Highlighting Strong Partnership

Indian Institute of Technology Mandi

&

Durham Univerisity

[2020-2025]

Preface

The partnership between Durham University and IIT Mandi is well-established, built upon years of collaborative research and academic exchange. Prior to joining IIT Mandi, Dr. Ashutosh Kumar worked within the Department of Engineering at Durham University with Professor David Toll as a Postdoctoral Research Associate. Since then, their collaboration has continued through significant projects such as the UKRI NERC SEAL (Landslide Susceptibility and Adaptability in South-East Asia) project and the UKRI EPSRC CACTUS (Climate Adaptation Control Technologies for Urban Spaces) global project. Under the SEAL project, IIT Mandi successfully organized an international workshop and a short course related to landslide susceptibility, which attracted a wide international audience of more than 250 participants. The CACTUS project focuses on investigating climate adaptation methods for landslide protection, and IIT Mandi has contributed by constructing a prototype barrier system to support this research. The collaboration between Durham University and IIT Mandi has resulted in numerous joint publications in leading international journals such as Geotechnique, Canadian Geotechnical Journal, ASCE Journal of Geotechnical and Geoenvironmental Engineering, Acta Geotechnica, Landslides, and several reputed conference publications.

Following the catastrophic 2023 summer monsoon disaster in Himachal Pradesh, IIT Mandi and the Institute of Hazard, Risk and Resilience (IHRR) at Durham University worked together to document the damages. This work has been published as a journal article. Furthermore, Dr. Ellen Robson is collaborating with IIT Mandi on the LIFE project (Landslides Impact on Family and Environment) to investigate the impact of the 2023 monsoonal disaster on the lives of the affected people.

Additionally, the IHRR has supported the academic exchange of two postgraduate students from IIT Mandi, Ms. Abhiparna Dasgupta and Ms. Aditi Rana, who were jointly supervised by faculty members from IIT Mandi and the IHRR. Another milestone in this collaboration is the achievement of Mr. Sonu Kumar, a PhD student from IIT Mandi, who was awarded the prestigious Commonwealth Split-Site Scholarship by the Government of the United Kingdom. His research focuses on developing foundation design guidelines for onshore wind turbine foundations in unsaturated expansive soils.

The enduring partnership between Durham University and IIT Mandi continues to contribute to addressing critical challenges related to landslide susceptibility, climate adaptation, and disaster resilience through innovative research, student exchange, and collaborative publications.

Ashutosh Kumar

Ellen Robson

David G. Toll.

Two days' International Workshop on

Integrating Disaster Resilience into the

Transportation Engineering Curriculum

1-2 April 2025

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Background

Developing resilient road infrastructure in the Himalayan region is challenging due to its natural susceptibility to hazards including earthquakes, flash flooding, co-seismic and post-seismic landslides, and rainfall-induced landslides, frequently disrupting transport infrastructure and local communities. Most of landslides are often triggered by heavy rainfall, during the South-West monsoon season, spanning June to September, during which, this region receives 68% of its annual rainfall. For example- the state of Himachal Pradesh, located within the foothills of North-western Himalayas, was severely affected by 2023 Monsoonal rainfall. According to the Himachal Pradesh State Disaster Management Authority, heavy rainfall and landslides resulted in approximately 428 fatalities and the destruction of over 20,000 structures by the end of the 2023 monsoon, with estimated losses amounting to 1.2 billion USD.

Fig. 1. Swept away sections of National Highway (NH-03) due to flash floods from cloudbursts in Kullu district, Himachal Pradesh (2023) and Landslides in Mandi damaged the under-construction bridge in Mandi district

Fig. 2 Devastation due to rainfall-triggered landslides at Sainj area of Kullu district, Himachal Pradesh during monsoon season (2023) - Several houses got washed away blocking the road

During the 2022 monsoon season, the road and rail networks in the state of Assam, eastern Himalayas, were severely disrupted through several landslides triggered by the heavy rainfall, directly impacting the lives of 30,000 people. In 2017, there was a particularly devastating landslide in the Mandi district of Himachal Pradesh, the Kotropi slide, which resulted in the loss of more than 50 lives.

These climate disasters are becoming more widespread as climate change is increasing the frequency and intensity of heavy rainfall events in the Himalayan foothills causing extensive rainfall-triggered landslides and flooding (Velore et al. 2020) which is exacerbated by haphazard and poor construction practices. It is also important to highlight that the Himalayan region of India is one of the most seismically active areas worldwide, presenting a significant threat to road infrastructure due to earthquake-induced landslides. For example: Notable earthquakes such as Uttarkashi (1991), Chamoli (1999), Kashmir (2005), and Sikkim (2011) have caused a significant number of landslides along the road infrastructure (Martha et al. 2015). Therefore, considering co-seismic and post-seismic landslide hazards while designing this infrastructure is essential to ensure disaster preparedness.

The current transportation engineering module within civil engineering curricula fail to address disaster preparedness, revealing critical gaps in education. Additionally, there is a lack of continuous professional training in disaster risk reduction for road engineers in the region. Thus, there is an urgent need for improved education on constructing resilient road infrastructure in India's hilly terrain.

Through this project, we aim to bridge the gap between industry and academia by bringing together leading academicians from India and the UK and industry stakeholders from India to develop a new M.Tech module curriculum that integrates disaster preparedness and transportation engineering (focussing on road infrastructure) for India's hilly terrain.

This module will first be introduced within the civil engineering M.Tech course taught at IIT Mandi, and will then be offered as a stand-alone online module hosted by the CDRI virtual platform DRI connect for professional around the world to access.

This module aims to meet industry requirements for designing disaster-resilient transportation infrastructure in India's hilly regions, supporting the Indian government's agenda to enhance transportation connectivity in the Himalayas (ETGovernment, 2023). Additionally, it will resonate with India's New Education Policy (NEP) highlighting this urgency for a paradigm shift, prompting the merger of conventional educational methods with a model that encourages industry collaboration (Financial Express 2023).

The module will provide students with a holistic understanding of transport disaster preparedness, including disciplines beyond traditional engineering (e.g. qualitative methods, cost analyses and network analyses).

Aims and Objectives of the workshop:

This module aims to meet industry requirements for designing disaster-resilient transportation infrastructure in hilly regions. Overall objective is to catalyse industry academia partnerships that will allow academia and industry to work in sync, prepare work ready workforce, reduce on the job training cost, and make learners more employable. This aims to build stronger, more inclusive, industry connected higher education systems that support global development impacts

Following objectives have been identified:

- **Curriculum Development:** To outline the key topics and interdisciplinary components that should be included in the M.Tech module, ensuring alignment with industry requirements and best practices.
- **Industry-Academia Collaboration:** To foster partnerships between academia and industry to create a curriculum that integrates practical knowledge, case studies, and real-world applications.
- **Policy and Practical Insights:** To bring together policymakers, practitioners, and academics to share insights on disaster preparedness strategies and transportation resilience in hilly regions.
- **Pedagogical Approaches:** To explore and incorporate modern teaching methodologies, including digital tools, field-based learning, and simulations, into the module design.
- **Knowledge Exchange:** To facilitate an exchange of experiences and best practices among experts from different domains, enhancing the module's effectiveness and impact.
- **Implementation Strategy:** To discuss the roadmap for integrating the module into IIT Mandi's curriculum and its availability as an online course through DRI Connect, ensuring accessibility for professionals worldwide.

