Imperial College London

# Department of Civil and Environmental Engineering

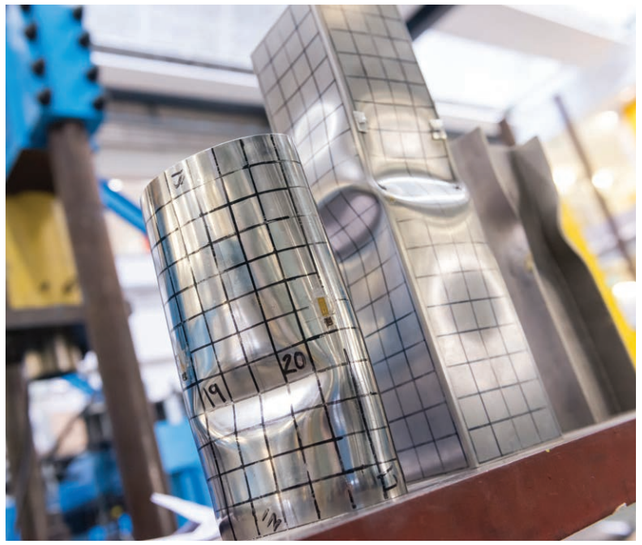
## Shaping a better built environment

# Contents

# Introduction

**It gives me great pleasure to introduce the Department of Civil & Environmental Engineering at Imperial College London.**

We focus on interactions between the built environment and the natural world and recognise that civil and environmental engineering are crucial to meeting the major challenges faced by society; including climate change, economic recovery, growing population and urbanisation, conservation of natural resources, development of renewable energy sources, sustainable transport, environmental quality and infrastructure ageing and resilience. Our graduates possess the skills, knowledge and attitudes necessary to lead society's response to these challenges.



*Clockwise: Professor Nick Buenfeld; new temperature-controlled equipment for characterising the thermo-hydro-mechanical response of engineered barrier systems for nuclear waste disposal; Hydrodynamics laboratory wind-wave-current flume; and buckling experiments.*

## About the Department

The Department is recognised internationally as a leading centre of excellence for research and education in Civil and Environmental Engineering. The Department has been awarded the top rating in every national Research Assessment Exercise held since 1986. The most recent review (REF2014) confirmed that the Department is the largest Department of Civil Engineering with the greatest concentration of top-ranked research within the UK; 95% of its staff being judged as world-leading or internationally excellent. Outstanding research is vital for the Department in terms of its impact and standing.

The Department is unique in having world-leading research capabilities in laboratory-based experimentation, advanced modelling, field monitoring, and underpinning theoretical research, enabling a rigorous approach and confidence in our research discoveries. Strong links with industry and continuous involvement in real engineering projects are key characteristics of our research activities that ensure practical relevance.

## Vision for civil engineering

With significant political interest and investment into infrastructure in the UK and internationally, the opportunity for embedding research and innovation in civil engineering is arguably at its greatest level since the golden age of Victorian engineering entrepreneurship. Drivers, including population growth, the needs of developing countries, climate change and digitalization demand new approaches and skills while also requiring maintenance of high standards in traditional disciplines. The Department's mission is to deliver world-leading research and education and to provide state-of-the-art advice to government and industry. The aims are to:

- advance the fundamental science at the core of civil engineering and its sub-disciplines.
- explore opportunities for discovery at the intersections of existing disciplines.
- build a future without barriers by participation in cross-disciplinary research teams to address global challenges.
- foster long-term, strategic relationships with companies, foundations, governmental organisations, and other partners to advance the discipline.
- nurture and develop the next generation of globally recognised engineers and researchers.
- engage with wider society to communicate the importance and benefits of science and engineering.

Nick Buenfeld

PROFESSOR NICK BUENFELD
Head of Civil and Environmental Engineering

## Rankings

**1st**

*THE COMPLETE UNIVERSITY GUIDE 2018*

*Civil Engineering*

**1st**

*THE GUARDIAN UNIVERSITY GUIDE 2018*

*Civil Engineering*

**1st**

*THE TIMES/SUNDAY TIMES GOOD UNIVERSITY GUIDE 2018*

*Civil Engineering*

## Research Environment and Impact


In the latest Research Excellence Framework (REF–2014)

- Imperial achieved the highest score of any institution for Civil & Construction Engineering research environment.
- Imperial is home to the greatest concentration of high-impact research of any major UK university.

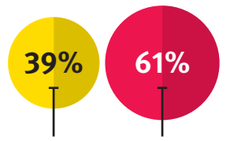
## People

**146**
STAFF

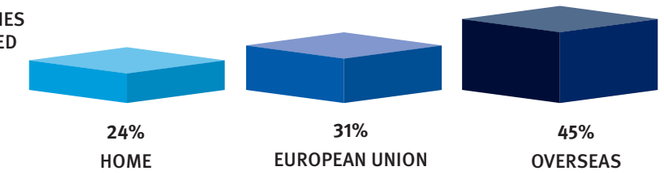

**881**
STUDENTS

- **205** *Postgraduate Research*
- **307** *Postgraduate Taught*
- **369** *Undergraduates*

GENDER




STUDENT NATIONALITIES REPRESENTED






## More durable materials with £5.8M research lab

Improving construction materials to make infrastructure more sustainable and durable will be the focus of research at a new Advanced Infrastructure Materials Laboratory (AIM).

The Lab will be the centrepiece of a new Imperial Centre for Infrastructure Materials where researchers will develop a new generation of construction materials that are more durable and robust, able to withstand ever greater loads, and more cost effective to manufacture and maintain. The researchers will also train the next generation of engineers, via an MSc course in Infrastructure Materials, which will start in October 2019.

The Imperial Lab is funded by the Engineering and Physical Sciences Research Council and sit under the 'umbrella' of the UK Collaboratorium for Research in Infrastructure & Cities (UKCRIC). It forms the major part of a new National Centre for Infrastructure Materials.

**75+**
Industrial collaborating companies

**Top**
Largest and top-ranked Department of Civil Engineering within the UK

# Research highlights

**Groundbreaking research,**
**world-changing collaborations,**
**and critical policy interventions.**

01

## Dynamically Adaptive and Resilient Water Supply Networks

*Academic lead* • **DR IVAN STOIANOV**

Dr Ivan Stoianov received EPSRC funding in 2017 for a 5-year Fellowship, the overall goal of which is to develop fundamental scientific methods for the design, optimisation and control of next generation resilient water supply networks that dynamically adapt their connectivity (topology), hydraulic conditions and operational objectives. A dynamically adaptive water supply network can modify its state in response to changes in the operational conditions, performance metrics, an increase in demand and a failure. This is a new category of engineering (cyber-physical) systems that combine physical processes with computational control in a holistic way in order to achieve dynamic adaptability, resilience, efficiency and sustainability. An unprecedented experimental programme of "Impact Labs" are being created as dynamically adaptive water supply networks operated by Bristol Water, Anglian Water, Severn Trent Water, and Welsh Water.

**QUICK FACTS**

- **Smart water systems market is expected to grow from $7.3 billion in 2015 to $18.3 billion by 2020.**
- **The Adaptive Networks Interest Group (ANsIG), part of the Fellowship, has membership of four water companies who collectively represent over 35% of the UK's potable water supply.**



02

## Extreme surface water waves

*Academic lead* •
**PROFESSOR CHRIS SWAN**

In both coastal and offshore engineering the description of extreme waves, with a given return probability, is key to the design of new structures and the re-assessment of existing infrastructure. Current research on this topic at Imperial was initiated as part of the CREST and SHORTCREST Joint Industry Projects (JIPs) and continued with the EPSRC funded SUPERGEN project.

The work has combined field observations, laboratory investigations and numerical calculations and has established the inadequacy of existing design practice in several important respects.

In terms of the incident crest heights, the competing influence of nonlinear amplifications and the dissipative effects of wave breaking can lead to significant departures from present practice; the latter typically based upon second-order approximations. These can have profound implications in terms of increased crest heights, reduced directional spreading and larger near-surface fluid velocities. Since these all have a direct influence on the wave loads, particularly wave-in-deck loading, the practical implications are significant and have already been picked-up and implemented by the relevant regularity authorities. The findings are presently being extended to cover intermediate and shallow water depths within the LOWISH III JIP sponsored by six international oil and gas companies. This work has led to the development of new crest height and wave height distributions appropriate to design applications.

03

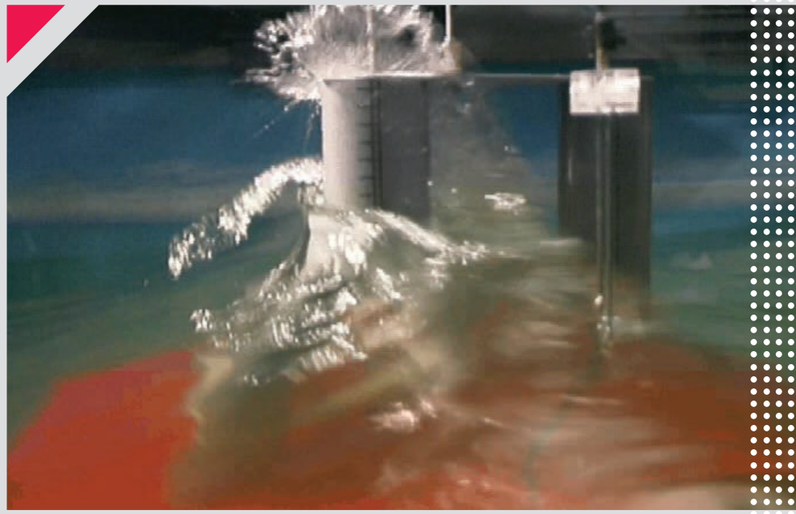
## Wave-structure interactions

*Academic lead* • **PROFESSOR CHRIS SWAN**

This work was originally funded by Shell International Oil & Gas and was motivated by the unexpected occurrence of wave impact damage on the underside of a large North Sea structure. A fundamental investigation of the nonlinear wave-structure interactions identified a new mechanism for wave scattering associated with the movement of fluid around a column. This led to the scattering of a pair of non-concentric, high-frequency, wave fronts that cannot be predicted by existing diffraction theory. The interaction between these waves and the next incident wave forms part of a classical long-wave short-wave interaction that can produce a very substantial increase in the maximum local water surface elevation, hence the wave impact damage on the underside of the deck.

While the initial work was experimental, the results have now been simulated numerically, allowing the wider implications of the work to be assessed. This has established the practical importance of the high-frequency wave scattering for a wide range of offshore structures. Specifically, it provides an explanation for the increased occurrence of wave slamming on a column face. In the case of a dynamically sensitive structure, it also provides the origins for the high-frequency forcing arising above the mean water level and the consequent excitation of the structure at frequencies well above those of the incident waves, the latter commonly referred to as a "ringing" response.

The occurrence of these forces and motion modes is highly relevant to the design of offshore wind turbines, not least because their chosen location is such that they will be subject to large / steep (perhaps breaking) wave events. The work is presently being continued with funding from Hyundai Heavy Industries to consider the implications for shipping, most notably the occurrence of bow and side-shell slamming.

