A System Engineering Approach to Disaster Resilience—An Introduction

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Abstract In this dynamic earth, each and every place is affected from natural, technological, biological, environmental hazards and/or related impacts. Depending on the extent of resilience measures in place and socioeconomic status of the countries, their infrastructures and environmental sensitiveness, the damage, and loss patterns are exposed. So to ensure basic security and quality of life against all, impending hazards have been the key issues for the academia and industries vis-a-vis administrative setup. Therefore, disaster resilience has become a systemic challenge for the mankind, and eventually, responding to disasters has been into the mainframe of all concerned governance from the time that natural resources are being extracted and used for the exploiting more and more from the mother nature. But in recent times as we are making lots of infrastructural growth, it is more so critical with the onset of deadly infectious disease outbreaks, acts of terrorism, social unrest, and fluctuation in the share market leading to financial disasters. From perspective of system engineering approaches, this chapter explains various facets of disaster resilience paradigm with particular motivation to the infrastructure growth and sustenance. Additionally, a summary of the 38 selected papers categorized into six sub-themes about the necessary approaches to elevate resilience to disasters is presented.

Keywords Disaster management · Resilient infrastructure · Disaster risk reduction · Sustainable development goal · Sendai framework · System engineering

1 Introduction

The recurrence interval, ferocity, social, and economic impacts of disasters show exponential trends in recent decades. Cities and countries around the world have been facing hydro-meteorological events such as cloud burst, cyclone, storms, droughts

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resulting humongous impact to the economy, and life loss. More than a billion population of the world live within 10 m from the coastline and with projected sea level rise of 1 m by the year 2100 [1, 2], several of these sea protection dykes will become either ineffective or to raising them cost will be substantial. However, for developed countries, like Netherlands, UK, and Germany, dykes so built up have the higher protected value, yet raising of these dykes to cater sea level rise would be of monumental task. In fact, the reliable and resilient protection of low-lying regions and coastal cities from flooding, land loss, water-logging, and groundwater salinity is a both costly and technologically complex process. From this one aspect of potential disaster threat domain, amid accelerated urbanization throughout this century, more and more economic activity are going to be concentrated in risk-sensitive areas; especially as new cities throughout South Asia and Africa are likely to be concentrated in the highest risk areas [3, 4], which is as much as they are now being faced in the North America and Europe. Disaster management, in general, aims to mitigate the potential damage from the hazardous event and ensure real-time immediate rescue and assistance to the victims, and attain effective and rapid recovery in the motto of "building back better." The mitigation of and the adaptation to the risks due to natural and/or man-made events can be accomplished through the application of systems engineering perspectives consisting of Internet of Things, Drones integrated with GIS for mapping of facilities, analytical and numerical modeling techniques, AI-ML, data science tools, and information, education and communications technology (IECT). Such integration work has recently attracted multidisciplinary teams, and more so there are ample avenues to explore real-time broad-based simulation modeling not only for accelerating academic zeal, but also devise measures to reduce the exposures of lives and property damages. As many disasters including COVID-19 are of trans-boundary nature, the national and government sector at local, regional levels, as well as the private/public sectors, and re-insurance companies, have strong emphasis in harnessing various system engineering approaches. Some of the long-range IoT based wireless technologies including customized UAVs provide real-time panic alerts, tracking trapped/victims, and communication during disaster situations. They are also able to account for the safety of human and animals, real-time remote measurement of air-quality like temperature, humidity, pressure, CO_2, and light-intensity and contact tracing of the disease causing pathogens in the vicinity. This chapter considers how a systemic approach can improve resilience measures against portending risks and thereby to explore recovery process [4, 5]. Based on the contributions from the experts, six sub-themes are made: disaster preparedness; climate change adaptation and mapping tools; resilient city and flooding; community resilience measures; dams and slope mitigation; and strengthening and retrofitting measures. In the subsequent section, some aspects of system engineering measures toward resiliency including some of the current international framework in disaster risk reduction (DRR) will be discussed followed by salient points made in each of the paper.

