Appendix IX: Research Challenges Identified by the Survey Respondents

As part of the online surveys, recipients were asked:

"What research areas or challenges do you feel are currently the most important ones that ground and structural engineering researchers should be working on? For example, these might be areas of particular socio-economic need. Please list concisely as many areas as you can (maximum of 3)."

The responses were clustered by EPSRC into a number of categories (a. to x.) and are listed against these categories below. Blue, yellow and pink shading refer to responses from the surveys to UK academia, UK industry and overseas academics, respectively.

Contents

a. Adaptation to Climate Change

Adaptation of infrastructure given climate change.
Adapting the built environment to climate change
Adapting to a changing climate
Adapting to the impacts of climate change
Affects of climate change on infrastructure Efficient construction - lean & mean, avoiding waste, increasing productivity
Climate change
Climate change
climate change
Climate change
Climate Change
Climate change and impacts on infrastructure
climate change and likely alterations to ground water levels and flow patterns
climate change and practical applied work that helps UK PLC
climate change impact adaptation
Climate change impact on foundations.
climate change impacts on geotechnical structures; how should design of earthworks / cuttings etc be modified to incorporate changing ground/groundwater conditions over engineering time due to climate change.
climate change, energy
Consequences of climate change and variability for building design and retro-fitting
Dealing more effectively with climate change and related challenges.
Effect of climate change on current infrastructure (home and overseas)
effect of global warming on infrastructure
Effects of climate change in sustainable economy.
Geotechnics associated with climate change.
Ground Engineering: Effects of climate change on infrastructure
Impact of change of climate on soil properties and behaviour
Impact of climate change
impact of climate change and sustainable engineering.
Impacts of climate change on the built environment
Implications and mitigation of climate change effects on infrastructure
Implications for ground engineering in adaptation to climate change
Living with climate change
long-term risk assessment for structures influenced by various uncertainty factors, in particular climate change
rainfall induced landslides
Refurbishment of the Built Environment for climate-change mitigation.
Structural design in areas of climate change and energy conservation
The integration of conventional civil engineering (geotechnics & structure) with other relevant areas such as environmental, coastal, hydraulics and response to climate change challenge.

b. Codes and Standards

Development of Standards
Eurocodes are not comprehensive or always adequate - need significant attention.
Structural Engineers and Geotechnical Engineers are faced with a completely new set of design codes in the Eurocodes. In many cases however, there is still national differences in the way the rules are applied. In addition the drafting process has thrown up a number of areas where further work is required to improve the codes. Research should be aimed at resolving the differences in national application and resolving the remaining areas of technical uncertainty within the codes. This should be carried out with international collaboration
Two structural Eurocodes for the construction materials of glass and fibre reinforced polymer.

<u>c. Carbon and Resource Reduction</u>

Carbon capture and storage
CARBON IMPLICATIONS OF PROJECTS IN PRACTICE RATHER THAN IN CONSTRUCTION
Carbon Neutral Design
CARBON REDUCTION IN ALL OF ITS CONSTRUCTION ASPECTS
Decarbonisation of Built Environment
Decarbonising construction.
Design for reduced carbon emissions
Energy efficiency of Structures over their lifetimes
energy efficient infrastructure
Energy efficient lightweight building technologies and procedures
energy reduction and generation
Energy saving in buildings
Energy, carbon and resource efficient construction
energy and water resource saving
How can resource input be significantly reduced for all foundations
Integration of energy management schemes with structural form (as heating, lighting, etc., become more efficient further savings on carbon must come from how we build).
Low carbon energy efficient construction.
low carbon tools and techniques
Low embodied energy buildings
low energy products;
Low-energy / low CO2 technologies
Minimising climate change
More energy-efficient buildings, using alternative sources such as ground thermal energy
Reduction of energy use in process, manufacturing and implementation of civil engineering systems. Considering the balancing of whole life costs, sustainability and immediate need.
Water
Water & energy w.r.t. structures and the ground beneath them.
Water scarcity

zero emission buildings (performance and technology)

d. Design Against Blast and Impact

Design for extreme situations (e.g. terrorist attacks)
Design of structures against terrorist attack
energy efficiency protection against blast and impact
Large scale hybrid testing of structures under combinations of extreme loads (fire, blast) to understand true levels of safety of structural assemblies (collaborations with control, comms, e-Science/HPC, electro-mechanical sensing engineers)
man-made hazard mitigation
Practical assessment of disproportionate collapse of structures, particularly with respect to terrorist attack
Retrofit and design for extreme loading