Agenda:

- Formal Introduction
- Project presentation by IIT Mandi and Durham University
- Presentation on Landslide Impact on Family and Environment in Himachal (LIFE in Himachal) project.
- Presentation on Landslide Monitoring System developed at IIT Mandi
- Group Discussion on
    - *How could have the 2023 monsoon disaster of Himachal Pradesh been prevented (engineering intervention, early warning system, societal contribution and policy making)?*
    - *Hazard reduction, transportation planning*
    - *Exposure reduction*
- Curriculum planning and development
- Development of a training module for online and offline delivery

Attendees:

1. Professor Deepankar Choudhury, IIT Bombay, India (Chairman of Disaster Resilience and Capacity Building Committee of State Disaster Management Authority (SDMA) of Govt. of Maharashtra)
2. Shri Nishant Thakur, Additional Secretary of Education and Project Director of the Project Management Unit (SDMF) HP, Himachal Pradesh, India.
3. Dr. Gopi Basyal, Director, National Society for Earthquake Technology, Nepal
4. Dr. Ashutosh Kumar, Assistant Professor, School of Civil Engineering, IIT Mandi, India
5. Dr. Shyamasree Dasgupta, Associate Professor, School of Humanities and Social Sciences, IIT Mandi, India
6. Dr. Uday V Kala, Associate Professor, School of Civil and Environmental Engineering and Chairperson, Centre for Climate Change and Disaster Management, IIT Mandi, India
7. Dr. Ellen Robson, Postdoctoral Research Associate, Institute of Hazard, Risk and Resilience, Durham University, United Kingdom
8. Professor David Toll, Emeritus Professor, Department of Engineering, Durham University, United Kingdom (Online)
9. Dr. Sravan Mugunda Viswanath, Assistant Professor, Durham University, UK (Online)
10. Dr. Arash Azizi, Lecturer, James Watt School of Engineering, University of Glasgow, UK (Online)
11. Dr. Mike Winter, Director, Winter Associates Limited, United Kingdom
12. Mr. Rudra Budhbhatti, Technical Head (India and Nepal), Maccaferri, India
13. Dr. Bhim Kumar Dahal, Tribhuvan University, Nepal
14. Mr. Kiran Gowda, Advisor-Transport, CDRI, India
15. Mr. Empati Uday Kumar, Analyst-Technical Studies, CDRI, India
16. Dr. Ankita Sood, International Consultant- Climate and Disaster Resilient Planning, India.
17. Dr. Milind Patil, Project Manager, AFRY India Pvt Ltd, India.
18. Er. Gajendra Kumar Jha, Vice-Principal, Universal Engineering & Science College, Nepal
19. Dr. Tanmoy Das, Institute Post-doctoral Fellow, IIT Bombay, India
20. Dr. Dipali Jindal, Senior consultant, NDMA, India

News about the project advertised on Durham University Website

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Durham researchers awarded grant to help improve the resilience of roads in the Indian Himalayas affected by devastating monsoon rainfall

3 October 2024

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Our researchers have been awarded a British Council grant for a project aiming to improve the resilience of roads in the Himalayan region of India by integrating disaster preparedness into transportation engineering education.

Dr Ellen Robson and Professor David Toll, from our Institute of Hazard, Risk and Resilience and Department of Engineering, are collaborating with the Indian Institute of Technology (IIT) Mandi, led by Dr Ashutosh Kumar, to assess the damages caused by landslides in Himachal Pradesh, India, triggered by a devastating monsoon last year.

The area was badly affected after the daily rainfall levels reached 436% higher than the normal daily monsoonal average.

The research team is now focusing their attention on how to better protect the area from harm if future monsoon seasons reach similar levels.

Creating resilient infrastructure

The team recognised that a postgraduate module on transportation engineering taught in India could be refined to create a workforce better suited to constructing and maintaining disaster-resilient roads.

The award of the British Council's £30,000 Industry Academia Collaborative Grant will allow Durham researchers to collaborate with IIT Mandi and Rudra Budhbhatti at Maccaferri Environmental Solutions PVT. Ltd to explore how best to refine the module. The project is also supported by partners, Professor Deepankar Choudhury at IIT Bombay, Mumbai, India, and Dr Milind Patil at AFRY India Pvt. Ltd.

The module will be adapted to make it more holistic by bringing in other disciplines beyond traditional engineering approaches, which often focus on the construction of artificial structures to control natural processes.

This will include introducing skills in geology and geomorphology to better understand the landscape they are working in, in economics to determine the most cost-efficient approaches, and in communication to determine the needs of the communities using the roads.

Supporting future engineers

A workshop is planned with industry partners alongside policymakers in the region to understand what they need from a workforce for preventing future disasters, and shaping a curriculum that meets industry requirements.

The module will first be introduced at IIT Mandi, and will then be offered as a stand-alone online module hosted by the Centre of Continuing Education at IIT Mandi

Ultimately, it is hoped that engineers who take this module will have a refreshed approach to transport engineering and be better equipped for designing roads in disaster-prone areas.

The project will get underway at the end of September 2024 and run to September 2025.

Find out more

- Discover more of the work of **Dr Ellen Robson**, **Professor David Toll**, **Dr Ashutosh Kumar**, and **Professor Deepankar Choudhury**.
- View the research paper, published in **Springer Link**, on the preliminary assessment of the landslides.
- Read a piece written by the researchers in **The Conversation** on how climate change has been linked to the landslides in the area.
- Find out more about the **Indian Institute of Technology Mandi**.
- Learn more about the **British Council's** Industry Academia Collaborative Grant.
- Read more about Durham University's **Institute of Hazard, Risk and Resilience.**
- Our Department of Engineering is ranked fourth in the UK in the Complete University Guide 2025. Visit our **Engineering webpages** for more information on our undergraduate and postgraduate programmes.

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Happy to announce that UKIBC member Durham University received the British Council's Going Global Program (GGP) Grant. They are one among the four universities to have gotten shortlisted for the same.

https://lnkd.in/e_3ZQwSX

Congratulations to Shilpi Prasad and the team!

list_of_successful_applications_ggp_ia_grant_2024-25.pdf
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IHRR was pleased to welcome Dr. Ashutosh Kumar from Indian Institute of Technology, Mandi, India, who visited us for a week. Dr Ashutosh kumar, an assistant professor in the School of Civil and Environmental Engineering, is collaborating with our PDRA Ellen Robson and Co-director Professor David Toll. They are working on the LIFE Project (Landslide Impact Family & Environment), studying the impact of landslides on human lives following the unprecedented monsoonal rainfall in 2023.
You can access some of their joint research here:

https://lnkd.in/ewJKfVMu

https://lnkd.in/eAyPk2M4

IIT Mandi- Durham University collaborative work

Societies worldwide are confronted with escalating risks from hazards such as floods, landslides, earthquakes, and water pollution, as well as mounting social pressures driven by migration, population growth, and urbanisation. In response, we are enhancing our resilience to these challenges through innovative local initiatives, such as community-driven action, nature-based solutions, and novel financial strategies. The **Exploring Risk Visual Arts Festival 2025** is about documenting, capturing, and inspiring the transition from being impacted by hazards to being resilient.

Exploring Risk 2025 explores stories of increasing resilience through visual arts approaches. We are looking for visual depictions of **how communities and individuals adapt, endure, and thrive amid complex global shifts from environmental to societal crises**. These could be stories from global scientists, practitioners, and artists' perspectives about our responses to, for example, floods or climate migration.

Investigation of landslides triggered by unprecedented rainfall events during 2023 monsoon in Himachal Pradesh, India

Recent Landslides | Published: 13 February 2025
(2025) Cite this article

Landslides
Aims and scope →
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Eedy Sana, Kritika, Ashutosh Kumar, Ellen Robson, R. Prasanna, Uday Kala & David G. Toll

Abstract

Himachal Pradesh, a northern state of India, experienced unprecedented heavy rainfall between July and August 2023 that triggered several devastating and fatal landslides across the state. This paper presents the findings of two key studies that aim to further our understanding of the failure trends and mechanisms that occurred during the 2023 monsoon season. Firstly, the systematic mapping of the landslides using satellite imagery and field mapping techniques to identify trends in the landslide characteristics was conducted. Approximately 6500 landslides were mapped that were triggered during the 2023 monsoon season across an area of approximately 3100 km^2 in the Mandi and Kullu Districts. The key failure mechanisms for these landslides are presented and analysed. It was found that the most critical combination for slope failures in the Himachal Pradesh region consists of sandstone lithology. Slides were the most common observed types of failures. Additionally, the rainfall anomaly index clearly highlighted the change in the trend of rainfall in the mountainous region indicating the evident impact of climate change. Secondly, a coupled hydro-mechanical finite element analysis to investigate the detailed mechanisms of failure for an exemplary slope was performed. The numerical modelling revealed that the progression of a wetting front brought about by continued rainfall infiltration caused a reduction in the soil suction and the resulting loss of the shear strength of the soil forming the slope along the potential slip surfaces. The studies presented in this paper significantly contribute to knowledge of rainfall-triggered landslide mechanisms in Himachal Pradesh.