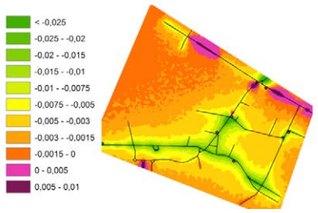


*Experimental investigation of wave slamming on a gravity based structure to examine the "ringing" response.*

04

## Adaptive traffic management for sustainability

*Academic lead* • **DR KE HAN**




*Reduction of Black Carbon concentration after implementing the proposed signal control and route guidance strategies. Negative values indicate reduction compared with the no-control scenario.*

The aim of the CARBOTRAF project was to support traffic operators in real time to adopt optimal intelligent transport control strategies to mitigate traffic congestion while reducing $CO_2$ and Black Carbon emissions. The project team included 2 academic and 5 industrial partners, and 2 cities (Glasgow, Graz) as test sites.

The system developed includes off-line and online modules. The off-line module generates a library of traffic and emission simulation results in relation to a variety of traffic control strategies, including coordinated signal control and variable message sign, for different traffic network scenarios. The on-line module combines a real-time monitoring of traffic and air pollution with a decision support system, which recommends the best control strategy to the operator through innovative optimization techniques and machine learning.

**QUICK FACTS**

- **€3.1M EU-funded project that has made its way to China through knowledge transfer.**
- **$CO_2$ and Black Carbon are the first and second major causes for global warming, BC also causes acute health effects.**
- **In the EU, 28% of $CO_2$ is from transport, BC exposure is highly related to transport.**

Simulation and field implementation of the CARBOTRAF system have shown very promising results. The project was showcased in the International Big Data Expo in May 2017, and won the Excellence Award in the China Intelligent Transport and Big Data Application Innovation Contest in September 2017.

05

## Transfer of Organic Contaminants to the Food Chain from Waste-Derived Products Recycled in Agriculture

*Academic lead* • **PROFESSOR STEPHEN SMITH**

Increasing amounts of waste-derived materials are recycled in agriculture; for example, sewage sludge and combustion residues are applied to land as soil conditioners and fertilizer replacements, and materials such as untreated waste wood are marketed as livestock bedding. This practice is critical to ensure sustainable food production by recycling nutrients, reducing biodegradable waste sent to landfill and conserving natural resources. Large numbers of organic compounds are manufactured by the international chemical industry and are essential to a modern industrial economy, and may be present in these waste-derived products. The UK Food Standards Agency required an evidence base to validate food chain models that determine the level of exposure of consumers to environmental organic contaminants that may be found in waste-derived materials recycled in agricultural applications. Hence, a research programme was funded to investigate the transfer and uptake of contaminants into food arising from the use of recycled wastes and waste-derived products in agriculture, led by Professor Stephen Smith of Imperial's Department of Civil and Environmental Engineering, in collaboration with the Centre for Dairy Research, The University of Reading and Fera, York. Crop transfer studies to investigate the transfer of organic contaminants from waste-derived products recycled on agricultural land to plant tissue were conducted in controlled laboratory experiments and under field conditions, and controlled dairy cattle ingestion trials investigated the transfer of organic contaminants to milk from waste-derived materials spread to agricultural land or used as animal bedding.
This high impact research will be used to underpin regulatory controls and guidelines relating to food quality and waste recycling, and to enable the waste-recycling industry to improve their practices to minimize contamination of food products and protect human health.

**QUICK FACTS**

- **The use of waste-derived products in agricultural applications reduces biodegradable waste sent to landfill, conserves natural resources and ensures sustainable food production.**
- **Research has been completed to determine the transfer of organic contaminants from waste-derived products, used either as recycled livestock bedding or landspread, to the milk of dairy cattle and to crops.**
- **The data provides an evidence base to underpin regulatory controls and food chain models to determine the level of exposure of consumers to organic contaminants.**




*Above: Dr Ana Mijic, part of the team behind Blue Green Dream.*

*Below: Crop transfer experiments completed as part of Professor Stephen Smith's work on the use of waste derived products in agriculture.*

06

## Blue Green Dream

*Academic contact* • **DR ANA MIJIC**

Intensifying climate extremes (floods, droughts and heat waves), combined with increasing urbanisation, call for rethinking existing ways of planning, designing, constructing, operating and maintaining urban water systems (blue assets) and urban vegetated areas (green assets), not as separate systems as is the case today, but in combination. The expected multiple benefits of multi-functional Blue Green Solutions include: increased amenity and urban health, enhanced resilience to drought and flood risk, reduced air pollution, noise and energy requirements, mitigation of extreme heat and urban heat island effects and enhancement of biodiversity and quality of life.

**QUICK FACTS**

- **Winner of R&D Programme of the Year award at Business Green Technology Awards 2015.**
- **13 demo sites set up across Europe at a variety of scales – ranging from green roofs equipped with sensors, including Imperial College (Eastside) Green Roof, to sites in Berlin (10,000m2) and Paris.**

This project brought together academic, NGO and industry partners from across Europe and focussed on the development of innovative paradigms, models, tools and methodologies by sharing expertise between academic research and consultancy partners from 4 countries (France, Germany, the Netherlands and the United Kingdom). Taking an integrated approach, jointly developed project deliverables were tested and demonstrated in selected sites established in Berlin, London, Paris and Rotterdam, to demonstrate the benefits of Blue Green infrastructure for both retrofit and new developments.

The outputs of the project include various new modelling and methodological tools including:

- Multi-Hydro model
- Adaptation Support Tool (AST)
- Urban Water Optioneering Tool (UWOT)
- BGD Toolbox, BG Solution Evaluation Matrix, BGD E-Learning, BGD Green Façade BIM module, and
- BGD Integrated Modelling System (IMS)

07

## Fluid mechanics for the built environment

*Academic lead* • **PROFESSOR GRAHAM HUGHES**

Our urban landscapes are becoming increasingly complex and populated, presenting broad-ranging challenges regarding the sustainability and resilience of our cities, neighbourhoods and buildings. Understanding of the interaction between air flow, urban form and human activity is crucial in tackling many of these challenges, such as indoor and outdoor air quality, urban microclimates and wind engineering.

We employ a full suite of numerical simulation techniques, laboratory experiments and field data to inform and develop mathematical models. These models are capable of improved predictions to guide government agencies, city planners, developers and architects. We provide leadership within the UK Low-Energy Ventilation Network (www.lowenergyventilation.org), the Urban Fluid Mechanics (www.urbanfluidmechanics.org) and Experimental Flow Diagnostics (fluids.ac.uk/sig/xFD) Special Interest Groups – membership of which is open and comprises currently of more than 200 researchers and practitioners.

**Urban air quality and microclimate**
We develop modelling capability for urban air quality and microclimate, both through very high resolution models for detailed design, and much simpler models that can be used in the Master Planning stage. Current work involves:

- Effect of vegetation on air quality and microclimate
- Coupling with state-of-the-art traffic emission models
- Active strategies to mitigate air pollution.

**Efficient, Healthy and Productive Indoor Environments**
We investigate the flows through buildings that determine our indoor environment. For example, a current PhD student project is examining affordable solutions to better ventilate the polluting smoke from dwellings where open fires and solid fuel stoves provide cooking and heating – a practice used by a third of the worldwide population and responsible for 3–4 million premature deaths each year.

**Inverse Modelling**
In addition to predictive models, we develop techniques for flow optimisation and inverse modelling. These approaches address problems involving uncertainty in design, such as determining

- boundary conditions that correspond to observations;
- extreme events and worst-case scenarios;
- optimal control strategies for building ventilation;
- flow reconstruction from surface measurements.

*Investigating the ventilation of polluting smoke from rural dwelling using analogue laboratory experiments*


*Tunnel boring machines used on the Crossrail project in London. Imperial research explored the effect of new tunnel construction on existing tunnels and the ground response.*

08

## Crossrail

*Academic lead* • **DR JAMIE STANDING**

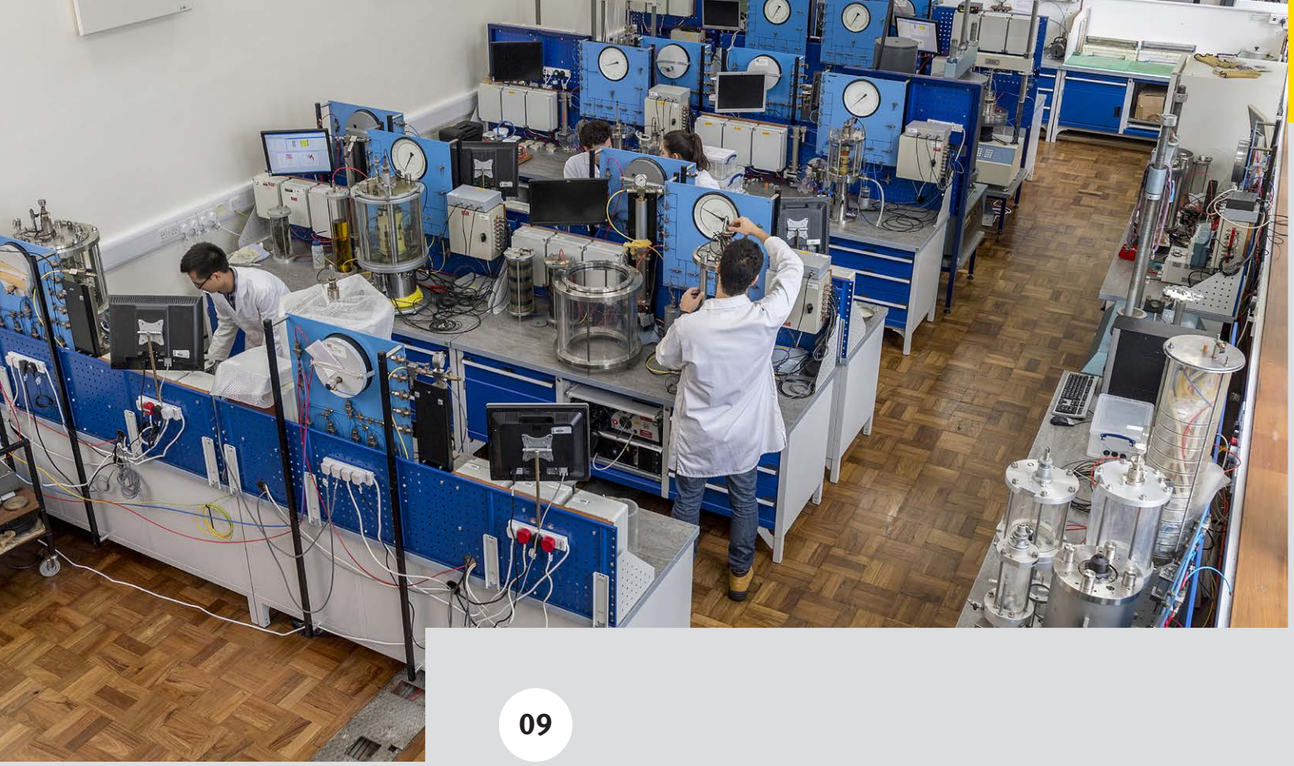
**QUICK FACTS**

- **£2.0M EPSRC and Crossrail funded project, run in conjunction with the Crossrail tunnelling project.**
- **New insights on the effects of tunnelling on existing tunnels.**
- **20+ unique case study publications.**

This research project was run in conjunction with the Crossrail project – involving construction of 21km of twin-bore railway tunnels through central London where the new tunnels interface with existing networks of London Underground tunnels and other utility tunnels. For the western tunnel section, the twin tunnels are constructed using 7.2m diameter earth-pressure-balance tunnel boring machines (TBMs), mostly in London Clay.