2 Disaster Preparedness

Giving an account of our foreseeable existence in this earth, how well we are fit to live with sustainable future and what are the footprints in terms of infrastructure such as dams, roads, transportation facilities, telecommunication, industries, education, exports and imports of goods, and other various developments, K. Sukumaran gives a full treatise in his paper titled *Impact of Human Activities Inducing and Triggering of Natural Disasters*. It is also mentioned that with annual increase of 74 million peoples per year, the global population will become 8 billion by 2024 and thereby needing huge quantity of natural resources in various forms that cause depletion of natural resources, resulting in environmental degradation, generation of wastes, greenhouse gases predominantly CO_2, pollution of air, water, land, deforestation, urban heat islands, traffic congestions, etc., which are causing disasters and calamities. The paper also cited various reports defining ecological footprints, and as per 2019 data that global average economic loss due to all types of natural disasters amounted to $232 billion. The world population is unevenly distributed as developed countries have less population (1 billion) than in developing countries (6.8 billion). The author explained several aspects of environmental degradation, exploitation of huge quantum of all forms of natural resources for human needs and in turn producing waste, pollution, depletion of natural resources, loss of bio-diversity, emission of greenhouse gases that inflict to the global warming and climate change. The repercussion of earthquakes, hurricanes, tsunamis, floods, droughts, melting of glaciers, rise in sea level, wildfires, landslides, heat and cold waves, etc., causes loss of human lives, destruction and damages to infrastructure, epidemic and pandemic, etc.

Nosini et al. explained in *Implementation of Build Back Better Concept for Post-Disaster Reconstruction in Sri Lanka* that post-disaster reconstruction (PDR) can be considered as an opportunity to undertake improvements in lifestyle, safety, and economy of disaster-affected community. Citing successful adoption of the Build Back Better (BBB) approach after Indian Ocean Tsunami (2004), this study determines the practices of in PDR projects to accomplish disaster risk reduction and community recovery through effective and efficient implementation of PDR in three landslides affected areas in Sri Lanka. Further, they suggest the necessity of identifying strategies to overcome the challenges of BBB implementation in order to succeed in future PDR projects worldwide.

In a paper titled *Disaster Affected People's Vulnerability Assessment Through Addressing Padma River Bank Erosion,* Awual Baksh et al. identified the extent of damages of the resources, economic crisis, unemployment problem, food crisis, various diseases, social problems. household income, availability or cost of building materials, legal and social limitations on land use, etc. The researchers suggest specific actions, such as construction of protection dykes and maintaining the health of same by community to prevent the rapid river erosion along the Padma river banks in Bangladesh.

Dev and Dash (*An investigative study on material and its performance of intermediate disaster relief shelters*) explore the types of intermediate relief shelters with

respect to various materials available and case studies addressing the key factors related to the environmental, economic, technical, and sociocultural criteria affecting the provision and performance of relief shelters. They proposed key aspects to be taken into consideration during the decision-making and design processes of such shelters for the effective and better performance for the community. The authors made critical remarks on the regional cultural disparities, livelihoods, lifestyle, sociopolitical setup, available resources, materials, technology, modality of financial resources, and context-specific constraints and opportunities that foster local capacity for reconstruction. The authors tried to identify the most reliable method which would be productive, fastest, and satisfactory when empowered by affected people themselves. It is further noted from the paper that every organization's external participation could best be directed at improving peoples' efforts to build their intermediate shelters by promoting gaps in the material, finance, expertise, technical guidance, and needed craft tools.

Emphasizing on the development of an emergency food aid plan (EFAP), Satesh Balachanthar and Lee Lai Kuan (*Development of Emergency Food Aid Plan for Renal Disease Patients: A Vital Disaster Preparedness*) presented a predictive tool to inform both individual, household, and evacuation centers of the appropriate dietary recommendations during disaster for chronic kidney disease victims. Selection of food was based on the following three scenarios: Ready-To-Eat (RTE), Emergency Food Basket (EFB), and Emergency Congregate Feeding (ECF) at the evacuation centers. The authors explained about cost-effective food aid by employing linear programming and scenario development, and this study established the designation of a nutritionally appropriate, cost-effective, socially acceptable, and sustainable emergency food aid plan for disaster preparedness and abatement.

