

NIA Project Registration and PEA Document

Date of Submission

Nov 2024

Project Reference Number

NIA2_NGET0078

Project Registration

Project Title

Earth Friendly Concrete Trials – Tunnel Linings

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NIA2_NGET0078

Project Licensee(s)

National Grid Electricity Transmission

Project Start

January 2025

Project Duration

0 years and 4 months

Nominated Project Contact(s)

Muhammad Shaban

Project Budget

£159,174.00

Summary

In alignment with National Grid Electricity Transmission's (NGET's) objectives of achieving net-zero construction, we aim to evaluate the suitability of polymer concretes as a sustainable alternative to traditional concrete for NGET's construction operations, appraise their readiness for construction trials, and support NGET in undertaking some of the required trials to demonstrate these materials' suitability. Earth Friendly Concrete (EFC) has been utilised on the LPT2 (London Power Tunnels 2) project in several areas, but mainly for bulk fill or in temporary works. To further this concrete technology and use EFC more extensively, HMJV in conjunction with its Supply Chain Partners will conduct trials to establish the potential for use in Precast Segmental Lining Elements for the benefit of future projects as part of the LPT legacy.

Third Party Collaborators

HOCHTIEF-MURPHY Joint Venture (HMJV)

Nominated Contact Email Address(es)

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Problem Being Solved

The production of cement generates enormous amounts of CO₂, accounting for 8% of all manufactured carbon worldwide. It has also been said that if the cement industry were a country, it would be the third-biggest emitter of carbon on the planet, ranking only behind China and the USA. In 2016, it was reported that the cement industry generated three billion tonnes of CO₂. With an ever-growing focus on net zero targets, through the UN Sustainable development goals, National Strategies and National Grid targets, there is an expectation and a need to significantly reduce the carbon emissions within construction.

Method(s)

Earth-Friendly Concrete (EFC) is a groundbreaking, cement-free material that offers a significant reduction in carbon emissions, with performance comparable to standard concretes, aligning with the construction industry's urgent drive to reduce its carbon footprint. EFC is compliant with BSI PAS 350 Flex and presents a critical opportunity for National Grid to lead in innovation while advancing its net zero goals.

National Grid Electricity Transmission (NGET) has partnered with HOCHTIEF-MURPHY Joint Venture (HMJV) to conduct the study. Wagner's Earth Friendly Concrete (EFC) has been employed in construction projects in Australia over the past 12 years, garnering numerous awards and accolades for sustainability and innovation. Its geopolymer binder has no traditional Portland cement; instead, an alkali activator chemically reacts under ambient curing conditions with two well-known industrial waste by-products – GGBS (waste from iron production) and Fly Ash (waste from coal-fired power stations). Both materials have been used as supplementary cementitious materials (SCMs) in concrete production for decades.

Scope

Tunnels are essential infrastructure that provide mass transportation, hydroelectric power plants, sewerage, potable water supply and other utilities that can improve quality of life, the economy, public health, and the environment.

Tunnels can, at a network and system level, reduce CO₂e emissions. For example, by providing fast and efficient train or metro services, car use can be reduced. Or, by providing a shorter, flatter route, a tunnel through a mountain can reduce journey times, energy consumption and air pollution. Compared to other potential solutions, e.g. a bridge or surface option, tunnels are often more resilient and durable, require less maintenance, and have less impact on the environment.

Most tunnels are constructed with concrete tunnel linings. Other lining types, such as timber, steel or cast iron, are only used in special cases and represent a tiny proportion of the total length of tunnels in the world. Therefore, the easiest way to have the biggest impact is to reduce the CO₂e emissions associated with the concrete tunnel linings, and this is the focus of this project.

The project will provide guidance on how to reduce CO₂e emissions for all types of concrete tunnel linings, including:

- precast concrete segmental linings,
- cast-in-place concrete.

Trialling of the C50/60 mix in accordance with EC2 and BSI standards will be carried out with the expectancy that the mix will comply with the following:

Fresh Concrete - BS EN 12350:2019

Slump Testing and Slump Retention – BS EN 12350-2

Fresh Density – BS EN 12350-6

Bleed Testing – ASTM C232-14

Hardened Testing - BS EN 12390:2019

Compressive Strength – BS EN 12390-3

Density (saturated/oven dry) – BS EN 12390-7

Flexural Strength – BS EN 12390-5

Tensile Splitting – BS EN 12390-6

Total Shrinkage – ASTM C157

Hot Box – Temperature Rise/Coefficient of Thermal Expansion/Temperature Differential

Fire Testing – ISO 384:1:1999

ISO384 Curve

Final report will be published with all the learning outcomes and will be shared with all the licensees. A dissemination event will present all the results to relevant stakeholders with the recommendations of certain technologies ready to use in business as usual (BAU).

