Kandy road (A1), between culvert 98/4 and 99/1

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Abstract

The landslide prone slopes in Sri Lanka are formed by residual and colluvial soil types. A Kadugannawa slowly moving landslide occurred contain the colluvial/talus mass disrupting the traffic on Kandy-Colombo main road which is located adjacent to a major highway. Landslide affected slope segment being a very narrow road corridor, the only available option was to ensure the road safety by stabilizing unstable slopes since it directly makes significant impacts on country's economic since. Six cross sections were analyzed at the failure location, using soil profiles derived from seismic surveys and bore-hole investigations. Soil shear strength parameterswere obtained according to Standard Penetration Test. Based on the geomorphology, two cross sections were selected as the most critical sections. Back analysis indicated that the lower part of the cross section is the critical failure surface as the Factor of Safety (FoS) was 0.8. As it had lower soil parameters than similar of the usual colluvial mass, the zone was identified as comprised of debris and a slow moving-rotational slides. Stability analysis was conducted for the debris section and two rectification measures that are soil nailing with sub surface and a gravity wall were proposed. With the designed mitigation measures FoS became increased to 1.4. Drainage improvement measures were proposed to minimize impact from storm water. During the half completion of the construction, difficulties in deep slope excavations were experienced and additional shoring method was adapted to avoid the construction difficulties. No indication of an active landslides reported in the locations after the completion of construction.

Keywords: Colluvial soil, Slope stability, Soil nailing, Gravity wall, Factor of Safety

02

Innovations in Resilient Buildings

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Development of pervious concrete for landslide protection using recycled concrete aggregates

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Abstract

At present, different types of research and development works are conducted to control surface water runoff and infiltration on steep terrains as novel techniques for slope protection. Shotcreting is a popular solution to stabilize slopes, however covering large area of land with concrete significantly increases surface water runoff and minimizes the rainwater infiltration. On the other hand, thick vegetation on slopes may result in very low surface water runoff but significantly high rainwater infiltration. Therefore, a study was conducted to develop a medium that can control surface water and water infiltration toward slope protection. Furthermore, with the abundance of concrete materials on earth, research into recycling of concrete has become a popular theme in the construction industry. Therefore, this study focuses on applying recycled concrete to develop a slope protection medium called porous/pervious concrete. By vegetating the surface of pervious concrete, the medium can achieve several other benefits in controlling surface water runoff and infiltration. Therefore, in this research laboratory tests were conducted to identify physical and mechanical parameters of recycled aggregates. Based on test results, pervious concrete mix design was formulated and test samples were prepared to identify the compressive and flexural properties. The average compressive strength of 6.15 MPa and average flexural strength of 1.49 MPa were obtained for the formulated mix design as per the British standard test methods. Considering the physical and mechanical parameters and based on the literature, this type of pervious concrete is suitable for applications such as ground covering or paving. Further study was extended towards identifying a grass type that can be recommended to endure the high alkaline property of pervious concrete.

Keywords: Pervious concrete, Recycled aggregate, Vegetation

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Industrial development for determination of moisture vapor transmission rate of different cementitious waterproofing materials

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Abstract

The primary objective of the study was to assess the water vapor transmission rate (WVTR) of various construction materials, specifically waterproofing slurries, utilizing the cup method as outlined in the ASTM E96 standard. This method independently measured water vapor transmission while accounting for the influences of temperature and relative humidity. The investigation revealed that materials with higher WVTR values demonstrated increased permeability to water vapor. However, the study acknowledged exceptions and challenges, such as the suitability of materials for specific applications and the potential for WVTR values to fluctuate over time due to aging or environmental factors. The cup method has been shown to be a reliable and consistent way to assess WVTR in a variety of building materials. It employed a load cell balance for precise weight measurements, particularly effective in high relative humidity conditions. The research strongly recommended the integration of WVTR testing into standard construction material testing procedures to enhance the overall quality control in the industry. In the context of cementitious waterproofing slurries, the study specifically examined Sample Material A, B, C, and D, proposing a WVTR range of 0.1 to 10 gm-2day-1. Notably, Sample Material B and Sample Material D fell within this range, prompting a suggestion for further laboratory comparisons to validate the method's efficacy. The study concluded by advocating for the inclusion of WVTR testing in standard procedures and emphasizing the imperative of accurate measurement tools to ensure the reliability of experiments conducted, especially in highly humid conditions. This comprehensive research contributes valuable insights to the field of construction material testing, laying the foundation for enhanced industry standards and practices.

Keywords: ASTM E 96, WVTR, Waterproofing, Cup method, Relative Humidity

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Introducing locally produced ISO standard sand for cement testing

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Abstract

ISO standard sand is a siliceous natural material used in testing laboratories in government institutes and cement manufacturers for the testing of cement. Due to the prevailing economic crisis, testing laboratories in government institutes and cement manufacturers face difficulties in importing standard sand. Hence, this study was initiated to investigate the feasibility of producing ISO standard sand using locally available material. According to the previous study, one type of standard sand type is required for quality testing in all testing laboratories to maintain the quality of cement testing. Further, the production of ISO standard sand from locally available silica sources has been demonstrated successfully, as indicated by the test results of the inter-laboratory comparison of locally produced ISO standard sand. This study was conducted to establish the production process of standard sand using local sources to meet the local demand. The market survey conducted indicates that approximately 40,000 packets of standard sand were used by testing laboratories in 2021. Initially, the production process was implemented to minimize the production delays and reduce the raw material wastage. Some additional processes were incorporated into the production line to improve raw material quality. In the initial stage, production was started using the available machinery. To meet the local demand for standard sand, certain processes were integrated into the design of the machinery. The entire production process is subjected to rigorous quality control procedures, starting from the selection of raw materials to the client's order processing stage. Among the quality parameters outlined in the ISO 679 standard for standard sand, particle size distribution stands out as a crucial property. The production of ISO standard sand using local sources was carried out in strict compliance with the quality procedures specified in ISO 679 to meet the demand in Sri Lanka.

Keywords: Standard sand, Quality control, Silica

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Investigation to estimate the degraded quality of in-situ concrete structures in government-owned buildings in Sri Lanka

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Abstract

The quality of in-situ concrete structures is crucial for ensuring safety, durability, and functionality throughout their service life. It is influenced by several factors, including material quality, curing, reinforcement positioning and workmanship. Reinforced concrete(RC) is widely used in construction for a variety of structures. However, various degradation mechanisms affect RCs, such as rebar corrosion, chemical attack, Alkali-Aggregate reaction, freeze-thaw degradation, and delayed ettringite formation. Due to the high humidity and salt content in the air in both coastal and inland regions, embedded rebar corrosion and concrete carbonation are key issues observed in Sri Lanka. The Building Material Research and Testing Division of NBRO conducts numerous field tests to ensure the quality of materials used in both existing and recently constructed reinforced concrete structures. This study focuses on the government-owned concrete structures that were investigated by the NBRO using non-destructive and destructive(NDT/DT) testing since 2021. Core sampling, rebound hammer testing, ultrasonic pulse velocity measurement, half-cell potential analysis, resistivity assessment, chloride content examination, and carbonation depth determination were analyzed, covering 30 government-owned building investigations. According to the study, most concrete structures show a higher degradation rate with respect to their age. This is often due to insufficient concrete cover, the use of poor-quality materials, improper construction techniques and a lack of quality control during the construction process. These factors result in lower-quality construction with a higher rate of degradation.