Using psychological mindset and socioeconomic conditions over the levels of disaster preparedness, Kolathayar et al. (*Understanding Disaster Preparedness Level in The South Indian City of Chennai)* developed a Disaster Preparedness Index (DPI). The authors developed a questionnaire based on the parameters such as past disaster experience, perception toward disaster risk, personal and community participation; roles of individuals, community and government in disaster management, preparation measures, and demographic details. Taking case study of Chennai city, India, the study showed that the society is mostly poorly prepared, and there is a need to increase the social awareness and preparedness measures to build a secure disaster resilient society.

S. Divya Sankar et al. *(Emergency Preparedness and Response—an Evidence Based Onsite Audit Conducted in Two Hundred Organizations)* explained occupational health and safety management system (*BS 18001, ISO 45001*), which is an integral part of most of the organizations across the world along with other management systems like quality, environment, and energy. The authors emphasized that the emergency preparedness and response procedure is not a onetime documented information, but it is a proactive and ongoing process which has direct correlation with the hazard identification and risk assessment. Further, the industry-specific research

study could be conducted to determine the adequacy and suitability of the emergency preparedness and response. At the end of the paper, the author provided a questionnaire on "Emergency Preparedness and Response."

Amarjeet Kumar et al. (*Framework for location-allocation of shelters for evacuation during cyclones*) discussed about the framework by using location-allocation model with constraints such as supply at shelters, travel cost between origin and destinations, and risk clustering for the case of cyclones frequently happening in the East coast of India. Their studies are aimed for the emergency planners in devising appropriate strategies to minimize the cost of operation by allocating resources efficiently for a successful evacuation. This study attempted to identify evacuee-allocation methodology and the impact of staged evacuation on shelter allocation (in both permanent and temporary shelters) and on the travel distances arising from such shelter choices. Presenting an elaborate case study for a district in the coastal belt of West Bengal, India, the authors recommend to study many hazard scenarios to identify long-term and short-term strategies for planning locations of permanent shelters, relief supplies, hospitals, and resource personnel's for effective disaster response.

3 Climate Change Adaptation and Mapping Tools

Citing 2020 unseasonal flood in the capital city of India's Telengana district, Abdul J Sharief and B Vangipuram (*Assessment of Socio-Economic Impact of Urban Flooding In Hyderabad Due To Climate Change*) presented various factors for alarming rates of urban disasters. Representative concentration path (RCP) method for future rainfall data is presented till the year 2100 using socioeconomic factors such as the per capita income of people, the extent of disruption of economic activity, supply chain disruption, and the possibility of people pushed into poverty again. The authors emphasized that their model will help future policy making and mitigation efforts for the reduction of damages caused by urban flooding. The study could foresee the poor and low-income group section being affected more by the flooding than other income range of the corresponding flood-surveyed areas. The study also mentioned that the economic losses due to urban flooding in India account for the range of 1.1$ billion to 5$ billion a year, and these losses do not account for the impact of these floods on informal settlements like slums that reside usually in flood-prone areas and small businesses in these localities which are subjected to the vulnerability of shutting down their respective business.

Kiran et al. (*Application of ArcGIS and HEC-RAS in Assessing Sedimentation in Godavari River Reach*) used the weighted coefficient of determination ($\omega r2$), Nash–Sutcliffe efficiency (E), modified Nash–Sutcliffe efficiency ($E1$), and modified index of agreement ($d1$) to provide an objective assessment about the closeness between the simulated and observed values. However, compared to HEC-RAS for the Godavari river between Perur and Polavaram stations, India, the Wilcock-Crowe model provides more accurate estimates of sediment discharge and deposition and erosion at each cross section along river reach.