e. Energy Generation and Supply

Developing cleaner energy, dealing with waste and ensuring re-use and recycling of resources
Energy
energy
Energy - in particular offshore marine energy including wind/wave/tidal
Energy (conventional, renewables AND nuclear)
energy extraction from ground & global warming by structural isolation
Energy generation
energy generation and supply infrastructure
energy generation infrastructure (esp. renewables)
Energy issues
Energy production
Energy production through renewables
energy recovery intelligent systems
Energy related issues
Energy systems
gas hydrates, both as fossil fuels and as a means of carbon dioxide storage
I'm trying to avoid buzzwords here! As a major contributor to the UK economy is offshore developments, which is already leading to solving future energy issues (e.g. current/wave/wind energy), it would seem prudent to help these industries push their boundaries further.
Implications for new and existing ground structures of ground energy harvesting
Linkage of civil engineering to offshore structures and offshore energy device;
marine structures linked into to renewable energy systems
Meeting energy needs while being sensitive to climate change impact
Offshore Wind Energy (Foundations and cable laying)
Renewable Energy
Renewable energy
Sustainable energy

The overwhelming challenge for the whole sector is sustainable and secure energy supply. With that in place the remaining problems would become minor. If we fail to solve this problem, the UK will become impoverished. Surrounding the problem are peripheral issues such as water supply, transport etc.
Where are the ground and structural engineering colleagues in terms of the Severn barrage/

f. Environmental Hazard Engineering

Behaviour under extreme conditions
Earthquake Engineering
Earthquake engineering (not in the UK)
earthquake engineering including soil-structure interactions
engineering seismology related to soil amplification of strong ground shaking and application to seismic hazard mapping and zonation, land use and building code
Geohazards
hazard assessment and mitigation
Hazard prediction (landslides, earthquakes)
human factors and geotechnical risk
Impact of geohazards and increasing urbanisation
Maintainable open-source community computational software platforms for modelling of hazards and consequences (collaboration with informatics, e-Science/HPC, computational mechanics experts and mathematicians)
Mitigation of natural hazards
Multihazard Engineering
Pavements Buildings Dynamics (Seismic and Impact)
Resilience of structures in the face of natural hazards
Resistance of the built environment to natural disasters (earthquakes, flooding, hurricanes etc.)
Risk modelling
Robustness of structures in areas of seismic activity and economic remediation.
Vulnerability to uncertainties, etc environmental hazards.

g. Flood Risk Management

1. Flooding and effect on buildings - from a civil engineering PRACTICAL point of view, as companies and government agencies I collaborate have asked for, rather than the currently funded projects of management best practice, etc which are mostly theoretical dos and don'ts rather than real civil engineering science of what actually happens to structures and the soil, and how to remediate the situation.
Coastal protection structures against rising sea levels
Flood damage to buildings.
Flood defence
risk assessment of flood defences

h. Investigation

geotechnical modelling with site validation.

INSTRUMENTATION AND OBSERVATIONAL TECHNIQUES
investigation
Long-term monitoring of as-built real-life objects of infrastructure (over ground and underground) to improve understanding of their ACTUAL behaviour which is the biggest challenge for the sector relying so heavily on unverified design guidelines (which, therefore, need to be conservative, which not viable economically and environmentally).
Step change in investigation techniques and characterisation

i. Improved Construction Process

Construction and site technologies to maximise efficiency of materials usage.
Construction in high urban densities
Developing innovative new construction techniques
Energy efficiency in construction and building operation
Impact of low carbon construction products and techniques
Improved building construction, transfer emphasis from purely structural issues
increasing the speed of construction projects robustness of infrastructure networks deteriorating infrastructure wind loads and climate change tunnelling technologies
Managing innovation in the supply chain.
New construction techniques

j. International Development

Application of existing knowledge to dealing with global warming, particularly in developing countries, which are ill equipped to deal with the potential problem (s)
Appropriate technology for developing economies.
Issues of prime importance to developing and under-developed countries.
Obviously I'm keenest on the fields I'm working in - Earthen construction - little current scientific knowledge, UK is leading in the world, and a novel construction technique for sustainable and developing countries' development. Nice mix of ground and structural engineering too.
Sustainable technologies for developing countries
Working overseas, the impact of bad governance on the sustainability of projects. Introducing genuine direct and indirect life cycle costing to all works which should include socio economic effects which requires the monetisation of these together with environmental impact.

k. Improvement of Safety

Building safety
design structures against multiple hazards including terrorist threats
Development of performance-based structural engineering framework which equi-distributes risk in the structure and leads to economic designs of quantifiable safety (collaboration with Mathematics, risk experts, consulting and insurance industry)
Fire safety
Improvement of public safety
Post fire stability of structures. Assessing the residual strength of structures and their associated foundations during their life. The relationship of bolted connections

adopted compared to those intended in the design process.