Preliminary assessment of series of landslides and related damage by heavy rainfall in Himachal Pradesh, India, during July 2023

Landslide News | Published: 27 January 2024
Volume 21, pages 919–931, (2024) Cite this article

Eedy Sana, Ashutosh Kumar, Ellen Robson, R. Prasanna, Uday Kala & David G. Toll

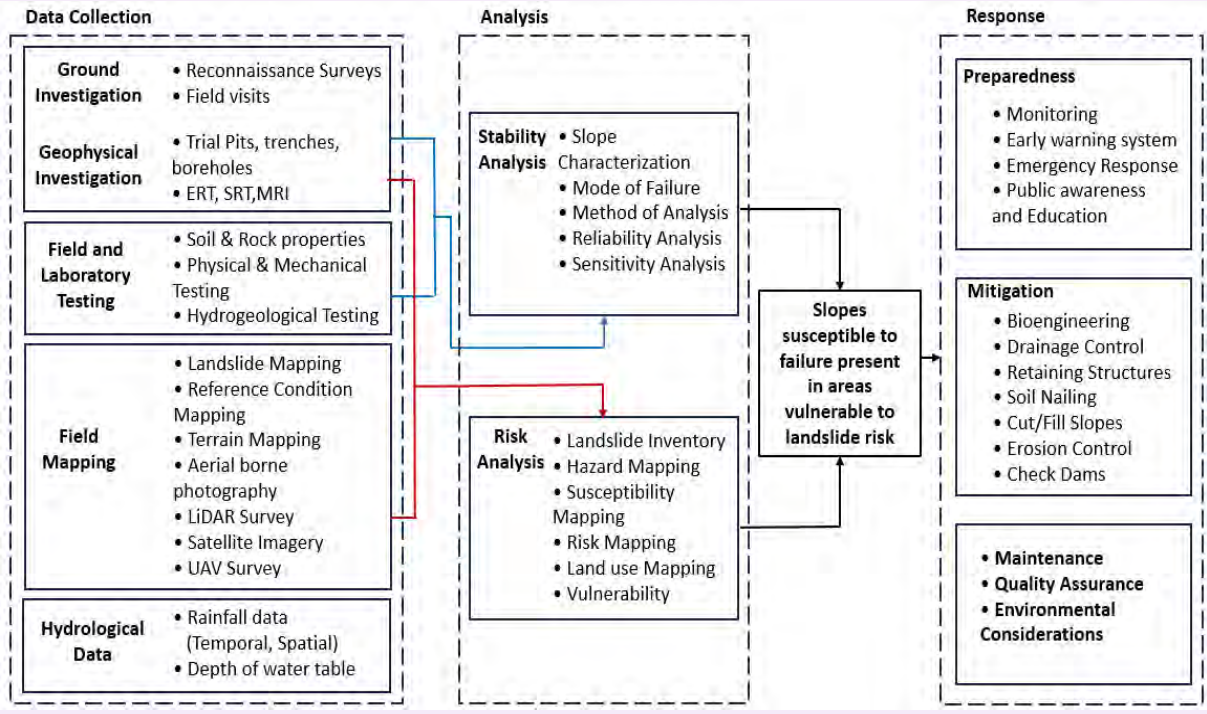

Fig. 3. Proposed road map for landslide analysis and response (ERT: Electrical Resistivity Tomography, SRT: Seismic Refraction Tomography, MRI: Magnetic Resonance Imaging, LiDAR: Light Detection and Ranging, UAV: Unmanned Aerial Vehicle)

THE CONVERSATION

Academic rigour, journalistic flair

Himalayan communities are under siege from landslides – and climate change is worsening the crisis

Published: October 24, 2023 4.12pm BST

Twenty people were killed when a temple in Shimla, northern India, collapsed under a landslide in August 2023. EPA

Authors

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Three-quarters of annual rain in the Himalayas arrives in the monsoon season from June to September. Within this rainy period are sudden and extremely intense cloudbursts, which often "pop" over a relatively small area (akin to a cloud bursting open like a balloon).

As climate change is making these cloudbursts and other forms of heavy rainfall more intense and more frequent in the Himalayan foothills, the hilly slopes are becoming saturated more frequently, and thus unstable. Rainfall-triggered landslides are already happening extensively across the Himalayas, and things are likely to get worse.

From July to August 2023, the Indian Himalayas, particularly the state of Himachal Pradesh in the northern part of the country, experienced an unprecedented number of cloudbursts which triggered thousands of devastating landslides. The state's disaster management authority reported that by the end of August, heavy rain and rainfall-triggered landslides had caused 509 fatalities, destroyed at least 2,200 homes and damaged a further 10,000. It is estimated that Himachal Pradesh's losses from this period amount to US$1.2 billion. Much of the destruction took place during two short periods, one in mid-July and one in mid-August.

The level of damage to buildings, roads and bridges is extremely difficult to comprehend. Several sections of national and state roads have been washed away, a temple in Shimla collapsed and killed 20 people, rural dwellings largely constructed on sloped ground were washed away by rain, and houses are still sliding downhill.

Schools and hospitals have been damaged, posing an ongoing threat to lives. A school in Kullu district was closed for 52 days because the bridge which connected it to a town had been washed away. Local people have had no option but to live in tents with minimal facilities. They are hugely concerned about their safety ahead of a cold and snowy winter.

Four days of heavy rainfall in July 2023 triggered landslides that blocked around 1,300 roads including five national highways, leaving the state almost cut off from the rest of India. This had huge knock-on effects as 1,255 bus routes were suspended, 576 buses were stranded, more than 70,000 tourists had to be evacuated, and people could not access key facilities and services. This impeded emergency responders, causing critical delays in search and rescue operations as well as delivery of aid.

Across the whole of India, the summer monsoon and its related cloudbursts are decreasing. But in the Himalayan foothills, they are increasing significantly – partly because when warm moist air encounters the Himalayan barrier it rapidly lifts and cools, forming large clouds that then dump their rain. With intense rain happening more and more often in the Himalayan foothills, it is likely that 2023's summer of disasters will occur again.

Unnecessarily vulnerable

Although climate change may be to blame for the rise in cloudbursts, in an ideal world rainfall alone needn't lead to disastrous landslides. But the Himalayas have been made more vulnerable by human actions.

The region has largely been deforested, removing tree roots which reinforce the ground and form a crucial barrier that stops soils washing away. And unplanned developments and haphazard construction have destabilised already fragile slopes.

Initial reports on this year's landslides suggest the worst damages occurred along artificially cut slopes (for roads or buildings), where there has been a lack of proper provisioning for drainage and slope safety. In both India and Nepal, many of the hill roads have been haphazardly constructed, which makes landslides during rainfall more likely. Construction guidelines and building codes are outdated and have been ignored anyway, and there is little assessment of the link between urbanisation and landslide risk.

One obvious solution is to prevent rain from penetrating the ground, so the slopes avoid losing any strength. However, if the soil is entirely prevented from absorbing any rain, the water will instead run off the surface and cause greater flooding problems further downhill.

One engineering solution is to place an artificial soil layer above the natural soil to temporarily hold water in the surface when it is raining extremely hard, preventing it penetrating deeper within the slope. This "climate adaptive barrier layer" will then release water back to the atmosphere during a later drying period.

As the heavy rain intensifies, it will be hugely important for the Himalayas to implement new user-friendly and reliable construction guidelines that factor in how the climate is changing. Landslides can't be avoided entirely, and India certainly won't be able to reverse global warming and the increase in cloudbursts any time soon. But these preventive actions should at least make communities more resilient to the changing climate.

Canadian Geotechnical Journal

Research Article

Deterioration of a compacted soil due to suction loss and desiccation cracking

Ashutosh Kumar[a], **Arash Azizi**[b], **and David G. Toll**[c]

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Canadian Geotechnical Journal
Volume 62
2025

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Abstract
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Abstract

This paper presents the results of laboratory testing of a clayey soil taken from a road subgrade in Tanzania. The results revealed a reduction in the soil water retention capacity, accompanied by shifts in the water retention curves with successive cycles. These changes affected the soil response to shear loading, resulting in decreased shear strength and stiffness with hydraulic cycles. While the soil experienced suction losses due to desiccation cracks and hysteresis effects, these suction variations alone could not account for the observed changes in shear strength, implying that the development of desiccation cracks contributed to reduced strength and stiffness. The results showed that the degradation effect of crack development on the shear strength and elastic modulus of the soil during hydraulic cycles could be justified using a macroscopic degree of saturation, i.e., the degree of saturation of large pores external to the aggregates, through a microstructural-based effective stress approach. This allowed the increase in the large pores resulting from crack development to be accounted for and hence the successive reductions in shear strength and stiffness with drying-wetting cycles. These deterioration effects need to be considered for design of geotechnical infrastructure to ensure stability and resilience of infrastructure over time.