Giving the list of blast events happened between 1998 and 2004 in almost all the states and Union Territories of India, C Murali Krishna and Tezeswi P Tadepalli (*Decision Support Tool for Blast Mitigation)* developed a standalone and straightforward MATLAB based GUI-GIS tool for blast damage prediction as well as blast mitigation efforts such as access control, standoff, and hardening of critical infrastructure. Only explosions caused by high explosives (chemical reactions) are considered within the study, and building damage level and number of causalities were not considered in the tool.

In the paper *(Pavement Design Considering Changing Climate Temperature) by* Swapan Kumar Bagui et al., the use of performance grade (PG) or polymer modified bitumen (PMB) with higher softening point to cater for the thermal changes are explained. They have highlighted the impact of environmental conditions change, faster pavement deterioration; thus incurring additional costs to the road construction authorities. Life Cycle Cost (LCC) and initial construction cost of pavement are also calculated and presented in the paper for conventional pavement and permanent pavement.

Nur Mohammad Ha-Mim and Zakir Hossain (*Application of GIS and AHP Based Integrated Methodology for Mapping and Characterization of Associated Socioeconomic Vulnerability to Natural Hazards at Union level: A Case Study of Southwestern Coastal Bangladesh*) elaborated on reason for vulnerability in Bangladesh such as the flat topography, heavy monsoon rainfall, discharge of sediments, drainage congestion, active fault line, low river gradients, and shallow funnel-shaped Bay of Bengal. They have selected 20 indicators to construct the socioeconomic vulnerability index under three major components: physical and infrastructural, socio-demographic, and economic components. Based on the three districts chosen for this study, the results demonstrate the extent of socioeconomic vulnerability as very high (17.8%), high (46.6%), moderate (21.7%), low (11.5%), and very low (2.4%). The paper emphasizes for policymakers to make decisions regarding development strategies and to plan for disaster risk reduction by exploring the level and extent of vulnerability at the local level. Overall, the authors state that land use planning is the key for resilience and sustainable urban development.

Citing climate change resilience through land use in urban regions due to density, population, and extent of economic prosperity, Meghna Anilkumar and Shyni Anikumar's study *(Resilient sustainable land use planning for climate change adaptation for an urban area)* identifies a pathway for its adoption into mainstream decision making. For this management, quantification and threshold analysis are required through carrying capacity analysis and ecological management plan. This paper also shows how to bridge the gap between planning and disaster management through adaptation and also between climate change studies and land use planning.

4 Resilient City and Flooding

Sánchez Y. et al. in their paper on *Identification of Risks in the Water Conduction Infrastructure for Supply Systems, a Strategy to Increase Resilience* proposed to identify and assess risks in the main water conduction systems in Cuba. They have identified various aspects of vulnerability such as inadequacy of infrastructure, lack of monitoring, inadequate management policies and many others aspects described in the paper. The authors presented the methodology to be followed for the identification and evaluation of risks in water supply conduction systems, resulting in the adaptation to the Cuba's context, and also linking to the international methodologies available.

KY Lim and KY Foo (*A State-of-The-Art Review on the Unique Characteristics, Key Driving Causes and Mitigation Measures of The World Catastrophic Flood Disasters*) explained about diverse characteristics, frequency, magnitude, causes, and impacts of the sudden flooding, which are largely affected by the unique physical geographical elements, population distribution patterns, socioeconomic status, land uses, river training, and hydro-meteorological dynamics. This paper postulates the initial platform to provide a concise and comprehensive information on the evolution of historical flood events recorded in each continent of the world since nineteenth century. The authors presented a complementary set of structural and non-structural measures, which have brought both beneficial and detrimental changes in the hydrography and ecology of riverine environments.

