UNIVERSITY OF BIRMINGHAM

National Buried Infrastructure Facility

Annual Report 2024

We celebrate
We activate

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Contents

Introduction

from the NBIF Director

Welcome to our second National Buried Infrastructure Facility (NBIF) Annual Report. The last twelve months were another year of successes and firsts for NBIF. We have conducted many different experiments in NBIF using its full range of capabilities. Each experiment is unique, and you will find out much more in the report. We continue to design one-off experiments, which could not be carried out elsewhere. We have also expanded our academic base of colleagues who engage with NBIF. And we have seen our work recognised through national awards.

I am proud of all our new PhD students who have joined the University and will be using NBIF. One of our PhD students associated with NBIF has graduated in the past 18 months. We have seen many of our PhD students publishing their first papers or present their work at international conferences.

We have also said goodbye to our project officer, Mrs Ann Smith in May, but welcomed our Research Technician, Iain Annett and a new project officer Mrs Sukhi Kaur Smith. They both already have had a significant impact to NBIF and enable us to conduct these large-scale experiments to time and budget.

We continue to publicise NBIF widely with updates to our website (www.birmingham.ac.uk/nbif) and visits to NBIF. NBIF remains an attractive place to visit on our beautiful campus with over 500 visitors not only from the UK but internationally covering industry, government and academia. It started off strongly with a visit by Peter Kyle MP, then Shadow Secretary of State for Science, Innovation and Technology in January 2024, followed by visits by colleagues from Malaysia, Italy, Japan to mention a few.

You will find out a lot more about what has been happening in NBIF in the last 12 months in the following pages. I hope you enjoy reading our second annual report.

Nicole Metje

Professor of Infrastructure Monitoring

Director of the National Buried Infrastructure Facility

A View from the Facility Manager, Kieran Hansard

Reflecting on the past year at NBIF, it has been a period of growth, achievement, and exciting developments. As the Facility Manager since 2020, I have had the privilege of overseeing the evolution of our facility, ensuring that it remains a leading hub for innovation and research. This year, in particular, has been exceptional due to the strides we have made in expanding our team, the groundbreaking research we have supported, and the well-earned recognition our efforts have received.

One of the most significant milestones of the year has been growing our team to match the increasing workload within NBIF. As our projects have expanded in scope and complexity, it has been essential to build a team capable of meeting these challenges. Seeing new team members integrate, develop their skills, and contribute meaningfully has been incredibly rewarding. The collaborative spirit and shared commitment to excellence have been key drivers of our success.

A highlight of the year has been working on some truly exciting research projects. From their inception as initial ideas to their final reports, witnessing these projects come to life has been an inspiring experience. The ability to support and assist PhD students in their research journeys has been particularly fulfilling. Watching them progress, overcome challenges, and make significant contributions to their fields reinforces the importance of the work we do at NBIF.

This year, we also had the opportunity to attend award evenings to showcase the dedication and hard work of the NBIF team. A defining moment was winning the Studies and Research Award at the ICE West Midlands Awards 2024. This recognition stands as a testament to the collective effort of our team, highlighting the impact of our research and the collaborative environment we have fostered.

Personally, I have relished the chance to be actively involved in research that interests me. The dynamic nature of the work at NBIF ensures that no two days are the same, making each day both challenging and rewarding. Overseeing and completing a variety of industry projects has instilled a strong sense of achievement, both for myself and for NBIF as a whole.

However, beyond the projects, research, and accolades, what truly makes NBIF special is the team culture. The dedication and drive of every individual to improve and enhance NBIF is what sets us apart. It is this collective passion for innovation and excellence that makes being a Facility Manager here so fulfilling.

As we look ahead, I am excited about the continued growth and new opportunities that await us. With such a strong team and an unwavering commitment to progress, the future of NBIF looks brighter than ever.

NBIF Industry Advisory Board

Our board now consists of over twenty representatives from various sectors of the buried and geotechnical infrastructure industry, including government research organisations, contractors, design consultants, and materials suppliers.