l. Improved Simulation and Design of Structures

Advanced decision making tools for design
Design for re-use of structures and elements of structures
Development of advanced computational models for making better use of existing structural technologies and materials
Development of novel simulation tools
Developing design tools and construction methods to meet multiple socio-economic performance limit states.
Establishing performance levels for structures of the future
Fast structural analysis for new design
Improve efficiency of design of structures/buildings
Improved structural efficiency to reduce use of resources
Inter-disciplinary design
Lightweight Concrete Floors -Longer span with increased stiffness but less weight.
Optimisation through ductility/adaptability at every level
performance-based design of civil infrastructure, moving away from codified safety factors
Providing robust fast computational analysis (and design) methodologies which allow engineers to become more creative (and safer) in their solutions.
Robust, fast modelling methods which work on a PC
Structural design, Numerical simulations
Validity of current design methodologies

m. Mechanics and Fracture

Behaviour of concrete material and structures
computational solid mechanics reinforced concrete structures failure/fracture modelling of concrete
Experimental validation and testing of robustness and disproportionate collapse in concrete structures to validate the range of currently proposed computer models in this field.
Fundamental mechanics
Mechanics of partially saturated soils
Understanding Structural behaviour beyond what it is designed for (during failure)

n. Maintenance, Repair and Retrofit

Ageing infrastructure
Aging infrastructure
Considering long term durability. Extending the life of structures. Managing down costs. Developing technologies to reduce the impact on users e.g. automated and improved methods of bridge inspection.
Economic and human-scale maintenance of transport, housing and building infrastructure
effective repair/re-use strategies for existing structures.

Historic building conservation
Increasing the resilience of old infrastructure through comprehensive use of digital technologies
Infrastructure maintenance
Infrastructure rehabilitation
Low cost Structural retrofitting
Maintaining elderly infrastructure
maintenance and retrofitting infrastructure
maintenance! (of crumbling infrastructure). doesn't sound sexy but it can be and has major impact
Ongoing maintenance of existing aging infrastructure
Our construction industry is a major sector of the economy and research aimed at improving the efficiency of any part of the sector is important. In particular we need to maintain, manage and extend the life of our existing infrastructure and build new infrastructure that will last longer and consume less resources to operate. Allied to this is the need to tackle both the causes and consequences of climate change - something that will have to be lead by civil engineers.
Pavement maintenance techniques
Preservation of existing structures to prevent the environmental costs of building new ones.
Reducing the environmental impact of constructing and maintaining infrastructure.
Retrofit and adaptation of existing structures for changes in use and improved performance
Retrofit and refurbishment
Retrofitting of ageing structures
reverse engineering analysis for rehabilitation of old/existing structures.
Strengthening of existing masonry and (above all) RC structures

o. New Durable Infrastructure

Development of maintenance free structures
Durable/sustainable design for new infrastructure
future infrastructure
Resilience of Infrastructure
Resilience of buried and surface infrastructure
Resilience of Infrastructure
Resilient infrastructure
Structural longevity of component systems
Understand the degradation of construction materials

p. Novel Materials

Application of novel materials
Appropriate use of new materials in construction.
Creation and use of innovative materials
Design for better use of local materials leading to low carbon and development of a well distributed diversified skills and industry;

Examining new, low carbon, economic structural materials
growth in composite material applications and lack of understanding and applications of these materials
Linkage of other disciplines (such as biology) with civil engineering construction material or geotextiles;
Low carbon materials
Low carbon materials and solutions
low energy / smart materials for construction
low energy and/or novel construction materials
Materials Engineering
Moving away from reliance on cement-based materials in construction
New materials
New materials and processes
New materials in construction
New sustainable material for structural engineering.
Novel structural materials
Prefabricated Construction Timber, Concrete and steel.
Quantifying properties for construction materials and the execution of structures so that we can reliably calculate embodied energy over a project's working live.
Renewable and low carbon materials
The improvement of understanding and modelling materials is crucial to better design, that is more adapted to current climate and more economic.
Use of New Materials
Use of new materials and structural optimization while ensuring public safety.
Where are the structural engineering fraternity when it comes to using new and exciting materials etc in civil engineering?
working on new materials and design to anticipate next century mars colonization and make this industry look as cutting-edge technology (would be a dramatic change!)

q. People and Structures

Human perception and interaction with environment
Socio-Technical Design (Human Behaviours)
Soft Engineering: Human-Structures interaction

r. Sustainable Construction and Infrastructure

Areas related to sustainability; i.e., geothermal energy, carbon sequestration; nuclear waster containment; energy intensity of the construction business, esp. the use of concrete; bio-geo engineering; multi-hazard mitigation, including the challenges of global climate change.
Designing sustainable, low carbon, healthy buildings for the 21st Century.
Efficient and sustainable construction
Establishing a consistent generic framework for defining and achieving sustainable performance of systems. The framework needs to be able to translate high level, vaguely couched, stakeholder needs into controllable technical performance variables. An integrating systems approach. Joined-up thinking about natural hazards (climate, seismic, etc.) and human generated hazards.