Based on Ministry of Road Transport and Highway data, India, Priyank Trivedi and Jiten Shah considered human factors, vehicular factors, road and environmental factors (*Road Accident Hazard Prevention by Applying the Haddon Matrix)* in their paper. The Haddon Matrix highlighted the major influencing determinants for the state of Gujarat, India, and the analysis provides the most affecting factors at pre-crash, during the crash, and post-crash scenario with suitable preventive strategies at every stage. It is noted that road accident-related disaster is very much alarming with 90% of road accident deaths share by only lower- to middle-income countries of the world. The authors noted that Indian road accident death rates and the hazardous scenario if goes unchecked right now, the number of death may cross the mark of 250,000 by 2025. The authors' finding supports the importance of road safety awareness education among citizens and intrinsically, existing road safety practices according to crash phases have to be reconsidered for further improvement with interdisciplinary crash hazard reduction strategies.

R. Jeya Prakash et al. *(No Fine Concrete Pavement—A Sustainable Solution for Flood Disaster Mitigation)* presented the results of elaborate experimental investigations on the mechanical properties of no fine concrete pavement (NFCP) by including compressive strength, split tensile strength, and the hydraulic conductivity of fiber reinforced no fine concrete (FRNFC). The porosity in pavement can be ensured through the removal of fine aggregates in mixture design and maintaining the acceptable void content, so that excess runoff water does freely infiltrate being a self-resilient infrastructure. The results clearly indicate that both the compressive

strength and permeability of FRNFC linearly depend on the dry unit weight of the samples and values obtained are found within acceptable limit specified for NFC.

Highlighting about recent recurrent flood disasters amid the rapid urbanization in Kerala, Amrita Vinod and Manoj Kumar Kini (*Disaster-resilience and Rehabilitation in Kerala: A Critical Review of CARe-Kerala's Housing Scheme*) described how the state government adopted housing solutions for the affected population. The authors presented an assessment report with a critical examination of the prominent features of CARe-Kerala housing projects. The projects emphasized resilient modules utilizing alternative methods and construction techniques. The paper mentioned how the climate change impacts compounded by the state's absence of the adaptive ability to floods, droughts, and mudflows that led to the increase in the disaster frequency and severity. The second author of this paper is involved in the entire project CARe, in which, technical support and advisory provided appropriate interventions on the diverse terrains of construction to ensure maximum efficacy and safety with optimum resource consumption.

5 Community Resilience Measures

Bindu. C. A. and Subha Vishnudas (*Measuring Disaster Resilience at Community Level And Exploring the Prospects of Revitalizing Communities Coalescing Disaster Risk*) emphasized on the efficiency of disaster response, discouraging development in vulnerable areas and increasing the resiliency of community toward disasters in dealing with disaster risk reduction and mitigation. The authors corroborated by establishing that coalescing disaster risk into development activities contributes to long-term endurance, resurgence, resilience, and revitalization of the community.

Addressing the various natural hazards and their impacts on to the society, it is very much imminent to anticipate about the communication for evacuating, safeguarding, and preventing humans as soon as possible. S. Arvindan and D. S. Vijayan (*Safeguard and Preventive Measures of Natural Disasters Using Early Warning Systems—A Comprehensive Review*) present the role of early warning systems in major natural disasters such as earthquakes, tsunamis, landslides, volcanos, wildfires, and epidemics. The authors reviewed current literatures on providing and improving monitoring equipment, building capacity, and training in the way weather stations are maintained and data collected, etc. Notable among them are about the development of integrated biosensor system with mobile health and wasted water-based epidemiology to monitor the feasibility of the widespread COVID-19 worldwide. This system also helps preventing the rapid intervention and diagnosis, and it responds to the information everywhere quickly and thus minimize the pandemic's spread. The paper discusses about the current state of the art in the EWS related to earthquake, volcano, Tsunami, flood, and landslides.