The IAB meets biannually, supporting the NBIF team with operational and strategic matters. We have grown and become more diverse allowing the board to provide valuable thought leadership on the challenges facing our buried infrastructure.

It has been fantastic to see the board develop over the last 18 months, with many of its members being active in relevant studies at the facility. In the last year we have demonstrably provided a link between academic research and industry that has gone on to impact some of the UK's major infrastructure projects, bringing tangible commercial benefit.

Through its work, NBIF is forging an ever-stronger reputation. The team has expanded under its dedicated leadership, bolstering the number of experts, researchers and technicians that can collectively advance our understanding of our underground spaces. The facility's growth reflects its commitment to addressing critical national needs through cutting-edge research. Staff members bring diverse expertise in geotechnical engineering, sensing technologies, and infrastructure assessment, creating a collaborative environment where we can make innovate ideas, technical knowledge and practical applications converge.

The challenges in delivering infrastructure, and the wider built environment, cost effectively and sustainably do not diminish and the Industry Advisory Board is determined to play its part in tackling some of the issues, both in the UK and internationally. The next twelve months promise to be more exciting than ever.

Jim de Waele

Chair of NBIF's Industry Advisory Board

MOTT MACDONALD

Balfour Beatty Ground Engineering

KELLER

WONDERFUL ON TAP

SEVERN TRENT

IRR TRENCHLESS Trenchless Consultancy

Tensar A Division of CMC

CECL GLOBAL

HUESKER Ideen. Ingenieure. Innovationen.

RSK

NetworkRail

mtc Manufacturing Technology Centre

Research Highlights

Geogrid-stabilised temporary working platforms (Tensar)

Tensar®
A Division of CMC

Temporary Working Platforms (TWPs) provide stable ground for heavy equipment such as piling rigs and cranes, particularly in areas with weak soils. Traditionally, TWPs are designed using high-quality quarried aggregates, which are often transported over long distances. This results in high carbon emissions and increased costs. Moreover, conventional design methods frequently fail to fully consider the benefits of geogrid stabilisation, leading to over-designed and resource-heavy solutions.

When granular fill is placed and compacted over a geogrid, the particles interlock with the geogrid apertures. This creates a confinement effect within the fill material, forming a mechanically stabilised layer (MSL) which is a stronger composite of aggregate and geogrid. To quantify the potential reduction in fill material when using geogrids, Tensar has developed the T-Value design method, which accounts for the stabilisation effect provided by the geogrid.

This collaborative project between NBIF and Tensar delivered the first independent, full-scale assessment of geogrid-stabilised TWPs.

The study involved three large-scale tests, using the 2,000 kN actuator, fibre optic sensing, and innovative methods for constructing large-scale platforms.

The NBIF provided a unique opportunity to carry out full-scale load testing on granular working platforms, under controlled loading conditions and a consistent subgrade.

The results demonstrated that geogrid-stabilised platforms significantly reduce both the carbon footprint and material costs, marking a step-change in sustainable construction practices. The research validates the T-Value design method, offering engineers a scientifically proven, efficient approach to TWP design. The findings are already influencing industry standards and best practice, highlighting the project's technical merit, sustainability impact, and practical value.

In May 2024, one of the full-scale tests was showcased to a group of practitioners and educators, including contractors, the Temporary Works Forum, consultants, and representatives from Mid Kent College.

Aqua Fabrications Ltd

Drainage sump catch pit units are an essential component of transport infrastructure providing an effective mechanism for silt management and access for pipe maintenance. These units are made from a variety of materials with traditional brick and concrete structures increasingly being replaced with plastic units, commonly using High-Density Polyethylene (HDPE) and Glass Reinforced Plastic (GRP). HDPE and GRP offer several advantages including relative ease and speed of construction, especially in areas such as railways, where site possession is limited to only a few hours at a time.