Fig. 4. Drying-wetting deteriorates the compacted structures of soils and affect the engineering property

Géotechnique
ISSN 0016-8505 | E-ISSN 1751-7656
Volume 73 Issue 5, May, 2023, pp. 401-417

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Coupling cyclic and water retention response of a clayey sand subjected to traffic and environmental cycles

Authors: Arash Azizi* Ashutosh Kumar† David G. Toll‡
Department of Engineering, Durham University, Durham, UK.

Section: Choose

Abstract

Compacted soils used as formation layers of railways and roads continuously undergo water content and suction changes due to seasonal variations. Such variations, together with the impact of cyclic traffic-induced loads, can alter the hydro-mechanical behaviour of the soil, which in turn affects the performance of the superstructure. This study investigates the impact of hydraulic cycles on the coupled water retention and cyclic response of a compacted soil. Suction-monitored cyclic triaxial tests were performed on a compacted clayey sand. The cyclic response of the soil obtained after applying drying and wetting paths was different to that obtained immediately after compaction. The results showed that both suction and degree of saturation are required to interpret the cyclic behaviour. A new approach was developed using (*a*) a hysteretic water retention model to predict suction variations during cyclic loading and (*b*) Bishop's stress together with a bonding parameter to predict accumulated permanent strain and resilient modulus. The proposed formulations were able to predict the water retention behaviour, accumulated permanent strains and resilient modulus well, indicating the potential capability of using the fundamentals of unsaturated soils for predicting the effects of drying and wetting cycles on the coupled soil water retention and cyclic response.

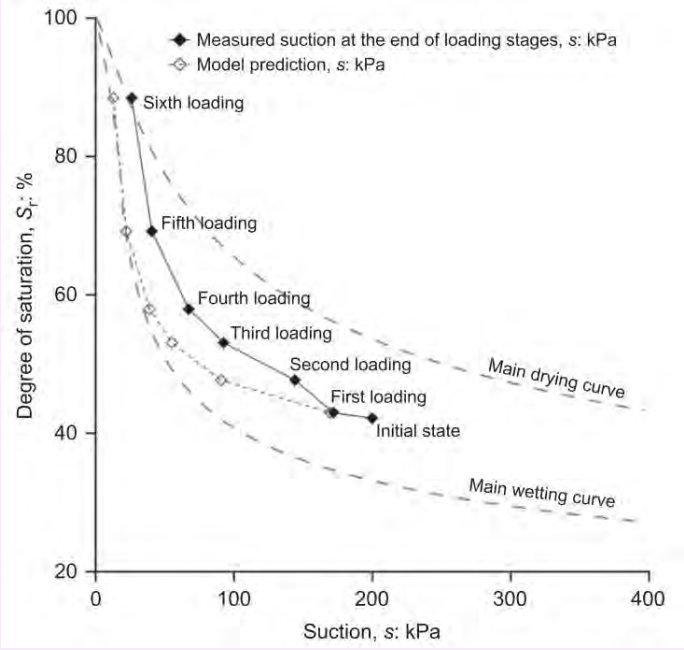

Fig. 5. Cyclic train and hydraulic loading deteriorate compacted soils

The bounding effect of the water retention curve on the cyclic response of an unsaturated soil

Research Paper | Open access | Published: 31 October 2022
Volume 18, pages 1901–1917, (2023) Cite this article

Arash Azizi, Ashutosh Kumar & David Geoffrey Toll

Abstract

The water retention properties of soils present in formation layers of roads and railways continuously vary due to repeated traffic loads and periodic rainfall events. This is important because the accumulated deformation and resilient modulus of such soils under cyclic loading are profoundly affected by water retention properties. This paper discusses the cyclic and water retention response of a clayey sand subjected to repetitive cyclic loading and wetting stages. The results show that the accumulated permanent strains and resilient modulus of the tested soil are dependent on the suction level while the main wetting water retention curve of the soil dictates the variation of the suction measured during cyclic loading and wetting. This bounding effect of the water retention curve is found to be dependent on the void ratio where the suction can even increase due to the accumulation of strains under cyclic loading while the degree of saturation increases. This contradicts the suction reduction typically observed with an increase in the degree of saturation. A void ratio dependent water retention model is developed accounting for the observed bounding effect and employed to predict the measured suction during repetitive cyclic loading and wetting. The suction values predicted by the void ratio dependent water retention model are in good agreement with the experimental data. The predicted suctions are then used in semi-empirical formulations to obtain the accumulated permanent strains and resilient modulus. A better correlation between model predictions and experimental data is achieved where the suction values predicted by the void ratio dependent water retention model are used. The results imply that predictive frameworks proposed for the cyclic behaviour of road and railway formation layers require water retention counterparts that incorporate the bounding effect of void ratio on soil water retention curves.

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PREVIOUS ARTICLE NEXT ARTICLE

Technical Papers | Feb 11, 2022

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Application of Suction Monitoring for Cyclic Triaxial Testing of Compacted Soils

Authors: Ashutosh Kumar, Arash Azizi, and David Geoffrey Toll AUTHOR AFFILIATIONS

Publication: Journal of Geotechnical and Geoenvironmental Engineering • Volume 148, Issue 4
https://doi.org/10.1061/(ASCE)GT.1943-5606.0002766

Abstract: The performance of compacted soils that are used for the construction of railway embankments are impacted by weather-driven suction and water content fluctuations. Hence, the accurate measurement of the water retention properties of soil during cyclic loading is essential to evaluate the soil cyclic behavior under repeated train-induced loads. This paper presents a suction monitoring setup for soil cyclic triaxial testing and its application to evaluate soil water retention and volumetric response. The setup uses a high-capacity tensiometer to measure suction and on-sample displacement transducers to measure volume changes mounted at the midheight of the soil sample. Compacted soil samples were subjected to cyclic loads under different testing conditions: (1) testing a saturated sample under a free-to-drain condition showed the accumulation and dissipation of excess pore-water pressure during cyclic loading, (2) testing unsaturated samples under constant water content conditions demonstrated that the accumulated volumetric strain was smaller than the saturated sample and suction decreased during cyclic loading due to an increase in the degree of saturation, and (3) applying successive packets of cyclic loads and wetting to unsaturated samples showed a progressive increase in the volumetric strain and degree of saturation, leading to loss of suction. The accumulation of the volumetric strain measured for the tested soil was dependent on the magnitude of the confining stress, cyclic deviator stress, and suction. The soil water retention response during cyclic loading was governed predominantly by the suction level and the distance between the current soil water retention state and the main water retention curves. The accurate measurements of the soil water retention properties allowed the evaluation of the evolution of the stress path during cyclic loading in terms of Bishop's stress and the dynamic nature of water retention properties of the soil. The void ratio of the tested soil measured in the resilient state was found to be dependent on the applied stress levels and degree of saturation, and changes in the void ratio also affected the water retention behavior under cyclic loading.

DOI: 10.1061/(ASCE)GT.1943-5606.0002766.

