REAAA Technical Report

Resilience and Disaster Management: iCHE2024, Thailand

REAAA Climate Change, Resilience and Disaster Management Working Committee

Caroline Evans and David Rolland

REAAA Technical Report TC-15

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TECHNICAL REPORT – *RESILIENCE AND DISASTER MANAGEMENT*: ICHE2024, THAILAND

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REAAA Profile

The Road Engineering Association of Asia and Australasia (REAAA) promotes the science and practice of road engineering and related professions in the Asia-Pacific region through the development of professional and commercial links within, and between, countries in the region. REAAA Chapters have been set up in Australia, Brunei, Korea, Malaysia, New Zealand and the Philippines. REAAA is also active in Indonesia, Japan, Singapore, Taiwan and Thailand.

REAAA was established in June 1973 with a permanent secretariat in Malaysia. Currently there are more than 1,200 members in 23 countries. It holds regular events including two Governing Council meetings each year, business forums, a quadrennial international conference, technical visits and study tours, trade exhibitions, seminars, forums and workshops. It also published technical reports addressing issues of concern in the region and a Newsletters twice each year.

REAAA Technical Reports

This is the fourteenth in the series of Technical Reports since the first report was published in 2008. The following Technical Reports have been published to date:

TC-1	Guide to privatisation of expressways and highways
TC-2	Disaster risk management
TC-3	Efficient operation of the road network
TC-4	Road safety – make it happen
TC-5	Pavement durability
TC-6	Guide to the public-private partnership of road and highway projects
TC-7	Incorporating Japanese pavement design practice for a community road in Mongolia
TC-8	Pavement maintenance and rehabilitation practices
TC-9	Compendium on pavement recycling
TC-10	Report on FEHRL scanning tour to South Korea and Japan: infrastructure resilience
TC-11	Compendium on pavement structural design and rehabilitation methods
TC-12	Incorporating Japanese pavement design practice for a community/local road in Myanmar
TC-13	Compendium on pavement maintenance and rehabilitation practices
TC-14	Vulnerable road users: safety status among REAAA countries
TC-15	Resilience and disaster management: iCHE2024 Thailand

REAAA Technical Sub-Committee: Climate Change, Resilience and Disaster Management

The REAAA Climate Change, Resilience and Disaster Management Working Committee is one of three sub-committees reporting to the Technical Committee. It was established at the 108th Governing Council meeting in Brisbane, Australia, in May 2020. The objective of the Committee is to address issues of concern to REAAA member countries in the area of climate change, resilience and disaster management of roads. The Committee has published several articles for the REAAA Newsletter and has contributed to international seminars in cooperation with PIARC. It has representation from REAAA and PIARC so that collaborative activities of mutual interest to both Associations can be addressed.

REAAA Working Group: Contributors to iCHE2024 Resilience and Disaster Management Session

Member	Organisation
Caroline Evans	Co-Chair REAAA Climate Change, Resilience and Disaster Management Working Committee
Auckpath Sawangsuriya	Civil Engineer – Expert Level, Bureau of Road Research and Development, Department of Highways, Bangkok, Thailand Moderator of REAAA session
Dr Apiniti Jotisankasa	Assoc. Prof., Department of Civil Engineering, Kasetsart University, Bangkok, Thailand
Keijiro Tsurukawa	Project Chief, NEXCO-West
Keizo Kamiya	NEXCO Central, JAPAN
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SUMMARY

Road owners and operators are increasingly required to manage many threats, including climate change and extreme weather, natural disasters, and man-made events. These have significant impacts on the availability and functionality of roads, the safety of its users, and communities. Consequently, owners and operators must address these challenges and provide accessibility and mobility of goods, services and people, whilst minimizing these impacts in the most efficient way possible.

In September 2024, the Department of Highways (DOH), Ministry of Transport, the Kingdom of Thailand, in collaboration with the Roads Association of Thailand (RATh) hosted the 5th International Conference on Highway Engineering 2024 (iCHE204): Future-Proofing Roads for Asia and Beyond. As part of this event, the Road Engineering Association of Asia and Australasia (REAAA) was invited to organize a session hosted by the REAAA Climate Change, Resilience and Disaster Management (CCRDM) Working Committee.

The REAAA session at iCHE2024 focused on increasing the resilience of roads and recovering from disasters. The session provided an overview of the key actions being undertaken by the REAAA CCRDM Working Committee, and collaborative activities with other road associations such as PIARC. The session highlighted activities in REAAA member countries being used to improve the resilience of roads through adaptation solutions, best-practice learnings to recover from earthquakes and effective ways to manage disasters.

This report outlines four presentations delivered at the REAAA session and documents the key issues and discussions in support of this initiative.

ACKNOWLEDGEMENTS

The REAAA Climate Change, Resilience and Disaster Management Working Committee acknowledges the hosts of the iCHE2024 for their assistance in coordinating this session. The Committee also gratefully acknowledges the input from the member countries who presented at the iCHE2024 REAAA session on '*Increasing the resilience of roads and recovering from disasters'.*

Contents

1 INTRODUCTION

The REAAA Climate Change, Resilience and Disaster Management Working Committee (CCRDM) was formed during the 108th REAAA Governing Council meeting, held in Brisbane, Australia, in 2020. It exists as one of three REAAA Technical Working, the other two committees covering the topics of Pavement Technology and Road Safety.