NBIF was commissioned by Aqua Fabrications Ltd to undertake a series of physical tests at full scale on nine types of GRP units to evaluate fatigue loading conditions that these units experience under two offsets from a railway (510mm and 1410mm), reflecting normal working and most adverse offset loading conditions. Cyclic loading tests were undertaken in NBIF's large pit, using dynamic actuators, with extensive monitoring of displacement, strain and soil pressure on and around the sump units. This work is feeding directly into key insights of performance at field scale, but under controlled and repeatable testing conditions, providing valuable insight on product performance.

Project Greystone – Collaboration with the UK National Authority for Counter Eavesdropping (UK NACE)

In 2024, the NBIF team and UK NACE collaborated in a pioneering research project evaluating different sensing technologies to look in and beneath concrete floor slabs and walls. The set-up simulated a real-world scenario of a British Embassy in the early stages of construction, complete with an accessible service tunnel underneath the foundations.

This was the first time where the experimental set-up allowed access to a buried feature through an access shaft, which allowed both people access as well as robots. Most critically, it was vital to carefully locate all the different features in the floor slab and in the ground, thereby providing ground truth. Not only was it a technically unique project, but it also generated significant interest across the security community both in the UK and overseas, seeing approximately 90 visitors to NBIF, many evaluating their technology in the set-up. By creating a controlled environment to test search equipment, the teams at UK NACE could accurately measure the effectiveness and strength of their detectors, knowing exactly what had been included in the build, from the foundations, steel reinforced and fibre reinforced concrete floor, plaster boarded walls and conduits.

The design included irregular surfaces and hard to reach areas, taking into consideration real life scenarios such as rooms with thick walls or unusual room layouts. The model was also constructed using a variety of techniques and materials in different areas to emulate varied building regulations in other parts of the world, and it also incorporated modern technology innovations from the building industry.

Technical experts were able to test and evaluate how equipment responded to covert activity in a subterranean presence, detect concealed objects in different construction materials and distinguish between generic building materials and human and electronic artefacts. The NBIF team also evaluated different sensing technologies including optical fibres, acoustic emission, Ground Penetrating Radar and gravity.

While it was never envisaged to conduct this type of research in NBIF, it shows the flexibility of the facility. As a result, a community, dedicated to protecting the UK against national security risks, has been built on sharing resources and findings and the scope to expand on this is in future promising.

Pipebots – Large-scale demonstrator

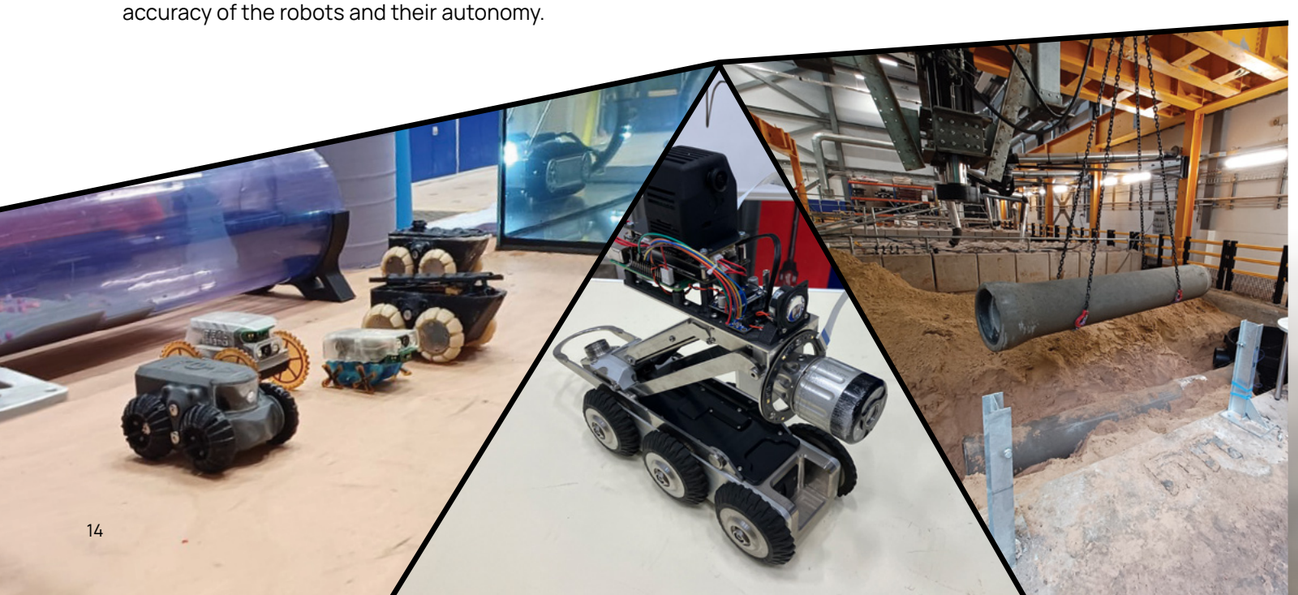
Pipebots is an EPSRC-funded programme grant with a vision to move towards failure-free operation of buried sewerage, drainage and water pipe networks through the deployment of autonomous inspection robots. It brings together the expertise of the Universities of Leeds, Bristol and Birmingham under the leadership of the University of Sheffield.