Keywords: Degradation, Reinforced Concrete, Non-destructive & Destructive testing

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Manufacturing of stupa clay bricks for restoration of Deeghavapiya stupa in Sri Lanka

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Abstract

Clay brick is commonly used brick type for historical buildings and structures in Sri Lanka. Relatively large bricks were used for ancient stupa construction and brick size was altered based on the construction era, as well as architectural and structural aspects of the stupa. Focusing on the restoration works of the Deeghavapiya stupa, production was established for stupa clay bricks belongs to two strength categories. Type 1 for the square chamber and star wall of the stupa and type 2 for outer wall construction. The Stupa clay brick production process consists of quality testing of soil, controlling production parameters and quality testing of burnt bricks. The manufacturing phases of stupa clay brick production differ from conventional engineering clay brick production process due to the dimensional changes and quantity requirement. Dimensions of the manufactured stupa clay bricks are 400mm x 400mm x 50mm. The production process is managed under raw material preparation, forming, drying and firing stages. During the selection process overheated and unburned bricks are removed and then representative samples are selected as per the SLS 2 standard. Corresponding lots are tested for quality assurance and categorization, which is based on average wet compressive strength. Type 1 is identified as strength greater than 8.0N/mm2 and Type 2 is defined as strength lies in the range of 6.5N/mm2 - 8.0N/mm2. Water absorption of both categories was maintained below 18% and the average flatness of 400mm x 400mm faces was maintained below 0.65%, as per the specified requirements. The Stupa, being a massive brick structure, demands a considerable quantity of bricks and the stupa clay brick requirement is satisfied by two production plants to fulfill the continual supply for restoration works while adhering to quality control procedures.

Keywords: Stupa clay bricks, Deeghavapiya Stupa, Restoration, Manufacture, Quality

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Review on factors affecting early age strength development of cement

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Abstract

Temperature and humidity conditions of the environment and the test specimen play a vital role in the strength development of cement-based products as per findings of several research studies. Higher initial curing temperature has the capability to accelerate hydration reactions while contributing to improving the early strength of test specimens. However, microstructural analysis of test pieces showed the diffusion of hydrated products (ettringite, calcium silicate hydrate, calcium hydroxide, etc) on nearby locations to the point of reaction which reduces the strength development at a later age due to lack of space for more hydrated products as a result of accelerated hydration reaction. The strength development of cement-based specimens is significantly affected by different temperature conditions. Below 5°C, the early strength development is significantly retarded, and temperature varies in the range of 5–10°C are poor curing conditions for the development of early strength. The ambient temperature that ranged from 15-250C is to be the most suitable for strength development because that temperature range showed good early and later strength. Further to proceed the hydration reaction, relative humidity should be greater than 80% and if not cement particles stop hydration. The relative humidity of the test specimen decreases due to water consumption for cement hydration reaction and surface water evaporation. Water consumption for hydration is relatively much lower than that of surface evaporation. Therefore, it is important to minimize surface water evaporation to better strength development. Accordingly, the cement hydration process, namely the strength growth process, is seriously affected by both temperature and humidity conditions.

Keywords: Strength, Temperature, Humidity, Cement

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A comprehensive study on defects in school buildings in Sri Lanka for enhanced construction standards

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Abstract

The built environment of a school plays a pivotal role in shaping the educational experience for students, educators, and the community at large. Despite a notable allocation of 11.3% of the total government expenditure to education in 2018, with 2.1% of the gross domestic product dedicated to the same cause (The World Bank, 2018), the absence of the expected quality of construction of school buildings in Sri Lanka remains a critical concern. Recognizing this urgency, the National Building Research Organization (NBRO) has undertaken the task of identifying common defects in order to identify the underline causes for depreciating quality of school buildings. The study leveraged case study reports obtained from the National Building Research Organization (NBRO), encompassing 58 buildings across 22 schools. The data collection involved visual observations and a combination of destructive and non-destructive testing techniques. The obtained data were then meticulously summarized, documented, and analysed using statistical methods to categorize identified defects. This analytical approach aimed to categorize and prioritize the identified defects based on their location and severity and facilitated the identification of the most frequent reasons for defects in completed school buildings. The utilization of statistical analysis added a quantitative dimension to the findings, providing a robust foundation for identifying the most common and critical defects in school buildings. The outcomes of this methodological approach contribute valuable insights into the construction quality of school buildings in Sri Lanka. By identifying and prioritizing common defects, the study provides a basis for minimizing or eliminating these issues in future construction projects. Insights gained from this completed research contribute valuable information for the formulation of targeted construction guidelines for school buildings in Sri Lanka, aligning with the evolving needs of the Sri Lankan education system.

Keywords: School building, Construction quality, Defect analysis, Visual Observations, Destructive and Non-destructive testing

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A tool to appraise retrofitting proposals to enhance wind and seismic performance of defective buildings

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Abstract

The common practice of appraising buildings in Sri Lanka is to compare the buildings with design codes. The buildings are considered defective if they contradict the design guidelines. The remedial measures are either retrofitting to enhance their load-carrying capacity to comply with the design codes or demolishing to ensure the people's and neighboring buildings' safety. However, the code-based evaluation of buildings does not indicate the level of risk involved with defective buildings and the degree of safety enhancement after retrofitting because design codes usually evaluate serviceability and ultimate limit state building performances. Still, the degree of defectiveness can vary widely, and as remedial measures, retrofitting proposals can be prepared to achieve various desired safety levels, none of which can be reflected by code-based appraisals. This study proposed a tool based on performance-based building design principles to estimate the severity of building defects and appraise the effectiveness of retrofitting proposals. The tool follows performance-based wind and seismic design guidelines and performance objective matrices and uses linear elastic analysis, non-linear static pushover analysis, non-linear dynamic time-history analysis, incremental dynamic analysis, and fragility assessment. The tool's workflow is demonstrated by analyzing a defective building and its retrofitting proposal. The proposed tool revealed that the building does not have adequate load carrying capacities. Its wind-induced base shear for the design return period exceeded the ultimate non-linear base shear capacity. The building is likely to exceed the operational, life-safe, and near-collapse damage limit states during seismic events within the specified return periods. Although the retrofitting proposal substantially enhanced the overall structural performance of the defective building, the retrofitted building did not meet the anticipated performance objectives and thus required further revisions. This study, therefore, showcases the potential of the proposed tool in estimating the danger involved with poorly designed and constructed buildings and appraising the effectiveness of retrofitting proposals.

Keywords: Existing buildings, building retrofitting, pushover analysis, time-history analysis, fragility assessment

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Analysis of existing repair and retrofitting techniques for defects due to corrosion in reinforced concrete buildings in Sri Lanka

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Abstract

Existing buildings are salient due to numerous reasons including resilience and stability, cultural heritage, adaptive reuse possibilities, sustainability concerns, and economical benefits. However, building defects are complementary with existing buildings due to age, inadequate maintenance of buildings, weak construction practices, and the quality of the used building materials. Corrosion is amongst the primary deterioration mechanisms observed in reinforced concrete buildings. Hence, repair and retrofitting techniques adapted to rectify the damages due to corrosion attract a vital importance. Currently, there are various techniques that are being followed to provide solutions to the defects observed in various building elements due to corrosion. However, absence of a properly established guideline to distinguish the most appropriate technique based on the type and scale of the subsequent damage due to corrosion is problematic. Hence, this study aims to conduct a comprehensive analysis of the repair and retrofitting techniques to address subsequent damages due to corrosion. A qualitative and quantitative comparison has been executed to provide in-depth insights on the currently employed techniques, types of defects encountered, adaptability and effectiveness of these techniques, and constraints associated. The study highlights the importance of considering the aspects of cost, location of the building, building usage, type of materials utilized for defect repair and their availability, and severity of the damage, when selecting the optimum viable defect rectification technique.