The challenges of climate change and disaster management of roads are shared with other related associations, including the World Road Association (PIARC). As a result, the REAAA CCRDM Working Committee was established to address issues of concern to REAAA member countries in the area of infrastructure resilience. The area of 'climate change resilience and disaster management' was identified as being of great interest to both REAAA and PIARC for the following reasons:

- The topic is a major focus of the REAAA Technical Working – noting that this subject had not been a specific topic previously addressed by the REAAA Working Committee. The establishment of this REAAA Committee addressed this omission.
- There were clear connections between this REAAA Working Committee and PIARC Technical Committees which were focused on these topics in the (2020-2023) PIARC cycle and extending to the (2024-2027) cycle.
- Some key REAAA member countries were represented on both PIARC and REAAA Committees.
- Whilst not the subject of a specific Sub-committee in the previous REAAA Council term, the topic was one of the drivers of the activities of the former REAAA Technical Sub-committee TC.4.1 (Pavements). Led by Japan, relevant outputs during the previous term included:
    - REAAA Technical Report TC-2: Disaster Risk Management
    - REAAA Technical Report TC-5: Pavement Durability.

The goals of the CCRDM Working Committee are to investigate issues of major concern in REAAA member countries and to conduct collaborative work which would be beneficial to both REAAA and PIARC. Whilst the REAAA Committee is not a sub-committee of any PIARC Technical Committee, a task was to brief each association on developments being undertaken by each association. This was beneficial in that it enabled the sharing of case studies and practices, particularly from REAAA member countries which are not members of PIARC.

The objectives of the REAAA CCRDM Working Committee are to:

- address issues of concern to REAAA member countries in the area of infrastructure resilience to natural hazards including those related to climate change
- where relevant, complement the topics addressed by PIARC
- act as a liaison between the REAAA member countries and PIARC Committees addressing the topics of resilience and disaster management.

Since 2020, the REAAA CCRDM Technical Working has collaborated with PIARC to jointly coordinate seminars and conferences. These opportunities include:

- PIARC International Seminar on Climate Change, Resilience and Disaster Management for Roads, organised as a joint collaboration with PIARC Technical 1.4 (Climate Change and Resilience of Road Networks), Technical Committee 1.5, (Disaster Management), the Ministry of Public Works and Housing (PURR), the Indonesian Road Development Association (HPJI) and REAAA. This event took place in November 2022, and a briefing note was published to document this event: Detail of a publication | Virtual Library of PIARC | Climate Change, Resilience and Disaster Management for Roads – Seminar
- PIARC Road Disaster Management – Using Latest Information Technologies International Workshop, June 2022, Kyoto Japan. This event was organised by PIARC Technical Committee 1.5 and the Japan Road Association (JARA) in cooperation with the REAAA CCRDM Technical Committee. A briefing note was published: Detail of a publication | Virtual Library of PIARC | Road Disaster Management – Using Latest Information Technologies – Briefing Note
- Executive session of the International Road Federation (IRF) – Global Asia-Pacific Virtual Conference on Building Resilience into Road Infrastructure, 2021.

In September 2024, the Department of Highways (DOH), Ministry of Transport, the Kingdom of Thailand, in collaboration with the Roads Association of Thailand (RATh), hosted the 5th International Conference on Highway Engineering 2024 (iCHE204): Future-Proofing Roads for Asia and Beyond.

This event was also shared with PIARC Technical Committee TC1.1 (Road Administration), where an International Seminar was held, together with combined meetings of PIARC TC1.1 and TC3.1 (Road Safety). The topic of this Seminar was *Envisioning the Transport Agency of the Future*, exploring the need to embrace transformative external outcomes in the transport sector with a changed mindset and innovation, taking consideration of the essential need for changes in internal institutional structures, processes and resources. It also included a Workshop on *Creating a Stronger Future Focused Workforce* and discussed a range of issues related to future skills and transport agencies workforces. Further details on these events are provided in a report published by PIARC TC1.1: https://www.piarc.org/en/activities/PIARC-Directory-Technical-Reports/PIARC-Technical-Reports-2024-2027.

Additionally, and as part of this event, REAAA was invited to organize a session managed by the REAAA CCRDM Working Committee.

At the 121st REAAA Governing Council meeting, it was agreed that the CCRDM Working Committee would develop a series of reports/articles summarising case studies and key themes emerging from these events.

In line with these goals, at the 122nd Governing Council meeting in Bangkok, the CCRDM sought approval from the REAAA Technical Committee and the REAAA Governing Council to develop a technical report on the outcomes of the iCHE2024 REAAA session. It was agreed that the purpose of this report would be to share the outcomes of best practices being used in REAAA member countries for the resilience of the road network and the management of natural disasters for road infrastructure.