As the programme matured, a pipe run in NBIF was set up in 1/3 of our large pit to demonstrate and evaluate the performance of different robotic prototypes autonomously travelling around the network. Easy access was achieved through some large access chambers that allowed the robots to be launched into the network.

The pipe network comprised both 300mm diameter concrete and medium density polyethylene (MDPE) and 100mm MDPE pipes joined using both push fittings and clamps. Both straight runs and different types of bends were included in the trial network. Different blockages and other defects (simulated cracking, open joints) were included in the pipes, both to evaluate the performance of the sensors on the robots and trial data processing algorithms, positioning accuracy of the robots and their autonomy.

This set-up was used in a demonstration event in June 2024 which attracted 52 visitors from industry, Government, academia and the funders to NBIF and allowed the Pipebots team to showcase their work. We had four 'stations' within NBIF demonstrating the capability of the ultrasound sensor, the locomotion of the robots, the ability to work in water, and the progress of the project as a whole to set the agenda of using robots in gravity fed wastewater and pressurised water pipes.

The interest generated by the demonstration resulted in invitations to present at the subsequent UKSTT National Conference on Trenchless Technologies, the 2024 No Dig Live Conference and Exhibition organised by the UK Society for Trenchless Technology, and the January 2025 bi-monthly webinar of the International Society for Trenchless Technology. Pipebots have become well known in UK circles as a critical component of the 'Future of Trenchless Technology', and progressively throughout the international buried infrastructure community.



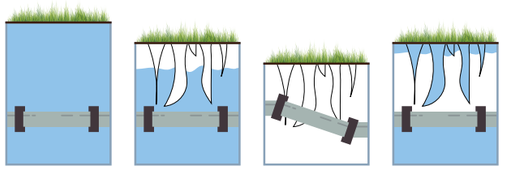
Assessing Climate Risks to Buried Utility Networks

The UKRI-funded **STORMS** project is developing a groundbreaking framework to assess climate risks to buried infrastructure, such as underground cables and pipelines. By integrating weather, climate, soil, and infrastructure data, and utilising NBIF's advanced numerical and physical modelling capabilities, the project provides insights into how extreme weather events impact underground networks. With industry collaboration and advanced modelling, STORMS is helping utilities identify vulnerabilities and build more resilient infrastructure for the future.

Buried infrastructure systems are vulnerable to meteorological shocks or extreme weather events, such as floods and droughts due to extreme precipitation, as well as extreme temperatures. Such events can lead to soil movement, thermal contraction and expansion, and sinkholes, among other problems. The financial implications are significant; the damages to buried infrastructure in the UK amounts to over £2.4 billion per year. Despite the urgency, our society is not well prepared for the impacts of these shocks on buried infrastructure.