Sharmin Akter et al. *(Potentiality Assessment of Community Open Space for Disaster Management Purpose: A Participatory Approach to Reduce Disaster Vulnerability on a Community)* defined the concept of the community participated

disaster vulnerability reduction to identify associated risk, capacity, and potentiality of using open spaces for disaster management purposes. Based on the study, the authors proposed community developed strategies and different types of proposals from community peoples and experts to identify the ultimate potentiality. To assess the existing vulnerability associated with the study location, four different participatory tools, such as historical trend of open space and water body reduction, existing social and physical vulnerability of the area, cause-effect diagram, and pairwise ranking matrix, were used. The method, so developed, can be applied to identify all of the aspects of disaster management for other communities as well. The authors corroborate that while the traditional disaster management approach requires much time and has a high potentiality of failure of the plan, the community-based approach helps to find the root cause of the problems and also helps to find out the most reliable solution to the problems. Accordingly, the participatory approach helps to empower the community and helps to make them believe that they are also a part of the comprehensive planning procedure. This process, as explained, helps to create self-respect, ownership, accountability, and awareness among the community people.

Naga Venkata Sai Kumar Manapragada and PC Icy (*Approach to Simulate the Rainwater Runoff at Site Level Using Rhino Grasshopper*) explain that every social, cultural, traditional, economical, and technological system on earth is either directly or indirectly connected to climate change. Thus, predicting the impacts, risks, and vulnerabilities become necessary to recognize the mitigation and adaptation measures. They present a tool that facilitates the architects and urban designers to make assessment as a part of the early design analysis. The authors explain about the need to integrate the stormwater management during the conceptual design phase for a low impact design (LID) development. The study also demonstrates an approach to avail the extreme year precipitation data and simulated the DTM for the chosen location and its scenarios.

In this paper "*Applications of AI in Health Monitoring of Structures in Potential Seismic Areas—A Review,"* the authors outline the applications of AI in SHM in seismically active areas by evaluating on field, the resistive power of a structure against earthquakes, and simultaneously it is potential to carry forth the services, e.g., in case of multi-story buildings, bridges, special structures, and lifeline structures. Subsequently, the contemporary applications of AI in the field is reviewed, and alongside, the adaptability, sufficiency, and potentiality of those methods to overcome the barriers of the conventional ones are discussed.

Explaining the difficulty in the implementation of 2016 disaster insurance policy (*State-funded Macro Insurance Policy for Disaster Resilience: A Study on National Disaster Insurance Policy in Sri Lanka*), Liyanage et al. explain about key challenges and issues, such as loss adjustment and claim management, delay in processing claims, staff shortage, and lack of clear guidance on the claim process. While mentioning the case of USA after North Ridge earthquake (1994), private sector insurance providers covered 30% of all private and public direct damages and the federal government covered just 20% of total losses and thereby helping state governments rebuild damaged infrastructure. The paper mentions about micro-insurance by accentuating the difference of the same from other types of insurance through

the affordability of such insurances by low-income people. Furthermore, micro-insurance provides timely financial assistance following extreme-event shocks, and it reduces the long-term consequences of disasters. Based on a survey, the paper highlights that human activities on the environment have resulted in the changes in the environment which has led to long-term disastrous situations. Moreover, respondents highlighted that as Sri Lanka is facing landslides and floods frequently, the most common reasons for these disasters are continuous heavy rainfalls, lowland reclamation, forest clearance in hilly areas, sand mining in the river valleys, changes, and blocks in waterways, use of mountain areas for construction activities in an improper way, and water storing in highlands, among many other factors.

In this paper *titled Hydrological Analysis for Flood Forecasting at Sg Golok River Basin Malaysia,* Lariyah Mohd Sidek et al. explained about flood warning, which is one of the non-structural measures that have proved to be efficient and cost effective in minimizing the negative impacts of flooding. The authors described how to develop and maintain an integrated flood forecasting and river monitoring system, with flood dissemination, using national network data, telemetry data, radar data, and rainfall forecasts and thus applying the NaFFWS for all the key river basins in Malaysia.