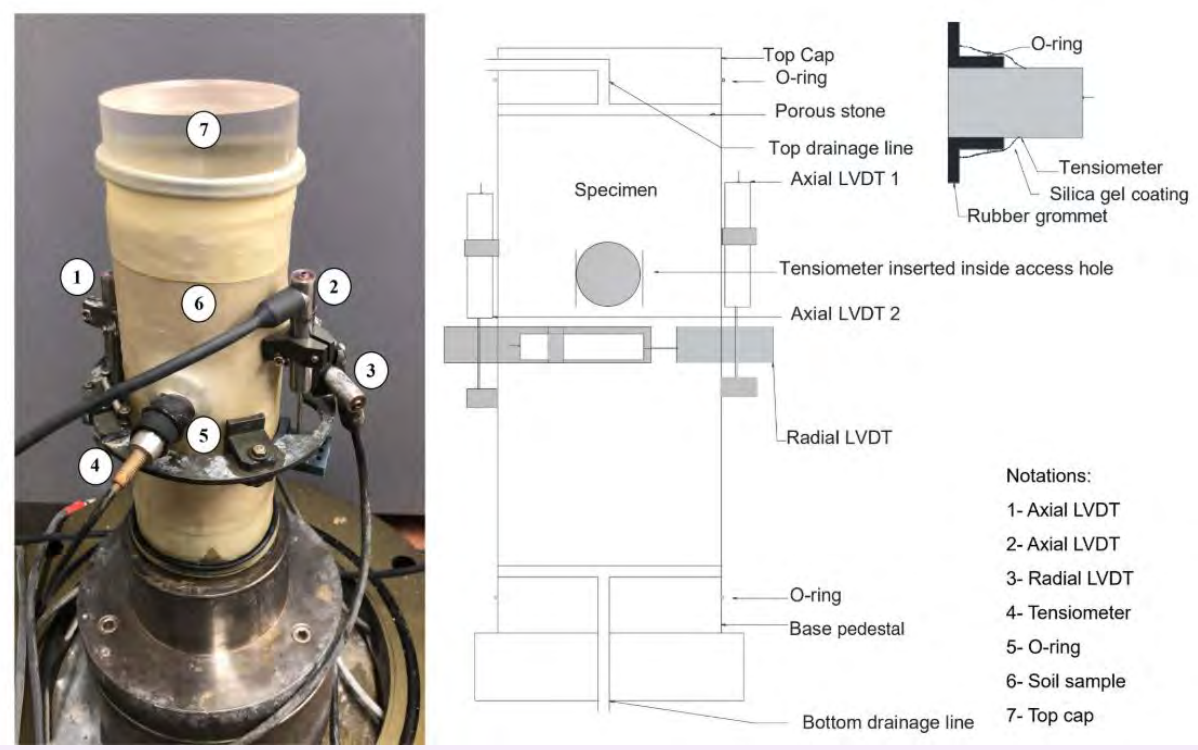


Fig. 6. Set-up to understand dynamic behaviour of unsaturated soil

Chapter | Jul 20, 2023

An Apparatus to Monitor Suction Evolution and Water Migration within a Soil Mass for Climate-Adaptive Infrastructure

Authors: Aditi Rana, Ashwani Kumar Sharma, Ashutosh Kumar, Arash Azizi, Sravan Muguda, Ashraf Osman, and David G. Toll
AUTHOR AFFILIATIONS

Publication: Geo-Risk 2023 • https://doi.org/10.1061/9780784484968.013

ABSTRACT

The present study investigates the potential utility of a capillary barrier system that limits water infiltration into the underlying soil. This was achieved by developing a cylindrical apparatus capable of monitoring matric suction and water content at different depths in real-time when subjected to hydraulic loading. The climate adaptive barrier layer (CABL) was prepared by using an amended soil containing a 5% by dry mass of waste produced from the water treatment plant. The result of monitoring without a CABL indicated the quick reduction in suction and quick increment in the volumetric water content under artificially induced rainfall. The top layer of the soil has shown the variation of suction up to 2,000 kPa under continuous air-drying (four months) where the suction was higher during the day compared to the night. Such variation was not observed under the application of the CABL, thereby limiting the changes in the water content and soil suction of the underlying soil, showing the potential applicability of the CABL to limit the impact of water content fluctuation.

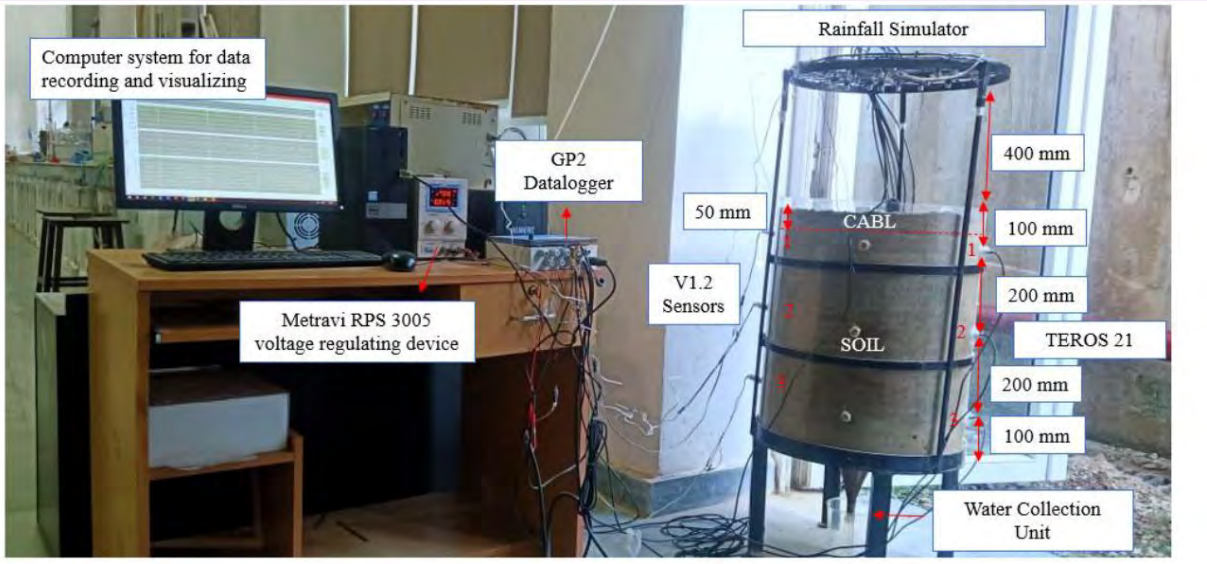
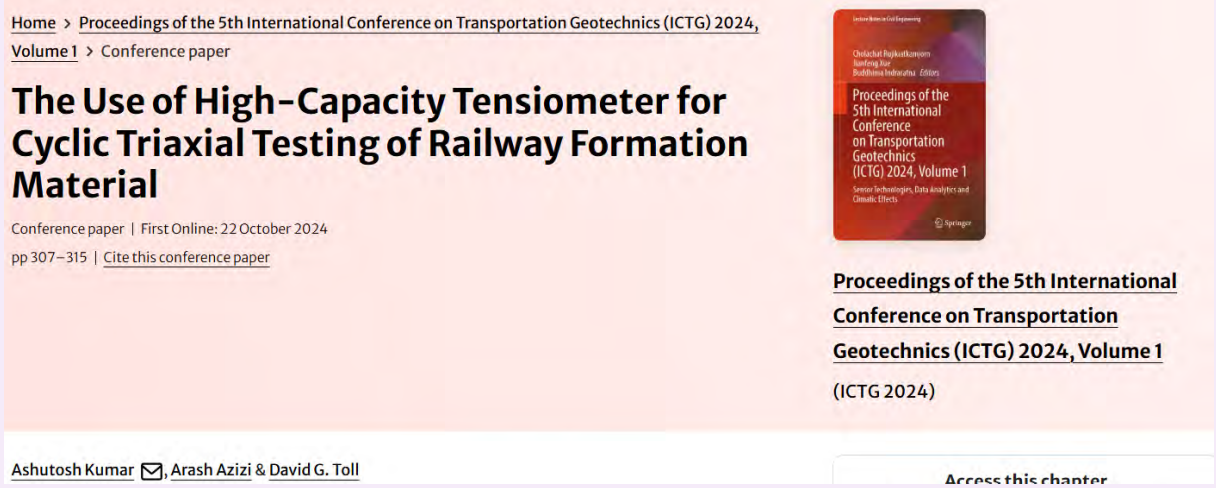


Fig. 7. Experimental Set-up for understanding efficacy of climate adaptive barrier layer

ABSTRACT

This paper presents the results of cyclic triaxial tests conducted on unsaturated soil samples recovered from the railway embankment of a South African coal line to investigate the influence of cyclic loading frequency on a formation layer material, in this case a clayey sand. The testing involved suction-monitored repeated loading tests accounting for the conditions likely to be encountered in practice under varying train speed. The results of single-stage loading tests with a frequency applied individually in a range of 0.5–4 Hz were compared to the results of multistage loading tests with a frequency increasing from 1 to 4 Hz. The results of the single-stage loading tests indicated that the accumulated axial strain increased with an increase in the cyclic frequency, implying that a higher train speed would result in a higher level of the permanent deformation. The staged increase in the frequency of the multistage loading tests showed that the permanent deformation mainly took place during the first packet of cyclic loads whereas the deformations measured during the following repeated loads were negligible. Suction reduction and an increase in degree of saturation during cyclic loading was dependent on the water-retention state of the sample. The results were then interpreted in terms of resilient modulus.



