Convective mass transport and thermomechanical response of partially saturated granular media

Background and information on the project

From sandcastles to powder metallurgy, granular materials are ubiquitous in engineering and natural environment. Understanding their behaviour under a range of loading conditions is essential in ensuring the structural integrity of the granular system e.g., landslides, chemical/pharmaceutical applications such as compacted tablets, food processing etc.

The mechanical response of a granular assembly depends on the interaction of the individual grains. In most of the natural and engineering systems, this interaction is further complicated by the presence of fluids and temperature gradient resulting in convective mass transport. The thermomechanical behaviour of the granular assembly depends on the temperature/concentration gradient, viscosity of the fluid, variation in fluid saturation, compressibility of the fluid etc. The presence of fluid would also influence the relative motion of the particles, especially in case of particles with varying size and shapes and directly contribute to the nature of compaction and flow of the granular assembly.

The aim of the project is to develop a deeper understanding of the mechanics of granular assemblies subjected to convective mass transport and to formulate a multiscale multiphysics model to predict the thermomechanical behaviour of granular assemblies. The model will be developed and calibrated using high quality experimental data acquired at multiple length scales. Custom designed experiments will be conducted in an x-ray CT environment to study the micromechanics of the underlying processes using time resolved x-ray tomography (in 4D).

There are four application areas for this project and the successful candidate would be able to select one of these areas.

Geological/geophysical application: Geothermal systems, particularly Enhanced Geothermal Systems where the energy from underground hot rock/fractured rock is used to generate electricity.

Steel production: Porous coke in the granular assembly of the blast furnace charge provides energy, heat and gas required to reduce the iron ore. Improved design of the granular assembly has potential to minimise the CO_2 emission in the steel making process.

Recycled Asphalt Pavements: Reclaimed and recycled asphalt are used in road pavements providing a cost effective and environmentally friendly option with a potential in decarbonising the industry.

Powder bed fusion, a metal additive manufacturing technique: The nature of granular assembly of metal powder bed informs the quality of the finished product.

About the studentship

This PhD project is advertised as a part of the Edinburgh Research Partnership in Engineering, a joint partnership between the University of Edinburgh and Heriot-Watt University. The successful candidate will be supervised by Dr Amer Syed and Professor Jin Ooi from the University of Edinburgh and Dr Elma Charalampidou of Heriot-Watt University (HWU). Some of the experiments involving micro x-ray CT system will be undertaken at HWU.

Application and selection process

The selection process is in two phases:

Stage 1: Interested candidates should contact Dr Amer Syed at Amer.Syed@ed.ac.uk by **19th of February 2025** with their CV and a covering email. Potential candidates will be invited to an interview and successful candidate will progress to Stage 2.

Stage 2: Selected candidate will complete a formal application to the University of Edinburgh by **26th of February 2025**. This application will be assessed by a panel for funding. Please note that this studentship attracts enhanced stipend, while the exact details are yet to be finalised, for 2024, it was £21,400 per annum.

UK and overseas students are encouraged to apply as the final decision of funding will be made at Stage 2 of the process.

Circular Roads: Improve Recycled Asphalt Content in Pavements by better understanding of Compaction Mechanics.

Background and information on the project

Asphalt recycling gained prominence since the 1970s, partly initiated by the oil crisis influencing the availability of bitumen as binder material. Since then, recycled and reclaimed asphalt continued to be part of the mix used in road and pavements providing a cost effective and environmentally friendly option with a potential to decarbonising the industry. Recent examples of roads using recycled asphalt include: 50% recycled asphalt was used in paving a section of M25 between junctions 25 and 26 and a section of A388 Bournemouth Spur Road, Dorset was paved using all the old road materials.

Rolled asphalt pavement comprises of different courses primarily the wearing, binder, base, subbase and capping layer. The degree of compaction determines the stiffness and strength of material along with its resistance to deformation and durability of the mixture. Compaction of the asphalt along with the binder results from the operation of the paving/construction equipment to impart systematic static, shearing and vibrational loads to achieve the required properties of each of the aforementioned course. The pavement is expected to withstand the design traffic load.

In the drive towards net zero carbon emission, there is an urgent need to significantly increase the use of the 100% recyclable Recycled Asphalt Pavement (RAP) in pavement construction. This poses significant challenges in the design and optimisation of the production and construction processes for which this current project seeks to address. For instance, is it possible to better characterise the RAP in terms of material properties to provide a more accurate initial assessment of its recycling readiness? Is it possible to match to assess, based on the RAP's material characteristics and the prevailing loading regimes, whether it would meet the required highway standards?

The aim of the project is to develop a deeper understanding of the RAP pavement construction and establish an experimentally calibrated numerical model to predict the compaction mechanics of recycled asphalt pavements during construction as well as operational period. The model will integrate the mechanics at different length scales. Experimental programme will include time-resolved (4D) X-ray tomography to capture the micromechanics of the granular assembly.

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