Keywords: Corrosion, Existing Reinforced Concrete Building, Repair and Retrofitting Techniques

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Behavior of damaged reinforced rubberized concrete beams strengthen with Carbon fiber reinforced polymers

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Abstract

For the scarcity of natural aggregates and the discharge of rubber waste in bulk volumes into the natural environment, developing rubberized concrete (RuC) for structural applications is an excellent solution. With the successful applications of rubberized concrete in structural elements, it is important to explore successful alternatives for restoration in case of deficiencies met in their service life. This study investigates the flexure behaviour of damaged reinforced rubberized concrete beams strengthened with Carbon Fiber Reinforced Polymer (CFRP) fabric. The average measured 28 days compressive strength of rubberized and normal concrete was 40.54 MPa and 51.7 MPa, respectively. A total of four medium-scale non-strengthened reinforced RuC beams, and a normal concrete beam were preloaded until a 0.3 mm crack occurs. Then the damaged beams were strengthened using CFRP with and without polymer anchors at the ends of bonded fabric. Four-point bending test was conducted subsequent application of cyclic load with the amplitude of 50% and 75% of the ultimate load. The beams were considered as simply supported with a clear span of 1500 mm. CFRP-strengthened reinforced rubberized concrete beams could reach a 53% higher load with 61% less displacement until a 0.3 mm crack occurs than non-strengthened reinforced RuC beams. It was found that the U-wrap end anchorage system increased the ultimate load by 5% than without end anchorage, delaying the debonding of CFRP fabric. CFRP-strengthened reinforced RuC also exhibited a similar load-deflection curve as strengthened normal concrete beams. The strengthened RuC beams using CFRP could reach the required strength enhancement similar to reinforced concrete beams. Overall, the experimental results exhibited the feasibility of strengthening rubberized concrete beams in structural applications with CFRP fabric.

Keywords: Rubberized concrete, Damaged concrete beams, Cyclic load response, Flexural strength, CFRP

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Crack damage assessment of low-rise masonry buildings: A comprehensive literature review with a focus on the Sri Lankan context

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Abstract

Masonry houses, renowned for their durability and aesthetic appeal, face a persistent challenge in the form of cracks, necessitating a systematic approach for prioritizing repairs. This study focuses on low-rise and load-bearing masonry structures, aiming to investigate crack damages comprehensively by considering both structural and functional aspects. Recognizing the absence of an agreement in assessing crack damages, the study introduces a novel prioritization matrix that addresses severity and safety concerns. Drawing on a database surrounded over 300 instances of cracks in approximately 70 houses from specific regions, this research explores key factors influencing severity and safety. Severity considerations include crack length, width, and separation level, while safety factors encompass shifting of walls, signs of collapse, crack location, propagation, and frequency. The crack prioritization system is based on preliminary analyses derived from past literature and field surveys. Notably, the analysis underscores the significance of crack width as a critical indicator, surpassing mere length, signifying higher stress and potential wall movement. External surface cracks are identified as having more significant implications over time than internal surface cracks. Critical locations such as wall corners, foundations, and lintels pose greater safety risks, while cracks near openings compromise the load-bearing capacity of the affected wall area. Additionally, the depth of cracks penetrating beyond plaster is highlighted as a key indicator of underlying stresses and force alignment. To construct a data-driven prioritization matrix, the study employs the Analytical Hierarchy Process, utilizing real-world data to assign reliable weightage to each parameter through pairwise comparisons. This matrix will assign scores to individual cracks based on contributing factors, empowering engineers, and homeowners to efficiently prioritize repair efforts and allocate resources based on potential risk. The proposed approach integrates advanced analytical techniques with practical insights to enhance decision-making in addressing crack damages in masonry houses.

Keywords: Masonry Cracks, Ranking Matrix, Severity and Safety, Analytical Hierarchy Process

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Development of a damage assessment matrix based on the severity of cracks

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Abstract

Cracks in masonry structures can compromise their structural stability and operational effectiveness. These cracks can emerge due to multiple factors, including poor craftsmanship, excessive loads, thermal shifts, reinforcement corrosion, design flaws, soil-related issues, and inadequate maintenance. Their presence can elevate structural stress, potentially leading to component failure or even structural collapse. Consequently, conducting a thorough damage assessment based on crack severity becomes imperative to ensure occupant safety, preserve property value, and uphold the integrity of our constructed environment. To address this necessity, this research aimed to devise a damage assessment matrix by considering crack severity to gauge the risk level associated with masonry buildings. Data was gathered from 69 affected masonry houses in Higurkgoda, Sri Lanka, identifying key parameters indicative of crack severity. The significance of these parameters in relation to crack severity was evaluated using the Analytical Hierarchy Process with the collected data. Subsequently, a damage assessment matrix was formulated based on these key parameters. Within this study, crack width and the nature of the crack (whether it's structural or non-structural) were identified as pivotal indicators of crack severity. This developed matrix assigns a value representing the severity level of a crack based on its width and nature. This matrix aids in determining the risk level of a masonry building by assessing the severity of all cracks in the structure, considering their width and nature. Considering that damages observed in Higurakgoda houses stem from expansive soil, this damage assessment matrix serves a practical purpose in evaluating damages in masonry buildings caused by such soil characteristics. By offering a method to quantify damage extent, predict potential risks, and facilitate timely corrective measures, this matrix proves invaluable in averting catastrophic incidents and reducing structural damage in masonry constructions.

Keywords: Crack Severity, Masonry Buildings, Expansive soil, Damage assessment, Crack Width, Structural cracks

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Fire-related damage assessment of low-rise buildings : A literature review

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Abstract

Low-rise buildings, common in urban and suburban areas, serve various purposes like housing, businesses and institutions. Despite their versatility, these structures are prone to fires, posing a significant risk. Importantly, these incidents extend beyond property damage, threatening life safety in various stages of fire. This risk leads to numerous casualties each year, emphasizing the critical need for effective fire safety measures in low-rise buildings to minimize devastating consequences. Research studies on assessing fire damage in buildings have been carried out both globally and in Sri Lanka, but there remains a distinct lack of focus on low-rise buildings in particular. This gap in research underscores the importance of addressing fire safety in low-rise structures specifically, given the unique challenges they pose. Existing studies have explored both personal characteristics and structure-related features; however, the majority have primarily concentrated on either one of these aspects, considering buildings of various types, rather than specifically focusing on low-rise structures. In the existing literature, gender stands out as the predominant high-impact factor among personal characteristics, with age also playing a significant role in fire safety. Meanwhile, research on factors such as income and education level reveals conflicting results across studies conducted in various countries. In terms of structure-related characteristics, the adherence of building plans to fire regulations and the implementation of correct construction practices show a more pronounced impact in minimizing fire damage while existing literature suggests that factors such as building height and floor area do not have a significant influence on fire risk. Active and passive fire prevention measures, widely examined in the literature, have demonstrated considerable impact, but their ranking has diverged due to the subjectivity of stakeholders involved in the conducted researches. Hence, considering country-specific contexts is crucial for resolving conflicts in outcomes of fire damage assessment studies.

