UK Research and Innovation

Transforming Foundation Industries

Lab-to-lab Projects with India

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Foreword

Within the Transforming Foundation Industries (TFI) Challenge, we support the Foundation Industries (FI) in their efforts to adapt to challenges in areas such as the adoption of new technology, international competition, sustainability, productivity and wider climate goals like energy and resource efficiency. After all, around three quarters of the materials we see around us in everyday life come from these industries, so their ability to evolve and thrive is crucial to more than just the businesses themselves. In producing 28 million tonnes of materials per year, they are the biggest industrial polluters, accounting for around half of the UK's total CO2 emissions.

The TFI Challenge is looking to make a transformational change for these industries in how materials are sourced and processed, and the types of products manufactured, making them competitive and helping us meet our commitments around reductions in greenhouse gases. To reach to Net Zero, breaking the link between materials production, carbon emissions and environmental degradation, is both an imperative and a defining environmental and economic challenge of the 21st century.

This is a global challenge, and one in which international collaboration between governments, companies and research institutes is essential for ensuring these sectors remain competitive while reducing their environmental impact. It was on this basis that the Lab-to-Lab Programme was established. TFI was provided with £500,000 from UKRI India to support the development of collaborative projects between the UK and India's FI research facilities. The goal was not only to develop closer ties between research in the two countries and to identify common challenges, but also to look at the potential business case for the development of new technologies and processes that will provide solutions to some of the core issues faced by these industries.

This will benefit both nations and support international efforts to decarbonise the materials sectors. It will also open channels for supporting international business-to-business collaborations.

As you'll see from the case studies of successful projects that follow, a number of paths were taken to achieve these objectives. Some projects required a focus on mapping the extent of issues, data and capabilities across a certain sector, while others were able to collect physical product samples to aid initial testing and proof of concept studies for sustainable alternative materials and technologies.

In each case though, building a wider network for research and collaboration was at the heart of the project. A number hosted substantial virtual workshops with key stakeholders from both countries, bringing together a new knowledge sharing opportunity that will help ensure potential solutions and innovations are appropriate and effective in the real world at all stages.

I'm happy to say that the programme has been a big success too, and the potential seen from the activity within the projects so far has been exciting to see. With the initial programme now finished, we will continue to support each of the teams in their efforts to reach wider audiences, continue their research, and apply for further funding to take concepts to the next stage of development. We will be collating the outputs both from the projects and the virtual mission, which ran in parallel, to begin to develop bilateral opportunities with India.

7 projects were funded within the programme:

1. **Liverpool John Moores University**
   Development of a low-carbon cementitious material by recycling Calcium Carbide Residue waste from foundation industries to decarbonise construction sector
2. **Durham University**
   UK-India Foundation Industries Sustainable Thermal Energy Management Collaboration
3. **Fraunhofer UK Research**
   Multi-functional fibre sensing for foundation industry process monitoring
4. **Aston University**
   Waste heat recovery and reuse in foundation industries
5. **Glass Futures**
   UK-India Lab to Lab collaboration in Glass Manufacturing and Research
6. **Manufacturing Technology Centre**
   Recovery of material value by reusing of metal machining waste as high-value powder feedstock
7. **London South Bank University**
   Circular cementitious products embedding digital manufacturing

1 Liverpool John Moores University

Development of a low-carbon cementitious material by recycling Calcium Carbide Residue waste from foundation industries to decarbonise construction sector

The challenge

Traditional clay-based brick is an extremely carbon-intensive material. On top of this, bricks require firing in a furnace for 36 hours at around 1,400˚C. As a result, both the product and process therefore have environmental and energy use challenges, as well as inefficient production times that are too long for the demand within the market.