This report details the presentations from REAAA member countries delivered at the iCHE2024 in support of this initiative.

2 CONTENT OF TECHNICAL REPORT

In September 2024, the International Conference on Highway Engineering (iCHE) was held in Bangkok, Thailand. The iCHE2024 aimed to foster the engagement of specialists, professionals, decision-makers, and industry leaders, and to help build resilient, adaptable, and future-proofed roads for Asia and beyond. This was an extremely successful event, attended by 1600 delegates (950 locals and 650 overseas delegates from 45 countries). It involved four 4 main tracks – Track A: efficient, inclusive and safe road management, Track B: smart mobility, digital technology and innovation for roads, Track C: sustainability and resilience of road networks, and Track D: PIARC International Seminar. There was a total of 150 presentations and 50 keynote and invited speakers, including a seminar organised by PIARC TC1.1 (Road Administration) and a workshop organised by PIARC TC3.1 (Road Safety).

As part of this conference an REAAA special session, organised by the CCRDM, was held on 6th September 2024. This session provided an overview of the latest actions being undertaken by the REAAA CCRDM, and included a summary of collaboration activities with other road associations such as PIARC. The session also highlighted activities in REAAA member countries being used to improve the resilience of roads through adaptation solutions, best-practice learnings to recover from earthquakes and effective ways to manage disasters.

This session provided an overview of the key actions being undertaken by this REAAA Working Committee and collaborative activities with other road associations such as PIARC. The session also highlighted activities in REAAA member countries being used to improve the resilience of roads through adaptation solutions, best-practice learnings to recover from earthquakes, and effective ways to manage disasters.

This report is structured to provide summaries of each presentation, a summary of the panel discussion, a wrap up, and recommendations. The aim was to share best practices and lessons learned from the REAAA region on activities and responses to extreme weather events affecting road networks.

The speakers and presenters for this session were as follows.

	**Caroline Evans** Co-Chair – Climate Change, Resilience and Disaster Management Working Committee Australia		**Dr Auckpath Sawangsuriya** Member of REAAA Climate Change, Resilience and Disaster Management Working Committee Department of Highways, Bangkok, Thailand
	**Assoc. Prof. Apiniti Jotisankasa** Member of REAAA Climate Change, Resilience and Disaster Management Working Committee Department of Civil Engineering, Kasetsart University, Bangkok, Thailand		**Keijiro Tsurukawa** Project Chief at NEXCO-West, Japan
	**Prof. Agus Setyo Muntohar** Member of REAAA Climate Change, Resilience and Disaster Management Working Committee Universitas Muhammadiyah, Yogyakarta, Indonesia		**Keizo Kamiya** Chair REAAA Pavement Technology Working Committee NEXCO-Central, Japan

The REAAA special session involved four presentations from REAAA member countries as follows.

Activities of REAAA

- Overview of REAAA Climate Change, Resilience and Disaster Management Working Committee Activities:
  - Caroline Evans, Australia

Enhancing the resilience of roads

- Experience in nature-based solutions for erosion control and slope stabilization for highway slopes in Thailand:
  - Dr Apiniti Jotisankasa, Thailand
- Disaster response of expressways in Kumamoto Prefecture, Japan, due to the torrential rain in July 2020:
  - Keijiro Tsurukawa, Japan
- Slope failure cases related to roads in Java, Indonesia:
  - Prof. Agus S Muntohar, Indonesia.

A series of articles are also published in the REAAA Newsletter (Issue 2024-2, April 2025[1]) covering the topic of climate change impacts on road engineering & management. The REAAA CCRDM Working Committee has addressed three major issues: planning for resilience, designing for resilience, and the technology and tools available to address these issues. The articles are supported by several case studies addressing examples of how to reduce the impacts of climate change on road infrastructure assets. Some of these case studies were showcased at the iCHE2024 REAAA special session.

1 REAAA Newsletter, Issue 2024-2: https://tin.al/sEJqUQ

3 REAAA SESSION PRESENTATIONS AT ICHE2024

This section provides detailed descriptions on each presentation. Further details can be found in the REAAA Newsletter (Issue 2024-2).

Presentation 1: Overview of the REAAA Climate Change, Resilience and Disaster Management Working Committee Activities

Abstract

The REAAA Climate Change, Resilience and Disaster Management Working Committee was established in 2020. It is one of three REAAA Working Committees established together with the Pavement Technology and Road Safety Working Committees. Climate change, resilience and disaster management are all issues of relevance to REAAA member countries, and the impacts of these events are increasing in frequency and intensity. This presentation provided an overview of the activities and developments by the committee, including opportunities for collaboration with other associations such as PIARC. It discussed emerging themes in the areas of resilience and identified case study examples of ways to adapt and improve the resilience of road infrastructure.

In particular, the presentation reported that the Committee has collected case studies and fact sheets from REAAA member countries. Many of these presentations have been presented in committee meetings. These focus on opportunities for implementing road and infrastructure climate, resilience and disaster management concepts, for example:

- rapid recovery post climate and natural hazards
- early warning systems for earthquakes, floods, storm surges and drought
- application of adaptation technologies and innovations.