Keywords: Fire resistance, Fire damage assessment, Residential fire safety, Building safety, Risk mitigation

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Investigation of drying shrinkage behaviour of concrete with composite cements

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Abstract

Understanding and exploring how concrete behaves during the drying process is crucial for ensuring the overall performance and long-term durability of concrete structures. Shrinkage-induced cracking, a common consequence of drying, can not only raise aesthetic concerns but also lead to functional limitations. The drying shrinkage of concrete is influenced by various factors, with the type of cement playing a significant role in determining this behaviour. This study specifically delves into the drying shrinkage behaviour of grade 30 concrete, examining two different cement types: Ordinary Portland Cement (OPC) and fly ash blended cement. Additionally, the research seeks to validate the shrinkage model outlined in Euro Code 2 (EC2) for local materials and conditions. The mix proportions for grade 30 concrete were determined through a BRE mix design, and tests such as slump tests and compressive strength tests were conducted to ensure the suitability of the concrete mix. Drying shrinkage tests utilized moulds measuring 75 mm × 75 mm × 280 mm, with specimens subjected to 3 and 7 days of curing before drying in normal room conditions. A laser transducer facilitated the daily measurement of shrinkage values over a 45-day period. According to the obtained results, corresponding drying shrinkage in concrete with fly ash blended cement showed low values compared to that of concrete containing 100% OPC. When comparing the values obtained from the drying shrinkage equation in EC2 with experimental values, up to about 17 days equation values underestimated the drying shrinkage in concrete and after 17 days equation values tend to overestimate the drying shrinkage in concrete. Since the EC2 equation is not applicable under local scenarios, suitable modifications need to be done for the equations before using it.

Keywords: Drying Shrinkage, Composite Cement, Fly ash blended cement, Ordinary Portland Cement (OPC)

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Mitigating concerns and implementing solutions for impact of adjacent construction on neighboring properties

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Abstract

Construction of buildings in close proximity to existing properties imposes difficult challenges due to damage caused to neighboring structures through construction activities. This adjacent construction intensifies with growing scarcity of land, population surge, and rapid urbanization. Most of the construction projects in urban areas seem to neglect the repercussions on neighboring structures, that may be resulting harmful vibration, swaying, tilting, ground settlement, and cracks in structures. It is therefore necessary to communicate with owners of adjacent properties to evaluate risks, carry out pre-condition assessment, and develop mitigation measures prior to starting of construction activities. The article underscores the necessity of pre – crack surveys, intermediate crack surveys, post- crack surveys conducted at strategic intervals to access the impacts. These surveys will support the development of suitable construction methodologies aimed at mitigating risks. In spite of legal precedence addressing losses from adjacent constructions, prevailing regulations and preventive procedures seemed inadequate. Through some case studies, this paper scrutinizes adverse effects of adjacent construction and proposes practical solutions. It further describes the significance of post-construction surveys, through evaluation of construction effects and potential risks, and the meticulous sequencing of construction processes. The recommended sequence aims at guiding skilled individuals with the guidance of professionals in conducting exhaustive assessments, providing a mechanism for societal benefit and aiding local government authorities. This systematic approach seeks to avert unnecessary demolition, minimize the need for relocation, and optimize resource utilization in construction endeavors, thereby contributing to sustainable urban development.

Keywords: Adjacent construction, Development of construction methodologies, Prevailing regulations, Preventive procedures

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Structural stability evaluation: Thalalla North college building stability assessment by NBRO

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Abstract

This case study was conducted to comprehensively evaluate the structural stability of a three-storey reinforced concrete frame structure at Thalalla North College in Matara. The study focused on identifying inadequacies in the strength of the building. The aim was to provide recommendations for restoration and to offer guidance for addressing similar issues in reinforced concrete frame structures. The methodology involved extensive material tests, advanced software-based structural analyses, and visual observation. The results revealed major issues with columns and slabs, including inadequate concrete strength and corrosion damage. It was also found that the building may be sensitive to shaking from a seismic event due to inadequate strength of masonry infill in one direction. The study concluded that strategic interventions such as concrete jacketing for columns, carbon fiber reinforced plastic, and the installation of universal steel beams for beams could restore the stability of the structure without the need for demolition. The implications of this study provide valuable guidance for addressing similar issues in reinforced concrete frame structures.

Keywords: Structural stability, Reinforced concrete frame structure, Material testing, Restoration techniques

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The implications of adopting Eurocodes with National Annexes for the National Building Code of Sri Lanka

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Abstract

Until now, the building design practice in Sri Lanka has relied on international codes and standards. British Standards are the most widely used standards for structural design in Sri Lanka, despite the Eurocodes superseded them in early 2000. Both British Standards and Eurocodes are prescriptive by assuming that the intended building performance is to meet the minimum requirements set in design codes. As a result, design codes do not evaluate the structural performance in disasters using performance objectives. By identifying this shortcoming, the upcoming Sri Lankan Building Code proposes resilience-based approaches, which set forth performance-based designs with performance objectives. Until that happens, the Sri Lankan construction industry must use international design codes and standards without knowing that the degree of disaster resilience is explicitly implemented. Therefore, this paper proposes a novel framework to evaluate the degree of disaster resilience of code-based building designs by demonstrating its workflow through an analysis of a typical three-story building designed according to Eurocodes. The building performance against wind loading was evaluated using Non-linear Static Pushover Analysis and a wind performance objective matrix. The seismic performance of the building was assessed by conducting a Non-linear Dynamic Time History Analysis and Incremental Dynamic Analysis, combined with a fragility assessment based on a seismic performance objective matrix. The results revealed that the Eurocode-based building design has a base shear capacity significantly larger than that induced by wind loading with a 1700-year return period. Compared to the wind load, the base shear induced by seismic loading with a 949-year return period is considerably larger, but it still does not exceed any performance criteria. This study, therefore, indicates the adequacy of Eurocodes to design low-rise buildings similar to the typical building with disaster-resilient qualities.

Keywords: Building codes, Eurocodes, Pushover analysis, Time-history analysis, Fragility assessment

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Unravelling the effects of expansive soil on masonry house construction: An in-depth review

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Abstract

The swelling and shrinkage of certain soils, a common occurrence known as expansive soil, have posed significant challenges to lightweight structures such as masonry houses and small masonry structures for many years. Soils with montmorillonite as the primary mineral tend to undergo noticeable changes in volume when they go through wet and dry cycles. The extent of these changes depends on factors such as the amount of clay minerals present, their interchangeable ions and the soil's internal substructure. Building on expansive soils frequently leads to the problems like tilting, settling, and cracking of masonry house, foundation and walls. Utility lines, doors, and windows can also be damaged. To understand the behaviour of expansive soil and predict potential damage, various studies have been conducted. A considerable amount of literature exists to categorize the types and extent of distress caused by expansive soil. Additionally, there are suggested remedial measures to counteract the swelling pressure. This paper reviews current research on different types of discomfort brought on by expanding soil, the level of masonry construction cracking damage, and proposed solutions. It also addresses considerations for selecting appropriate measures to deal with expansive soils. Understanding the behaviour of expansive soil and having effective strategies to mitigate potential damage is crucial for ensuring the longevity and stability of masonry structures built on such soil types. By examining the available literature and research findings, this paper aims to contribute to the body of knowledge on expansive soil and the steps that may be taken to reduce its adverse effects on masonry house.