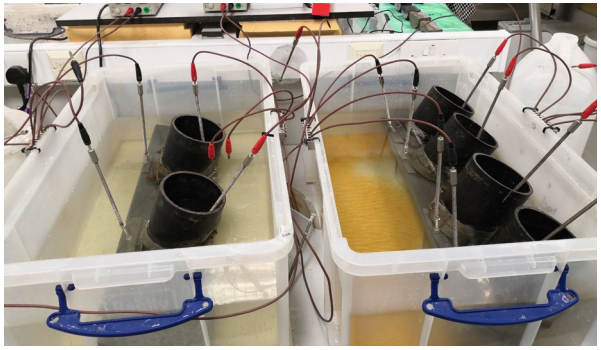
The challenge is therefore to provide technologically feasible and economically viable alternative products to traditional clay-based bricks and cement-based mortar blocks. These alternatives will need to meet the standards and expectations of a modern construction sector, as well as tackling energy use, waste products and time efficiencies.

Project team member with bricks created in the project

The solution

The project aimed to make use of waste material found from chemical and metallurgical industries – a Calcium Carbide Residue (CCR) – that can help create an alternative cementitious product to meet the challenges faced by the sector. Creating a geopolymer from foundation industry waste products such as blast furnace slag, paper waste and fly ash, the project sought to find a formula that not only provided comparable strength to existing clay-based bricks and cement-based mortar block, but reduced the energy requirements, production time and impact on natural clay resources in the UK.

The project also sought to increase research and engagement for the new CCR product in India. Working closely with Nirma University for obtaining sample waste materials, the project aimed to identify industries producing these waste products, as well as those who would benefit from the new CCR cement alternative bricks themselves for construction and manufacturing.



Tests of material properties within the laboratory

Progress and next steps

The project team worked to test a number of different dosages of CCR and other industrial wastes, sand and water formulas for the impact on the strength and durability of the resulting geopolymer products. Other benefits, such as improved chloride resistance and greater freeze and thaw durability, were also found in the most successful formulation, when compared to traditional bricks. The CCR products also benefitted from the ability to be air cured without a furnace, with this and the use of a steam chamber rather than underwater submersion helping move towards the project's ultimate preparation target of just three days.

The next steps for the project are now to disseminate their findings more widely across the brick, cement and paper industries to speak with interested manufacturers both from the waste materials and end product side. More sources of waste materials in India plan to be sourced and tested for their impact on further potential strength benefits, as well as for the ability to extend the concept beyond bricks to roof tiles and more. With the ultimate aim to be market-ready in 2024, the project intends to seek further grants in the UK and India to continue the preparatory work.

2 Durham University

UK-India Foundation Industries Sustainable Thermal Energy Management Collaboration

The challenge

Throughout the Foundation Industries, energy efficiency is a significant problem. Clean growth targets can often be hampered by ultra-low and low-grade heat loss occurring through a number of processes within these industries. It's imperative that this challenge is tackled, beyond the existing technology, into heat exchange and transfer, waste heat recovery and utilisation, energy storage and novel cooling applications.

Due to the variations in waste heat temperatures produced in different Foundation Industries, and the ability of each industry to re-use this energy, a variety of solutions are needed. Each are required not only to bolster sustainability, energy and emissions reduction aims in the UK and India, but also help support improved productivity and competitivity strategies.

The solution

The project worked alongside Amrita Vishwa Vidyapeetham, a leading Indian research and laboratory partner, to help assess the capacities in different sectors and how collaborative research could come together to identify new opportunities.

Due to the differing size of sectors in the UK and India, as well as their approach to the use of technology, the project aimed to gather data on a number of use cases, ROI opportunities and new technologies for different scenarios. By building a virtual network of interested stakeholders and beneficiaries to encourage open dialogue and knowledge sharing through engagement activities, such as webinars and a symposium, the project's plan was to assess the first realistic steps forward.

Progress and next steps

Initial work focused on the gathering of literature data and research profiles of waste heat recovery technologies, alongside identifying key stakeholders for individual Foundation Industries sectors. This capacity mapping was a necessary, but time-intensive stage – but attention has since turned to the business case for solutions and early demonstrations of technology.