The STORMS project aims to develop a comprehensive weather-related risk assessment framework for buried infrastructure, which include cables and pipes vital to cities and urban lives. In this collaborative project between the University of Birmingham, the UK Centre for Ecology and Hydrology and the British Geological Survey, the team have developed numerical models that integrate and analyse weather, climate, soil and infrastructure asset data to assess pipe damages due to ground movement and flooding at regional and national scales. These models have been validated through advanced full three-dimensional finite element models developed at NBIF, leveraging the cutting-edge computational resources and expertise in numerical analysis.

Additionally, a small-scale physical experiment was conducted at NBIF to replicate real-world conditions, ensuring the robustness and accuracy of the modelling framework. The models have been applied to gas networks, incorporating NBIF's advanced numerical and physical modelling techniques to simulate the impact of climate risks with high precision. The expertise in soil-structure interaction and computational modelling has allowed for detailed identification of vulnerable network sections. The results indicate that climate risks are likely to increase significantly in the future, with identified hotspots providing crucial data for proactive infrastructure reinforcement. At the end of the project, the models will be made available on the Data Analytics Facility for National Infrastructure (DAFNI) platform.



The project has attracted interests from a range of industry stake holders. Companies such as LSBUD (Linesearch Before U Dig), Cadent Gas, Thames Water and Northumbrian Water have engaged with the project by participating in the project workshop and sharing data. Through these activities, the team has also contributed to the Government Department of Science, Innovation and Technology's (DSIT) initiative of promoting data sharing among the infrastructure sectors.

In summary, the STORMS project is an important step for the utility sector to better understand the climate risks to their buried assets and develop effective adaptation strategies.

Quantum Hive

While much of the focus of NBIF to date has been on utilising the large pit and the strong floor, the outside 70m, 100mm diameter Medium Density Polyethylene pipeloop with its five access chambers has not received much attention. While not utilised from a water quality, leak detection or asset detection viewpoint, the large access chambers (~2m by 2m by 1.2m deep) have become a useful feature for geophysical monitoring, especially related to measuring microgravity.

Geophysical monitoring applications require signals to be detected both as a function of space and time to measure changes due to ongoing processes, including monitoring of water aquifers and reservoirs, geohazards such as volcanoes, carbon capture and sequestration and the development of sinkholes. Recurring surveys with relative gravity instruments are only repeatable whilst the gravity on a reference base station (a repeated measurement point which is used to remove drift and provide a reference value to which the other measurements are relative) remains stable, which is rarely the case over extended periods (e.g. due to water table changes or other environmental changes). Therefore, current survey strategies for these applications would involve repeated surveys using a single absolute sensor which provides limited data acquisition speed and hence, spatial resolution, and would be expensive to implement using quantum sensors alone.

Quantum Hive utilised the relative strengths of quantum gravity sensors (high sensitivity, absolute measurements, low drift) and MEMS sensors (cheap, light and easy to deploy) in a novel hybrid configuration to achieve a network of distributed absolute gravity measurements.

The project was a joint initiative between the University of Birmingham's quantum technology team of physicists and engineers and Silicon Microgravity (SMG), a market leader in the development of MEMS gravimeters to provide an innovative, viable way forward for commercialising University of Birmingham's cold atom quantum sensor by adopting an innovative hybrid approach with SMG's MEMS gravity sensors to monitor gravity signals with both a high spatial and temporal resolution for an affordable price in real world environments.

To evaluate the concept, testing was carried out at NBIF bringing the QT gravity gradiometer and the MEMS gravimeters together. It required a survey over a known feature, provided by the access chamber for the buried pipe, where a central "hive" QT sensor was used as an absolute reference to support a network of mobile MEMS "bee" sensors, with return visits to the hive being used to correct drift, separate it from variable signals on the base station and calibrate the MEMs sensors to absolute gravity values. Testing showed that the MEMS gravimeters were able to detect the feature, but over time needed drift corrections.

This unconventional use of NBIF highlights the facility's remarkable versatility.

Education

“Going Underground” exhibition at the Exchange, Birmingham

On 16th November 2024, academic staff, and researchers from NBIF hosted an interactive exhibition titled “Going Underground” at The Exchange, Birmingham. Aimed at the public, families, and young people, the event was designed to spark curiosity and offer insight into the unseen world beneath our cities and landscapes.