Keywords: Expansive soil, masonry house, adverse effect, foundation and walls

03

Empowering Communities for Resilient Settlements

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A call to action for landslide-resilient schools in Sri Lanka - The current status of landslide risk for educational infrastructures in landslide-prone areas

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Abstract

Landslides in the central highlands of Sri Lanka have become an essential factor threatening human settlements, a pressing environmental issue, impacting numerous buildings, including schools. In response, the National Building Research Organisation (NBRO) initiated the "Landslide Risk Profile Development" project from 2016 to 2022. Main objective of this project is to develop comprehensive landslide risk profiles at the divisional secretariat level across ten district prone to landslide. Additionally, the project develop a spatial database of communities at risk. The research paper highlighted the pressing need for relevant authorities to promptly design and implement comprehensive awareness programs. Using a structured questionnaire, the survey, conducted by Grama Niladhari Officers, focused on identifying exposure levels of different building types in landslide-prone districts and utilizing the NBRO's landslide hazard zonation map, the study concentrates on the status of school buildings and emphasizes the role of education awareness in mitigating landslide impacts. The findings reveal 261 schools across 10 districts with high landslide susceptibility, with Badulla (37%) and Nuwara Eliya (29%) districts having the highest number of high-hazard schools. The schools are categorized into daycare centers, pre-schools, primary schools, secondary schools, religious education institutes (Pirivena), and special schools for individuals with disabilities. The total student population at risk is 77,033, with secondary schools having the highest enrolment. Notably, special schools for individuals with disabilities accommodate 156 students, while 46 children in daycare centers and 1,099 in pre-schools are identified as high-risk. These programs should be address the specific vulnerabilities of children at various developmental stages, aiming to effectively safeguard them from the potential risks posed by landslide incidents. Emphasizing the critical role of education in minimizing the impacts of landslides, the paper advocates for strategic initiatives that prioritize risk communication and preparedness measures to ensure the safety and well-being of the younger population in landslide-prone areas.

Keywords: Landslide Hazard, Schools, Educational Awareness, Preparedness

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An analysis of landslides, early warnings, and risk communication in Sri Lanka during Second Inter - Monsoon season in 2023

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Abstract

A landslide is a major life-threatening event in the central highland of Sri Lanka. Accordingly, the National Building Research Organisation (NBRO) identifies fourteen landslide-prone districts in the country, approximately 30% (19,500sq km) of land, and 38% (7.6 Mn) of inhabitants. However, during the rainy seasons, NBRO issues the landslide early warning messages to the communities to ensure safety. Consequently, several studies showed that last-mile communication was not at a significant level, and it is required to evaluate the importance of last-mile communication. Understanding incident trends is crucial to mitigate future landslide impacts, necessitating improvements in early warning mechanisms and risk communication. Further, it is necessary to understand the correlation between the landslide early warning message dissemination and the occurrence of landslide events in the area. Accordingly, the recent rainfall monsoon period [September 28th to December 28th in 2023] was selected for the study.Here, the National Building Research Organisation has issued 100 landslide early warning updates, encompassing watch, alert, and evacuation measures to safeguard at-risk populations. Accordingly, 2052 landslide incidents have been reported within the period, resulting in a loss of LKR 160.1 million and 11 fatalities. Notably, 26% of incidents occurred in the Kegalle district, while Matara and Ratnapura districts recorded 26% and 14% of incidents, respectively, with cutting failures being the predominant incident type. The analysis underscores the lack of awareness regarding resilient construction and land use management contributes to these incidents. In terms of early warning message dissemination, the Ratnapura district received the highest number of messages related to evacuation actions, followed by Matara and Kegalle districts. Furthermore, a tailor-made solution is required to enhance early warning message dissemination and community awareness, aiming to mitigate the impact of landslide incidents in Sri Lanka.

Keywords: Landslide, Second Inter Monsoon, Early Warning & Risk Communication

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An application of generative AI towards resilient communities

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Abstract

Generative artificial intelligence (AI) relies primarily on the data it has been trained on using innovative AI algorithms. This uses a unique deep learning approach known as generative adversarial networks (GAN), which finds use in various domains such as text, image, and audio generation. Therefore, this technology is used in different sectors, such as health care, education, urban planning, and disaster management, to optimize efficiency. Hence, this research study aims to systematically identify the existing practices of generative AI in the field of disaster management. Moreover, to investigate the possible application of generative AI to foster community awareness, with a focus on enhancing community resilience. The research was undertaken utilizing publications, including the period from 2010 to 2023. A total of 88 articles were selected for the comprehensive study. The study reveals that Generative AI is employed for real-time updates and alerts, multilingual communication, and pre-disaster education and awareness in the context of floods, earthquakes, hurricanes, and wildfires. However, a critical observation emerges, revealing a notable deficiency in the application of generative AI in the context of landslides. Therefore, this research emphasizes the need for further investigations and research endeavors aimed at harnessing the full capabilities of generative AI in addressing the unique challenges posed by landslides. By advocating for continued exploration, generative AI technology can significantly enhance community awareness, fostering safer and more resilient communities in the context of landslide disasters.

Keywords: Generative artificial intelligence, Landslide, Resilient communities and Awareness

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Assessing stakeholder perspectives on landslide risk management: With special reference to landslide - prone regions, Sri Lanka

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Abstract

In collaborative platforms, diverse stakeholders influence landslide risk management, impacting community engagement, policy development, resource allocation, and adaptive planning. Sri Lanka grapples with challenges in soliciting and evaluating stakeholder viewpoints, especially in high-risk landslide-prone regions, due to existing top-down inadequacies. This research aims to explore stakeholder perspectives on landslide risk management, revealing challenges and advocating for community-centric solutions. Employing a multi-dimensional approach, primary data was collected through Focused Group Discussions in prioritized landslide-prone areas, in Kegalle, Ratnapura, Kaluthara, Matara, Hambantota, Galle and Matale Districts, involving key stakeholders like government representatives, Disaster Management Practitioners, and Community-based Organizations. Initial findings highlight critical challenges impeding effective landslide risk management. Accordingly, there is a notable lack of two-way communication between relevant authorities and the community, hindering risk communication. Limited grassroots knowledge and awareness pose obstacles to preparedness efforts, compounded by low risk perception. Weak inter-institutional coordination constrains risk reduction strategies. The absence of disaster management-oriented planning regulations hinders prevention and protection measures. Despite challenges, the research identifies a willingness among stakeholders to contribute to cost-effective community-based and nature-based approaches. There's an expressed need for further research addressing real ground issues in high-risk communities, emphasizing the importance of a bottom-up approach in Sri Lanka for greater resilience and reduced landslide impact. These findings underscore the significance of embracing a bottom-up approach to landslide risk management in Sri Lanka ultimately fostering greater resilience.