The network has been key, and the project has engaged with over 300 stakeholders either through general communication or participation in project engagement activities, that helped identify and discuss needs and challenges, as well as the projects which could be the first focus. Some areas of interest in both countries included sorption technology that can utilise waste heat and use renewable or off-peak electricity which to provide cooling, heat or electrical power, liquid desiccant and phase change materials for heat storage and regeneration.

The project is now considering pursuing further UKRI funding and commissioning case studies, as well as looking into business investment to show the commercial benefits of concepts.

Getty images: iron manufacturing

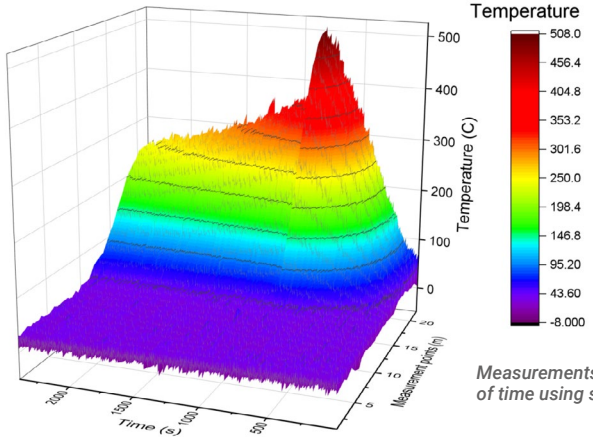
3 Fraunhofer UK Research

Multi-functional fibre sensing for foundation industry process monitoring

The challenge

The challenge of applying sensing technology to the foundation industries comes with engaging and educating the business to embrace new tools and innovations. These sensor concepts are available and, in many cases, waiting to be requested, but building connections and creating that understanding can be difficult. What this means is that at overall industry level, very few are spotting issues such as energy inefficiencies regularly enough to act.

In India this lack of overall engagement comes from barriers and reticence to taking part due to a lack of guaranteed funding to explore the benefits and solutions that may be available. There are also problems with many existing fibre sensors being unable to work in the harsh environments of foundation industries' processes – an issue which the project is aiming to tackle.



Measurements of temperature profile as a function of time using sensors developed in the project

The solution

The aim of the project is to help push the limits of what distributed fibre sensors can do, drawing on the experience of the project partners in photonics sensing. Particularly in glass and ceramics, where high temperatures are needed and therefore energy use is high, having the ability to monitor temperatures is essential.

In the lab, the project is testing different fibre coating materials in increased heat, above temperatures that standard fibres can deal with. It also aimed to bring together networks within the industries to identify how sensors could help in different ways, and highlight the benefits of ongoing testing both for catching problems earlier and for monitoring emissions with environmental targets in mind.

The project also planned to develop engagement for the use of acoustic and thermal sensors together for monitoring a whole process withing the production of materials in the foundation sector – for example, the benefits of monitoring microfractures in ceramics.

Progress and next steps

Throughout the project, engagement from industry has been developing a head of steam, with a core group of new partners and connections in India and the UK wanting to continue their involvement in the development of this technology. In India, this includes the Central Glass and Ceramic Research Institute, Kolkata and IIT Madras, Chennai – while, in the UK, this includes the Centre for Process Analytics and Control Technology at the University of Strathclyde. With other engaged stakeholders wanting further networking opportunities to discuss common challenges and solutions, the project aims to continue to bring together new partners – and assess the capacity to expand the concepts further into a network of fibre sensors on one system, measuring anything from voltage, heat, pressure and air quality.

Testing within the project has shown Fraunhofer's system to be able to function effectively up to 800˚C at present. The project is now looking for opportunities to partner for future funding to continue development work and industry engagement.