Sponsored by the School of Engineering at the University of Birmingham and the UK Quantum Technology Hub in Sensors and Timing, the exhibition brought together science, technology, and fun activities to showcase how emerging innovations, particularly in quantum sensing, AI, and robotics, are transforming our ability to explore and understand the subsurface. From mapping buried infrastructure to detecting ancient voids and geological formations, the demonstrations and activities on display were enabling new ways to monitor and manage the ground we build on.

Visitors were invited to “explore” the underground through a range of hands-on activities, engaging displays, interactive games, live demonstrations, and short talks by experts from the University of Birmingham. Highlights included a quantum-themed sandbox, a robot dog equipped with sensors, a Battleship-style exploration game, and the ever-popular infinity cube illustrating the concept of inversion in geophysics. The exhibition also included a treasure map that guided families through different zones of discovery, making the event both educational and fun for all ages.

The event was a great success, attracting over 150 visitors from a wide age range, including local families, school children, and curious members of the public. Attendees shared positive feedback, particularly noting how accessible and engaging the content was for younger audiences, as well as the clear enthusiasm of the researchers involved.

The Going Underground exhibition forms part of NBIF’s wider commitment to public engagement and outreach, helping to create awareness and understand complex engineering and geotechnical concepts of underground space, and to inspire the next generation of scientists and engineers.

Supercube: Engineering Innovation for a Sustainable Future

The Supercube competition is an event designed to challenge postgraduate taught students from the MSc and Degree Apprenticeships (DA) in Geotechnical Engineering to push the boundaries of sustainable engineering. The competition focuses on utilising recycled waste materials such as shredded tires, plastic waste, construction debris, and carpet fibres for soil reinforcement, promoting creative and environmentally responsible engineering solutions and applying theoretical principles to a real-world engineering problem, a crucial skill for their future careers.

Under the guidance of Dr Alexander Royal, Dr Ali Monzer, Dr Esdras Ngezahayo, Dr Daniel Boddice, Mrs Rachel Kennedy, and Mr Chris Harbutt, teams of students were tasked with designing and constructing reinforced soil cubes using their chosen recycled materials whilst making practical engineering and financial decisions and adhering to safe working practices. The cubes were 0.4m in length, width and depth. Throughout the event, the students demonstrated impressive creativity and commitment to sustainability, experimenting with blended materials and unconventional binding agents to achieve optimal results.
The cubes were then tested in NBIF, enabling participants to evaluate their designs under realistic conditions, and for final destructive testing of the cubes using NBIF's strong floor and loading actuators.

Two student teams participated: The Gneiss Engineers and La Terra CuboyZzzz, who were judged by an expert panel of industry experts from Amey Consulting and academic staff members. They were evaluated on various criteria, including the cube's overall strength, innovation, cost-efficiency, health and safety observations, and sustainability as well as teamwork, design and theoretical knowledge based on questions from the panel.

Whilst both teams produced commendable and inspiring designs and impressed the panel with the quality of their work, it was the Gneiss Engineers who emerged victorious for their innovative design to produce a cube that demonstrated exceptional strength. Their approach using carpet fibres was praised for its innovation, practical application, and dedication to sustainability.

Events like the Supercube competition 2024 are a testament to the University of Birmingham's commitment to nurturing the next generation of engineers. By providing students with access to cutting-edge facilities like NBIF, with its controllable conditions at a range of scales, the University ensures that they gain the skills and experience necessary to excel in an evolving industry focused on sustainability and innovation.

NBIF Geotechnical Centrifuge Facility

In addition to NBIF's large-scale testing capabilities, the facility is equipped with advanced small-scale physical modelling equipment. This setup enables the investigation of geotechnical engineering problems under controlled and scalable conditions, taking into account complexities in material behaviour, loading patterns, geometries, and boundary conditions. Such modelling offers a fast and cost-effective means of gaining insights before progressing to full-scale or real-world applications. It complements large-scale testing by enhancing flexibility, broadening the experimental scope, and providing valuable data to inform and de-risk engineering design and implementation of large-scale testing.