The project value was about £2M, funded by EPSRC and Crossrail. The research focus is on the ground response to tunnelling and the effect of new tunnel construction on existing tunnels lined with grey cast-iron segments, which are the most common type constructed pre-war in London.

Research methodology involved five interlinked aspects: (i) structural testing in our Structures Laboratory of a half-scale cast-iron lining ring; (ii) field measurements, at a site in Hyde Park, of ground movements and structural movements of the existing Central Line tunnels; (iii) numerical modelling of field conditions using the bespoke software ICFEP; (iv) numerical modelling of cast-iron segments with ICFEP; and (v) testing of London clay samples retrieved from Hyde Park in our Geotechnical Laboratory.



*General view of the main Geotechnics Laboratory with 100 mm triaxial stress-path cells in the foreground.*

09

## BEACON (Bentonite Mechanical Evolution)

*Academic lead* • **PROFESSOR LIDIJA ZDRAVKOVIC**

QUICK FACTS

- **€4 million EC funded project as part of Horizon 2020 EURATOM.**
- **25 academics and industry partners.**
- **8 major European national waste management organisations.**

The objective for this work is to contribute to the development of engineered solutions for the management of high-level radioactive waste, and in particular the implementation of the first-of-the-kind geological repositories. The current pan-European consensus solution for nuclear waste disposal involves burial of the nuclear waste-filled canisters in galleries and tunnels excavated deep in a host geological formation. The protection between the canister and the host formation is a buffer material, usually a highly swelling clay, such as bentonite, that is expected to mechanically evolve over time and seal the repository, thus preventing the long-term leakage of radioactive nucleoids into the surrounding ground.

The key drive for the project is to ensure efficient repository safety, thus contributing to the European Strategic Energy Technology (SET) Plan to make low-carbon technologies affordable and competitive. The aim is to verify the performance of the current designs for buffers, backfills, seals and plugs. The project comprises 25 academic and industry partners of which 8 are major European waste management organisations, including the UK's Radioactive Waste Management (RWM) Ltd.

The primary contribution of the Imperial Geotechnics Group is in the computational modelling of thermo-hydro-mechanical evolution of bentonite buffers with time, using the advanced modelling capabilities of the bespoke FE software ICFEP (Imperial College Finite Element Program). ICFEP will also be applied in the modelling of large-scale prototype repository experiments conducted in Sweden and Spain. The work on the BEACON project builds on current both experimental and computational research in the Geotechnics group, funded by RWM Ltd. (UK), AMEC Foster Wheeler (UK) and EPSRC.



10

## PISA (Pile Soil Analysis) project

*Academic lead* • **PROFESSOR LIDIJA ZDRAVKOVIC**

QUICK FACTS

- **£3.5M joint industry research project, part of Carbon Trust Offshore Wind Accelerator programme.**
- **New design methods leading to significant savings in cost of offshore wind turbine foundations.**

The PISA project is a £3.5M joint industry research project led by DONG Energy and run through the Carbon Trust's Offshore Wind Accelerator programme, with the industry group including companies who, collectively, own over 70% of the total offshore wind projects in the UK. The academic working group consists of academics from Oxford University (project lead), Imperial College and University College Dublin.

As the contribution of offshore wind in the UK's energy mix increases and the cost of generated electricity per MWh reduces, the imperative for industry has been to reduce the cost of wind turbine installations. The PISA project therefore resulted from the need to address the shortcomings of current design methods for wind turbine monopile foundations. These methods rely on the p-y methodology and have been shown to produce highly inefficient foundation designs when applied to short and stubby offshore wind monopiles.

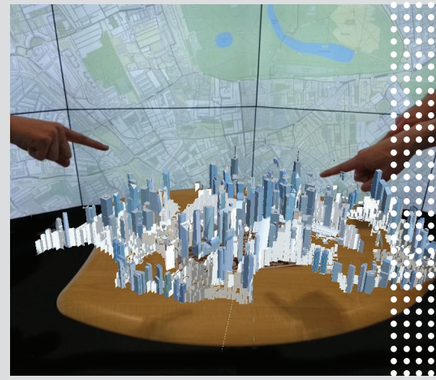
Imperial's research team led the work on advanced characterisation of two pile test sites and on advanced, site-specific, 3D finite element (FE) analyses of laterally loaded monopiles. Element testing of a stiff clay till from a site at Cowden and of a dense sand from Dunkirk was conducted in our Geotechnical Laboratories. The results served as input to advanced 3D FE analyses with the bespoke software ICFEP, which accurately predicted the response of medium-scale piles, tested under lateral loading at the two sites. Further ICFEP analyses of full scale monopiles, with up to 10m in diameter and the length to diameter ratios of between 2 and 6, produced numerical data as input for the development of new simplified and improved design methods embodied in a 1D FE model. The project demonstrates significant savings in the cost of offshore wind turbine foundations when applying the PISA design methodology compared to current industry guidance.

11

## Improved construction progress monitoring through augmented reality

*Academic lead* • **PROFESSOR JENNIFER WHYTE**

Based in the Centre for Systems Engineering and Innovation, Ranjith Soman is currently undertaking a PhD that is co-funded by Bentley Systems and a Skempton scholarship. Building on the team's track-record of research on virtual reality and the built environment, it focuses on developing and implementing a framework to enable bidirectional information flow between the construction site and construction office to aid construction monitoring and control. This doctoral work will use the potential of augmented reality to enable interactive visualisation of data acquired directly from the construction site and develop next-generation construction progress monitoring practices. An early prototype demonstrates the feasibility of the approach. The next steps of the research are to develop the tool to querying building information data across different formats, and combine this with constraint logic programming to develop and evaluate the performance of a new approach to look-ahead planning.



*Collaborative visualisation in augmented reality.*

12

## Predictive modelling of trabecular and cortical bone structural architecture

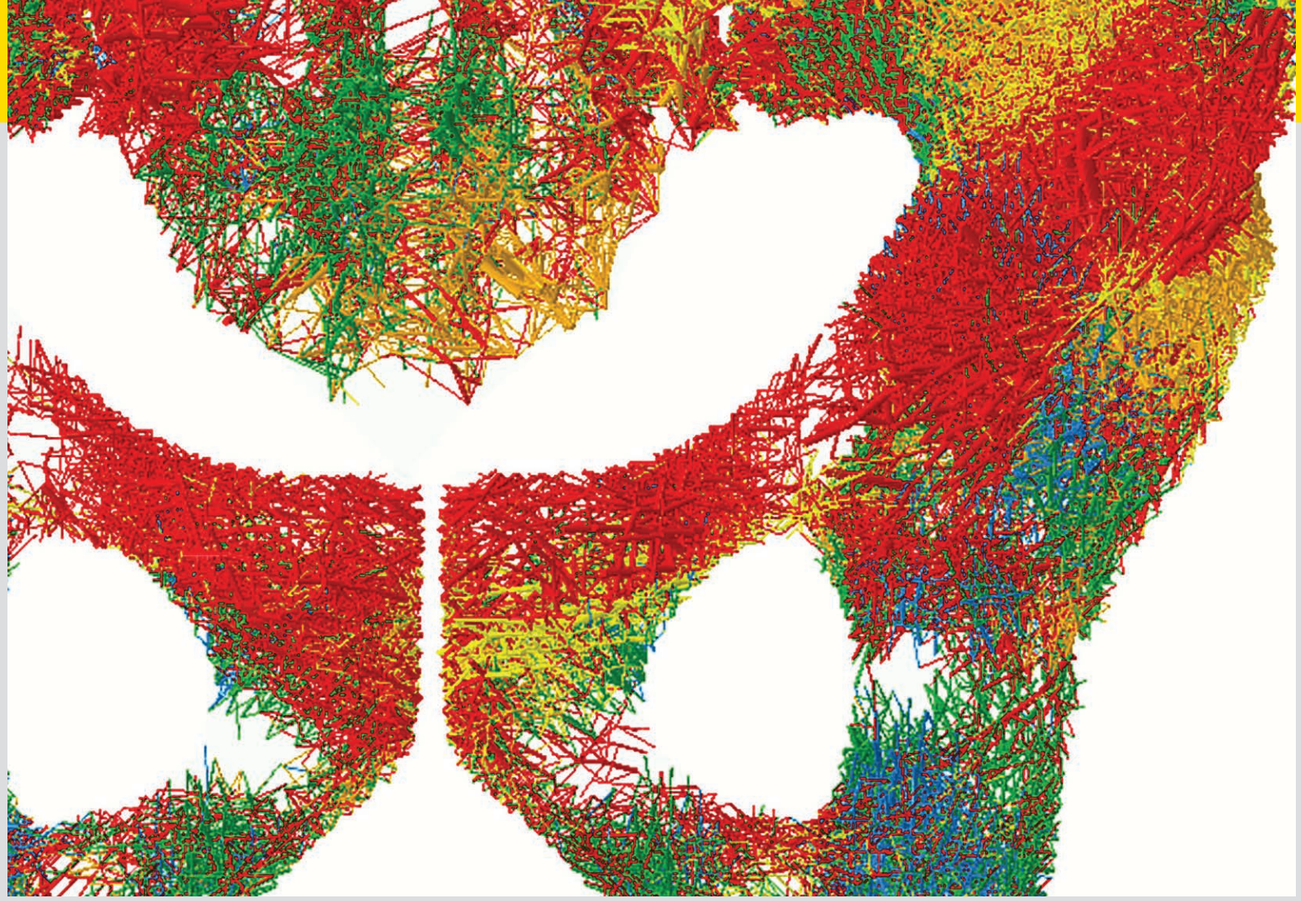
*Academic lead* • **DR ANDREW PHILLIPS**

Predictive modelling of trabecular and cortical bone structural architecture is a transdisciplinary research area. It uses a sophisticated range of data recording and computational modelling techniques. Movement data is collected from infra-red cameras to pick up the positions of a volunteer carrying out activities of daily living in a defined space. Coupled with ground reaction force data collected simultaneously, movement data is used in a dynamics model to determine moments in the joints of the lower limb (and more recently the spine). An optimisation problem is then solved using OpenSim musculoskeletal modelling software, to predict muscle forces resulting in joint movements. This is a complex problem owing to the number of muscles crossing a joint. The resulting muscle forces are used in unique structural finite element models of the musculoskeletal system, with a strain driven adaptation algorithm to derive optimised structures, capable of resisting the demands of human daily activities with a minimum volume of bone material.

An advantage of this unique approach to modelling the skeletal system is the ability to run fracture modelling rapidly. This is of value in investigating osteoporotic fragility fractures, civilian injuries sustained in vehicle collisions, and in the field of blast injury studies. A further advantage is the ability to manufacture the derived structures additively, with application in the design of frangible surrogates, tissue engineering scaffolds, and manufacture of endoprosthetics.