4 Aston University

Waste heat recovery and reuse in foundation industries

The challenge

Throughout the many energy-intensive Foundation Industries there is a common problem of waste heat – even up to a third of fuel energy loss for some in the glass, cement and steel sectors. Although some developments in waste heat recovery do exist, many industries lack the knowledge and tools to properly assess the amount of waste heat and their impact on emissions and energy cost, as well as the barriers, opportunities and financial implications of implementing a waste heat recovery solution. There's also little cross-learning between industries within the sector, despite there being many common energy and production challenges.

The solution

The project aimed to create a number of open-source tools to model and analyse the issue of waste heat potential, assess the economic feasibility of solutions, and offer useful information to industries in order for them to compare and tailor a solution to meet their different requirements. Working together with two academic partners from India - the Indian Institute of Technology Bombay India (IIT) and the National Institute of Technology Jalandhar India (NIT) - the project also sought to boost collaboration, engagement and knowledge exchange among industry stakeholders in both the UK and India.

Progress and next steps

As well as establishing contact with two local industries in the UK, the project has been gathering data from Indian industries, particularly from the steel sector, to assess the issue and appetite for solutions. A substantial remote workshop was also completed to discuss experiences, assess the viability of different technology, and form potential partnerships and collaborations for future activity.

The project's initial focus on the energy analysis tool now means there are outputs available to show interested partners and industries – with 30 already engaged for future involvement. The project will now work to provide an information website and free open access tool for companies to input their energy data and identify the quantifiable benefits of addressing the problem, before they engage with solutions that may make economic sense for them.

The project is also assessing opportunities to fund the production of a demonstration case study, and work as a project partner with an already engaged business looking to secure its own funding.

High temperature metal casting facility

5 Glass Futures

UK-India Lab to Lab collaboration in Glass Manufacturing and Research

The challenge

Sustainable practices in glass manufacturing are essential, so, at the government level, the UK and India have pledged to collaborate on developing technologies for sustainable manufacturing. Due to the nature of the production process and the use of furnaces, it's not uncommon for heat loss to be around 50% - creating a substantial energy inefficiency in the sector to address. Additionally, there are sustainability challenges across the end-to-end process, including the recycling of glass.

The drive for tackling this issue is not just in the UK, the Indian government has also set ambitious climate targets, as the country is a significant glass producer. Currently, there are no collaborative projects between the UK and India in this area and no real knowledge of sustainability challenges faced by Indian glass manufacturers.

The solution

The project aimed to take on the role of facilitating this all-important engagement. Looking across the full value chain, the project aimed to develop close ties and relationships with manufacturers and R&D centres in India, identify sustainability challenges they face, and bring together partners from the UK and India to create a series of collaborative projects on sustainable manufacturing of glass through workshop events.

From here, the project's plan was to map out some of the viable solutions that were generated from the events, and to provide a core team within a new network that will act as a hub for partnerships, connections, opportunities and questions – breaking down barriers and reticence among the industry to moving forward with pursuing innovative solutions for sustainable manufacturing of glass.

Getty images: bottle manufacturing factory

Progress and next steps

The project team ran a highly successful interactive webinar with over 130 people across the industry in the UK and India, as well as a range of supplementary workshops to understand and develop new connections and map out proposals on sustainability.

As a result, a number of collaborative proposals came out between the UK and Indian research centres involved, including novel ways to improve waste glass recycling, new technologies for using low-carbon alternative fuels in glass making, alternative raw materials for manufacture, and different sensor technology applications to support process efficiencies.

Following a great deal of successful engagement, the project has developed a new network that not only helps contributors access to new markets and contacts, but also builds understanding of what the international landscape looks like in glass manufacture.

Significant new partners on board include leading Indian R&D centres for glass manufacturing, leading UK academic institutions, UK digital technology companies, and an Indian recycling company. The next steps for the project are now to develop further on the ground experience with partners, consider extended industries such as fibreglass manufacture, and to engage with climate ministries in both countries with the opportunities for addressing sustainable glass manufacturing.