Abstract

The formation layers of railway embankments are often unsaturated and subjected to coupled cyclic traffic-induced and hydraulic loading. Understanding this coupled response requires the development of a testing protocol capable of subjecting soil samples to cyclic loading while continuously monitoring water retention response of the soil. An accurate measurement of the suction variation for the case of repeated cyclic loading is crucial for interpreting the response of the soil considering the principles of unsaturated soil mechanics that are commonly neglected during the design of this infrastructure. In this paper, we present the use of a high-capacity tensiometer of capacity 2 MPa and resolution 0.5 kPa developed at Durham University, capable of measuring suction on the body of soil samples. The setup allowed continuous monitoring of suction at the mid-height of the unsaturated soil sample during cyclic triaxial testing while continuously measuring the volumetric deformations with the help of local displacement transducers. The obtained results indicated that the volumetric compression during cyclic loading reduced the voids ratio leading to an increase in the degree of saturation under constant water content conditions that reduced the soil suction. The obtained results were then interpreted by using mean Bishop's stress where the permanent strain was consistently found to increase with an increase in the Bishop's stress ratio. The resilient modulus was also found to be correlated to Bishop's stress ratio.

OPEN ACCESS

Chapter

Prediction of resilient modulus of unsaturated soils considering inter-particle suction bonding

By A. Rana, A. Azizi, A. Kumar, M. Lloret-Cabot, D.G. Toll

Book Geotechnical Engineering Challenges to Meet Current and Emerging Needs of Society

Edition	1st Edition
First Published	2024
Imprint	CRC Press
Pages	4
eBook ISBN	9781003431749

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ABSTRACT

Understanding the behaviour of compacted soils in road and railroad formations is crucial for ensuring the long-term performance of transportation infrastructure. These formations are often under unsaturated conditions and their response to repeated traffic-induced loads is significantly influenced by soil water content and suction (i.e., water retention), which vary due to environmental factors such as precipitation and evaporation. This paper proposes a predictive framework to establish a relationship between the mechanical cyclic response and water retention properties of unsaturated compacted soils. The proposed framework employs two constitutive variables, i.e. Bishop's stress and an inter-particle bonding parameter, and is intended to predict the resilient modulus of unsaturated compacted soils subjected to repeated traffic and environmental loading. Both constitutive variables allow consideration of the effects of the degree of saturation and suction on the compacted soil behaviour and facilitate a smooth transition between unsaturated and saturated states. The proposed model is used to predict the resilient modulus of various unsaturated soils subjected to cyclic loading. The results show a good agreement between the predictions of the model and experimental data.

Geo-Resilience 2023 Conference, Cardiff, Wales
D.G. Toll & M.G. Winter (Eds)
British Geotechnical Association, London. 2024
https://doi.org/10.53243/Geo-Resilience-2023-3-5

Insight Into Soil Cyclic Triaxial Testing Using a High Capacity Tensiometer

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[1] Indian Institute of Technology Mandi, India [2]University of Portsmouth, United Kingdom [3] Durham University, United Kingdom

Corresponding author: Ashutosh Kumar (ashutosh@iitmandi.ac.in)

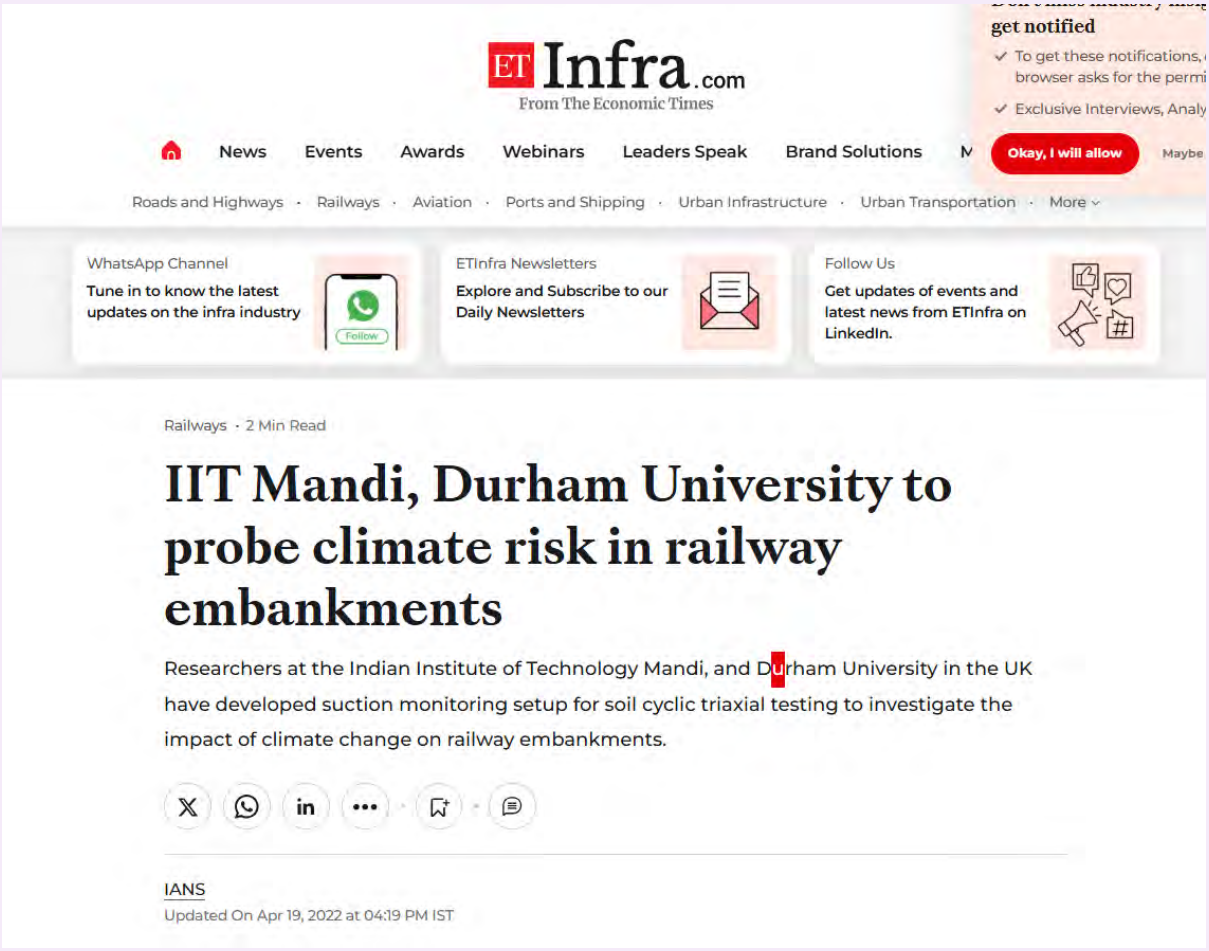
Abstract

Unsaturated soils often form part of geo-infrastructure such as road and railway substructures subjected to repeated traffic and train-induced loading. However, the principles of Unsaturated Soil Mechanics have commonly been neglected in design protocols of such infrastructure mainly due to the lack of appropriate experimental data and poor understanding of the response of unsaturated soils to complex loading. Advances in suction measurements using tensiometers have enabled practical analysis of the behaviour of unsaturated soils under laboratory and field conditions. This paper discusses the advantages of using a high-capacity tensiometer in studying the cyclic response of unsaturated clayey sand taken from a railway formation. The tests were carried out using a cyclic triaxial apparatus while suction was continuously monitored during testing using a tensiometer mounted on the body of soil samples. The soil cyclic behaviour including accumulated axial strains and resilient modulus was observed to be dependent on the soil suction levels as well as the confining pressure and cyclic deviatoric stress applied. The Bishop's stress ratio (defined as the ratio between the cyclic deviatoric stress and mean Bishop's stress) was used to interpret the test results where the accumulated axial strain was consistently found to increase and resilient modulus to decrease with the Bishop's stress ratio.

Keywords: suction measurement, triaxial testing, resilient modulus.

Some noted details:

1. Dr. Ashutosh Kumar Conferred the title of Visiting Fellow of the Institute of Hazard, Risk and Resilience of Durham University, UK for a period of 3 years through the Senate commendation. (February 2025)
2. Ms. Aditi Rana visited the Institute of Hazard, Risk and Resilience of Durham University, UK as a Visiting Student. (February 12- 28, 2023)
3. The setup developed to study the behaviour of compacted soil in railway embankments got coverage in the National print and electronic media.



4. Dr. Ashutosh Kumar visited the Institute of Hazard, Risk and Resilience, Durham University. (January, 2024)
5. Dr. Ashutosh Kumar visited the Institute of Hazard, Risk and Resilience, Durham University. (June, 2024)
6. Dr. Ashutosh Kumar invited as Academic Visitor as IHRR Global Fellow to the Institute of Hazard, Risk and Resilience (IHRR) of Durham University, United Kingdom. (January 03- February 10, 2023).
7. Ms. Abhiparna Dasgupta visited Institute of Hazard, Risk and Resilience, Durham University (May 2024)

IHRR hosts research visitors from IIT Mandi, India

27 February 2023

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Dr Ashutosh Kumar presenting IHRR seminar | Aditi Rana presenting IHRR seminar

Dr Ashutosh Kumar and Aditi Rana from the Indian Institute of Technology (IIT), Mandi, based in Himachal Pradesh in the Indian Himalayan Region visited the Institute of Hazard, Risk and Resilience (IHRR) at Durham University in February 2023.