**QUICK FACTS**

- Research made possible through funding from the Royal British Legion Centre for Blast Injury Studies and collaboration with the Human Performance Laboratory at Charing Cross Hospital.
- This work uses similar tools to those employed in digital design and has attracted interest from companies interested in innovative techniques in structural optimisation.
- A related project is being carried out in the EPSRC CDT in Sustainable Civil Engineering, sponsored by Robert Bird Group.



*Mapping for predicted mesoscale trabecular bone structure in the pelvis due to the influence of walking (red), going up and down stairs (yellow and orange), and sit-to-stand and stand-to-sit (green and blue).*

13

## Optimising headed bar joints

*Academic lead* • **DR ROBERT VOLLUM**

This research led to an improved understanding of the behaviour of headed reinforcement tension laps connecting precast concrete elements. The headed bars overlapped by 100 mm within a 200 mm wide insitu concrete joint in which transverse bars and vertical shear studs were installed to provide confinement as in the E6 flooring system developed by Laing O'Rourke. This type of joint facilitates the construction of continuously reinforced slabs from precast elements thereby enabling significant reductions in overall construction time and improvements in construction quality due to off-site fabrication. Ductile failure with yield of 25 mm diameter high strength headed bars was achieved with joint concrete having a cylinder compressive strength of 39 MPa.

**QUICK FACTS**

- PhD studentship funded by Laing O'Rourke.
- Reduction in construction time and improvements in construction quality.

*Failure of 3 bar headed bar tension splice.*

14

## Structural use of stainless steel

*Academic lead* • **PROFESSOR LEROY GARDNER**

The behaviour and design of stainless steel structures has been investigated at Imperial over the last 15 years. The primary focus of the research has been to develop an understanding of the behaviour of stainless steel as a structural material through experimentation and modelling and to generate design methods suitable for incorporation into international design codes. The work has been funded by EPSRC, the European Union and numerous industrial sponsors.

**QUICK FACTS**

- **4 textbooks and 200+ papers published covering structural testing, numerical modelling and the development of design guidance.**
- **3 million tonnes — estimated quantity of steel procurement in UK Government infrastructure Pipeline of Projects by 2020.**

Based directly on research at Imperial, a range of improvements have been made to key stainless steel design standards. The research at Imperial enables more efficient structural stainless steel designs, bringing about cost savings, more widespread use of the material and a reduction in the use of resources to the benefit of future generations.

15

## Airport safety-criticality

*Academic lead* • **DR ARNAB MAJUMDAR**

**QUICK FACTS**

- **Safety occurrences on the airport apron cost the aviation industry in excess of $10bn every year.**
- **One accident occurs per 5,000 movements.**
- **Research included 5 airport studies over 20 days, with 15 observations and 43 participants.**

Airport surface safety, in particular of the runway and taxiway, is an issue of growing importance due to steady growth in air traffic and associated problems from congestion and delays. To address this issue, the Lloyd's Register Foundation sponsored the Transport Risk Management Centre (TMRC) to undertake research to develop a model of airport surface safety.

A theoretical model of normal airport surface operations was developed. Subsequently, a global study of the critical factors that underlie airport surface accidents and incidents (occurrences) was conducted, and used to develop a new holistic taxonomy of causal and contributing factors. The taxonomy incorporates the viewpoint of all relevant aviation stakeholders (regulators, Air Navigation Service Providers, airlines, airport operators, ground handling companies, Accident Investigation Boards) involved in the subject matter. In a third step, statistical analysis is used to identify the impact of airport characteristics (e.g. airfield geometry, level of equipment, operations) on safety occurrences.

Airports can then be categorised in terms of airport surface risk. The final model of airport surface safety assesses the functional relationship between accidents and incidents and their underlying critical factors to outline effective safety mitigation strategies.

Recommendations from the research included development of new regulatory frameworks, improved design of ground service equipment, improved communication practices on the apron, and improved working conditions for ground service agents. The research has since been used for airport apron safety in Los Angeles, New York and JFK airports.

16

## Design for manufacture and assembly

*Academic lead* • **DR PANAGIOTIS ANGELOUDIS**

The aim of this Innovate-UK funded research is to optimise the design for manufacture and assembly (DfMA) of large preassembled components for reinforced concrete construction in nuclear and other large construction projects. The project team includes Laing O'Rourke, Arup, and BRE.

**QUICK FACTS**

- **Innovate-UK funded project and winner of 'Most Innovative Project' at Collaboration Nation event in March 2016.**
- **The use of preassembled components in large scale civil engineering construction projects has the potential to reduce construction site $CO_2$ emissions by 50%, water consumption by 30% and construction waste by more than 50%.**

The project explores the potential of a number of construction approaches, comprising of a range of elemental sizes and jointing techniques, for both sub- and super-structure applications in nuclear construction.

A new optimization technique has been developed in order to optimize the manufacturing and deployment of components in modern large scale construction projects. The outputs of this research have been acknowledged in the plans for the construction of a new nuclear power plant (Hinkley Point). More specifically, the scheduling algorithms will facilitate the determination of the optimal size and dimensions of the prefabricated components to be used in construction. The overall objective is to reduce the construction period of the entire project, while maintaining stringent safety standards (with respect to assembly processes and structural design codes) and keeping costs to a minimum.

*Top: Obtaining accurate material properties from testing stainless steel samples.*

*Bottom: Additive manufacturing, also called 3D printing, allows geometries and forms that are cost prohibitive or impossible with conventional forming methods. Material and structural testing is being carried out for the stainless steel MX3D Bridge.*

# Research and academic staff

## Environmental and Water Resources Engineering (EWRE)

**Research interests include: water, wastewater and sewage sludge treatment; smart, adaptive networks and sensors; resources and materials recovery and the circular economy; surface and groundwater hydrology, water resources engineering including modelling quality, drought, flooding and rainfall; urban hydrology, sustainable urban drainage and blue-green infrastructure; climate change; land management impacts; sanitation and waste management in developing countries.**

### PROFESSOR STEPHEN SMITH

*Professor of Bioresource Systems*
**Head of EWRE Section**

**s.r.smith@imperial.ac.uk**

Professor Smith has 30 years of experience investigating the treatment and properties of sludges and organic wastes focussing on recovering valuable resources, anaerobic digestion, biodrying technologies and renewable energy. A key interest is the recycling of organic wastes recycled to land for agronomic benefit and minimising their environmental impacts. Professor Smith has worked extensively overseas on the problems of sewage sludge treatment and recycling, notably in Egypt and Australia.

### DR ADRIAN BUTLER

*Reader in Subsurface Hydrology*

**a.butler@imperial.ac.uk**

Dr Adrian Butler's research is primarily associated with work on measuring, analysing and modelling subsurface flow and transport processes and their associated environmental impact. He has a particular interest in the Chalk of Southern England and has been involved in research on recharge processes, groundwater flow and contaminant transport using a range of geophysical techniques.

### DR WOUTER BUYTAERT

*Reader in Hydrology and Water Resources*

**w.buytaert@imperial.ac.uk**

Dr Wouter Buytaert is an expert on the impact of environmental change on the water cycle and its consequences for water supply and flood and drought risk. His work ranges from hydrological process understanding, to computer simulation, decision-support, the science policy interface, and sustainable development.

### PROFESSOR CHRIS CHEESEMAN

*Professor of Materials Resources Engineering; Director of EPSRC CDT Sustainable Civil Engineering*

**c.cheeseman@imperial.ac.uk**

Professor Chris Cheeseman leads a research group primarily focussed on developing beneficial reuse applications for waste materials and sustainable materials for infrastructure development. The research is driven by the need to move towards a more resource efficient, circular economy.

### DR GEOFF FOWLER

*Research Fellow*

**g.fowler@imperial.ac.uk**

Dr Geoff Fowler's primary research interests are in the management, recovery and reuse of end-of-life carbon containing materials. He is an expert in the manufacture, analysis and application of Activated Carbons and Carbon Black. His research has a strong commercial emphasis with a focus on solving real-world problems. He is pioneering the application of ultra-high pressure water jets to enhance materials recovery and recycling.

## DR MATTHEW GREETHAM

*Environmental Teaching Fellow*

m.greetham@imperial.ac.uk

Dr Matthew Greetham is a specialist in the optimisation of the design and management of infrastructure relating to potable water, wastewater and surface water. He has extensive industrial experience gained from working across Europe, Asia and Africa.

## PROFESSOR NIGEL GRAHAM

*Professor of Environmental Engineering*

n.graham@imperial.ac.uk

Professor Nigel Graham works principally in research related to the design, operation, performance and development of a wide range of unit processes in water and wastewater treatment, and in the management of water supply systems. In recent years Professor Graham has focused his research studies on oxidation, coagulation and filtration processes, and in aspects of water supply network analysis.

## PROFESSOR SUE GRIMES

*Professor and RAEng Chair in Waste and Resource Management.*

s.grimes@imperial.ac.uk

Professor Sue Grimes's research activities encompass a range of projects in waste and resource management involving the electronics, food and beverage, secondary metals, and waste industries. The focus of her research is recovery of value from such waste for conversion to commercially useful products, Closed-loop methodologies towards resource efficiency and Decision support tools for sustainable waste management.

## PROFESSOR CEDO MAKSIMOVIC

*Professorial Research Fellow*

c.maksimovic@imperial.ac.uk

Professor Cedo Maksimovic works in the fields of applied fluid mechanics in urban water systems: storm drainage, urban flooding water supply and interactions of urban water systems and infrastructure with the environment. His recent achievement stems from the EIT-European Institute for Innovation and Technology 'Blue Green Dream' project in which an innovative methodology (BGS-Blue Green Solutions) has been developed.

## DR ANA MIJIC

*Senior Lecturer in Urban Water Management*

ana.mijic@imperial.ac.uk

Dr Ana Mijic's research interests are in developing analytical, numerical and systems models and using full-scale experiments to explore how people use and manage water, and the role of cities in defining water security and sustainable development. The aim of her research is fundamentally to challenge principles of integrated water management in and for cities by exploring relationships between urban areas and their hinterlands and the role of factors exogenous to the water system that are playing a crucial role in its management.

## DR CHRISTIAN ONOF

*Reader in Stochastic Environmental Systems*

c.onof@imperial.ac.uk

Dr Christian Onof's main area of research is in the stochastic modelling of rainfall and related variables for the purpose of hydrological simulation and flood design in a changing climate, with a particular emphasis upon fine time-scales. Another focus of his interest is the integration of multiple sources of rainfall estimation, rain gauge, radar and satellite where he has worked on the development of methods that are sensitive to fine scale singularities in the precipitation field.



## DR ATHANASIOS PASCHALIS

*Lecturer in Hydrology*

a.paschalis@imperial.ac.uk

Dr Athanasios Paschalis's primary research interests are the physical understanding of the Earth system, the computational modelling of hydrological processes, and their links to atmospheric processes and vegetation dynamics. He has also worked extensively developing stochastic models for meteorological variables as numerical tools for probabilistic natural hazard risk assessment.