6 Manufacturing Technology Centre

Recovery of material value by reusing of metal machining waste as high-value powder feedstock

The challenge

Metal manufacturing operations, such as turning and machining, produce a significant amount of recyclable metal waste. However, current recycling methods are both labour and energy intensive, and often produce low yields and suboptimal feedstock product. Additionally, recycling metals instead of using virgin sources has significant environmental benefits by reducing biodiversity losses, chemical pollution and greenhouse gas emissions.

The solution

Project REVAMP is an ambitious project that undertook a feasibility study to explore potential collaboration between the Manufacturing Technology Centre (MTC) and a number of Indian research organisations to address these challenges. The study included investigating in recycling challenges and innovations, as well as mapping capabilities and expertise in both in India and the UK. Three workshops were organised for UK and Indian stakeholders to identify material and scrap preferences, barriers and drivers for metal recycling, and metal recycling priorities.

Progress and next steps

The project developed a strong network, with engagement with five Indian Research and Technology Organisations, as well as businesses in the sector. Significant metal recycling challenges were identified, with major opportunities for metal recycling identified within growing sectors. The project team is now looking for funding opportunities to develop the most promising project ideas with network partners.

Scrap metal being turned into powder to create additively manufactured components

7 London South Bank University

Circular cementitious products embedding digital manufacturing

The challenge

The construction sector is an intensive consumer of water, sand and a range of other materials, each with a significant impact on the environment - with little circularity and often a high carbon output. The sector also lags behind many others when it comes to managing the production of waste materials and the use of innovative technology to tackle these fundamental issues.

Given the demand for affordable and modern housing, particularly in India, and the building elements that will be required to meet this need, new ideas for construction are required to address these environmental, sustainability, production and waste issues.

The solution

This project aims to assess the potential for utilising construction, demolition and plastics wastes to achieve the optimal mix design for manufacturing modular blocks – prototypes of which will aim to be generated by the project. Properly utilising recycled aggregates due to their water absorption, these blocks have the potential to gain enhanced mechanical properties, to last longer and be more environmentally sustainable. There are also further benefits from reduced cement use, faster assembly times and reduced costs of repurposing aggregate waste.

A feasibility study undertaken by the project aimed to establish the sources of construction and demolition wastes, and their processing. Through engagement and development of a virtual network, the project also sought to develop the knowledge between UK and India in utilising locally available materials in construction and civil engineering sectors. Research dissemination activities were implemented to link the research with potential manufacture.

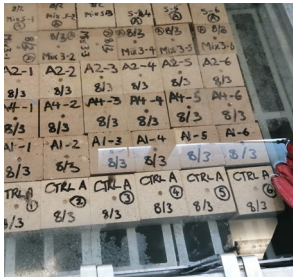
Progress and next steps

To date, work has focused on knowledge capture from the two nations and capability mapping in terms of the waste products available in different areas and industries. Engagement has also taken place with some stakeholders to gauge the appetite for the use of the new products, tackle areas of hesitancy, and to discuss the benefits of sustainable materials that can handle large-scale construction projects.

Samples have been collected and working prototypes are beginning to be developed. In order to optimise the quality and benefits of the products, different mixtures of fine and coarse aggregates are being tested to produce the greatest possible strength among combinations of waste materials that will be readily available.

Next steps include: comparing the carbon footprint between the traditional mix of cementitious products and the alternative digital manufacturing method, assessing the ability for the concept to be replicated in the manufacture of pavement slabs and roof tiles, as well as whether looking at expanding the reach of the research to other regions, such as Africa. Following the sharing of findings from the various aspects of the project, further funding will also be sought to extend the work to the physical demonstration stage.

Recycled aggregates from local construction and demolition wastes



Cementitious specimens made using different mix proportions of recycled wastes

Internal structure of cementitious specimens adopting both construction wastes and plastics wastes

Micro-structural observations of plastic fibre integrated into the cementitious specimen

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