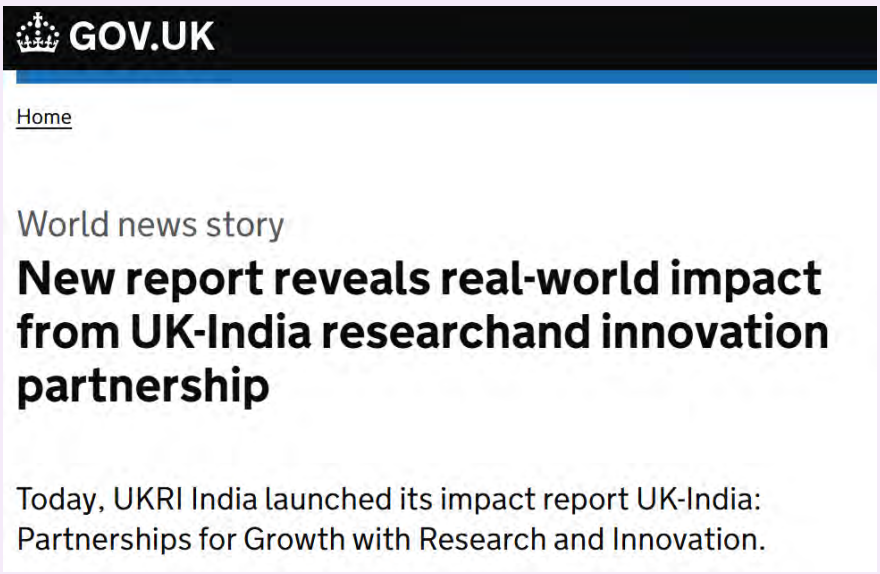
Dr Ashutosh Kumar visited from 9 January to 10 February 2023 and **Aditi Rana** visited from 13 February to 27 February 2023. Both visits were funded by the IHRR.

Dr Ashutosh Kumar is an Early Career Academic at IIT Mandi. The visit by Dr Ashutosh Kumar allowed fruitful discussions in the framework of the NERC funded **SEAL project (Landslides Susceptibility and Adaptability in South East Asian Countries)** led by Professors **Ashraf Osman** and **David Toll**. Dr Kumar has been a key collaborator in the SEAL, which brought together internationally recognised experts in **landslides and climate change impacts on civil engineering infrastructure**. As part of SEAL, he organised multi-stakeholder events involving participants from industry and academia focused on impact, outreach, and dissemination of the guidelines available for constructing and maintaining infrastructure on sloping ground. Dr Kumar gave an IHRR seminar on his work on a Climate Adaptive Barrier Layer for slope stabilisation during his visit.

During her visit to Durham University, MTech student Aditi Rana was trained in the use of advanced laboratory testing. She carried out **laboratory testing on soils from India** in the geotechnical engineering laboratory of the Department of Engineering. She presented her results on Climate Adaptive Barrier Layer for slope stabilisation during an IHRR landslide seminar. This work, carried out at IIT Mandi, was funded through Durham University from the **CACTUS (Climate Active Control for Urban Spaces)** and SEAL projects.

As a note, Aditi Rana has been welcomed back to Durham in December 2023. Since her first visit, she has been accepted for PhD studies at Portsmouth University and is now collaborating with Professor David Toll on her PhD on "*The effects of climate change on the performance of geo-infrastructure under cyclic loading*".

UKRI-NERC UK Grant: Developing a Framework for Landslide Susceptibility and Adaptability in Southeast Asia (SEAL)



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World news story

New report reveals real-world impact from UK-India researchand innovation partnership

Today, UKRI India launched its impact report UK-India: Partnerships for Growth with Research and Innovation.

- Project title: Developing a Framework for Landslide Susceptibility and Adaptability in South East Asia (SEAL) UK – Durham University

India - IIT Mandi and Seven Associated Consultants

The SEAL (Landslides Susceptibility and Adaptability in South East Asian Countries) project investigated the efficacy of an optimally designed capillary barrier system that limits water infiltration into the underlying soil. This was achieved by developing a cylindrical apparatus at IIT Mandi with Dr. Ashutosh Kumar, who was one of the

collaborators of the project. The instrument is capable of monitoring matric suction and water content at different depths of a soil column in real-time when subjected to hydraulic loading. The climate adaptive barrier layer (CABL) was prepared by using an amended soil containing a 5% by dry mass of waste produced from the water treatment plant. The outcome of this research has demonstrated the potential applicability of CABL in limiting the flow of water in the underlying soil column and has potential to safeguard the underlying infrastructure.

In addition, the project brought together internationally recognised experts in landslide, climate change on civil engineering infrastructure and organised a multi-stakeholder events involving participants from industry and academia focused on impact, outreach and dissemination of the guidelines available for constructing and maintaining infrastructure on sloped ground. IIT Mandi being one of the partner in the project, Dr. Ashutosh organised a short course, an international workshop and the outreach activities. One researcher Ms. Aditi Rana working at IIT Mandi got trained at IIT Mandi. The activities carried out under the SEAL project at IIT Mandi are listed below:

1. International workshop on "Landslides Susceptibility and Adaptability in South-East Asia: Theory to Practice", jointly organised by IIT Mandi and Durham University UK from March 29-30, 2022. Link: https://www.issmge.org/news/international-workshop-on-landslides-susceptibility-and-adaptability-in-south-east-asia-theory-to-practice

2. Interaction with Member Niti Ayog Dr. V.K. Saraswat to showcase the landslide barrier system getting developed at IIT Mandi Foundation Day on March 6, 2022.
3. Ms. Aditi Rana, the MS student working on the project presented during 3rd Edition of AGERP 2022 International Workshop on Unsaturated Soils on May 26, 2022.
4. Two Days Short Course Organized on Application of Unsaturated Soil Mechanics on the analysis of slopes jointly by IIT Mandi- Durham University UK and Universiti Kebangsaan Malaysia from 24-25 February 2022. Link: https://www.issmge.org/news/application-of-unsaturated-soil-mechanics-on-the-analysis-of-slopes

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Application of Unsaturated Soil Mechanics on the Analysis of Slopes

Home / News / Application of Unsaturated Soil Mechanics on the Analysis of Slopes

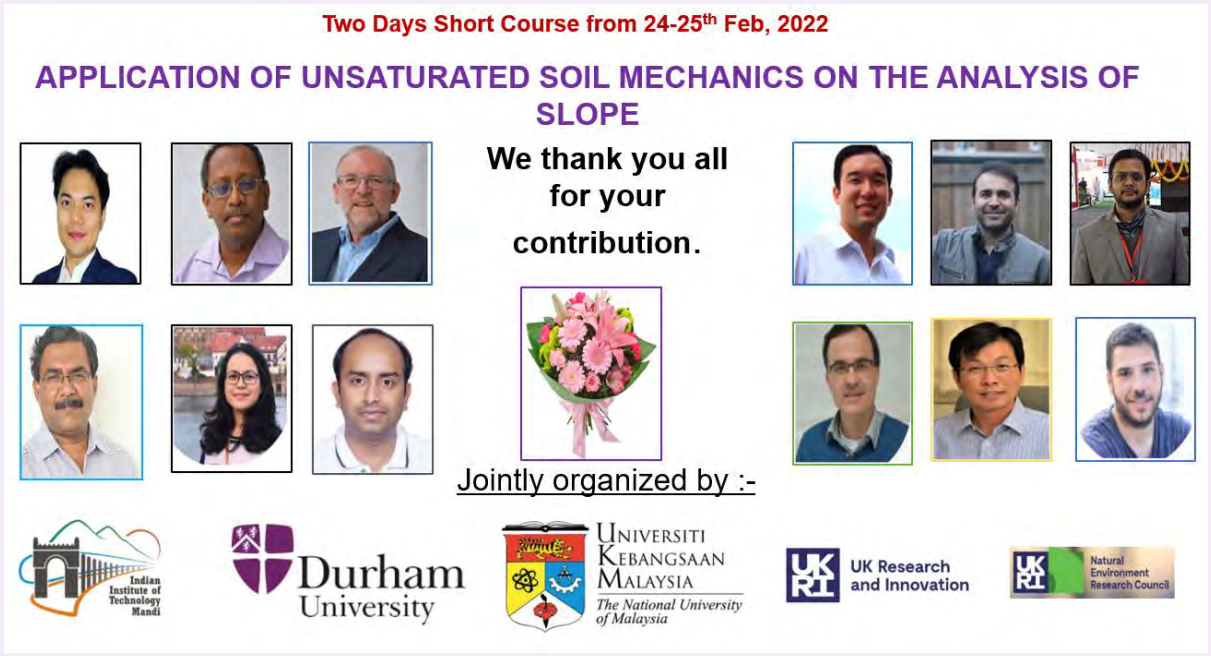
Anthony Leung | TC106 | 27-02-2022

Indian Institute of Technology Mandi, Durham University, UK and Universiti Kebangsaan Malaysia (UKM) organised a 2-day training course on the "*Application of Unsaturated Soil Mechanics on the Analysis of Slopes*", 24-25 February 2022.