The Committee has also assessed other REAAA activities and reports on resilience. This includes REAAA Technical Report TC-10 'Report on FEHRL scanning tour to South Korea and Japan: infrastructure resilience'. This report outlines research priorities in South Korea and Japan and key approaches/learnings to enhance infrastructure resilience. There are four principles outlined in the report aligned with the resilience cycle, and supported by case study examples:

- Preparedness – a means to plan and prepare for minimising disruptions due to natural and man-made events.
- Robustness – inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality.
- Recovery – speed at which disruptions can be overcome and safety and services restored.
- Adaptation – ability to adapt to events and/or implement technologies to minimise future impacts.

The presentation also outlined other REAAA resilience events such as the International Seminar on Climate Change, Resilience and Disaster Management for Roads: PIARC TC1.4 and TC1.5 Disaster Management, 22nd-23rd November 2022, Yogyakarta, Indonesia.

Emerging themes and observations from this Seminar were that:

- Natural hazards and climate change challenges are similar across countries: we live together in one world.
- There is an increased desire globally to be proactive rather than reactive to climate change events – this makes economic sense:
  - There is increased emphasis on preparing and/or adapting infrastructure for changing climate hazards, rather than continuing to react and recover after events.
  - The full economic, social and environmental costs of recovery are being increasingly recognised and documented.
  - Multi-party collaboration – transport authorities, experts, construction companies, transport users and local communities.

  - More experience is being gained at the global level.
- Vulnerability varies within countries and across countries:
  - Definitions of vulnerability varied, but generally included sensitivity, adaptive capacity, exposure, and condition.
  - An asset management challenge – can agencies afford the future-proofed assets every time or do they need to identify tolerable levels of flood protection?
- Structural and operational resilience are key:
  - Indonesia – Kretek bridge: built over fault line and flood plain, in tsunami zone and subject to liquefaction.
  - Detailed fault mapping, moved abutments, soil replacement, structural breaks, base isolation, multiple monitoring systems.
  - Gardens under bridge; cultural art works incorporated.

The presentation concluded with some observations and emerging areas of importance to the REAAA CCRDM Working Committee. These include the topics of maladaptation, where adaptation measures may be suitable to address one hazard, but can increase the risk of other hazards occurring. There is also a growing observation that more emphasis is being placed on nature-based solutions as viable and cost-effective options for improving the resilience of infrastructure, and the issue of 'managed retreat', which can include responses such as:

- accommodating for events, e.g. road closure times or enhancing drainage to reduce deterioration levels
- protecting or defending by providing structural modifications
- retreat – which can mean abandoning the infrastructure all together, or relocating or temporarily restricting the use of infrastructure. At a community level, there are many dimensions of retreat which also need to be considered.

The Committee will continue to share knowledge across REAAA member countries and will work closely with other associations such as PIARC to identify opportunities of joint benefit.

Presentation 2: Experience in Nature-based Solutions for Erosion Control and Slope Stabilization for Highway Slopes in Thailand

Abstract

This presentation explored various nature-based solutions (NBS) for erosion control and slope stabilization on highway slopes in Thailand. It highlighted the effectiveness of several vegetation techniques, including the vetiver grass system, capillary barriers, and erosion control blanket systems, when combined with simple, low-carbon engineering methods such as gabion walls, flapped soil bags, and screw piles. The potential of biochar-amended soils to enhance the sustainability of vegetated slopes and to function as carbon sinks was also emphasized. Long-term field monitoring of selected sites on highways and rural roads in Thailand was discussed to demonstrate the performance of these systems. The findings showed that the carbon emissions of NBS are significantly lower than those of traditional concrete structures, underscoring the potential of NBS to achieve carbon neutrality in highway slope construction in Thailand.

Introduction

Thailand's highways face increasing challenges from climate change, including more frequent landslides and erosion driven by short, localised and intense rainstorms or 'rain bombs'. These events de-stabilise slopes, disrupt transportation, and incur high maintenance costs. Shallow landslides, caused by surface runoff and soil saturation, are particularly prevalent in hilly and coastal areas such as Chiang Mai and Phuket (Figure 1). However, innovative nature-based solutions, such as soil bioengineering and biochar integration, are proving effective in mitigating these risks while delivering long-term ecological benefits.

Figure 1: Recent landslides in Phuket

Background

Soil bioengineering uses vegetation and natural materials along with engineering techniques to stabilise slopes. Native species such as vetiver grass, with its deep and fibrous root systems, reduce erosion and anchor the soil. Flexible bioengineering structures such as vegetated flapped soil bags and micro-screw piles (Figure 2) ensure long-term slope stability while supporting vegetation and promoting biodiversity. These cost-effective solutions restore ecological value, improve slope drainage, and require minimal maintenance once established.