## DR IVAN STOIANOV

*Senior Lecturer in Water Systems Engineering*

ivan.stoianov@imperial.ac.uk

Dr Ivan Stoianov holds a five-year EPSRC Fellowship through which fundamental scientific methods for the design, optimisation and control of next generation resilient water supply networks that dynamically adapt their connectivity (topology), hydraulic conditions and operational objectives will be developed and experimentally investigated.

## DR MICHAEL TEMPLETON

*Reader in Public Health Engineering*

m.templeton@imperial.ac.uk

Dr Michael Templeton's research focuses on the occurrence and control of chemical and biological contaminants in water, innovative water treatment processes, and effective water supply and sanitation interventions in low-income countries. His current projects include maximising the effectiveness of water, sanitation and hygiene interventions for preventing schistosomiasis in Africa and modelling and controlling nitrate pollution of groundwater by pit latrines in developing countries.

*Building robust environmental sensor networks with low-cost off-the-shelf components.*

# Fluid Mechanics

**Research interests of the section span fluid mechanics for the offshore, coastal and built environments with capabilities that include numerical simulation techniques, unique experimental facilities and analysis of field measurements.**

## PROFESSOR CHRIS SWAN

*Professor of Hydrodynamics;*
❖ **Head of Fluid Mechanics Section**

**c.swan@imperial.ac.uk**

Professor Chris Swan's principal research interests concern the description of surface water waves, particularly extreme wave events, and their interaction with both fixed and floating structures. Applications of this work concern both deep-water offshore and shallow-water coastal environments; with research funding provided by the offshore oil and gas industry, the maritime and shipping industries and the coastal engineering industry.

## DR JOSE M. ALSINA

*Lecturer in Fluid Mechanics*

**j.alsina@imperial.ac.uk**

Coastal Engineering, sediment transport and morphodynamics including detailed sediment transport measurements, large scale morphodynamics experimentation and the morphodynamics of the swash zone are the main research interests of Dr Jose M. Alsina. He is particularly interested in the morphodynamics of very shallow coastal areas such as the inner surf and the swash zones.

## DR HENRY BURRIDGE

*Lecturer in Environmental Fluid Mechanics*

**h.burridge@imperial.ac.uk**

Dr Henry Burridge's research interests centre on the transport of heat and mass by convection, with applications to the built environment. Examples include the effective ventilation of buildings with a focus on the implications for occupancy comfort, health & well-being, and energy consumption, to the modification of natural materials for use in the built environment.

## DR ADRIAN CALLAGHAN

*Senior Lecturer in Fluid Mechanics*

**a.callaghan@imperial.ac.uk**

Understanding the occurrence, frequency and severity of individual breaking waves at the ocean surface, with applications to offshore and coastal engineering and air-sea interaction studies are Dr Adrian Callaghan's main research interests. His most recent work has focused on developing a digital image-based remote sensing technique to estimate the energy dissipated by individual breaking waves.

## DR JOHN CRASKE

*Lecturer; Imperial College Research Fellow*

**john.craske07@imperial.ac.uk**

Dr John Craske has a background in both architecture and fluid mechanics, and his current research addresses flow optimisation in the context of building physics. The numerical and theoretical models that he develops are relevant to the optimal control, sensitivity, and stability of buoyancy-driven flows, which are concepts that play an important role in the robust design and operation of buildings.

## DR MARIOS CHRISTOU

*Lecturer in Fluid Mechanics and Mathematics*

**marios.christou@imperial.ac.uk**

Dr Marios Christou's research covers metocean, offshore and coastal engineering, fully nonlinear wave to wave, wave-structure and wave-vessel interactions, infragravity waves interacting with coastal structures and vessels and wave and crest height probability distributions.

## PROFESSOR GRAHAM HUGHES

*Chair in Environmental Fluid Mechanics*

**g.hughes@imperial.ac.uk**

Professor Graham Hughes's research covers a broad range of buoyancy-driven flows, including stratified turbulence and mixing, energetics, convection, plumes and jets, internal gravity waves, stratified exchange flows and interaction of flow with topography. He seeks to understand the physics governing these flows in a wide variety of environmental, engineering and geophysical applications. His current work examines questions relating to energy efficiency and the built environment, indoor and outdoor environmental quality, solar thermal power generation and ocean mixing.

## DR MAARTEN VAN REEUWIJK

*Senior Lecturer in Fluid Mechanics*

**m.vanreeuwijk@imperial.ac.uk**

Dr Maarten van Reeuwijk's research interests comprise transport processes in fluids, generally involving wall-bounded turbulence and buoyancy effects. Application areas include transport processes in urban areas (urban heat island, dispersion, microclimate), atmospheric convection, building ventilation (stratified environments, plumes/jets, exchange flows), water quality in distribution systems (mass transfer), groundwater flows and oceanography.

## DR FRANCESC FÀBREGAS FLAVIÀ

*Lecturer in Energy Systems*

**f.fabregas-flavia@imperial.ac.uk**

Dr Francesc Fabregas Flavia's research focuses on hydrodynamics and fluid- structure interaction, with application to marine renewable energy technologies. He seeks to develop numerical models to assist in the design and optimization of individual devices, such as wave energy converters and floating offshore wind turbines, as well as arrays composed of a large number of units.

*Researchers performing experiments in the wind-wave-current flume within the Hydrodynamics Laboratory; this experiment examines the influence of an overlying wind-stress on crest elevation statistics.*

# Geotechnics

**Research interests include: tunnelling, excavations, soil-structure interaction, advanced soil testing, computational geomechanics, offshore geotechnics, energy geotechnics, particulate soil mechanics, earthquake engineering and engineering geology.**

## PROFESSOR LIDIJA ZDRAVKOVIC

*Professor of Computational Geomechanics*

**Head of Geotechnics Section**

**l.zdravkovic@imperial.ac.uk**

Professor Lidija Zdravkovic's recent research includes foundation systems for offshore wind turbines, temperature effects on soil behaviour with application to nuclear waste disposal and exploration of geothermal energy, and life cycle and sustainability of flood defences. She is an expert in geotechnical numerical analysis, including development and application of soil constitutive modelling, boundary conditions, solution algorithms and advanced characterisation of geomaterials.

## PROFESSOR JOHN BURLAND

*Senior Research Investigator, Emeritus Professor of Civil Engineering*

**j.burland@imperial.ac.uk**

Professor Burland's current research interests are in soil-structure interaction, influence of foundation movements on building performance, deep excavations and tunnels, ground treatment of very soft clay deposits and the strength and stiffness of clays. Professor Burland is a Fellow of the Royal Society.

## DR ANTONIO CARRARO

*Senior Lecturer in Geotechnics*

**antonio.carraro@imperial.ac.uk**

Dr Antonio Carraro's research focuses on the development and application of advanced laboratory testing techniques to understand the fundamental mechanical behaviour of geomaterials. His research has been used in several applications in the offshore oil and gas, mining and transportation industries as well as in analyses of liquefaction response and CPT interpretation in transitional soils including sands with fines and carbonate sands subjected to particle crushing.

## DR RICHARD GHAIL

*Senior Lecturer in Engineering Geology*

**r.ghail@imperial.ac.uk**

Dr Richard Ghail undertakes research in the areas of; intraplate processes and the neotectonics of Great Britain, The London Basin Forum, Basin structures and Plate tectonics on buoyant lithospheres, and subcrustal plate tectonics on Venus.

## PROFESSOR RICHARD JARDINE

*Professor of Geomechanics; Deputy Head of Department*

**r.jardine@imperial.ac.uk**

Professor Richard Jardine's recent research concerns six main areas: advanced soil testing, offshore geotechnics, pile behaviour, soft ground engineering, underwater landslides and geotechnical impact of climate change. His current projects include leading the ALPACA Joint Industry Project with Oxford on offshore wind-turbine foundations in Chalk, funded by EPSRC and a consortium from Industry.



## DR STAVROULA KONTOE

*Senior Lecturer in Geotechnics*

**stavroula.kontoe@imperial.ac.uk**

Dr Stavroula Kontoe specialises in computational geomechanics and earthquake engineering. Her research portfolio includes projects on the seismic performance of tunnels, retaining structures and dams, on liquefaction, site response analysis and site effects. Other recent interests relate to offshore geotechnics, including design aspects of piles driven in Chalk and seismic performance of offshore foundations.

*Suction-controlled oedometers for characterising expansive and collapsible soils.*

## DR JAMES LAWRENCE

*Senior Lecturer in Geotechnics*

**j.lawrence@imperial.ac.uk**

Dr James Lawrence is currently undertaking research focused on Upper Cretaceous Carbonates (Chalk) driven by the needs of the geotechnical and petroleum industry. He is also working with stakeholders on a number of projects focused on the safe disposal of radioactive waste.

## PROFESSOR CATHERINE O'SULLIVAN

*Professor in Particulate Soil Mechanics*

**cath.osullivan@imperial.ac.uk**

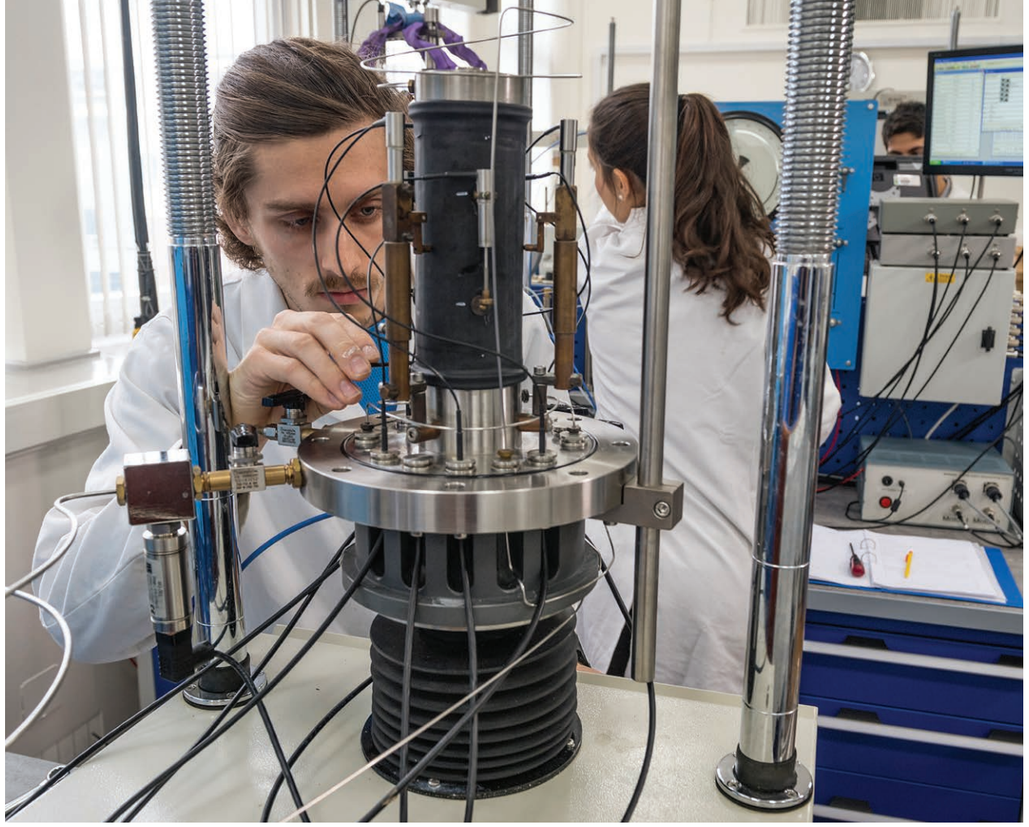
Professor Catherine O'Sullivan's main research interest is in particulate soil mechanics. Her research uses discrete element modelling (DEM) as well as experimental techniques including micro-computed tomography (μCT). She has been applying these techniques to look at fundamental sand behaviour, behaviour of reservoir sandstones, internal erosion and interpretation of laboratory tests.