Lariyah Mohd Sidek et al. *(Developing the Flood Risk Matrix for Impact Based Forecasting in Kelantan River Basin, Malaysia)* showed that using the IBF concept and the impact threshold values, the ArcGIS based FRM map can predict the impact in the nearby area of the Kelantan river basin. They explained that when communities can adapt proactively to a flood through early warning and early intervention, injury, distress, and the cost of emergency assistance are bound to decrease. The authors claimed that the impact threshold in Kelantan river basin has been verified and agreed upon by government agencies with local expert authority.

6 Dams and Slope Mitigation

Darshan J. Mehta et al. (*Hydrodynamic Simulation and Dam-break Analysis Using HEC-RAS 5*) carried out dam break analysis of the Ukai dam to generate a breach hydrograph and flood map as a result of the dam-break event under piping and overtopping failure. The process of collecting and preparing data, estimating breach parameters, developing a one-dimensional and two-dimensional unsteady-flow model in HEC-RAS 5 software and mapping of flood propagation are outlined in this paper. The authors claim that computed hydraulic parameters through simulation can be useful for preparing flood hazard risk maps and emergency action plans.

In the landmark paper on *Dam Safety—Living with the Risk of Failure,* David C Froehlich and David Gonzalez Diaz explained that dam-failure floods are almost always more sudden and violent than regular river floods. So, managing the contingencies caused by the failure of a dam and the uncontrolled release of water requires the coordinated efforts of both the dam owning/operating agencies and disaster management authorities. Taking the case study of Hirakud dam, India, the authors

used both 1D and 2DH numerical models to assess the consequences of its breach and produced flood inundation maps.

Prabhat Kumar et al. *(Response of Hill-Slope Buildings Subjected to Near-Fault Ground Motion*) analyzed the response of hill-slope buildings under the effect of near-fault pulse type ground motions in the Himalayan region. Through this study, it is found that the large amplitude pulses, primarily related to directivity effect, control the response of medium, and long-period structures, and therefore, the high frequency part of the NFGM plays an important role especially for short-period structures.

The paper by Vikalp Kumar and V. R. Balasubramaniam (*Microseismic Monitoring to Analyze Rock Mass Micro-cracking in Underground Powerhouse to Mitigate Potential Disaster*) explained micro-seismic monitoring (MSM) as an effective technique to locate zones of micro-cracking in the rock mass and further for the demarcation of potentially unstable zones in underground excavation. Based on one year of continuous monitoring of Tala Hydropower Plant, potential unstable zones were identified. Signifying the role of MSM, the authors emphasize that getting valuable information ahead helps auditing the safety measures taken at any site. Therefore, this technique is found to be one of the effective ways to evaluate rock mass behavior before occurrence of any disaster.

Koushik Pandit et al. *(Stability Analysis of a Debris Slope by Micropile Reinforcement Technique: A Case Study from the North-Western Himalayas)* carried out a parametric analysis to assess stability of the slope with single rows of micropiles with different diameters, spacing, and aspect ratios. The results show that the slope stability improves satisfactorily for certain cases. The authors used the slope material and factor of safety of the untreated slope under different degree of saturation and then evaluated by utilizing different limit equilibrium methods for static and pseudo-static conditions. The study finds that micropiles even if installed in just a single row can improve the overall slope stability significantly, and it can be very helpful in reducing the cost of construction since the pile diameter, in-plane spacings, and aspect ratios are optimized and chosen for the desired level of safety factor.

7 Strengthening Measures

Naqeeb U. l. Islam and R. S. Jangid in their paper (*Optimal Design of True Negative Stiffness Damper as a Supplemental Damping Device for Base-Isolated Structure*) described a simple optimization design for NSAD using complex eigenvalue analysis of the system matrix. Optimal parameters for NSAD are developed considering the stability of the system and effective fundamental mode damping. Optimal NSAD is supplemented to MDOF base-isolated shear structure as NSD. A suite of six ground motions consisting of three near-fault (NF) and three far-field (FF) motions are used by the authors. Results of the time history analysis show that NSAD works as efficient supplemental damping system for both NF and FF ground motions in contrast to conventional dampers.