Keywords: Stakeholders Perspectives, Risk Management, Landslide

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Enhancing resettlement housing : Evaluating house plan submissions for disaster resilience and public awareness

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Abstract

The resettlement of families affected by disasters is a critical programme undertaken by the National Building Research Organisation (NBRO). As part of this initiative, families are provided the opportunity to construct their own homes with the approval of NBRO, under an owner-driven approach. This study focuses on evaluating 100 house plans submitted by beneficiaries for approval, with a view to improving the house plan approval process and enhancing public awareness regarding house design. The evaluation was conducted based on four main criteria: Planning, Architectural, Structural, and General requirements, aligned with the core features of the resettlement project. Findings reveal several key insights. Firstly, a significant portion (60%) of beneficiaries submitted house plans exceeding the recommended floor area of 650 square feet, indicating a deviation from programme guidelines. Additionally, a majority (70%) of house plans were drawn by draftsmen and technical officers, highlighting a need for increased awareness among this group. Despite guidelines emphasizing the incorporation of resilient features, a staggering 95% of the submitted house plans failed to meet the minimum requirements for disaster resilience. This study underscores the importance of aligning beneficiary submissions with programme guidelines to ensure the effectiveness of resettlement efforts. Furthermore, it highlights the critical need for targeted awareness campaigns aimed at both house plan designers and beneficiaries to promote the adoption of disaster-resilient design principles. Addressing these findings through tailored interventions not only enhance the quality and resilience of resettlement housing but also contribute to long-term community resilience in the face of future disasters.

Keywords: Resettlement housing, disaster resilience, public awareness

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Enhancing resilience in landslide high - risk communities in estate settlements: Special reference to Poonagala estate

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Abstract

In recent decades, landslides have emerged as a grave concern in Sri Lanka, driven by climate change and human interventions. The landslide disasters have caused extensive damage to property and claimed the lives of people. According to the Landslide Hazard Zonation Maps prepared by National Building Research Organization (NBRO), about 9,558 estate households were identified as landslide-high-risk and majority of them were built over 100 years ago. Additionally, 2,243 households have shown landslide symptoms. Due to the antiquity of the buildings, substandard construction techniques, and inadequate land use practices the impact of landslides on estate settlements is worsened. Thus, guidelines integrating disaster risk reduction (DRR) into land use practices are crucial for estate settlements. Accordingly, this study aimed to reduce landslide disaster risk in estate communities through land use zoning with disaster resilient guidelines and DRR measures. Poonagala Estate was selected as the study area. A combination of the landslide hazard zonation concepts and slope categories were used in this study. The study classified the land use zone into four categories: restricted zone, control zone, warning zone, and development zone. The findings reveal that a significant portion of Poonagala Estate comprises restricted zones, necessitating the relocation of residents inhabiting these areas. The study also identifies individuals residing in warning zones as requiring high attention on landslide early warnings and preparedness. Moreover, the research identified essential strategies concerning land-use planning and DRR measures for each zone. Adopting a site-specific land use zoning plan is crucial at the local level to alleviate the detrimental impacts of sediment disasters. Additionally, this analysis facilitates the implementation of robust strategies that enhance the resilience of estate communities in the face of landslide risks and challenges.

Keywords: Land use, Land use zoning, Landslide hazard zoning maps and Estate settlements

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Institutionalizing anticipatory action in Sri Lanka : Prospects and constraints

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Abstract

Anticipatory action (AA) contributes to the objectives of disaster risk reduction (DRR), that are stipulated in the Sendai Framework as "preventing new and reducing existing disaster risk and managing residual risk." Traditional long-term DRR programmes focuses more towards post disaster response and relief distribution and is being shifted to pre-disaster risk reduction, addressing issue related to strengthen policies and governance, and community preparedness, capacity building, and mitigation of hazards, yet they often have limitations as to how much early action can be supported when an event is imminent. AA complements longer-term DRR by enabling shorter-term measures, implemented based on concrete warnings, supporting those living in high risk areas. Many DRR actions, especially those that aim to address underlying vulnerabilities, cannot be implemented within the often-short lead times of anticipated disaster, but AA can help to reduce or manage residual risks. Further, AA enables actors to get ahead of a shock and mitigate its impact on vulnerable people. Predictive analytics can help anticipate humanitarian needs arising from different shocks. Emerging evidence shows that AA is a more dignified, rapid, and cost- effective DRR intervention as a proactive approach. World Vision implemented an AA project in Nuwara Eliya integrating, early warning, early action and early finance. Project also integrated the gender, equity, disability and social inclusion aspects during the implementation. This paper discusses the prospects and constraints in institutionalizing AA at national, sub-national and grassroot level, based on the experiences gained from the project implemented in Nuwara Eliya and provides recommendations that could be adapted by various actors to institutionalize AA in the country.

Keywords: Anticipatory Action, Risk information, Forecasting, Pre-arranged finance

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Land regeneration initiatives as an innovate approach for urbanized high-risk landslide areas: With special reference to Suhuhumpola settlemets, Kandy

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National Building Research Organisation, Colombo, Sri Lanka

Abstract

Sri Lanka has seen a troubling surge in landslides over the last two decades, especially in high-risk zones, raising concerns for substantial life and property losses. In addressing this threat, relocating communities from high-risk zones is the most sensible approach. However, factors like land values, livelihoods, access to basic needs, and construction costs make offsite relocation more conventional, particularly in urbanized areas compared to rural settings. Hence, this study aims to explore an innovative approach that integrates with urban planning initiatives and community-driven efforts, incorporating land use, sustainable housing, and infrastructure development. This study focuses on Suduhumpola, an area within Kandy's municipal boundary, which having 66 settlements recommended to resettle due to being highly susceptible to landslide risks. Through focused group discussions, interviews, and field surveys, primary data collection was conducted, addressing the concerns of both the community and relevant authorities. Recognizing informal building patterns and long-term sustainability concerns, the study proposes an onsite relocation coupled with a regenerative plan to transform Suduhumpola into a resilient and sustainable community. The plan includes constructing fifteen two-story cluster houses, an organized road network, and essential utilities such as drinking water, sewer system, and a dedicated recreational area while liberating around 6.23 acres(68%), providing exciting prospects for future development within Kandy city limits. Thoughtful management of the liberated areas with nature-based solutions guarantees a vibrant and sustainable future for Suduhumpola. The study concludes by emphasizing three key contributions: improved living standards through enhanced housing and livelihoods, addressing cutting failures with nature-based mitigation, and utilizing newly freed lands for future development, maximizing opportunities for growth and prosperity. In conclusion, the comprehensive approach demonstrated in Suduhumpola offers a promising model for addressing challenges in high-risk landslide areas, presenting valuable insights that can be applied to enhance resilience in other vulnerable urban settlements in the future.