Rigorous analysis of environmental and sustainability engineering topics.
Sustainability
Sustainability
Sustainability
Sustainability
Sustainability - and not just climate change.
sustainability,
Sustainable construction
sustainable construction
sustainable construction
Sustainable construction (reduced CO2 impact)
Sustainable construction.
sustainable design of infrastructure
sustainable infrastructure
Sustainable use of materials
Sustainability, but from a geotechnical/structural point of view redevelopment of Brownfield sites, reuse of existing foundations
Sustainability
use of earth fills as a method for sustainable construction

s. Sensors and Structural Health Monitoring

Extending the life of existing structures (inc. through structural health monitoring and strengthening).
Innovative sensors to create systems of 'smart' infrastructure Innovation in geotechnical processes to improve environmental impact of construction
Life time performance and monitoring
Making use of advances in sensors
Serviceability of lightweight structures (e.g. vibration, human-structure interaction
Structural health monitoring
structural health monitoring for ageing infrastructure including underwater monitoring systems
structural health monitoring.

t. Smart Structures

Intelligent structures
Intelligent structures and novel building materials
SMART STRUCTURES

u. Urban Systems and Design

energy sustainability transport
Future urban infrastructure
Geotechnics associated with retrofitting megacities for transportation and sustainable building development.
Sustainable transport infrastructure

Transportation systems
urban redevelopment, focussing on public transport and on energy-efficient and waste-efficient buildings.
Urbanisation Demographic changes

v. Vibration Engineering

Structural dynamics
Vibration Engineering, wind-induced vibrations, ground-borne vibration and footfalls.
vibration performance of civil structures structural efficiency and environmental impact
Wind effects on structures.

w. Waste and Recycling

Brown field sites
Complex physical interactions around underground openings in the context of deep geological disposal of radioactive waste.
decarbonising the industry improving processes to reduce waste and energy and increase use of recycled materials
Development of further recycled materials
Environmental impact of construction
Recycling of construction materials. Reduction on reliance on cement and steel production.
Reuse and recycling
sustainability, e.g. use of waste;
underground nuclear waste disposal
Uses for recycled materials
Utilising new materials and converting waste into construction materials.
Waste disposal – landfill
Waste engineering in its broadest sense.
Waste management
waste,

x. Other

Attracting and retaining highly skilled technical experts
Collating, interpreting, distilling and disseminating the wealth of existing knowledge
Educating construction clients in sustainable methods.
Effective design of hydro-tunnels needs research to confirm adequacy of recently developed design practices.
Firstly, we need to assess what we want structural engineering research to achieve. Do we want to foster the innovative, risky ideas that might (just might) place UK research at the forefront of the next generation, or do we want to answer today's problems? I've had one research proposal criticised by reviewers for failing on one count and another savaged for perceived failings on the other. It does leave young researchers in a difficult situation when trying to interpret the smoke signals from EPSRC.
fundamental research still needs to be done before tackling practical problems

geo-engineering the climate
geotechnical engineering geo-environmental engineering
Ground effects on buried assets
Ground improvement technologies
Groundwater and aquifer recharge
harnessing natural bacteria for ground improvement
How to balance conflicts between Development, Environment & Sustainability. (e.g. Resistance to wind farms is delaying replacement of fossil fuel derived energy; bio fuels can cause more environmental harm; new roads reduce pollution but destroy habitat)
How to better communicate engineering choices and consequences to the public - for an informed debate.
planetary explorations (soil modelling and technology)
Shifting political and socio-economic horizons to the long term.
soil-structure interface.
Supporting industry in exploiting the full potential of BIM.
training and implementation of new technologies
transfer of knowledge each way universities and industry
Where are the ground and structural engineering colleagues in terms of collaborating with architects etc and in following up many of the impressive points raised by HRH Prince Charles?
Whole life assessment
A major cost driver for railway infrastructure is the inability of ground to support the applied loads. Innovative solutions are required.
Adaptation of new technologies in railway track foundations
Subterranean living
Use of underground space