K. M. Shaijal et al. in their study *(Material Uncertainty Based Seismic Robustness Assessment of Steel Moment Resisting Frames)* defined robustness index as the ratio of mean annual frequency of exceeding a given limit state of interest neglecting structural uncertainties to the mean annual frequency of exceeding a given limit state of interest considering all the uncertainties, which is often used to quantify the structural robustness. The study estimates the robustness index in terms of uncertainty robustness index (URI) and corresponding modification factors for design strength reduction factors corresponding to different hazards levels.

In the paper titled *Mitigation of Progressive Collapse of Multi-Storey Steel Building by Providing Chevron Bracings,* the authors evaluated the effectiveness of chevron bracing for mitigation of progressive collapse of a nine-story regular steel moment-resisting building, where the bracings are provided in the alternate bays of the top story. Linear static, nonlinear static, and nonlinear dynamic analyses using SAP2000 software under the middle column removal scenario from the ground floor of the perimeter frame in the longitudinal direction are presented in the paper. Based on nonlinear analysis, it is observed that the provision of bracings contributes to the redistribution of forces and effectively transfers the unbalanced vertical load developed due to the removed column to the adjoining structural members.

Hemant Kumar Vinayak et al. *(Seismic Evaluation, Strengthening and Retrofitting of Schools in Shimla, Himachal Pradesh*) used the integrated approach of qualitative assessment with visual inspection, non-destructive testing, masonry structure evaluation with analytical method for in-plane and out-of-plane safety and the method of capacity demand ratio based on elastic analysis and design for reinforced cement concrete structures. The retrofitting and strengthening of building in seismic zone led to the sensitization of the state disaster management authority of the state of Himachal Pradesh, India. They also discussed about the necessity of developing building resilience of important structures and thus increasing resilience. Through such study, the authors emphasized the need of seismic evaluation of schools in the state to prioritize the retrofit activity across the network of institutions. At the end, the authors recommend that buildings with random rubble masonry can be retrofitted without much hampering functionality of the same.

In a paper presented by Praveen Anand and Ajay Kumar Sinha (*Seismic Strengthening and Retrofitting Techniques and Solutions for an Existing RC frame: An Overview),* it is observed that a large number of RC structures lack the existing seismic demand and they clearly reveals an urgent need to upgrade and strengthening. The paper discussed about different techniques and practices available to strengthen the existing and damaged structures, and it also explains the research gaps along with identifying the scope of future research along with establishing effective retrofitting solutions.

Rohayu Che Omar et al. in their paper titled *Integrated Site Investigation Procedure (ISIP) for Managing Infrastructure Development* described about a tool for the decision makers to determine the condition before taking necessary technological steps; e.g., improve and evaluate desk studies and mapping methods that would allow fast and accurate landslide evaluations to be exercised from national to site-specific for the management of infrastructure planning. The approach, as claimed

by the authors, is useful for the evaluation of landslide hazards for land suitability requirements, particularly in Malaysia.

8 Summary

Disaster risk management is essential in modern cities to ensure long-term resilience and sustainability. Resilience includes the ability to withstand short-term risks, such as earthquakes, landslides or industrial disasters, and the ability to adapt to changing long-term conditions, e.g., changes in climate, or the advent of the era of artificial intelligence. Resilience also includes community resilience through public engagement. Disaster risk management includes two components: A quantitative risk assessment and management that is typically done prior to the disaster, and includes countermeasures, including warning systems, as well as public and community outreach and education. The natural disasters should not be considered as unpredictable, transitory events demanding emergency responses, but rather as ongoing risks with life cycles extending over years or centuries whose mitigation and adaptation should be permanently embedded in urban planning and policy. This framing points to the balance required of policymakers: the need to make large-scale investments or to exclude potential economic developments today for the sake of reducing the impacts of future events or, where possible, to enable the two policies to coincide [3]. The widespread application of terrestrial and satellite-based geophysical sensing and of our ability to capture such information through the IoT devices and augmented power computing as well as data analytics have the potential to transform our approaches to system engineering in disaster resilience.

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