## PROFESSOR DAVID POTTS

*GCG Professor of Geotechnical Engineering*

**d.potts@imperial.ac.uk**

Professor David Potts has worked extensively on the development of computer methods of analysis and their application in the solution and design of geotechnical problems, including tunnels, foundations, slopes, dams and offshore geotechnics. He is the principal author of the finite element code ICFEP, which is the bespoke computational research facility in the Geotechnics group and is extensively applied in industry.



*Creep-cells for testing the long-term behaviour of geomaterials used in flood defences and transport infrastructure.*

## DR JAMIE STANDING

*Reader in Ground Engineering*

**j.standing@imperial.ac.uk**

Dr Jamie Standing's main current research areas cover soil-structure interaction problems, tunnelling and deep excavations, piling, full-scale field monitoring, unsaturated soil mechanics, laboratory soil element testing and small-scale model testing. He has led three major research projects involving tunnelling and field monitoring in collaboration with the Jubilee Line Extension Project, Channel Tunnel Rail Link and Crossrail.

## DR DAVID TABORDA

*Senior Lecturer in Geotechnics*

**d.taborda@imperial.ac.uk**

Dr David Taborda's research has focussed mainly on energy geotechnics and numerical modelling of soil response to improve the prediction of the behaviour of geotechnical structures. His work is divided between the simulation of laterally-loaded offshore foundations and the development of new numerical and experimental methods to explore the use of the ground as a means to store thermal energy. This technology uses geotechnical structures such as pile foundations and retaining walls as heat exchangers, providing renewable low-carbon heating and cooling.

## DR KATERINA TSIAMPOUSI

*Lecturer in Geotechnics*

**aikaterini.tsiampousi05@imperial.ac.uk**

Dr Katerina Tsiampousi specialises in unsaturated soil mechanics conducting numerical and experimental research in the area of unsaturated soils, with applications on energy geotechnics and on environmental geotechnics. Her interest in energy geotechnics includes geological disposal of nuclear waste and ground source heating/cooling (GSHC) systems. Her work on environmental geotechnics focuses on the effect of climate on natural and man-made slopes (e.g. highway, railway and flood embankments, and cut slopes), and on Soil-Plant-Atmosphere Interaction (SPAI).



# Structural Engineering

**Research interests include: performance of building, industrial, offshore and bridge structures; material durability and long-term monitoring of structures; structural behaviour and robustness assessment under extreme loads including earthquakes, fire and blast; advanced computational and probabilistic modelling of structures; physical testing and analysis of reinforced and prestressed concrete, steel, composite, masonry, timber and biomechanical elements and components.**

## PROFESSOR NICK BUENFELD

*Professor of Concrete Structures;*
❖ **Head of Department**

**n.buenfeld@imperial.ac.uk**

Currently Head of Civil and Environmental Engineering, Professor Nick Buenfeld specialises in the long-term performance of concrete and concrete structures. His research group observe, measure, understand and model degradation processes so that the long-term performance of concrete structures can be predicted, our existing infrastructure can be preserved more effectively and new sustainable structures can be designed. He is also Principal Investigator for the new EPSRC-funded Advanced Centre for Infrastructure Materials.

## PROFESSOR AHMED ELGHAZOULI

*Professor of Structural Engineering;*
❖ **Head of Structures Section**

**a.elghazouli@imperial.ac.uk**

Professor Ahmed Elghazouli has over 25 years experience in research and practice, focussing on the behaviour and design of structures under extreme loads, including structural earthquake engineering, structural fire engineering and structural robustness. Current projects funded by industry and research councils include the development of pre-qualified seismic connections for steel and composite structures as well as the use recycled tyre components for improving ductility in reinforced concrete structures.

*Marking of cracks on reinforced concrete beam tested in shear.*

## PROFESSOR LEROY GARDNER

*Professor of Structural Engineering; Director of Research*

leroy.gardner@imperial.ac.uk

Professor Leroy Gardner's principal research interests lie in the areas of structural testing, numerical modelling and the development of design guidance for steel structures. Research topics within the steel structures group include design by advanced analysis, high strength steel and stainless steel structures, cold-formed steel, and 3D printing in construction. He is the UK representative for input into Part 1.1 of Eurocode 3 and has contributed to a number of international structural design standards.

## PROFESSOR ROGER HOBBS

*Senior Research Investigator*

r.hobbs@imperial.ac.uk

Professor Roger Hobbs' areas of expertise include: wire and high strength fibre ropes, including fibre and yarn buckling; torsional properties of chain; pipeline and plate upheaval buckling, and reliability-based design of submarine pipelines; plated structures; and (more generally) experimental and computational methods for structural mechanics.

## PROFESSOR BASSAM IZZUDDIN

*Professor of Computational Structural Mechanics*

b.izzuddin@imperial.ac.uk

Professor Bassam Izzuddin's research focuses on a number of areas including advanced non-linear finite element analysis, modelling of structures subject to extreme loading (blast, impact, fire, earthquakes), Simplified design-oriented structural modelling, Robustness and progressive collapse assessment of tall buildings and risk assessment of structures subject to extreme loading.

## DR LUKE LOUCA

*Reader in Engineering Structures*

l.a.louca@imperial.ac.uk

Dr Luke Louca's principal research interests lie in the area of behaviour and design of structures subjected to explosions. Much of this has focussed on steel structures for offshore applications but is currently actively engaged in both civil and defence applications using both traditional construction materials and fibre reinforced composite structures.

## DR LORENZO MACORINI

*Senior Lecturer in Structural Engineering*

l.macorini@imperial.ac.uk

Dr Lorenzo Macorini undertakes research in the areas of computational structural mechanics, earthquake engineering, historical masonry structures and steel and steel-concrete composite structures.

## DR CHRISTIAN MALAGA CHUQUITAYPE

*Lecturer in Structures*

c.malaga@imperial.ac.uk

Dr Malaga Chuquitaype has research interests spanning the areas of earthquake engineering, structural timber engineering, performance-based design and assessment under extreme loads, applied dynamics, and the development and implementation of passive and active damping systems.



*Overview of the Structures laboratory.*

## PROFESSOR DAVID A NETHERCOT

*Senior Research Investigator, Emeritus Professor of Civil Engineering*

d.nethercot@imperial.ac.uk

Professor David Nethercot has been particularly interested in the influence of connection behaviour on the overall performance of frame structures, where he has been responsible for major programmes of combined experimental and numerical work that underpin design treatments in British, European and other national standards. His current research interests include progressive collapse of structures and light gauge and stainless steel construction.

## DR ANDREW PHILLIPS

*Senior Lecturer in Structural Biomechanics*

andrew.phillips@imperial.ac.uk

Dr Andrew Phillips specialises in structural biomechanics and in particular the development of combined musculoskeletal and finite element modelling approaches. His most recent work investigates the application of optimisation strategies in structural engineering and skeletal biomechanics. He has a developing interest in bio inspired structures and the design of structural forms based on multiple environmental factors.

## DR SUNDAY POPO-OLA

*Senior Research and Teaching Fellow*

s.popoola@imperial.ac.uk

Dr Sunday Popo-Ola's research work spans across concrete structures, steel structures and environmental engineering.
Dr Popo-Ola specialises in cold-formed steel, modular construction and over/re-cladding of building and affordable housing.

## DR ANA M RUIZ-TERAN

*Senior Lecturer in Bridge Engineering*

**a.ruiz-teran@imperial.ac.uk**

Dr Ana M Ruiz-Teran's research is focussed on the area of Bridge Engineering. Her main research interests are related to the structural response and design criteria of innovative bridge types (such as under-deck and combined cable-stayed bridges, curved and spatial arch-bridges, and cable-supported bridges), the accidental breakage of stay cables, and the dynamic response of slender road bridges, footbridges and railway bridges (currently in collaboration with Laing O'Rourke) under traffic loading.

## DR ADAM JAN SADOWSKI

*Lecturer in Structural Engineering*

**a.sadowski@imperial.ac.uk**

Dr Adam Jan Sadowski conducts research in areas including the theoretical and computational simulation of the strength and stability of complex metal shell structures, for which he employs methods from shell theory, finite element analysis, applied mathematics and solid mechanics.

## DR PETER STAFFORD

*Reader in Engineering Seismology & Earthquake Engineering*

**p.stafford@imperial.ac.uk**

Dr Peter Stafford's principal areas of investigation and expertise relate to the fields of engineering seismology and earthquake engineering. He also maintains active research interests in applications of probabilistic methods to engineering applications (structural reliability theory), and applied structural dynamics.

## DR ROBERT VOLLUM

*Reader in Concrete Structures*

**r.vollum@imperial.ac.uk**

Dr Robert Vollum's research interests encompass: long-term deflections of reinforced concrete slabs, beam-column joints, shear in beams, punching shear, numerical modelling of reinforced concrete structures, strut and tie modelling, and control of early age thermal cracking. He has developed a method for predicting the deflection of slabs that takes construction loading into account. The numerical work has been calibrated with data from the in-situ concrete building at BRE Cardington with which he was closely involved.

## PROFESSOR AHMER WADEE

*Professor of Nonlinear Mechanics; Director of Postgraduate Research*

**a.wadee@imperial.ac.uk**

Professor Ahmer Wadee leads the research group specializing in the field of nonlinear structural stability. His primary research interests involve modelling buckling instabilities in metallic and composite material structures using analytical methods. In 2014, he was listed as one of the 100 leading UK practising scientists by The Science Council. He has won prizes for his research work from the Institution of Civil Engineers and the Institute of Mathematics and its Applications.

## DR HONG WONG

*Senior Lecturer in Structures and Materials*

**hong.wong@imperial.ac.uk**

Dr Hong Wong's research aims to advance the understanding of how microstructure influences the performance, ageing and degradation of concrete structures. His work focuses on developing and applying imaging techniques to characterise microstructure, understanding mass transport processes that control concrete degradation and developing models to predict macroscopic properties from microstructure. He has expertise in 2D and 3D microscopy, X-ray microanalysis, image analysis, mass transport characterisation and computational modelling.



## Systems Engineering

**Research interests include: systems integration, digital transformation, innovation, production systems (design and manufacturing), infrastructure interdependencies, infrastructure life-cycles, resilience and project-operation interactions; systems engineering principles, approaches and methods enabling work across engineering disciplines.**

## PROFESSOR DAVID FISK

*Emeritus Professor*

**d.fisk@imperial.ac.uk**

Professor Fisk's research interests include systems approaches to optimising the outturn performance of buildings and other complex mechanical and electrical systems, understanding the onset of unsustainable development and how this might be best included in risk assessments particularly for large complex systems such as cities.