The NBIF geotechnical centrifuge is one such piece of equipment that offers a versatile approach to experimental modelling of geo problems under realistic conditions. By increasing the gravitational field through centrifugation, this technique enables scaled-down models to experience stress levels equivalent to those in full-scale scenarios. This allows for realistic modelling of dynamic processes such as deformation, failure, and soil-structure interaction under controlled conditions. Engineers can directly observe and measure these behaviours, making it a valuable tool for understanding complex ground responses. It is also a cost-effective and reliable approach that provides critical insights for the design process and supports the validation of analytical and numerical models.

At the NBIF, several researchers are currently using a 300g centrifuge with a 1.2m diameter to perform their research projects. One ongoing project examines the impact of sheet pile installation near an existing tunnel, while another investigates the effects of bored tunnelling close to existing piles. The facility is equipped with a model bored tunnelling system integrated into the centrifuge package, enabling the simulation of tunnelling activities and the observation of ground and structure responses. Additionally, a project is focused on designing an innovative supporting structure for floating offshore wind turbines and assessing the impact of additional structural elements on the installation resistance of the proposed novel anchors.

Awards

Institution of Civil Engineers Award

In September 2024, academics and colleagues from the National Buried Infrastructure Facility were presented with an award in the Studies and Research category of the ICE West Midlands awards for a project exploring the impact of polymer and bentonite slurries on bored piles, a construction technique used to transfer the weight of a structure above ground safely into the soil and rock below.

Federation of Piling Specialists

In November 2024, the NBIF team received the Sustainability Award at the Federation of Piling Specialists (FPS) 60th Anniversary Awards 2024 for a collaborative project with Tensar (a division of CMC). The research investigated geogrid-reinforced Temporary Working Platforms (TWPs) to reduce fill material, achieving significant reduction in carbon and cost. Full-scale testing at NBIF under realistic site conditions demonstrated clear environmental and performance benefits of the geo-grid reinforced TWPs.

Len Threadgold Award

The Midland Geotechnical Society Early Career Award, presented by Len Threadgold. Our very own Dr Wuzhou Zhai, Field Trials & Experimental Officer was shortlisted from a very strong field of submissions.

This award is an opportunity for young geotechnical professionals to showcase their work and early career progression.

External Engagements

International

Fugro,
Netherlands

Harsco Environmental,
United States of America

International Society for Soil Mechanics and Geotechnical Engineering,
Finland

Poznań University of Technology,
Poland

Railway Technology Research Institute,
Japan

Sao Paulo State University UNESP,
Brazil

The University of Melbourne,
Australia

University of Illinois Urbana-Champaign,
United States of America

University of New South Wales,
Australia

VTT Technical Research Centre,
Finland

Worldwide Railway Organisation

Prof Dongming Zhang
Professor of Intelligent diagnosis and early-warning for linear underground structures
Tongji University, China

Dr Ian Moore
Professor and Research Director, GeoEngineering Centre
Queen's University & Royal Military College, Canada

The Italian Utility Group
HERA Group

Dr Noordin Ahmad & Colleagues
Member of Board
Land Surveyors Board, Malaysia

Visitors from UK Service Avoidance Group

Prof Charlotte Watts
Chief Scientific Adviser (09/2020 - 03/2025)
Foreign Commonwealth and Development Office, UK

Rt Hon Peter Kyle
Then Shadow Minister for DSIT

Visitors from the Royal Academy of Engineering

UK

Atkins Realis

Cancer Research UK

Centre for Postdoctoral Development in Infrastructure Cities and Energy

Department for Transport

Fisher/German

Geotechnical Observations Ltd

Historic England

Institution of Civil Engineers

Institution of Structural Engineers

International Union of Railways

Loughborough University

National Grid

National Highways

Overpipe UK

QinetiQ

Thomas Dudley Ltd

UK National Authority for Counter Eavesdropping

Weatherhaven

Wolverhampton University

Wrangler-surgical

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