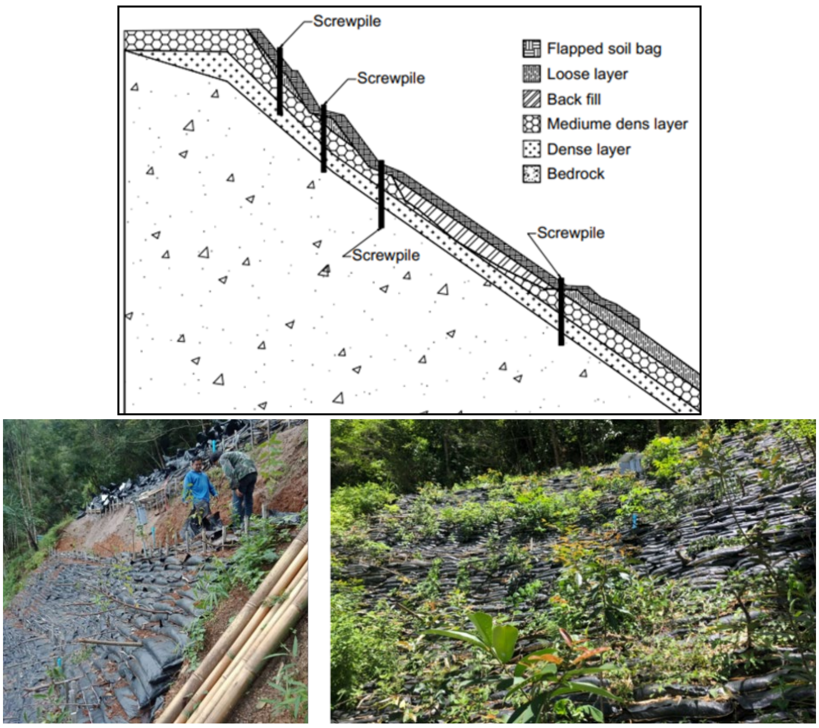

Figure 2: Bioengineered slope using screw-piles and vegetated flapped soil bags at rural road 4088, Kanchanaburi Province, Thailand

Performance and Effectiveness of Biochar Capillary Barrier Systems

Biochar, a carbon-rich material derived from organic waste, has emerged as a promising soil amendment for slopes in highway projects. Its porous structure (see Figure 3) enhances soil moisture retention while preventing infiltration, fosters vegetation growth, and reduces erosion over time. By sequestering carbon, biochar aligns with Thailand's bio-circular-green economy (BCG) goals. Demonstration sites in northern Thailand have showcased the potential of biochar made from plant residues generated during roadside tree trimming, integrating waste management into highway sustainability practices. Training sessions for Department of Highways staff have emphasised biochar production from tree trimmings collected during landscape maintenance. This initiative has not only increased awareness of sustainable practices but also showcased how organic waste can be transformed into a valuable resource for highway stabilisation projects.

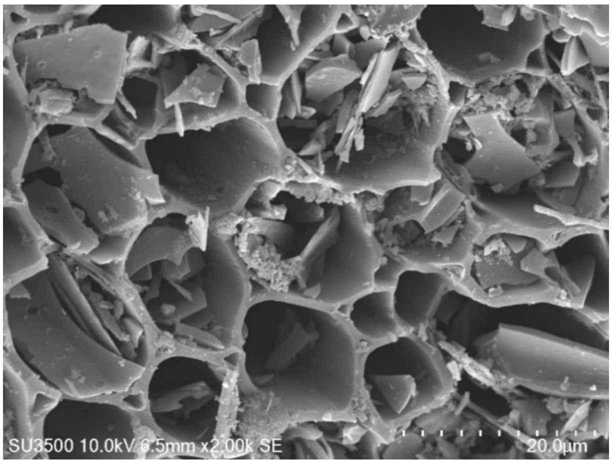

Figure 3: SEM image of bamboo biochar

Case studies have highlighted the success of these approaches. In Chiang Mai, a capillary barrier system (CBS) combined with biochar, prevented water infiltration and stabilised slopes prone to landslides (Figure 4). Life cycle assessment (LCA) of the CBS revealed reduced carbon emissions due to local material sourcing and biochar integration.

The bioengineering technique was used in Phuket to stabilise the failed slope by using flapped soil bags, biochar-amended soil and erosion control blankets to facilitate robust vetiver grass growth (Figure 5). While nearby untreated slopes failed during heavy rains, the bioengineered sections remained stable, underscoring the effectiveness of combining vegetation with biochar and engineering solutions.

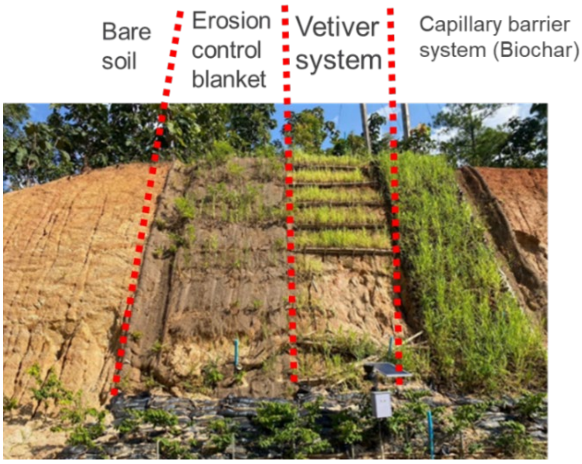

Figure 4: Bioengineering test sections in Chaing Mai province, highway No. 1192 (KM 11+500)