## PROFESSOR JENNIFER WHYTE

*Laing O'Rourke / RAEng Chair in Systems Integration; Director of the Centre for Systems Engineering and Innovation*

**j.whyte@imperial.ac.uk**

Professor Jennifer Whyte's research addresses the growing complexity of infrastructure systems. The ambition is to rethink infrastructure systems engineering, with a particular focus on systems integration in civil infrastructure. Research projects seek to develop next-generation tools and approaches for systems integration, to provide decision-support tools, where infrastructure projects are organizationally complex and deliver physical assets (and digital asset information) as interventions into wider infrastructure systems.

# Centre for Transport Studies

**Research interests include: transport demand, economics and policy; intelligent transport systems and environment; safety and risk management; engineering geomatics and air traffic management; urban mass transit operations and management; logistics and port operations; smart cities/ urban systems.**

## PROFESSOR WASHINGTON OCHIENG

*Professor of Positioning and Navigation Systems;*
❖ **Head of the Centre for Transport Studies**

**w.ochieng@imperial.ac.uk**

Professor Washington Ochieng's research interests are in the design of positioning and navigation systems for land, sea and air applications; Air Traffic Management (ATM) and Intelligent Transport Systems (ITS). He has made significant contributions to major international projects including the design of the European Geostationary Navigation Overlay Service (EGNOS) and GALILEO, GNSS measurement error modelling, and specification of aircraft trajectory management tools for the Single European Sky's ATM Research (SESAR) programme.

## DR PANAGIOTIS ANGELOUDIS

*Senior Lecturer in Urban Engineering*

**p.angeloudis@imperial.ac.uk**

Dr Panagiotis Angeloudis is Director of the Transport Systems and Logistics Laboratory within the Department and leads the Port Operations Research and Technology Centre (PORTeC) within the Centre for Transport Studies. His work to date has spanned the areas of network optimisation, urban transport systems, logistics and maritime transport.

## PROFESSOR DAN GRAHAM

*Professor of Statistical Modelling*

**d.j.graham@imperial.ac.uk**

Professor Dan Graham is Director of the Statistical Modelling and Economics Research group, and Research Director of the Railway and Transport Strategy Centre within the Centre for Transport Studies. His research involves the development and application of statistical methods for transport analysis and modelling, causal inference, analysis of networks and spatial data, and performance benchmarking of infrastructure systems.

## DR KE HAN

*Lecturer in Transport Operations and Logistics*

**k.han@imperial.ac.uk**

Dr Han's research focuses on transport modelling and management, sustainable transport, air traffic management, and urban big data. His work aims at improving the level of service of multi-modal transport in cities by reducing congestion, delay and health impact. His ongoing projects include simulations of UK national rail network and Shanghai metro system, adaptive traffic signal control system in Glasgow, and big data enabled urban transport planning in Beijing and Shanghai. He is Chief Scientist of Cloud Guizhou Big Data (english.gzdata.com.cn).

## DR ARNAB MAJUMDAR

*Reader in Transport Risk Management*

**a.majumdar@imperial.ac.uk**

Dr Arnab Majumdar is Director of the LRF Transport Risk Management Centre (TRMC) in the Centre for Transport Studies. His recent research has focused on the human and social factors associated with safety and risk in transport, especially for aviation and railways. He leads the team at the TRMC covering a broad spectrum of research assessing human and social factors in risk safety of safety critical systems, including human behaviour during evacuation from emergencies.



## PROFESSOR JOHN POLAK

*Professor of Transport Demand*

**j.polak@imperial.ac.uk**

Professor John Polak is the Director of the Urban Systems Laboratory at Imperial and a Director of the ESRC London Interdisciplinary Doctoral Training Partnership. Professor Polak has published extensively on a number of aspects of travel demand modelling, network performance estimation, network control and traffic management and intelligent transport systems. He serves as a member of the Mayor of London's Smart London Board, and on the Strategic Roads Reform Expert Group for the UK Department for Transport.

## DR ARUNA SIVAKUMAR

*Senior Lecturer in Travel Behaviour and Demand*

**a.sivakumar@imperial.ac.uk**

Dr Aruna Sivakumar's research interests include econometric models of demand, travel behaviour and the role of ICTs, integrated urban system models, and transport policy. Dr Sivakumar is PI on the EPSRC funded 'Airport Capacity Consequences Leverage Aviation Integrated Modelling' (ACCLAIM) project, and is a member of several international scientific committees such as the Transportation Research Board (TRB) Committee on Travel Behaviour and Values.

## DR MARC STETTLER

*Lecturer in Transport and the Environment*

**m.stettler@imperial.ac.uk**

Dr Marc Stettler is Director of the Transport & Environment Laboratory within the Centre for Transport Studies at Imperial College. His research aims to quantify and reduce environmental impacts from transport using a range of emissions measurement and modelling tools. Examples of recent research projects include evaluating real-world vehicle emissions and evaluating economic and environmental benefits of Kinetic Energy Recovery Systems (KERS) for road freight.

## Railway and Transport Strategy Centre (RTSC)

**The Railway and Transport Strategy Centre (RTSC) was established as a centre of excellence serving the railway industry on strategic, economic and technology issues.**
**The RTSC is well known within the transport industry for its research in the field of public transport operations & management, statistics & analytics, transport economics and policy, and its expertise in relation to the initiation, facilitation and management of multi-year international benchmarking projects.**


### RICHARD ANDERSON

*Director, Railway and Transport Strategy Centre (RTSC)*

**richard.anderson@imperial.ac.uk**


Richard Anderson is the Managing Director of the RTSC, an applied research and consultancy division within the Centre for Transport Studies. He directs a growing, multi-disciplinary team, currently of 30 researchers and consultants, specialising in mass transport in cities, international benchmarking and public transport operations, economics, manage-ment and engineering. Richard is a specialist in international benchmarking and mass transit and provides strategic and technical advice to the leaders of major urban railways throughout the world.


### BEN CONDRY

*Associate Director / Head of Railway Benchmarking, Railway and Transport Strategy Centre (RTSC)*

**b.condry@imperial.ac.uk**


Ben Condry is a Senior Research Associate at the RTSC. He manages the ISBeRG international suburban railway benchmarking group as well as conducting related research in the area of public transport. He has over 17 years experience in rail and other public transport covering a broad range of aspects including benchmarking, policy, management strategy, operational analysis, demand forecasting and modelling, economic appraisal, financial and revenue analysis and survey techniques.




**Top 10**
Imperial is a global top ten university with a world-class reputation in science, engineering, business and medicine.

# Department facilities

**The Department maintains an extensive range of research facilities and equipment, bringing together researchers, businesses and partners to share ideas, expertise and technology.**

*Development of excellent analytical skills for postgraduate students form an important part of the EWRE laboratory postgraduate education. Environmental Engineering MSc students undertake over 50 hours of intensive laboratory training prior to starting their 4 month research dissertation.*

*The Roger Perry Laboratory utilises state-of-the-art advanced analytical equipment to enable a fundamental understanding of how elements and compounds behave in the built and natural environment. The ICP-OES (above) is being used to accurately determine, simultaneously, the concentrations of 30 elements in samples of soils collected from contaminated sites.*

## EWRE Roger Perry Laboratory

The Roger Perry Laboratory is one of the most modern Environmental Engineering facilities within the UK, offering an almost unrivalled selection of analytical techniques. The laboratory was designed around the concept of total flexibility through the provision of a central service core (offering multiple at-bench gas and water services) associated with movable benching and service connections. These features enable large experiments and pilot-scale equipment to be set up and run under fully serviced and controlled conditions.

The Lab is divided into three main areas:

- general experimental and sample preparation
- a dedicated and fully-equipped microbiological facility, and
- a large fully serviced advanced instrument laboratory.

**Research Facilities:**

The Lab is particularly well equipped in terms of sample preservation and preparation capability including: A walk-in freezer & fridge for cold storage; sample drying, concentrating, grinding and digestion. Samples in all media (air, water or solids) can be analysed enabling all aspects of the research activities to be supported (from water quality through to resource/materials efficiency). Uniquely, the lab owns a Waters Synapt (Ultra High Pressure Liquid Chromatography-Ion Mobility-Time of Flight Mass Spectrometer) used for high resolution analysis of organic compounds in water.

**Other equipment includes:**

Gas Chromatography–Mass Spectrometry; Inductively Coupled Plasma – Optical Emission Spectrometry; Fourier Transform Infrared Spectrometry; Differential Scanning Calorimetry-Thermogravimetric Analysis; Total Organic Carbon analysis; Ultra Violet & Visible Spectrometry; Atomic Absorption Spectrometry; Polymerase Chain Reaction Analysis; Zeta Potential; Surface area analysis; Ion Chromatography; Bomb Calorimetry.

**www.imperial.ac.uk/environmental-and-water-resource-engineering**

*Enquiries* • Dr Geoff Fowler g.fowler@imperial.ac.uk

## Fluid Mechanics Hydrodynamics Laboratory

The Hydrodynamics Laboratory has a reputation for leading research in civil engineering fluid mechanics and is the largest university facility of its kind in the UK. The Laboratory has a unique variety of flow apparatus and broad-ranging capabilities in the areas of wave mechanics, fluid-structure interaction, coastal engineering, sediment transport, buoyancy-driven flows and mixing. These capabilities underpin applications such as design and modelling of offshore structures, coastal processes and flows in the built environment.

**Key facilities include:**

- A wave basin (20 m x 12 m), capable of simulating a wide range of sea states
- A coastal basin (27 m x 6 m), capable of simulating a range of shallow flows and wave-current interactions
- A towing tank (62 m x 2.8 m x 1.5 m deep) for simulating flow loading, obstacle wakes, sediment transport and shoaling wave behaviour
- A wind-wave-current flume (23 m x 0.7 m deep) for simulating wave-current and wind-wave interactions
- Recirculating flumes (1.3 m wide and 0.2 m wide) for simulating the interaction of objects with an ambient flow
- Three large-scale visualisation tanks (1.5 m x 1.0 m x 1.4 m) capable of visualising a wide range of civil engineering flows

**www.imperial.ac.uk/fluid-mechanics**
*Enquiries* • Rebeccas Naessens r.naessens@imperial.ac.uk

## Centre for Transport Studies Laboratory

### Intelligent Infrastructure and Transport Systems Laboratory

The Intelligent Infrastructure and Transport Systems laboratory aims to provide a world-class environment for teaching and research. It provides specialist facilities for the development, calibration, commissioning and storage of novel data acquisition systems. A suite of tools and software is used to provide specialist data analysis and scenario simulation for decision support systems. It has been used in conjunction with support of field trials and outreach activities, and has been playing a key role in research-led teaching. Key laboratory features include a state of the art prototyping facility, a temperature-controlled experimental facility, an instrumented vehicle used as a mobile research platform, and sensors for emissions and air pollution measurements.