The speakers were:

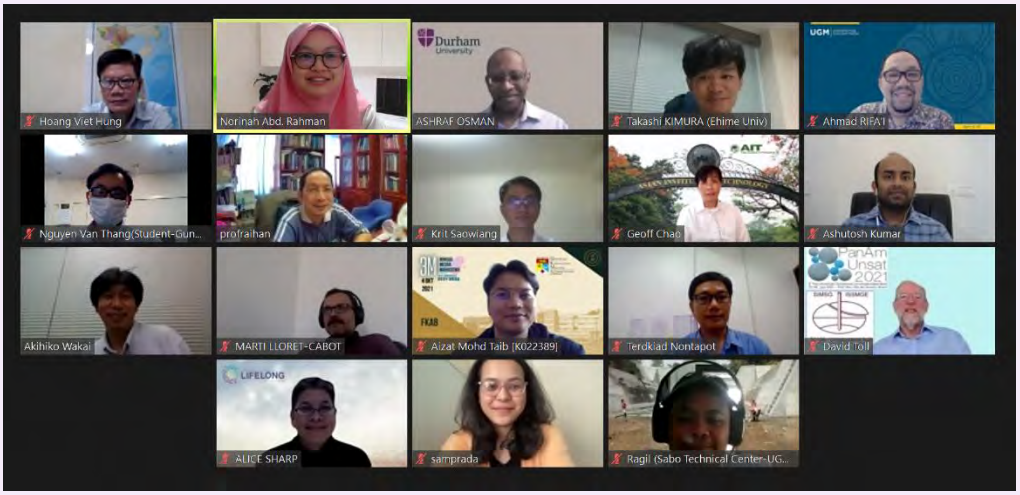
Prof. David Toll, Durham University
Dr. Arash Azizi, Portsmouth University
Prof. D.N. Singh, IIT Bombay
Dr. Uday Kala, IIT Mandi
Dr. Marti Lloret-Cabot, Durham University
Dr. Aizat Mohd Taib, UKM
Dr. Kuo-Chieh Chao, Asian Institute of Technology
Dr. Ashutosh Kumar, IIT Mandi
Dr. Apiniti Jotisankasa, Kasetsart University
Dr. Samprada Pradhan, Durham University
Dr. Alexandros Petalas, Durham University
Mr. Faris, UKM

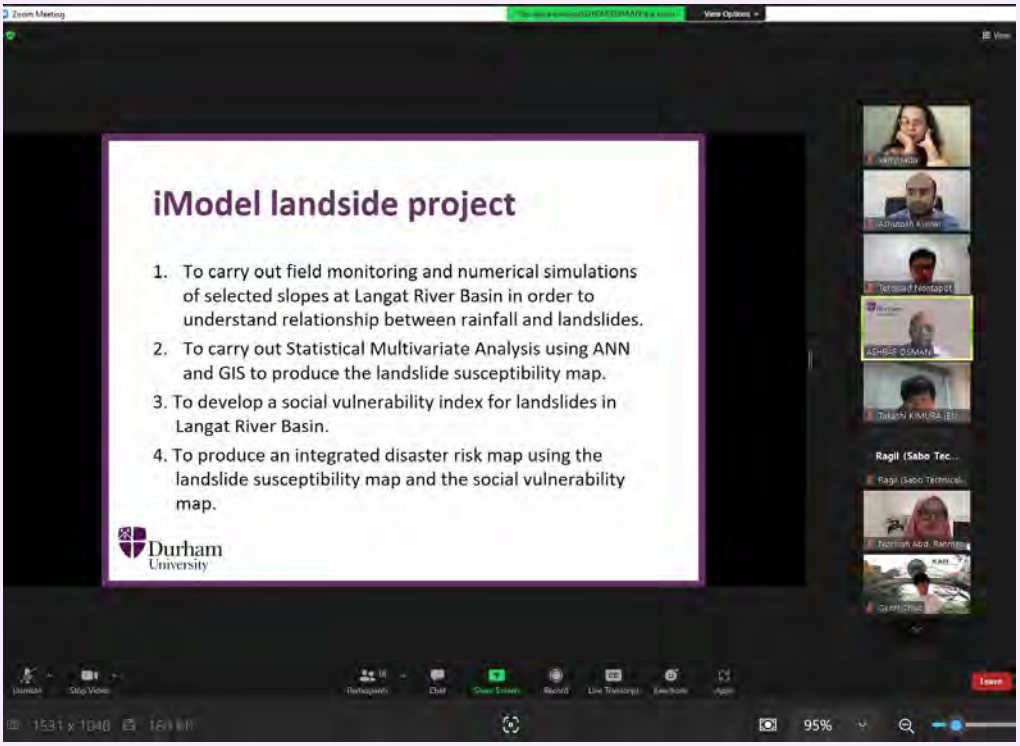
The course was organised under the project theme "Understanding Landslide Susceptibility and Adaptability in South East Asia" (SEAL) (funded by UKRI-NERC). The course was attended by 160 people from 15 countries.

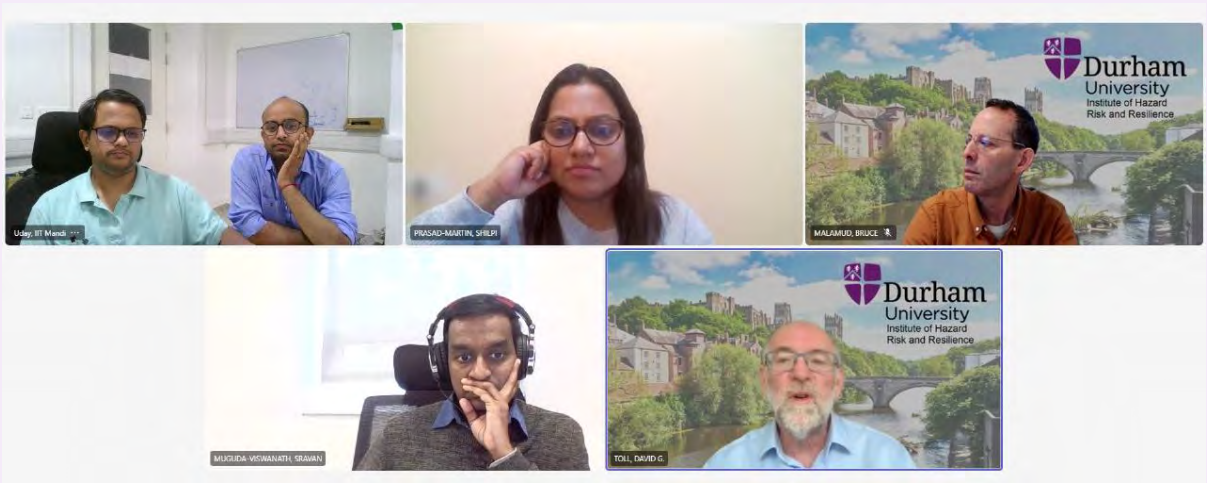


5. Mr. Sonu Kumar was awarded Commonwealth Split-Site Scholarship offered by the government of the United Kingdom to conduct research at Durham University. (July 2023)

During Covid Period we were connected virtually







Researchers from IIT Mandi visited Durham University

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Strengthening global resilience through collaboration - The enduring partnership between Durham University and IIT Mandi continues to pioneer innovative research in disaster resilience and climate adaptation. Together, we aim to shape a safer, more sustainable future for vulnerable regions.