Keywords: Innovative Approach, Land Regeneration, Urbanized

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Landslide risk, human mobility, and climate-induced loss and damage in Sri Lanka - Case study in Bulathkohupitiya divisional secretariat

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Abstract

Sri Lanka, a tropical South Asian Island, faces increasing landslide risks exacerbated by climate change, affecting human mobility and resulting in economic and non-economic losses. This study, centred on the Bulathkohupitiya Divisional Secretariat in the Kegalle district, investigates the interplay between landslide history and human mobility. The region's topography, affected by monsoon patterns and deforestation, significantly elevates landslide susceptibility, as evidenced by the 2016 Aranayake Landslide. The research encompasses three distinct sites within the Bulathkohupitiya Division, representing medium-risk (Malliawatte), high-risk (Pushpane), and a resettlement area (Kiriporuwa), reflecting varied risk levels and encompassing diverse human settlements and ecological systems. The study provided an in-depth understanding of the local conditions, community experiences, and policy environment governing disaster management and climate change adaptation. Policies like the National Disaster Management Act and the National Adaptation Plan for Climate Change Impacts in Sri Lanka are analysed alongside international frameworks like the (UNFCCC) and the Sendai Framework. Preliminary findings reveal concerns related to relocation, including income loss, increased expenses, and inadequate infrastructure. Community members in at-risk areas expressed concerns about landslides, mental health, and the need for better early warning systems and infrastructure. Balancing risk management with livelihoods, education, and access to infrastructure is crucial in planned relocations. This study addressed these challenges and emphasised the importance of considering economic, social, and cultural factors when designing effective measures for vulnerable communities. The study concludes by stressing the intricate interplay between landslides, human mobility, and climate-induced loss and damage in Sri Lanka. It highlights the need for comprehensive strategies to safeguard the communities' well-being while addressing the multifaceted challenges posed by landslides and climate change.

Keywords: Landslide Risk; Human Mobility; Climate Change; climate-induced loss and damage

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Spatial resilient development approach in Central Highland with special reference to Kandy district

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Abstract

This study focuses on the Kandy district, the fourth largest city in Sri Lanka, where approximately 25% of the land is identified as being at high risk of landslides according to the Landslide Hazard Zonation map. The primary objective of this research is to develop a spatially-informed map to guide development in the Kandy District. To achieve this objective, six criteria were identified through a comprehensive literature review and needs assessment. These criteria include high-hazard landslide zones, environmentally sensitive areas, land use distribution, internal connectivity, proximity to major towns, and urban declared areas. Suitability maps for each criterion were generated, with weights assigned using the Analytic Hierarchy Process (AHP). Integration of these maps through weighted overlay analysis resulted in a comprehensive suitability map, depicting varying levels of suitability across the study area. Findings reveal that 202 km² (10.7%) of the district's land is highly suitable for development, while 643 km² (32%) is moderately suitable, 305 km² (15.2%) is of low suitability, and 854 km² (42.6%) is deemed unsuitable for resilient spatial development. Specific areas such as Gampola, Pilimathalawa, Kundasale, Katugastota, Nawalapitiya, and Thalathuoya are identified as highly suitable for development, whereas certain zones within the Udadumbara divisional secretariat division are considered unsuitable. Moreover, this study contributes to simulating development patterns in the remaining areas of the central highlands in Sri Lanka. Additionally, the research serves as a guide document to inform the development planning process, aiming to maximize resilience and sustainability in spatial planning.

Keywords: Resilient Spatial Development, Landslide Hazard, Urban Vulnerability

04

Sustainable Environment for Healthy Living

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Developing a particle board using currency wastes collected from the Central Bank Sri Lanka

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Abstract

The Building Material Research and Testing Division (BMRTD) at the National Building Research Organisation (NBRO) is at the forefront of a groundbreaking initiative aimed at transforming currency waste obtained from the Central Bank of Sri Lanka into a valuable and eco-friendly product. Taking inspiration from successful global projects that repurpose shredded currency waste with additives like cement, chemicals, and natural materials such as coconut shells, this research specifically focuses on the development of a soft particle board. This research draws insights from diverse international endeavors, such as the Egyptian Central Bank's use of shredded banknotes in the production of high-quality paper, involving significant chemical inputs. Similarly, the Lithuania Central Bank employs acid hydrolysis to extract Cellulose nanocrystals from purified cotton in banknotes. Notably, a Malaysian university has successfully created a noise-reduction plywood board using a combination of coconut shells, waste newspapers, and cement. The approach of the current research involves the creation of a soft particle board using a non-toxic binder in the form of briquettes made from shredded currency waste. Rigorous testing, adhering to industry standards, will be conducted during subsequent molding and casting processes. This comprehensive assessment encompasses factors such as compressive strength, bonding strength, flexural strength, thermal behavior, density, toxicity and noise absorption capacity. Through this innovative initiative, the objective of this research is to contribute to sustainable practices by repurposing currency waste into an environmentally friendly building material. This aligns with global efforts to promote responsible resource utilization, addressing both environmental concerns and efficient waste management.

Keywords: Currency waste, Particle Board, Compressive Strength

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A simplified approach to model an instantaneous chemical spillage in industrialized areas of the Kelani river

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Abstract

Chemical spillages into water bodies occur frequently around the world, often happening instantly or with very little warning. These are mostly accidental releases from industrial accidents, navigation mishaps, or failure of chemical holding tanks or ponds. The released pollutant mass propagates downstream in the river while gradually being dispersed and partially retained, due to various heterogeneities in the river channel impairing the downstream water uses and ecosystem balance. Alarm models are currently implemented by different European river basin authorities, and probably around the world. A simple one-dimensional mathematical model with dispersion-advection equations was used to predict chemical concentrations of the Kelani River as a function of the downstream distance and the time after an instantaneous release to provide a tool that can help in evaluating the environmental consequences of a chemical spill in the river. Monitored baseline data along with river hydraulics was used to define the model boundary. The results depicted over-predicted peak concentrations at greater distances because the model did not consider chemical removal processes occurring during the long travel time. The major benefit of using such a tool is emergency response to warn downstream users and to mitigate secondary damages, e.g. by shutting down water intakes during the passage of the pollutant mass or limiting recreational uses by pre-determining the risk.

Keywords: Instantaneous chemical releases, Modelling, Environmental consequences

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Assessment of risk associated with air pollution in urban areas of Sri Lanka

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Abstract

Air pollution is regarded as the 5th leading risk factor for mortality worldwide. The mortality rate caused by air pollution in Sri Lanka is higher since more than 90 percent of the country's population is exposed to air pollution levels exceeding the WHO Guidelines (2021). In urban areas, air quality is of significant concern due to the pollutants emitted by local pollution sources such as vehicles, open burning, construction activities, industries, domestic activities etc. Air pollution levels in 17 selected urban areas are monitored using the validated sensor-based real-time monitoring network developed by National Building Research Organisation for the assessment of urban air pollution in Sri Lanka. This network operates to measure pollutants, namely carbon dioxide and particulate matter (PM) in two size ranges ($PM_{2.5}$ and PM_{10}). The ambient Particulate Matter ($PM_{2.5}$ & PM_{10}) levels in each urban area measured under this program in 2022 were assessed with the National Ambient Air Quality Standards (NAAQS), US Air Quality Index (US-AQI), and WHO guidelines. Of the yearly data, the highest percentage of dates that exceed NAAQS (49.8%) and WHO guidelines (100%) and unhealthy levels of US-AQI (8.2%) is recorded in the Jaffna urban area while the second highest percentage (3.3%) is recorded in Colombo and 3rd (2.7%) was recorded in Puttalam. The lowest percentage of dates that exceeded NAAQS (1.1%) and WHO guidelines (98.1%) and unhealthy levels of US-AQI (not exceeded) was in Nuweraeliya. The chemical and physical properties of PM vary greatly with time, region, meteorology, and the source of emissions. The study highlights the requirement of defining local plans for air quality management and increasing the awareness of decision-makers and the population.