**www.imperial.ac.uk/transport-studies**
*Enquiries* • cts.admin@imperial.ac.uk

*Left:Ring-shear apparatus for determining the residual strength of materials and for characterising soil-pile interfaces.*

*Right: Use of sensors for emissions and air pollution measurements.*

*Our Hydrodynamics laboratory is one of the best-equipped facilities of its kind covering a floor area of some 3000 square meters, including a multidirectional wave basin, which has an adjustable bed capable of water depths from 0.5m to 1.5m.*

## Geotechnics Laboratories

The Geotechnics Laboratories are best known for the bespoke development and manufacturing of their advanced element testing apparatus and novel experimental techniques. Soil testing is carried out to provide mechanical characterisation of geomaterials, enabling the calibration of advanced material models for numerical analysis of geotechnical structures.

The widely used equipment comprises locally instrumented 38 mm and 100 mm triaxial stress-path cells, osmotic oedometers for testing unsaturated soils, medium to high-pressure triaxial cells, ring-shear apparatus for evaluating the residual strength of soils and characterising soil-pile interfaces, and a set of hollow cylinder apparatus for characterising soil anisotropy. A specialist micro-mechanics laboratory includes optical microscopes, interferometer and laser measurement techniques for particle roughness and sphericity.

The most recent apparatus developments include temperature-controlled triaxial and isotropic cells and oedometers, which have enabled developments in energy geotechnics, in particular ground source energy systems. New active humidity controlled chambers and incorporation of this technique in suction-controlled thermal oedometers have advanced our work in deep nuclear waste disposal, in particular the design of engineered barrier systems. The latest triaxial “creep” cells are leading the work on long-term behaviour and sustainability of geomaterials, with particular emphasis on road, rail and flood defence infrastructure.

**www.imperial.ac.uk/Geotechnics**
*Enquiries* • Sue Feller • s.feller@imperial.ac.uk

## ICFEP – Imperial College Finite Element Program

The Imperial College Finite Element Program, ICFEP, has been continuously developed under the leadership of Professor David Potts for almost 40 years, through a combination of research projects and practical applications. A systematic development strategy has resulted in a general geotechnical code with a wide range of capabilities, including a fully-coupled THM formulation, algorithms for analysing dynamic problems and those involving unsaturated materials and advanced material models for soils and structural components. Application of ICFEP has provided solutions to some of the most challenging geotechnical problems, including the stabilisation of the Tower of Pisa, the failure of the Carsington dam, the stability of the Jubilee Line extension excavations, the stability of underwater slopes in the Gulf of Mexico and soil-structure interaction problems associated with energy exploration from oil & gas and renewables. The software facilities are complemented by the bespoke hardware facilities and ICFEP computing laboratory.

**www.imperial.ac.uk/Geotechnics**
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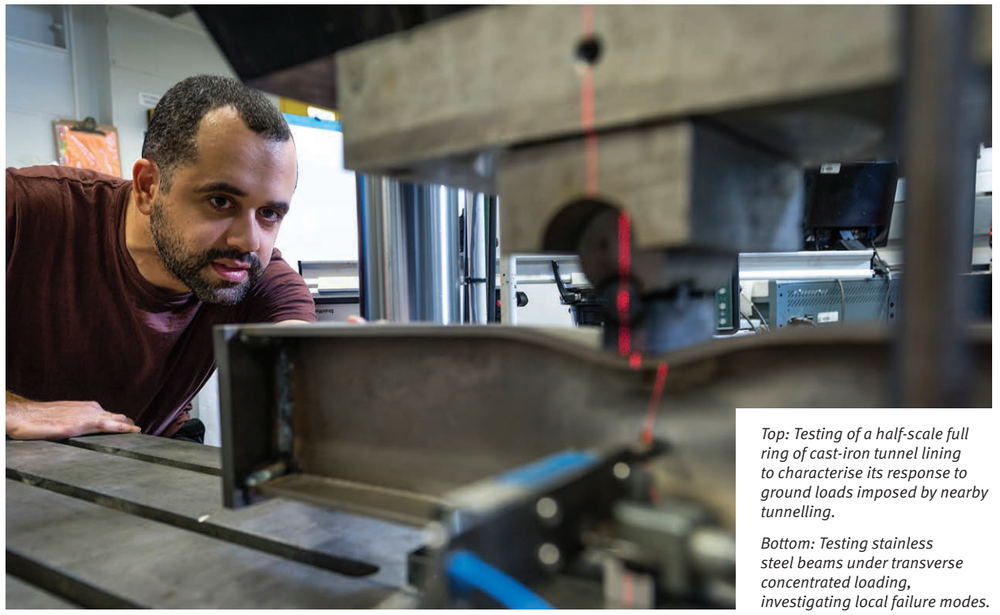

*Top: Testing of a half-scale full ring of cast-iron tunnel lining to characterise its response to ground loads imposed by nearby tunnelling.*

*Bottom: Testing stainless steel beams under transverse concentrated loading, investigating local failure modes.*



## Structural Engineering Laboratories

### Structures Testing Laboratory

The new Structures Testing Laboratory includes a recent £14M investment in infrastructure and equipment to provide a prestigious facility within the UK university sector for research into engineering structures.

- £1.9M investment in new servo-hydraulic test equipment including static, dynamic and impact loading with high speed capabilities.
- Controlled concrete preparation, casting and curing facility.
- New workshop area and equipment.

The structures testing laboratory facilities include:

- Controlled rate uniaxial load testing up to 10MN.
- Cyclic/fatigue testing of large and small scale components.
- Material creep testing.
- Fixing technology for concrete and masonry structures.
- Manufacture and testing of new materials and structural specimens, including beams, column, slabs, connections and test frames.

### Concrete Durability Laboratory

The Concrete Durability Laboratories house state-of-the-art facilities for investigating all aspects of concrete degradation. Our research aims to develop more effective methods for the design, assessment and repair of concrete structures and is usually based on establishing a better understanding of deterioration processes. Group capabilities include:

- Simulated/accelerated environmental exposure and measurement of molecular transport.
- Assessment/monitoring of corrosion and concrete deterioration.
- Analysis of cement and concrete with a wide range of techniques including scanning electron and confocal microscopy and micro x-ray fluorescence spectrometry .
- Computer based modelling of transport and deterioration.

**www.imperial.ac.uk/structural-engineering**
*Enquiries* • structures@imperial.ac.uk

# Centre for Doctoral Training in Sustainable Civil Engineering

**Combining interdisciplinary skills and industry-linked research experience to contribute to the delivery of multi-faceted complex civil engineering projects.**

*CDT students from cohort 1 visiting the Thames Flood Barrier as part of their Grand Challenge Project. The aim is that Grand Challenge Projects mimic the way leading companies in the Sustainable Civil Engineering sector address major problems, providing additional skills and training to students*

## EPSRC Centre for Doctoral Training (CDT) in Sustainable Civil Engineering

The EPSRC Centre for Doctoral Training (CDT) in Sustainable Civil Engineering, launched in 2014, provides a different type of doctoral training experience. CDTs aim to train future experts for industry and research, retaining the depth, rigour and focus of a conventional PhD while providing a broad training experience through a taught component, the Grand Challenge Project and cohort based activities.

Research undertaken by the CDT is at the very forefront of research in sustainable civil engineering across six key themes: uncertainty associated with future change, whole life cycle, delivering maximum value from existing infrastructure, multiple use infrastructure, developing the circular economy and low carbon construction. This research spans across all major areas of research within the Department.

The CDT has a number of core industrial partners who represent a strong collaborative team from across the major industrial sectors associated with sustainable civil engineering. These core partners include Anglian Water, Arup, Atkins, Bam Nuttall, Buro Happold, Ellen MacArthur Foundation, EIT Climate KIC, GCG, Laing O'Rourke, MWH, Robert Bird Group, CSI, Shell, and Useful Simple Trust.

Industrial partnerships and strong collaborations are central to the CDT funding model, which is based around a 50:50+ funding scheme for each studentship. Leveraging EPSRC investment, the CDT provides a cost effective mechanism for industry to support and contribute to high quality collaborative civil engineering research.

The minimum cost of supporting a CDT student (living costs and fees) over 4 years is approximately £80,000. Under the 50:50+ scheme the EPSRC supported CDT will pay 50% of these costs with industry funding the remainder. This model has proved an effective way to develop industrial involvement and for the Department to discuss mutually beneficial research with industry partners. To date the CDT has leveraged industrial project funding in excess of one million pounds and has attracted additional funding of £300,000 from other non-EPSRC sources, including departmental scholarships and College contributions.

**www.imperial.ac.uk/sustainable-civil-engineering**
Enquiries: Steve Hullock s.hullock@imperial.ac.uk

*CDT students during a trip to Snowdonia where they stayed in the Imperial College Mountain Hut. In addition to climbing Mount Snowdon, the students had the opportunity to present updates to their PhD projects.*

### Shaping the next generation

**If you are interested in supporting the CDT as a 50/50 industry partner or you are a student who would like to join the CDT programme, get in touch today.**

*Enquiries* • Steve Hullock
s.hullock@imperial.ac.uk

**Further PG Research Opportunities:**
The Department have a number of PhD scholarships to award annually, as well as opportunities to support applicants applying to Imperial scholarship schemes, Industry funded scholarships and self-funded students.

*Enquiries* • Sarah Willis
s.willis@imperial.ac.uk

# Collaborate


**The Department has a long and successful history of collaboration with industry and international researchers. We champion academic and industrial partnerships.**

We are redefining what a university can do to meet the needs of our partners and capitalise on innovation. Working with companies, large and small, we value collaborative research that brings together complex real-world challenges, academic curiosity and rigorous research.

**Centre and Fellowship sponsorship**
Associate your company with our researchers. Imperial's dedicated Corporate Partnerships team can create a bespoke sponsorship package that suits your organisation's needs.

**Research collaborations**
Participate in thought leadership for the industry by becoming a formal partner on research council funded research. In-kind support is encouraged as much as cash contributions. Secondments into your organisation, or vice versa, may also be valuable.

**Innovation collaborations**
Work with us to translate our research into real-world applications. The Department has a good track record of accessing funding from Innovate UK and Imperial has world-leading expertise and support for innovation management.

**PhD studentships**
Fully funded industry studentships allow you to determine the research direction and provide greater control of intellectual property and knowledge generated from the research.

**50/50 CDT studentship**
The EPSRC Centre for Doctoral Training (CDT) in Sustainable Civil Engineering trains future experts for industry and research. Under the 50:50+ funding scheme the CDT will pay 50% of the studentship costs and fees with industry funding the remainder.

**Donations and scholarships**
Pioneer a new wave of philanthropy at Imperial to support the next generation of civil engineers, help sustain academic excellence and develop frontier research areas. The Department would be delighted to discuss priority areas including scholarships and flexible support funds.

**Consultancy**
Find the right expert to address your latest challenge from our world leading academic and research staff.

**Facilities hire**
We host a wide range of state of the art laboratory facilities for research and consultancy.

**Guest lecturing**
The CDT in Sustainable Civil Engineering has an annual keynote lecture delivered by a leading industry figure. Also put your name forward for our Department-wide guest lecture series.

**Host field studies and/or site visits**
Help us make our research real by providing sites for real-world research monitoring and analysis. Open up your sites for visits from our research staff and students to give them crucial insights into real construction site challenges.

*The Department's undergraduate students at Constructionarium, gaining construction experience by building scale models of iconic structures — here we see The Gherkin from the City of London.*

## Connect with us


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Department of Civil and Environmental Engineering.
Designed by Beth Elzer Design.