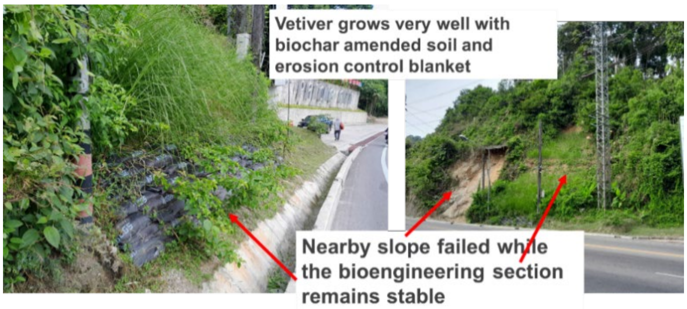

Figure 5: Bioengineered slope with vetiver and biochar in Phuket province

In conclusion, soil bioengineering and biochar offer sustainable, practical solutions to Thailand's highway challenges. Vegetation such as vetiver, coupled with innovative structures, stabilises slopes while restoring ecosystems. Biochar enhances soil properties and contributes to long-term erosion control and carbon sequestration. Successful case studies have demonstrated the feasibility and benefits of these approaches, from mitigating landslides to reducing carbon footprints. As climate change intensifies, integrating nature-based solutions into highway infrastructure will not only reduce disaster risks but also foster environmental conservation and resilience for future generations.

Presentation 3: Disaster Response of Expressways in Kumamoto Prefecture, Japan, following Torrential Rain in July 2020

Abstract

In recent years, unprecedented flood damage due to torrential rains has occurred in many areas of Japan. Under such severe conditions, expressways are required to function as 'Roads for Life'. Torrential rains in July 2020 caused extensive damage, mainly in Kumamoto Prefecture. Although the expressway was spared from long-term road closures, the concrete slabs of the tunnels were lifted, and the slopes collapsed. The Kumamoto Expressway Office of West Nippon Expressway Company worked to restore the road as soon as possible to minimize the impact on road users. In addition, as a support for the affected areas, Expressway charges were waived, and emergency gates were opened for residents in the area. This report summarizes the responses during natural disasters.

Background

In recent years, extreme weather conditions and severe disasters have frequently been occurring because of the effects of global warming. In a disaster, expressways are expected to serve as an emergency route as 'Roads for Life' to facilitate relief efforts and disaster recovery in cooperation with the affected local governments.

In July 2020, maximum hourly rainfall over 70 mm/h and cumulative rainfall of 800 mm for the first three days were recorded on the Kyushu Expressway in Kumamoto Prefecture. Engineers at the Kumamoto Expressway Office worked hard and quickly to repair the damaged parts of the roadway. They then delivered life support for local people by offering free gates at its Parking Area so they could be used for emergency purposes.

Disaster response

1. Quick repair of the damage to the expressway

   (1) Lifted concrete pavement slab

Core holes were drilled to promote drainage under the concrete slabs to prevent further lifting. Urethane foam was then injected at 1 m intervals into the cavity under the slab. For quick operation, early-strength Portland cement, called ONE DAY PAVE, which achieves sufficient compressive strength in 24 hours, was used.

   (2) Damaged embankment slopes

Left lane restrictions were introduced, and steel sheet piles were placed to ensure the stability of the slope.

2. Life support for disaster-stricken areas

   (1) Overview

Following the heavy rain, National Highway Route 219 in southern Kumamoto Prefecture had to be closed, effectively isolating local communities alongside the Kyushu Expressway. For this reason, an alternative free-charge-of-law route was applied on the toll road, by opening emergency gates at three locations.

(2) Installation of emergency gate

At each location, inbound and outbound runways had to be secured to enable access to and from local roads. While the Yamane Service Area was able to do this easily only by placing security guards, the Ayugaeri Bus Stop and Sakamoto Parking Area required new construction: an outbound runway at the Ayugaeri and both inbound and outbound runways at the Sakamoto. These facilities were built immediately by the NEXCO office.

(3) Operation of the gates

An example of the temporarily constructed outbound runway at Sakamoto PA is shown in Figure 6. The construction included the removal of entry barriers, guardrails and trees, the installation of flexible pipes in the drainage ditch, filling with crushed stone, and laying rubber plates on top of the flexible pipes. For securing safety, guards are stationed all day at the gate and junctions to check permits. The inbound and outbound Sakamoto Pas were still in operation in January 2023.

Before and after installation of the gate at Sakamoto PA (outbound)

Operation of the gate at Sakamoto PA (outbound)

Figure 6: example of the temporarily constructed outbound runway at Sakamoto PA

Presentation 4: Slope Failure Cases Related to Roads in Java, Indonesia

Abstract

The climate in Indonesia is predominantly hot and humid, with rainfall primarily concentrated in low-lying areas. Mountainous regions, on the other hand, tend to have lower temperatures. The wet season spans from November to April, while the period from May to October is generally characterized by dry weather. Indonesia undergoes arid conditions during El Nino and humid conditions during La Nina.