Keywords: Real-time monitoring network, Urban Air quality, Particulate Matter, Air Quality Index

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Determination of the rice matrix impact on pesticide residue by liquid Chromatography - Tandem Mass Spectrometry

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Abstract

The agricultural sector is vital to Sri Lanka's economy, contributing over 8% of its GDP though the industry faces challenges such as weeds, insects, and diseases. The use of pesticides to overcome these challenges has increased by 43% from 1991 to 2018. Extensive use of synthetic pesticides leads to negative environmental impacts that contaminate natural resources and the food chain, affecting human health in the long term. Thus, it is crucial to explore alternative solutions to minimize the use of synthetic pesticides and to protect the environment and human health. This study aimed to determine the fraction or percentage of reduced recovery resulting from the matrix effect of 50 commonly applied pesticides used in paddy cultivation in Sri Lanka. The Bond Elute QuECERS approach was used for the extraction of pesticides, while PSA (Primary Secondary Amine) was used for sample cleanup. The extracted samples were subjected to quantitative examination using the liquid chromatography-tandem mass spectrometric acquisition method. Recovery of spiked blank rice samples was determined at three different levels; 90.0 µg/kg, 110.0 µg/kg, and 190.0 µg/kg. Out of 50 pesticides, 14 showed lower recovery levels from 12.2% to 38.8%, and were significantly lower than the accepted recovery percentage: 80% of all three spiked levels which indicates 28% of the pesticides tested are not well suited for paddy because of their strong bonding with the rice grain matrix. The results further confirmed that the suppression is not due to the matrix influence on instrumental analysis in demonstrating the acceptable level of recovery (above 80%) by spiking blank extraction of rice samples with 14 pesticides that had low recovery percentages above. Furthermore, the findings infer that overuse of the aforementioned pesticide may result in the accumulation of rice grains and bioaccumulation along the food chain, which could result in serious health risks.

Keywords: Agricultural Pesticides, Tandem mass Spectrometry

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Environmental and social consideration of management of hazard street trees in urban landscape

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Abstract

Roadside trees offer urban ecological benefits like heat absorbance, air conditioning, and reduced emissions. They impact communities by cooling streets, preventing soil erosion, and providing wildlife habitat. Urban trees, vital yet posing risks, may cause harm during extreme weather or affect biodiversity. Effective local management enhances life quality and human well-being amid coexistence with trees. This study in the Colombo Municipal Council (CMC) area assesses roadside tree risks. It aims to identify issues, recommend user-centric improvements, explore social factors influencing hazardous trees, and analyze problems' impact on users and the surrounding area.Urban tree risk management grapples with critical challenges, including a lack of coordination, insufficient enforcement power, and financial constraints within responsible organizations. Local authorities struggle to allocate resources for urban tree upkeep. A shortage of skilled personnel exacerbates issues, as training opportunities are inadequate. The resultant delegation of tasks to inexperienced staff compromises overall tree management quality, elevating risks in urban environments. In CMC, mature street tree planting patterns pose problems when trees reach their height, affecting planting locations and users. Issues arise from improper planting spaces hindering tree growth and conflicts with overhead utility lines, leading to service interruptions. Inappropriate tree choices in pedestrian ways offer minimal shade and mature trees along unstable roads pose dangers during heavy rains. Uncontrolled tree roots damage paved areas and additional problems include decaying tree parts, falling limbs, and trees obstructing signs, requiring comprehensive solutions for a safer and sustainable urban tree landscape.Effective roadside tree management involves standards, organization, planning, and techniques ensuring public and worker safety. Proper management reduces liability costs, addresses tree risks, and enhances local authorities' service quality. Selecting appropriate tree species minimizes hazards, while public awareness fosters understanding, promoting healthier trees and integrated safety management within specific settings.

Keywords: Tree risk assessment, Urban tree risk management, Roadside tree

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Integrating Internet of Things (IoT) technology for effective environmental monitoring

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Abstract

With the technological development, Internet of Things (IoT) has incorporated in many data collection, transferring and management etc. This IoT flatforms are mainly use in systems or networks with wider spatial coverage in different domains as a feasible alternative approach to cost effective managements. In most of countries, IoT-based networks are developed for the environmental monitoring networks with Low Cost Sensor (LCSs) for non-regulatory technology, that are easier to operate than the standard equipment allowing the acquisition of measurements in more locations instantaneously. These measurements include remote visualization without personal involvement, spatiotemporal variability assessment, short to long-term trend analysis, emergency response, and educational purposes. Due to these advantages, the IoT plays a remarkable role in many applications including healthcare, industry, entertainment, agriculture, environmental protection, disaster management, and security. In Sri Lanka, the IoT has been used in real-time air quality monitoring network developed by the National Building Research Organisation in urban areas in Sri Lanka by installing twenty-three monitoring units to measure $PM_{2.5}$, PM_{10}, and CO_2, as well as meteorological factors temperature, and humidity. To collect real-time data from all monitoring units to a single data collecting platform, an IoT-based platform (IoT server) was designed. Data obtained from these units is disseminated for public awareness for signaling the public before exposure via the www.aq.nbro.gov.lk website. This usage of IoT-based sensors and communication technologies has proven to measure real-time changes in greenhouse gases (GHG) for the effectiveness of climate change adaptation and mitigation programs in line with both nationally determined Contributions (NDCs) and Sustainable Development Goals (SDGs). Real-time data on soil pH and nutrients create a shift from the traditional way of farming to modern farming practices that can be used to guarantee that available nutrients are managed efficiently and effectively, as well as to determine the optimum dose levels required to generate maximum yield using best crops real-time, and to reduce contamination of surface and groundwater and soil acidification etc.

Keywords: Internet of Things, Low-Cost Sensors, Real-time, Green House Gases, Modern farming practices

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Urban air pollution and percentage of hospitalization and hospital deaths due to diseases of Lower Respiratory System (LRD) in Sri Lanka

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Abstract

Air quality is the biggest environmental health risk in Asia and the Pacific growing momentum for effective air pollution mitigation through evidence-based action plans that integrate anti-pollution measures with actions to emissions. Fine particulate matter (PM2.5) is the problematic parameter that can enter the respiratory system and is linked to a range of respiratory and cardiovascular problems. In Sri Lanka, several strategic actions were taken to manage air quality in urban areas, resulting in air pollution levels in almost all urban areas being managed and within the National Standards for 9 months period (from March to October) in a year. However, the $PM_{2.5}$ levels are significantly increased from November to February period in each year due to the transboundary pollutant contribution. In this study, air quality data from the past two decades in Colombo were compared with the number of causes of hospitalization and hospital deaths. Although hospitalization is connected with several other diseases, diseases of Lower Respiratory system Diseases (LRD) were selected to assess the related health impacts of air quality. Also, regional pollutant levels in 2022 were taken to assess impact in other urban areas. The air quality trends indicate that pollutant levels are reduced with the implementation of air quality management actions and reduced significantly during the COVID lockdown period and fuel shortages with the economic crises in Sri Lanka. The reduced percentage of hospitalization and deaths due to the cause of LRD is comparable with the reduction of urban air pollution in most urban areas. Further, 2022, data indicate that the rank of the hospitalization and hospital deaths causes of LRD is high in area where the pollution rank is high.

Keywords: Urban air pollution, Hospitalization, Respiratory diseases

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