Objective(s)

The work will be delivered in discrete stages each with a focus on different objectives linked to the overall aim to explore concrete tunnel lining segment. This project is planned to take 4 months with the following major objectives:

- To develop an understanding of the EFC tunnel lining segment technology to allow for identification of usage cases, potential benefits, and readiness for construction trials.
- To review the technology and summarise the current state of knowledge, trends, challenges, and opportunities in utilising EFC as alternatives in Tunnel lining segments.
- To review the current design codes and approaches to explore how they might be applied in the design of polymer concrete structures.

- Final recommendations to identify the potential benefits and implementation learning outcome.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

Benefits to National Grid and the Wider Construction Industry

While there is no immediate impact on the LPT Phase 2 Enterprise, testing EFC has the potential to benefit both National Grid and the broader construction industry. Specifically, EFC could be instrumental in future National Grid cable tunnel projects and other large-scale schemes where ultra-low carbon concrete with appropriate fire ratings is required.

Significant Carbon Reduction

As demonstrated in the data above, using EFC in place of conventional concrete can reduce CO₂ emissions by up to 40% per tonne, translating to substantial savings on large-scale projects. For instance, applying EFC to the London Power Tunnels 2 tunnel lining alone would have resulted in a reduction of 7,641,728 kgCO₂e. This saving is equivalent to driving an average new car (with exhaust emissions of 114 gCO₂e/km) for 67,032,702 kilometres—roughly 1,673 times around the world.

Global Warming Potential (GWP) Impact

SF₆, a gas with a global warming potential (GWP) 22,800 times that of CO₂, serves as a powerful reference point. The calculated CO₂ savings from using EFC would equate to avoiding the emissions of 335.16 kg of SF₆.

Financial Savings

EFC currently incurs a premium in upfront costs compared to traditional concrete. However, this premium can be partially offset by its enhanced durability, lower heat of hydration, and the potential for carbon offsetting credits. As the demand for sustainable construction materials increases, it is anticipated that production costs will decrease, making EFC a more economically viable option in the long term.

Investing in EFC represents a significant step forward for National Grid in its pursuit of sustainability and innovation. By adopting this ultra-low carbon concrete, National Grid not only reduces its environmental impact but also positions itself as a leader in the construction industry's shift toward more sustainable practices.

Success Criteria

The project will be considered successful if the following stages are completed. The trials would consist of several stages to gain a full understanding of behaviour in this use and ensure all requirements have been met including workability, design, and practicality.

Stage 1 – Material trials conducted by HMJV's supply chain partners Shay Murtagh and Wagner's in MC Bauchemie labs in Ireland.

Stage 2 – Wet and hardened concrete testing of segmental lining mix.

Stage 3 – Casting of 2 full segmental lining rings using LPT2 moulds.

Stage 4A – Trial ring build of 2 number rings.

Stage 4B – BRE fire testing of panels.

Project Partners and External Funding

HOCHTIEF-MURPHY Joint Venture (HMJV) will conduct the testing and trials completing 5 stages of the trial. NGET is providing all the funding for the project and is the lead network.

Potential for New Learning

There is very limited amount of work being done in this area and especially the existing one focus on theoretical research, non-critical trials and pours. This work will provide the basis of our understanding of the capabilities of EFC when used in tunnel lining segment. The work will be valuable resource for NG and have immediate application in subsequent projects in development. The sustainability opportunities register will be used to seek our new ideas and areas of focus; these will help shape conversations with future suppliers. In addition to potential for new learning outlined above, promotion of EFC will aid in facilitating compliance with legislative requirements and achieving net zero targets by 2026.

The following will be new knowledge expected from carrying out the project:

- Development of new learning around ultra-low carbon construction techniques (EFC) and their efficacy.
- Operational performance data to understand design challenges.
- Like for like comparison of OPC and EFC.
- The outputs created from the project will be shared with the interested parties in energy sector especially the NGET construction

working group.

Scale of Project

All work is strategically linked and designed to deliver the defined objectives. Therefore, the scale of the project is as specified, and the studies will be undertaken to demonstrate the testing of the lining segment. There will be additional testing and trials in this project that would be undertaken to establish some recommendations for final report.

Technology Readiness at Start

TRL7 Inactive Commissioning

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

The study will be completed in 5 different stages and all stages will be completed within the UK (Ireland and London).

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£143,257

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

The project facilitates energy system transition by helping NGET to understand the environmental impact, in terms of carbon emissions arising from our construction activities. This project will conduct a series of tests and trials using Earth Friendly Concrete (EFC) in tunnel lining segments at our London Power Tunnel (LPT2). This will help us identify clear opportunities to reduce emissions with ultra-low carbon concrete and assist in commitments to reduce scope 3 emissions.

How the Project has potential to benefit consumer in vulnerable situations:

N/A

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

N/A

Please provide a calculation of the expected benefits the Solution

Total Tunnel Length: 56.5 km

Universal lining 3m ID: 6 segments per ring, 1.2m long. No. segments per km = $1000/1.2 \times 6 = 5000$.