The rapid development of the roadway in Jawa Island has changed the natural slope into a steeper cut slope. The slopes may be more likely to be unstable during an intense rainfall or earthquake. Java is characterized by a central hilly to mountainous volcanic belt composed of deeply-weathered Tertiary ashes and tuffs resting on a relatively weak and unstable sedimentary sequence dominated by mudstones. The region is one of the most tectonically active in the world. This presentation presented details of three roadside slope failure cases in Central Jawa and East Jawa. The roadside slopes were mainly comprised of weathered rock and silt sand. The main problem associated with these roadside slopes is the construction of the cut slopes. It is also suggested that a geometrical method, such as terracing and a gravity wall, may be beneficial.

Introduction

The climate in Indonesia is predominantly hot and humid, with rainfall primarily concentrated in low-lying areas. Mountainous regions, on the other hand, tend to have lower temperatures. The wet season spans from November to April, while the period from May to October is generally characterized by dry weather. Indonesia undergoes arid conditions during El Nino and humid conditions during La Nina. The rapid development of roadways in Java Island has, in some cases, changed the natural slope into a steeper cut slope. The slopes may be more likely to be unstable during intense rainfall or an earthquake. Java is characterized by a central hilly to mountainous volcanic belt comprised of deeply-weathered Tertiary ashes and tuffs resting on a relatively weak and unstable sedimentary sequence dominated by mudstones. The region is one of the most tectonically active in the world. This case study overviews roadside slope failure cases on national roads and toll roads in Central Java.

Roadside Slope Failure: Residual Soil Cases

The national road studied was a section of the Tawangmangu-Cemorosewu road in Karanganyar, Central Java. The topography is relatively high due to steep hills and valleys with the problematic geological condition of weathered rock and silty sand (Figure 7). The main problem with these roadside slopes is the construction of cut slopes. Geotechnical exploration was conducted after the slope failure. The use of a geoelectric-resistivity test for the investigation, combined with hand boring for soil sampling, was a reasonable choice in terms of interpreting the potential failure of the surface of the slope and for determining the soil properties. The investigation suggested that a geometrical method, such as terracing and a gravity wall, may be beneficial to prevent further slope failures. The installation of low-cost technology for slope monitoring was necessary to increase road safety. The IoT-based technology comprises a rain gauge and soil moisture sensors.

Figure 7: Debris deposit of the roadside slope failure: Tawangmangu-Cemorosewu road in Central Java

Roadside Slope Failure: Clay-shale Cases

In 2012, a landslide occurred on toll road Semarang-Bawen in Central Java due to the exposure of the clay shale slopes following cuts during the construction of the toll road (Figure 8). The exposed layer of clay shale reacted with the atmosphere, leading to a sudden collapse of the weathered clay shale slope. Due to the weathering, the initial properties of the clay shale changed following the degradation of the structure. The degradation of the clay shale reduced its shear strength, leading to slope instability. Shotcrete and bolts were applied as a remedial measure to prevent further slope failures (Figure 9). In some areas, the shotcrete used to prevent weathering did not work well and, as a result, slope failure is progressing.

Figure 8: Slope failure at Toll Road Semarang-Bawen, Central Java, Indonesia

Figure 9: Slope remedial measures using shotcrete and bolt at Toll Road Semarang-Bawen: (left) successful work, (right) unsuccessful work

Toll roads represent high-cost infrastructure and investment for the country. The slope health monitoring system should be implemented regularly, efficiently, and effectively. InSAR technology was applied to evaluate the potential slope movement over time. A detailed InSAR result for the Semarang-Bawen toll road, overlaid with data points representing ground displacement rates – measured in millimetres per year (mm/year) – is shown in Figure 10. The colour scale on the left side of the image ranges from –10 mm/year to +25 mm/year, indicating varying rates of ground movement. This visual representation allows for an in-depth analysis of the ground displacement patterns across the region. The findings highlighted the effectiveness of InSAR in detecting ground displacement with high precision, enabling timely intervention to prevent infrastructure damage and ensure safety.

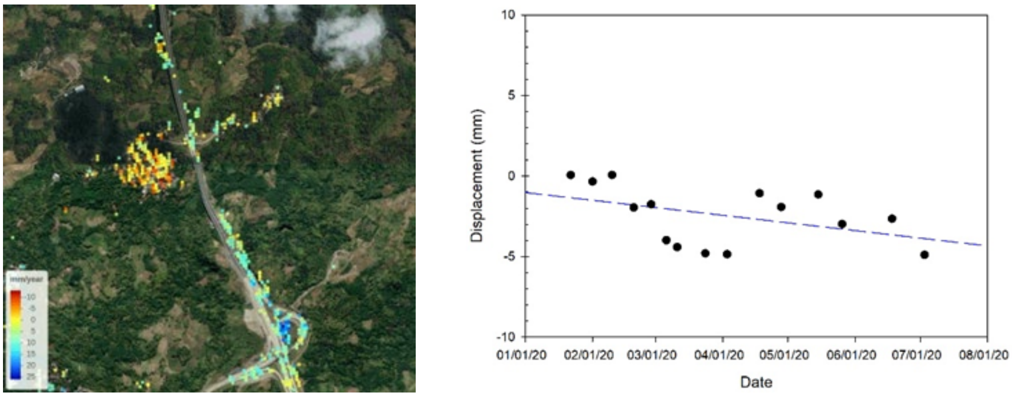

Figure 9: Visualization of InSAR results for Semarang-Bawen Toll Road (left); Time-series result for Semarang-Bawen toll road (right)