Cost per Segment: £213.87

EFC Segment cost: £239.53

Tunnel lining Cost (Concrete) = $5000 \text{ segments} \times 213.87\text{£/segment} = 1,069,332 \text{ £/km}$

Tunnel lining Cost (EFC) = $5000 \text{ segments} \times 213.87\text{£/segments} \times 1.12 = 1,197,652 \text{ £/km}$

Tunnel lining Cost (Concrete/56.5 km) = £60,417,258

Tunnel lining Cost (EFC/56.5 km) = £67,667,338

Please provide an estimate of how replicable the Method is across GB

The developed methodology is of generic nature and would be applicable to all electricity network Licensees across GB, this would be inclusive of transmission and distribution owners. The outcome of the project will determine how much emissions can be reduced by the implementation of such materials. The success of the project will boost the confidence on the material reliability and safety practices.

Please provide an outline of the costs of rolling out the Method across GB.

If the project is successful, the method can be further developed to roll out across GB. The estimated cost will be reviewed at the completion of the project. Conservative estimates of costs have been made for the purposes of assessing the value of this project, they are based on the cost of polymer materials. There is some cost associated to changing the technical specification to allow the use of polymer materials in the business and across GB.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

- ☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).
- ☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)
- ☐ A specific novel operational practice directly related to the operation of the Network Licensees system
- ☐ A specific novel commercial arrangement

RIIO-2 Projects

- ☐ A specific piece of new equipment (including monitoring, control and communications systems and software)
- ☒ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven
- ☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)
- ☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology
- ☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution
- ☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The learning will be used in the planning and designing of new substations and upgrading the existing infrastructure to reduce the carbon emissions. It is the learning that may be directly applied to other networks with similar assets at similar voltages. The disseminated results will be shared with all licensees so that the reasons for the conclusions may be understood. It will be the responsibility of others to determine to what extent it applies to other equipment types and different voltages but the underlying work from this project is likely to help.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

N/A

Is the default IPR position being applied?

- ☒ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

This project explores EFC trial at LPT2 for tunnel lining segments which have not been explored or implemented before. The project intends to generate evidence to change the construction activities since the technical specifications do not allow such materials now hence, they are not utilised currently. There are no other projects in development looking at EFC that can help reduce the emissions. The risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other

Network Licensees.

N/A

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

This project is innovative because it explores the application of cement-free concrete specifically for tunnel segmental linings - a concept that has not yet been extensively researched. While there has been increasing interest in low-carbon construction materials, such as those outlined in the BSI Flex 350 and the ITAtech Activity Group's report on Low Carbon Concrete Linings, the focus has predominantly been on general structural applications.

The unique demands of tunnel linings, including strength, durability, and environmental resistance, require tailored solutions. By trialling cement-free alternatives, this project addresses a significant gap in current research and aims to meet both sustainability and engineering requirements in an untested, highly specialized context.

There are currently no NIA/SIF projects looking at polymer concretes with potential trials within the UK. As a responsible business, NG need to cover the knowledge gap to address the issue and manage the expectation to meet the commitments of reducing the scope 3 emissions. There is no overlap between this work focusing on foundations and the work currently under way in different trials and studies.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained about the EFC use in Tunnel lining segments and their performance advantages over OPC. The learning will be brought together for like for like comparison and development of segment rings to be tested in LPT2 and gather some data.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at <https://smarter.energynetworks.org>, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at <https://www.nationalgrid.com/uk/electricity-transmission/innovation>
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

There exists no data that supports the evidence of using ultra-low carbon polymer concrete in tunnel lining segment. National Grid has done previous trials with other polymer concretes like CemFree and Earth friendly concrete however none of the trials involved tunnel lining segment which is a critical asset providing strength. A strong test data along with validation data is required to change the technical specification to utilise EFC widely within the business. There is a risk factor involved which needs thorough testing and trials before it can be adopted. The risk of alternatives not performing up to certain standards is also a possibility and that is why business as usual cannot fund such activities.

This project aims to update the specification based on the data obtained through a series of testing. This is not a business-as-usual activity as there is considerable risk associated with the development and implementation.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

Testing to date suggests that the work will be successful, but it cannot be guaranteed. If the feasibility study identifies more challenges than benefits, the project will not proceed to BAU and technical specifications will not be changed. The project is anticipated to generate sufficient benefit to justify the expenditure over 10 years. So, the success of the project will only become truly apparent over a longer period. During that time alternative, currently unforeseeable, solutions may arise that provide greater benefit.

There are technical risks associated with any innovation project as the proposed solution may not work. Replacing the existing materials like concrete has high risk requiring additional work like finding the unknowns about the material strength, exploring the supply chain, associated technical risks, validation, and verification of results, and identifying viable sources of relevant data and science. Therefore, considering the risks associated with the success of the project, NGET believes NIA funding is the best route for

the project.

This project has been approved by a senior member of staff

☒ Yes