Need for Low-cost Technology for Slope Monitoring

In many low-to-middle income countries, a low-cost technology for slope monitoring is a solution that can be effectively implemented. Traditional monitoring systems are often expensive and difficult to maintain, particularly in resource-limited settings (Figure 10). The integration of Internet of Things (IoT) technology into slope monitoring offers an innovative low-cost technology. The primary technology in IoT-based monitoring systems includes low-cost environmental sensors. These sensors measure a variety of parameters, including: soil moisture, inclinometers and accelerometers, vibration, and temperature and rainfall. Once the data is collected, it is transmitted via wireless communication technologies (e.g. Wi-Fi). However, many developing countries face challenges related to inadequate infrastructure and poor network connectivity, especially in rural or mountainous areas. Ensuring reliable data transmission is critical for the success of IoT-based systems.

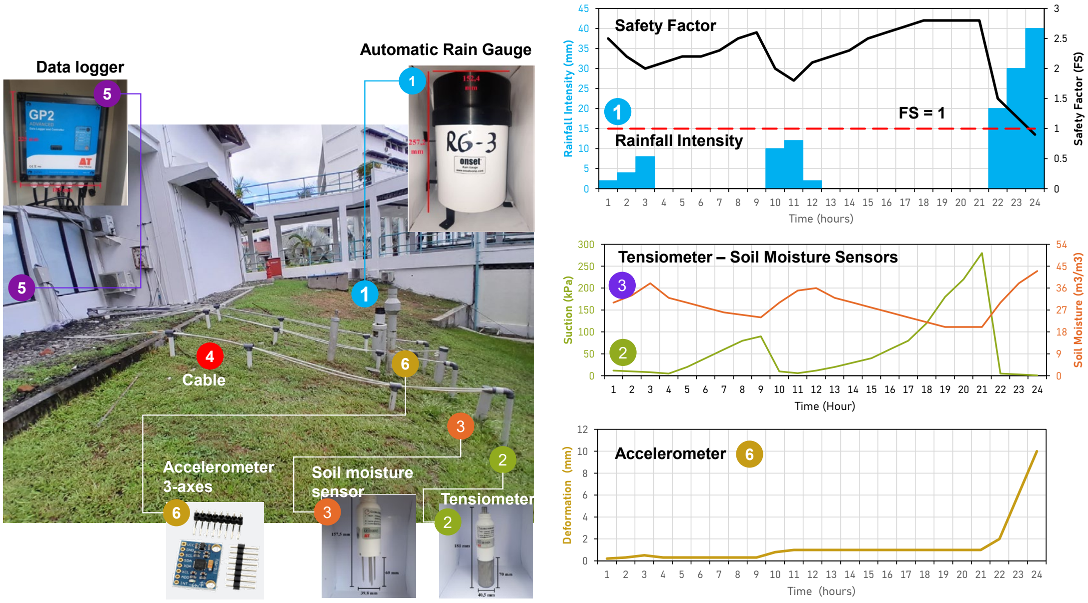

Figure 10: Traditional slope monitoring systems (Muntohar et al. 2024)

4 DISCUSSION AND KEY ISSUES

There are many aspects of resilience to consider. These include identifying ways for infrastructure managers to be more prepared, robust, and to enhance the effectiveness of recovery and adaptation. The presentations at the session showed how the use of data and technologies can be used to provide better communications between roads, the users both before, during and after events. There were also a series of technologies which are being used such as low-cost technologies for slope monitoring, slope remedial measures using shotcrete and the use of alternative materials such as biochar as a successful measure to increase performance and effectiveness of the nature-based solutions.

The session highlighted the need for quick repair of the damages on expressways in Japan following earthquake events. This involved lifted concrete pavement slab, repairing damaged embankment slopes, and installation of emergency gates to secure areas and ensure that inbound and outbound traffic was safe.

The session also captured the need to maintain road connections to rural or remote communities as there is often a lack of alternative connections. These routes are essential to ensure communities remain connected when alternative routes are cut-off due to natural disasters such as floods or earthquakes.

Case studies from the REAAA Committee provide examples of technologies and tools that play an important role in supporting the ongoing resilience of road networks, ranging from a risk-based approach in the planning, investment, design and asset management phases through to post-disaster management. These case studies can also be used to highlight the importance of efficient and effective collaborative sharing of real time data in geospatial formats., which is fundamental to ensuring that infrastructure is more resilient and can manage disasters both now and in the future.

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